Compression of dry lysozyme targets: The target preparation pressure as a new parameter in protein thin film production by pulsed laser deposition

Film growth of the well-known protein, chicken lysozyme, produced by the dry technique, pulsed laser deposition (PLD), from a compressed powder target has been investigated as a function of the target preparation pressure. PLD is a versatile technique for fabricating high quality films of inorganic materials, but the laser beam will typically produce fragments of molecules in the target and subsequently in the deposited films. We demonstrate that the pressure applied to compact the target prior to the laser irradiation is an important parameter that determines the deposition rate as well as the extent of fragmentation of the deposited molecules. The deposition process was carried out in vacuum using dry targets prepared with compaction pressure in the range 10–160 bar. The residual water in pockets of the lysozyme molecules drives fragments or intact lysozyme out of the target. At the intermediate fluence of 2 J/cm², the deposition rate of the material (fragments or intact molecules) rises from 3 to 9 ng/cm² per shot as the compaction pressure increases from 10 to 160 bar. However, the number of intact molecules falls down by almost two orders of magnitude in the same pressure range. This is explained by a stronger cohesion of the target material prepared at higher compression pressure, such that more energy and thus a higher temperature are required for the onset of material ejection. At the highest compression pressure, it means that no intact molecules survive the ejection. The results indicate that there is a pressure range where both a reasonable deposition rate and a considerable fraction of intact molecules in the films can be achieved. These experimental observations are consistent with the results of coarse-grained molecular dynamics simulations, where the fraction of intact lysozyme molecules is observed to vanish as the maximum temperature in the irradiated target increases.
Comparison of potassium-functionalized Cu2ZnSnS4 nanoparticles annealed in different reactive sulfide atmospheres

Kesterite Cu2ZnSnS4 (CZTS) can be a promising, alternative material for thin-film solar cells, because it is earth-abundant, non-toxic and displays relevant physical properties. For future up-scaling possibilities and to decrease the environmental impact of the photovoltaic technology, solution-processing deposition methods are desired. This paper deals with CZTS absorber layers fabricated from CZTS nanoparticles that are functionalized with KCl, and investigates two different types of furnaces for the annealing process; a hydrogen sulfide (H2S) flow furnace and a nitrogen atmosphere closed furnace. We find that more uniform grain growth is achieved when annealing in a closed furnace, while very large grains on the surface of the film are obtained when annealing in H2S.

Large process-dependent variations in band alignment and interface band gaps of Cu2ZnSnS4/CdS solar cells

Electron–hole recombination at the Cu2ZnSnS4/CdS interface is believed to play a major role in limiting the efficiency of Cu2ZnSnS4 solar cells. In this work, we experimentally determine detailed Cu2ZnSnS4/CdS interface band diagrams as a function of process conditions, and correlate them to chemical processes occurring during interface formation and subsequent post-annealing. The newly devised experimental method involves a combination of photoemission spectroscopy and spectroscopic ellipsometry. Our measurements reveal that, under most process conditions, the band gaps of both Cu2ZnSnS4 and CdS decrease by several hundred meV near the interface. Furthermore, interface band bending and conduction band offsets are highly process-dependent and roughly correlated to the amount of chemical interdiffusion. The interface electronic properties are found to be unfavorable under all process conditions studied in this work, either due to a cliff-like conduction band offset, or to substantial band gap narrowing in Cu2ZnSnS4, or to both effects. According to the present study, the least harmful process conditions for the interface electronic properties are a low CdS deposition temperature without post-annealing. Even in such a case, a minimum open circuit voltage loss of 230 mV is expected due to interface- or near-interface recombination.
Liquid phase assisted grain growth in Cu2ZnSnS4 nanoparticle thin films by alkali element incorporation

The effect of adding LiCl, NaCl, and KCl to Cu2ZnSnS4 (CZTS) nanoparticle thin-film samples annealed in a nitrogen and sulfur atmosphere is reported. We demonstrate that the organic ligand-free nanoparticles previously developed can be used to produce an absorber layer of high quality. The films were Zn-rich and Cu-poor, and no secondary phases except ZnS could be detected within the detection limit of the characterization tools used. Potassium was the most effective alkali metal to enhance grain growth, and resulted in films with a high photoluminescence signal and an optical band gap of 1.43 eV. The alkali metals were introduced in the form of chloride salts, and a significant amount of Cl was detected in the final films, but could be removed in a quick water rinse.

Micro-scale Real-Time Wear Dynamics Investigated by Synchrotron Radiation

In situ wear measurements on a hard coating of TiAlN and CrN layers deposited on vitreous carbon have been carried out with synchrotron radiation. The results show that wear dynamics can be successfully monitored on a lateral micrometer scale and with a submicrometer depth resolution. The wear process is highly irregular and the local wear rate may vary strongly from one position to another in the same wear track. Most of the ridges and grooves are generated within the first 500 nm and exist over several micrometers.
Pulsed laser deposition of chalcogenide sulfides from multi- and single-component targets: the non-stoichiometric material transfer

The mass transfer from target to films is incongruent for chalcogenide sulfides in contrast to the expectations of pulsed laser deposition (PLD) as a stoichiometric film growth process. Films produced from a CZTS (Cu$_2$ZnSnS$_4$) multi-component target have no Cu below a fluence threshold of 0.2 J/cm$^2$, and the Cu content is also very low at low fluence from a single-component target. Above this threshold, the Cu content in the films increases almost linearly up to a value above the stoichiometric value, while the ratio of the concentration of the other metals Zn to Sn (Zn/Sn) remains constant. Films of a similar material CTS (Cu$_2$SnS$_3$) have been produced by PLD from a CTS target and exhibits a similar trend in the same fluence region. The results are discussed on the basis of solid-state data and the existing data from the literature.
Development of CZTSSe Thin Film Solar Cells with Inclusions of Selenium in the Precursor Stack

Cu$_2$ZnSn(S$_x$Se$_{1-x}$)$_4$ (CZTSSe) solar cells were produced by sputtering of a precursor stack, where the element Se was thermally evaporated onto the precursors in two different configurations, followed by annealing in H$_2$S using an RTP furnace. The absorbers produced exhibited blisters. The S/(S+Se) profile in each configuration and blister formation investigations in CZTS are presented.

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Effect of alkali elements in thin-film Cu$_2$ZnSnS$_4$ solar cells produced by solution-processing

The effect of adding Li, Na, and K to Cu$_2$ZnSnS$_4$ nanoparticle thin-film absorber layers has been investigated. Among them, K is found to enhance grain growth as well as increase the photoluminescence of the films.

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Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems
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High-energy deposition methods for CZTS and CTS solar cells

General information
Publication status: Published
Organisations: DTU Danchip, Department of Photonics Engineering, Photovoltaic Materials and Systems, Technical University of Denmark, Consiglio Nazionale delle Ricerche
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Investigation of Cu$_2$ZnSnS$_4$ nanoparticles for thin-film solar cell applications

We study the effect of the annealing atmosphere on grain growth of ligand-free and ligand-coated Cu$_2$ZnSnS$_4$ (CZTS) nanoparticle-based thin films by thermal analysis. We use thermogravimetric analysis (TGA) coupled with mass spectrometry (MS) to simultaneously monitor mass changes and evolved gases of both nanoparticle powders and inks. The investigation focuses on annealing in air, nitrogen and forming gas (5% H$_2$ in Ar), i.e., oxidizing, inert, and reducing atmospheres. We find that the oleylamine capping ligands thermally decompose into smaller organic fragments starting
na-assisted grain growth in CZTS nanoparticle thin films for solar cell applications

We have studied the effect of Na in Cu2ZnSnS4 nanoparticle thin films [1]. The as-synthesized CZTS nanoparticles were inherently ligand-free [2], which allows us to use of polar solvents, such as water and ethanol. Another advantage of these particles is that the user- and environmentally-friendly NaCl salt can be directly dissolved in controllable amounts. This further circumvents the need for later incorporation of dopants, or a ligand-exchange step to functionalize the surface of the nanoparticles. In addition, the homogeneous distribution of Na in the ink allows uniform grain growth within the deposited absorber layer. By including Na in the nanoparticle ink, micron-sized grains throughout the whole absorber are achieved after annealing in a sulfur atmosphere at 600°C. The absorber layer appeared to be of full density, and no closed porosity could be detected. In addition, the photoluminescence signal increased by a factor of 200 after Na-inclusion. Without Na, the grains were very difficult to sinter, the film was porous, and the photoluminescence was low. A concentration of Na/(Cu+Zn+Sn)=30% was necessary for the densification of the absorber, which is significantly higher than that used in other Na-doped CZTS systems. The annealed films were found to be of the desired Cu-poor and Zn-rich composition. We also found that a sulfidation temperature above 550°C was required. At 550°C, NaCl-crystals appeared on the surface of the thin films, suggesting an incomplete transformation of Na into the liquid phase Na2Sx-additive during sintering. At this temperature, grain growth was only detected in close proximity to the NaCl regions. It was also observed that the NaCl crystals could be easily removed by a quick water rinse, but that this treatment reduced the photoluminescence signal. This is relevant as it is customary to leave the absorber layer in a water-based solution after annealing before buffer layer deposition.

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Department of Micro- and Nanotechnology, Nanyang Technological University
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Event:
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2017 › Research › peer-review
Nonstoichiometric transfer during laser ablation of metal alloys

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Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems, Paul Scherrer Institute, Swiss Federal Institute of Technology Zurich, Università degli Studi di Napoli Federico II
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Non-stoichiometry in sulfides produced by pulsed laser deposition
Pulsed laser deposition or PLD is known as a technique by which complex materials can be stoichiometrically transferred from a target to a substrate, providing that the ablation threshold is exceeded. For a multi-target component, it frequently happens that there is loss of the lightest and the most volatile component in the film. A very well studied case in the one of oxides, for which the O₂ or N₂O background gases can reduce the loss of oxygen in the growing films. A much less studied case is the one of sulfides or selenides, such as the solar cell absorber layers of CIGS (Cu(Ga,In)Se₂) and CZTS (Cu₂ZnSnS₄). While the former material was studied comprehensively during the last thirty year as absorber layer, the latter is relatively new, promising material, which recently has reached a solar cell efficiency slightly below 10 %. Films of CZTS have turned out to be difficult to produce by PLD because the mass transfer from target to films is significantly incongruent. The films were produced by PLD at a fluence from 0.2 J/cm² to 2 J/cm² at room temperature with nanosecond lasers with wavelengths of 248 nm or 355 nm in vacuum. The resulting film composition was deficient in sulfur in general, but the most surprising feature was a strong decrease in the copper content of the films with decreasing fluence. There was a clear decrease of the number of droplets on the films with decreasing fluence as well. A similar trend was observed for Cu₂SnS₃ or Cu₂ZnSn.

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Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems
Contributors: Canulescu, S., Cazzaniga, A. C., Ettlinger, R. B., Schou, J.
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Pulsed laser deposition(PLD) of multi-component oxide target for Cu₂ZnSnS₄ solar cells

General information
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Organisations: Photovoltaic Materials and Systems, Department of Photonics Engineering, Nanophotonic Devices
Contributors: Gansukh, M., Schou, J., Canulescu, S.
Pulsed laser deposition (PLD) of the CZTS absorber for thin solar cells with up to 5.2-% efficiency

General information
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Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems, DTU Danchip, Department of Energy Conversion and Storage, Electrofunctional materials, Applied Electrochemistry, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Department of Micro- and Nanotechnology, University of New South Wales
Contributors: Cazzaniga, A. C., Canulescu, S., Ettlinger, R. B., Pryds, N., Hansen, O., Schou, J., Crovetto, A., Hansen, O., Yan, C., Sun, K., Hao, X.
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Spray-coated Cu2ZnSnS4 thin films for large-scale photovoltaic applications

The kesterite material, Cu2ZnSnS4 (CZTS), has in the preceding ten years been investigated and developed as a new Earth-abundant material for solar cells. The interest in this inorganic semiconductor originates in its optimal energy band gap of approx. 1.5 eV, high absorption coefficient, and the high material abundance and low toxicity of all elements included. The current challenges are related to unavoidable antisite disordering stemming from the chemical similarity of the cations, which causes bulk defects and lowers the open-circuit voltage detrimentally. This, however, did not restrict the “cousin”-material, CuInGaSe2 (CIGS), which is currently one of the main thin-film photovoltaic (PV) technologies on the market. In this work, CZTS thin films have been fabricated by solution-processing, which allows relatively fast and inexpensive deposition when compared to vacuum-processed films. The nanoparticles are synthesized by the hot-injection method by mixing targeted ratios of metal salts with sulfur in diethylene glycol, resulting in a phase-pure CZTS material [1]. Inks are formulated by dispersing the particles in ethanol and water using a suitable dispersing agent. The solvents used allow that alkali metal chloride salts can also be dissolved in controllable amounts, which we have found enhances grain growth in the films during the subsequent annealing step. A Sono-tek spray-coating system with ultrasonic atomization is used. We investigate the effect of ink concentration, and spray-coating conditions, including spray power, flow rate from syringe pump, and time between consecutive spray layers. The films are annealed in a tube furnace, and to avoid decomposing the material into secondary phases, a graphite box is used to enable an overpressure of sulfur and tin-sulfide. The annealed, spray-coated films are characterized by scanning electron microscopy (SEM), optical microscopy, and Dektak profilometry.
Spray-coated ligand-free Cu2ZnSnS4 nanoparticle thin films

We have fabricated Cu2ZnSnS4 (CZTS) thin films from spray-coating ligand-free nanoparticle inks. The as-synthesized CZTS nanoparticles were inherently ligand-free [1], which allows the use of polar solvents, such as water and ethanol. Another advantage of these particles is that user- and environmentally-friendly alkali metal chloride salts can be directly dissolved in controllable amounts. The homogeneous distribution of alkali metals in the ink allows uniform grain growth within the deposited absorber layer as a result of liquid phase assisted sintering. We find that particularly beneficial effects are seen by including potassium in the film. This produced micron-sized grains, an increased photoluminescence signal, and a bandgap of approx. 1.43 eV. The composition was Cu-poor and Zn-rich, and phase-pure kesterite CZTS was detected by Raman spectroscopy and X-ray diffraction (XRD) as well as an unquantifiable amount of ZnS. A Sono-tek spray-coating system is used which utilizes ultrasonic atomization. We investigate the effect of different binders, ink concentration, and spray-coating conditions, i.e. spray power, flow rate from syringe pump, distance between spray nozzle and the substrate, and time between consecutive spray layers for multiple layers. The spray-coated films are characterized by scanning electron microscopy (SEM), optical microscopy, and a Dektak profilometer.

Technology for Si/CZTS Tandem Solar Cell

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, InMold Biosystems A/S
Contributors: Engberg, S. L. J., Murthy, S., Kofod, G., Schou, J.
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Temperature dependent photoreflectance study of Cu2SnS3 thin films produced by pulsed laser deposition

The energy band structure of Cu2SnS3 (CTS) thin films fabricated by pulsed laser deposition was studied by photoreflectance spectroscopy (PR). The temperature-dependent PR spectra were measured in the range of T = 10–150 K. According to the Raman scattering analysis, the monoclinic crystal structure (C1c1) prevails in the studied CTS thin film; however, a weak contribution from cubic CTS (F-43m) was also detected. The PR spectra revealed the valence band splitting of CTS. Optical transitions at EA = 0.92 eV, EB = 1.04 eV, and EC = 1.08 eV were found for monoclinic CTS at low-temperature (T = 10 K). Additional optical transition was detected at EAC = 0.94 eV, and it was attributed to the low-temperature band gap of cubic CTS. All the identified optical transition energies showed a blueshift with increasing temperature, and the temperature coefficient dE/dT was about 0.1 meV/K.

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Organisations: Theoretical Atomic-scale Physics, Department of Micro- and Nanotechnology, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Tallinn University of Technology
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The effect of dopants on grain growth and PL in CZTS nanoparticle thin films for solar cell applications

We have studied the effect of dopants such as Na, Sb, and Li in Cu2ZnSnS4 nanoparticle thin films [1]. The as-synthesized CZTS nanoparticles were inherently ligand-free [2], which allows the use of polar solvents, such as water and ethanol. Another advantage of these particles is that the user- and environmentally-friendly chloride salts can be directly dissolved in controllable amounts. This further circumvents the need for later incorporation of dopants, or a ligand-exchange step to functionalize the surface of the nanoparticles. In addition, the homogeneous distribution of additives in the ink allows uniform grain growth within the deposited absorber layer. By including Na in the nanoparticle ink, micron-sized grains throughout the whole absorber are achieved after annealing in a sulfur atmosphere at 600°C. The absorber layer appeared to be of full density, and no closed porosity could be detected. In addition, the photoluminescence signal increased by a factor of 200 after Na-inclusion. Without Na, the grains were very difficult to sinter, the film was porous, and the photoluminescence was low. This suggests that including Na reduces interface recombination in CZTS nanoparticle absorber layers. A concentration of Na/(Cu+Zn+Sn)=30% was necessary for the densification of the absorber, which is significantly higher than that used in other Na-doped CZTS systems. The annealed films were found to be of the desired Cu-poor and Zn-rich composition.

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Department of Micro- and Nanotechnology
Contributors: Engberg, S. L. J., Crovetto, A., Hansen, O., Schou, J.
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Event: Abstract from EMRS Spring meeting 2017, Strasbourg, France.
Ultra-thin Cu$_2$ZnSnS$_4$ solar cell by pulsed laser deposition

We report on the fabrication of a 5.2% efficiency Cu$_2$ZnSnS$_4$ (CZTS) solar cell made by pulsed laser deposition (PLD) featuring an ultra-thin absorber layer (less than 450 nm). Solutions to the issues of reproducibility and micro-particulate ejection often encountered with PLD are proposed. At the optimal laser fluence, amorphous CZTS precursors with optimal stoichiometry for solar cells are deposited from a single target. Such precursors do not result in detectable segregation of secondary phases after the subsequent annealing step. In the analysis of the solar cell device, we focus on the effects of the finite thickness of the absorber layer. Depletion region width, carrier diffusion length, and optical losses due to incomplete light absorption and back contact reflection are quantified. We conclude that material- and junction quality is comparable to that of thicker state-of-the-art CZTS devices, even though the efficiency is lower due to optical losses.

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Micro- and Nanotechnology, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Department of Energy Conversion and Storage, Electrofunctional materials, The VILLUM Center for the Science for Sustainable Fuels and Chemicals, University of New South Wales, Technical University of Denmark
Contributors: Cazzaniga, A. C., Crovetto, A., Yan, C., Sun, K., Hao, X., Estelrich, J. R., Canulescu, S., Stamate, E., Pryds, N., Hansen, O., Schou, J.
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Versatile two-dimensional transition metal dichalcogenides

Two-dimensional transition metal dichalcogenides (2D-TMDCs), such as MoS$_2$, have emerged as a new class of semiconducting materials with distinct optical and electrical properties. The availability of 2D-TMDCs with distinct band gaps allows for unlimited combinations of TMDC monolayers (MLs) and enables engineering of van der Waals (vdW) heterostructures with characteristics fundamentally different compared to the conventional 3D-covalently bound heterostructures. Although various 2D materials have been successfully synthesized by mechanical exfoliation or chemical vapor deposition (CVD), a strategy for the fabrication of 2D heterostructures must be developed. Here we demonstrate a novel approach for the bottom-up synthesis of TMDC monolayers, namely Pulsed Laser Deposition (PLD) combined with a sulfur evaporation beam. PLD relies on the use of a pulsed laser (ns pulse duration) to induce material transfer from a solid source (such as a sintered target of MoS$_2$) to a substrate (such as Si or sapphire). The deposition rate in PLD is typically much less than a monolayer per pulse, meaning that the number of MLs can be controlled by a careful selection of the number of laser pulses. In the paper, we will discuss the growth of high-quality MoS$_2$ in the form of one or several MLs over large areas and several substrates, such as sapphire, SiO$_2$/Si and indium tin oxide (ITO). This approach allows the synthesis of 2D-TMDCs without the use of catalyst and with a good control of the sulfur vacancies. We have found that the absorption spectra of the MoS$_2$ films exhibit distinct excitonic peaks at $\sim$1.8 and $\sim$2 eV when grown in the presence of a sulfur evaporation beam as compared to those deposited in vacuum. The structure of the PLD-grown MoS$_2$ films will be further discussed based Raman spectroscopy analysis, photoluminescence, as composition/thickness determined by Rutherford backscattering (RBS). Some challenging issues and future directions on the use of PLD for the synthesis of complex heterostructures by PLD will be discussed.
Band gap tuning of amorphous Al oxides by Zr alloying
The optical band gap and electronic structure of amorphous Al-Zr mixed oxides, with Zr content ranging from 4.8 to 21.9\% were determined using vacuum ultraviolet (VUV) and X-ray absorption spectroscopy (XAS). Thelight scattering by the nano-porous structure of alumina at low wavelengths was estimated based on the Mie scattering theory. The dependence of the optical band gap of the Al-Zr mixed oxides on Zr content deviates from linearity and decreases from 7.3 eV for pure anodized Al2O3 to 6.45 eV for Al-Zr mixed oxide with Zr content of 21.9\%. With increasing Zr content, the conduction band minimum changes non-linearly as well. Fitting of the energy band gap values resulted in a bowing parameter of 2 eV. The band gap bowing of the mixed oxides is assigned to the presence of the Zr d-electron states localized below the conduction band minimum of anodized Al2O3.

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Comparison of Pulsed Electron Deposition and Pulsed Laser Deposition of selected materials

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Organisations: Department of Photonics Engineering, Department of Micro- and Nanotechnology, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Photovoltaic Materials and Systems, Consiglio Nazionale delle Ricerche, Technical University of Denmark
Contributors: Ettlinger, R. B., Pattini, F., Rampino, S., Cazzaniga, A. C., Crovetto, A., Bosco, E., Gilioli, E., Hansen, O., Schou, J.
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Depth-dependent composition of sputtered ZnO:Al

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Dielectric function and double absorption onset of monoclinic Cu2SnS3: Origin of experimental features explained by first-principles calculations

In this work, we determine experimentally the dielectric function of monoclinic Cu2SnS3 (CTS) by spectroscopic ellipsometry from 0.7 to 5.9 eV. An experimental approach is proposed to overcome the challenges of extracting the dielectric function of Cu2SnS3 when grown on a glass/Mo substrate, as relevant for photovoltaic applications. The ellipsometry measurement reveals a double absorption onset at 0.91 eV and 0.99 eV. Importantly, we demonstrate that calculation within the density functional theory (DFT) confirms this double onset only when a very dense k-mesh is used to reveal fine details in the electronic structure, and this can explain why it has not been reported in earlier calculated spectra. We can now show that the double onset originates from optical transitions at the Γ-point from three energetically close-lying valence bands to a single conduction band. Thus, structural imperfection, like secondary phases, is not needed to explain such an absorption spectrum. Finally, we show that the absorption coefficient of CTS is particularly large in the near-band gap spectral region when compared to similar photovoltaic materials.

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Publication status: Published
Formation of copper tin sulfide films by pulsed laser deposition at 248 and 355 nm

The influence of the laser wavelength on the deposition of copper tin sulfide (CTS) and SnS-rich CTS with a 248-nm KrF excimer laser (pulse length τ = 20 ns) and a 355-nm frequency-tripled Nd:YAG laser (τ = 6 ns) was investigated. A comparative study of the two UV wavelengths shows that the CTS film growth rate per pulse was three to four times lower with the 248-nm laser than the 355-nm laser. SnS-rich CTS is more efficiently ablated than pure CTS. Films deposited at high fluence have submicron and micrometer size droplets, and the size and area density of the droplets do not vary significantly from 248 to 355 nm deposition. Irradiation at low fluence resulted in a non-stoichiometric material transfer with significant Cu deficiency in the as-deposited films. We discuss the transition from a non-stoichiometric material transfer at low fluence to a nearly stoichiometric ablation at high fluence based on a transition from a dominant evaporation regime to an ablation regime.

General information

Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Micro- and Nanotechnology, Silicon Microtechnology, Department of Energy Conversion and Storage, Electrofunctional materials, Technical University of Denmark
Contributors: Ettlinger, R. B., Crovetto, A., Canulescu, S., Cazzaniga, A. C., Ravnkilde, L., Youngman, T. H., Hansen, O., Pryds, N., Schou, J.
Number of pages: 10
Pages: 1-10
Publication date: 2016
Peer-reviewed: Yes

Publication information

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Ratings:
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.52 SJR 0.508 SNIP 0.744
Web of Science (2016): Impact factor 1.455
Web of Science (2016): Indexed yes
Original language: English
Keywords: PLD
Electronic versions:
Large CZTS Nanoparticles Synthesized by Hot-injection for Thin Film Solar Cells

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Department of Energy Conversion and Storage, Imaging and Structural Analysis, Optical Microsensors and Micromaterials, Nanyang Technological University
Contributors: Engberg, S. L. J., Mirbagheri, N., Simonsen, S. B., Lam, Y. M., Schou, J.
Publication date: 2016
Peer-reviewed: Yes
Event: Abstract from 2016 E-MRS Spring Meeting and Exhibit, Lille, France.

Lattice-matched Cu$_2$ZnSnS$_4$/CeO$_2$ solar cell with open circuit voltage boost

We report a reproducible enhancement of the open circuit voltage in Cu$_2$ZnSnS$_4$ solar cells by introduction of a very thin CeO$_2$ interlayer between the Cu$_2$ZnSnS$_4$ absorber and the conventional CdS buffer. CeO$_2$, a non-toxic earth-abundant compound, has a nearly optimal band alignment with Cu$_2$ZnSnS$_4$ and the two materials are lattice-matched within 0.4%. This makes it possible to achieve an epitaxial interface when growing CeO$_2$ by chemical bath deposition at temperatures as low as 50 °C. The open circuit voltage improvement is then attributed to a decrease in the interface recombination rate through formation of a high-quality heterointerface.

**Publication information**
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Ratings:
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.67 SJR 1.673 SNIP 1.249
Web of Science (2016): Impact factor 3.411
Web of Science (2016): Indexed yes
Original language: English
Electronic versions:
CeO$_2$_manuscript_revised.pdf
1.4971779.pdf. Embargo ended: 06/12/2017
DOIs:
10.1063/1.4971779
Source: PublicationPreSubmission
Source-ID: 127575850

Material transfer in Pulsed Laser Deposition of the solar cell materials Cu$_2$SnS$_3$ and Cu$_2$ZnSnS$_4$.

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, DTU Danchip, Department of Energy
Novel field test design for acquisition of DC and AC parameters during service

Being able to monitor early signs of PV module degradation, is needed to ensure stable power production throughout the service life of a PV installation. Recently, impedance spectroscopy is proven to be a useful tool for detection of the presence and location of significant errors, and may have potential for more. In this work we describe a field test design where the modules are operating at their maximum power point, and via relays is switched out one by one for acquisition of an IV curve and an impedance spectrum. Some of the modules involved will undergo stimuli to accelerate certain degradation mechanisms, and fitting parameters extracted from the field test will be correlated with irradiance and compared to similar parameters of virgin modules of same kind, and conventional laboratory measurements on the same modules. The proposed method will provide data for exploration of early degradation signs using impedance measurements.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Optical Microsensors and Micromaterials, EmaZys ApS, Aalborg University
Contributors: Thorsteinsson, S., Poulsen, P. B., Schou, J., Andersen, A. R., Basu, R., Sera, D., Spataru, S., Oprea, M.
Pages: 1608-1610
Publication date: 2016

Host publication information
Title of host publication: Proceedings of IEEE 43rd Photovoltaic Specialist Conference 2016
Publisher: IEEE
ISBN (Print): 978-1-5090-2724-8
Electronic versions:
PVSC_43_Field_Test_abstract_may_2016.pdf
07749892.pdf
DOI: 10.1109/PVSC.2016.7749892
Source: PublicationPreSubmission
Source-ID: 124998306
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2016
peer-review

Novel field test design for acquisition of DC and AC parameters during service

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Optical Microsensors and Micromaterials, EmaZys ApS, Aalborg University
Contributors: Thorsteínsson, S., Poulsen, P. B., Schou, J., Andersen, A. R., Basu, R., Sera, D., Spataru, S., Oprea, M.
Number of pages: 1
Publication date: 2016
Peer-reviewed: Yes
Electronic versions:
Poster_IEEE_2016_Field_test.pdf
Source: PublicationPreSubmission
Source-ID: 124999841
Research output: Contribution to conference – Annual report year: 2016
peer-review

On performance limitations and property correlations of Al-doped ZnO deposited by radio-frequency sputtering: Paper

The electrical properties of RF-sputtered Al-doped ZnO are often spatially inhomogeneous and strongly dependent on deposition parameters. In this work, we study the mechanisms that limit the minimum resistivity achievable under different
deposition regimes. In a low- and intermediate-pressure regime, we find a generalized dependence of the electrical properties, grain size, texture, and Al content on compressive stress, regardless of sputtering pressure or position on the substrate. In a high-pressure regime, a porous microstructure limits the achievable resistivity and causes it to increase over time as well. The primary cause of inhomogeneity in the electrical properties is identified as energetic particle bombardment. Inhomogeneity in oxygen content is also observed, but its effect on the electrical properties is small and limited to the carrier mobility.

**General information**

**Publication status:** Published

**Organisations:** Department of Micro- and Nanotechnology, Silicon Microtechnology, Department of Energy Conversion and Storage, Fundamental Electrochemistry, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Physics, Experimental Surface and Nanomaterials Physics, Technical University of Denmark

**Contributors:** Crovetto, A., Ottsen, T. S., Stamate, E., Kjær, D., Schou, J., Hansen, O.

**Number of pages:** 11

**Publication date:** 2016

**Peer-reviewed:** Yes

**Publication information**

**Journal:** Journal of Physics D: Applied Physics

**Volume:** 49

**Issue number:** 29

**Article number:** 295101

**ISSN (Print):** 0022-3727

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- Scopus rating (2016): CiteScore 2.07 SJR 1.135 SNIP 1.122
- Web of Science (2016): Impact factor 2.588
- Web of Science (2016): Indexed yes

**Original language:** English

**Keywords:** ZnO, AZO, Sputtering, Stress, Correlations, Line profile analysis, Bombardment

**Electronic versions:**

AZO_distributions_postprint.pdf. Embargo ended: 24/06/2017

**DOIs:**

10.1088/0022-3727/49/29/295101

**Source:** FindIt

**Source-ID:** 277732739

**Research output:** Contribution to journal › Journal article – Annual report year: 2016 › Research › peer-review

**Optical and electrical properties of polycrystalline and amorphous Al-Ti thin films**

The structural, optical, and transport properties of sputter-deposited Al-Ti thin films have been investigated as a function of Ti alloying with a concentration ranging from 2% to 46%. The optical reflectivity of Al-Ti films at visible and near-infrared wavelengths decreases with increasing Ti content. X-ray absorption fine structure measurements reveal that the atomic ordering around Ti atoms increases with increasing Ti content up to 20% and then decreases as a result of a transition from a polycrystalline to amorphous structure. The transport properties of the Al-Ti films are influenced by electron scattering at the grain boundaries in the case of polycrystalline films and static defects, such as antisite effects and vacancies in the case of the amorphous alloys. The combination of Ti having a real refractive index (n) comparable with the extinction coefficient (k) and Al with n much smaller than k allows us to explore the parameter space for the free-electron behavior in transition metal-Al alloys. The free electron model, applied for the polycrystalline Al-Ti films with Ti content up to 20%, leads to an optical reflectance at near infrared wavelengths that scales linearly with the square root of the electrical resistivity.

**General information**

**Publication status:** Published

**Organisations:** Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Mechanical Engineering, Materials and Surface Engineering, Risø National Laboratory for Sustainable Energy, Paul Scherrer Institute, Danish Technological Institute

**Contributors:** Canulescu, S., Borca, C. N., Rechendorff, K., Daviðsdóttir, S., Pagh Almtoft, K., Nielsen, L. P., Schou, J.

**Number of pages:** 5

**Publication date:** 2016

**Peer-reviewed:** Yes

**Publication information**

**Journal:** Applied Physics Letters
Pulsed laser deposition of Cu$_2$ZnSnS$_4$ absorber layers assisted by a reactive sulfur beam for solar cells

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems, Department of Energy Conversion and Storage, Technical University of Denmark
Number of pages: 1
Publication date: 2016
Peer-reviewed: Yes
Event: Abstract from Annual Meeting of the Danish Physical Society, Middelfart, Denmark.
Electronic versions:
Joan_Abtract_Danish_Physic_Society.pdf
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2017 › Research › peer-review

Pulsed Laser Deposition (PLD) of the Solar Cell Materials CZTS and CTS

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Photovoltaic Materials and Systems, DTU Danchip, Department of Physics, Experimental Surface and Nanomaterials Physics, Silicon Microtechnology, Department of Micro- and Nanotechnology, Department of Energy Conversion and Storage, Electrofunctional materials
Number of pages: 1
Publication date: 2016
Peer-reviewed: Yes
Event: Abstract from 2016 MRS Spring Meeting & Exhibit, Phoenix, United States.
Electronic versions:
Abstract_MRS_2016.pdf
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2017 › Research › peer-review

Synthesis of ligand-free CZTS nanoparticles via a facile hot injection route
Single-phase, ligand-free Cu$_2$ZnSnS$_4$ (CZTS) nanoparticles that can be dispersed in polar solvents are desirable for thin film solar cell fabrication, since water can be used as the solvent for the nanoparticle ink. In this work, ligand-free nanoparticles were synthesized using a simple hot injection method and the precursor concentration in the reaction medium was tuned to control the final product. The as-synthesized nanoparticles were characterized using various techniques, and were found to have a near-stoichiometric composition and a phase-pure kesterite crystal structure. No secondary phases were detected with Raman spectroscopy or scanning transmission electron microscopy energy dispersive x-ray spectroscopy. Furthermore, high resolution transmission electron microscopy showed large-sized nanoparticles with an average diameter of 23 nm ± 11 nm. This approach avoids all organic materials and toxic solvents that otherwise could hinder grain growth and limit the deposition techniques. In addition the synthesis route presented here results in nanoparticles of a large size compared to other ligand-free CZTS nanoparticles, due to the high boiling
point of the solvents selected. Large particle size in CZTS nanoparticle solar cells may lead to a promising device performance. The results obtained demonstrate the suitability of the synthesized nanoparticles for application in low cost thin film solar cells.

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Energy Conversion and Storage, Mixed Conductors, Department of Micro- and Nanotechnology, Silicon Microtechnology, Experimental Surface and Nanomaterials Physics, Center for Individual Nanoparticle Functionality, Nanyang Technological University
Number of pages: 8
Publication date: 2016
Peer-reviewed: Yes

**Publication information**
Journal: Nanotechnology
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Article number: 185603
ISSN (Print): 0957-4484
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Scopus rating (2016): CiteScore 2.87 SJR 1.339 SNIP 0.945
Web of Science (2016): Indexed yes
Original language: English
Keywords: CZTS, Large nanoparticles, Ligand-free, Synthesis
Electronic versions:
Synthesis_of_ligand_free_CZTS_nanoparticles_via_a_facile_hot_injection_route.pdf. Embargo ended: 23/03/2017
DOIs:
10.1088/0957-4484/27/18/185603
Source: FindIt
Source-ID: 277363105
Research output: Contribution to journal → Journal article – Annual report year: 2016 → Research → peer-review

**Thermal analysis of CZTS nanoparticles and inks**

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Department of Energy Conversion and Storage, Mixed Conductors, Department of Micro- and Nanotechnology, Silicon Microtechnology, Experimental Surface and Nanomaterials Physics, Optical Microsensors and Micromaterials, Nanyang Technological University
Publication date: 2016
Peer-reviewed: No
Event: Poster session presented at 2016 E-MRS Spring Meeting and Exhibit, Lille, France.
Research output: Contribution to conference → Poster – Annual report year: 2016 → Research

**Chalcogenide compounds made by pulsed laser deposition at 355 and 248 nm**
Thin films made by pulsed laser deposition may differ depending on the laser wavelength. We compared ZnS, Cu2SnS3 and a target enriched with SnS relative to Cu2SnS3 using 355 nm and 248 nm lasers

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Micro- and Nanotechnology, Silicon Microtechnology, DTU Danchip, Department of Energy Conversion and Storage, Electrofunctional materials, Technical University of Denmark
Contributors: Ettlinger, R. B., Cazzaniga, A. C., Crovetto, A., Ravnkilde, L., Youngman, T. H., Pryds, N., Schou, J.
Number of pages: 1
Publication date: 2015
Peer-reviewed: Yes
Event: Poster session presented at 2015 E-MRS Spring Meeting, Lille, France.
Large CZTS Nanoparticles Synthesized by Hot-Injection for Thin Film Solar Cells.

The kesterite material, Cu2ZnSn(SxSe1-x)4 (CZTS), shows great promise as the absorber layer for future thin film solar cells. Solution processing allows for comparatively fast and inexpensive fabrication, and holds the record efficiency in the kesterite family. However, for nanoparticle (NP) solution processing to be a feasible fabrication route, the amount of carbon in the film has to be limited. In our work, we try to limit the organic material in the film by synthesizing larger NPs. Larger particles can be obtained by longer reaction durations, slower reaction rates of the precursors, or slower injection rates of the sulfur/selenium precursors. In our group, we have synthesized NPs larger than 200 nm by controlling the monomer concentration during growth. Transmission electron microscopy (TEM) allows us to image the NPs and determine their individual composition. Size-selective methods can be carried out in order to isolate the desired particle sizes, and films will be deposited through wet-chemical means. Mixing large NPs with small NPs can also improve the film-quality as a result of densification at the optimal packing density. The films are characterized by scanning electron microscopy (SEM) as well as other surface characterization techniques. Our first photovoltaic device consisting of soda lime glass/Mo/CZTS/CdS/ZnO has been built from doctor blading of approx. 20 nm Cu2ZnSnS4 NPs in octanethiol, and annealed in Se-atmosphere. It had an efficiency of 1.4%.

Morphology of Copper Tin Sulfide Films Grown by Pulsed Laser Deposition at 248 and 355 nm

Thin films solar cells based on Cu2ZnSnS4 (CZTS) as absorber layer have seen a rapid development leading to a world record of 8.8% [1]. However, other p-type semiconductors with fewer elements and reduced complexity compared to CZTS are also available, such as ternary Cu–Sn–S systems, i.e. Cu2SnS3 (CTS) [2].
Optical properties and surface characterization of pulsed laser-deposited Cu2ZnSnS4 by spectroscopic ellipsometry

Cu2ZnSnS4 films prepared by pulsed laser deposition at different temperatures are characterized by spectroscopic ellipsometry. The focus is on confirming results from direct measurement techniques, by finding appropriate models of the surface overlayer for data fitting, and extracting the dielectric function of the films. It is found that the surface overlayer changes with film thickness and deposition temperature. Adopting different ellipsometry measurements and modeling strategies for each film, dielectric functions are extracted and compared. As the deposition temperature is increased, the dielectric functions exhibit additional critical points related to optical transitions in the material other than absorption across the fundamental band gap. In the case of a thin film <200 nm thick, surface features observed by scanning electron microscopy and atomic force microscopy are accurately reproduced by ellipsometry data fitting. [All rights reserved Elsevier].

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Silicon Microtechnology, Department of Photonics Engineering, Optical Microsensors and Micromaterials
Contributors: Crovetto, A., Cazzaniga, A. C., Ettlinger, R. B., Schou, J., Hansen, O.
Pages: 203-207
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Thin Solid Films
Volume: 582
ISSN (Print): 0040-6090
Ratings:
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.84 SJR 0.726 SNIP 0.942
Web of Science (2015): Impact factor 1.761
Web of Science (2015): Indexed yes
Original language: English
Keywords: Copper zinc tin sulfide, Ellipsometry, Dielectric function, Optical properties, Pulsed laser deposition, Raman spectroscopy
Electronic versions:
cro_CZTS_ellipsometry_thin_solid_films_postprint.pdf
DOI:
10.1016/j.tsf.2014.11.075
Source: PublicationPreSubmission
Source-ID: 103565395
Research output: Contribution to journal > Journal article – Annual report year: 2015 > Research > peer-review

Optical properties of photovoltaic Cu2SnS3 films deposited on soda lime glass and Mo-coated glass

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Silicon Microtechnology, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Physics, Experimental Surface and Nanomaterials Physics
Contributors: Crovetto, A., Ettlinger, R. B., Schou, J., Hansen, O.
Number of pages: 1
Publication date: 2015
Peer-reviewed: Yes
Electronic versions:
cro_Poster_EMRS_2015.pdf
Source: PublicationPreSubmission
Source-ID: 114601561
Research output: Contribution to conference > Poster – Annual report year: 2015 > Research > peer-review

Optical properties of pulsed laser-deposited Cu2SnS3 films for photovoltaics

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Silicon Microtechnology, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Physics, Experimental Surface and Nanomaterials Physics
Optimized Packing Density of Large CZTS Nanoparticles Synthesized by Hot-injection for Thin Film Solar Cells.

The absorbing kesterite material, Cu2ZnSn(SxSe1-x)4 (CZTS), is very promising for future thin film solar cells. The material is non-toxic, the elements abundant, and it has a high absorption coefficient. These properties make CZTS a potential candidate also for large-scale applications. Here, solution processing allows for comparatively fast and inexpensive fabrication, and also holds the record efficiency in the kesterite family. Unfortunately, the record cell is deposited with a highly toxic solvent, hydrazine. This toxic solvent can be avoided through the nanocrystal ink approach, but to maintain good control of the nanocrystal formation during the synthesis, it is necessary to have organic ligands on the surface of the particles. These ligands are often long alkyl chains that potentially limit the quality of the film and degrade its electronic properties. For nanocrystal solution processing to be a feasible fabrication route in the future, the amount of carbon in the film has to be limited. Today, several methods are employed in order to surpass this barrier, for example ligand exchange. A successful ligand exchange was carried out by Carrete et al. [1], where they replace the organic ligands by an antimony salt; however the efficiency is 1.4% for a cell annealed in Se-atmosphere. In our work, we try to limit the carbon amount in the film by synthesizing larger nanoparticles. The bigger the particles are the smaller surface-to-volume ratio they have, which might decrease the amount of ligands necessary to stabilize the particles in solution. Today, CZTS nanoparticles synthesized through the so-called hot-injection method vary between 2 nm and 60 nm in diameter. In our group, we have synthesized particles larger than 200 nm. Transmission electron microscopy (TEM) allows us to image the faceted/hexagonal nanoparticles and determine their individual composition. Densification of the film will also improve the film-quality. The optimal packing density will be calculated, and size-selective methods can be carried out in order to try to isolate the desired particle sizes. Films will be deposited through wet-chemical means, e.g. doctor-blading, spin-coating and spray-coating. The annealing time required can be minimized when starting with larger nanoparticles, and thus the elemental losses associated with annealing at higher temperature reduced. The films are characterized by TEM and scanning electron microscopy (SEM) as well as other surface characterization techniques. A photovoltaic device of the structure soda lime glass (SLG)/Mo/CZTS/CdS/ZnO is built, and the power conversion efficiency will be determined. Our first CZTS solar cell made from doctor blading of approx. 20 nm Cu2ZnSnS4 nanoparticles in octanethiol, annealed in Se-atmosphere, had an efficiency of 1.4%.

Pulsed Electron Deposition of CZTS

Optimized_Packing_Density_of_Large_CZTS_Nanoparticles_for_Thin_Film_Solar_Cells.pdf

Research output: Contribution to conference › Poster – Annual report year: 2015 › Research › peer-review
Pulsed laser deposition from ZnS and Cu_2SnS_3 multicomponent targets

Thin films of ZnS and Cu_2SnS_3 have been produced by pulsed laser deposition (PLD), the latter for the first time. The effect of fluence and deposition temperature on the structure and the transmission spectra as well as the deposition rate has been investigated, as has the stoichiometry of the films transferred from target to substrate. Elemental analysis by energy dispersive X-ray spectroscopy indicates lower S and Sn content in Cu_2SnS_3 films produced at higher fluence, whereas this trend is not seen in ZnS. The deposition rate of the compound materials measured in atoms per pulse is considerably larger than that of the individual metals, Zn, Cu, and Sn.

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Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Ettlinger, R. B., Cazzaniga, A. C., Canulescu, S., Pryds, N., Schou, J.
Pages: 385-390
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Applied Surface Science
Volume: 336
ISSN (Print): 0169-4332
Ratings:
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.13 SJR 0.93 SNIP 1.236
Web of Science (2015): Impact factor 3.15
Web of Science (2015): Indexed yes
Original language: English
Keywords: PLD, Pulsed laser deposition, Zinc sulfide, Copper tin sulfide, ZnSCu2SnS3
Electronic versions:
ASS_EMRS14_RBEttlingeretal_RevisedManuscript_withProofCorrections_ForOrbit.pdf. Embargo ended: 06/01/2017
DOIs:
10.1016/j.apsusc.2014.12.165
Source: PublicationPreSubmission
Source-ID: 105562955
Research output: Contribution to journal › Journal article – Annual report year: 2015 › Research › peer-review

Pulsed laser deposition (PLD) of the solar cell materials CZTS and CTS

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Micro- and Nanotechnology, Silicon Microtechnology
Contributors: Cazzaniga, A. C., Engberg, S., Ettlinger, R. B., Crovetto, A., Schou, J.
Number of pages: 1
Publication date: 2015

Host publication information
Title of host publication: Book of Abstracts. DTU's Sustain Conference 2015
Place of publication: Lyngby
Publisher: Technical University of Denmark (DTU)
Article number: E-36
Electronic versions:
E36_DTU_Sustain_2015.pdf

Bibliographical note
Poster presentation
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2015 › Research › peer-review
Simulation of reflectance from white-anodised aluminium surfaces using polyurethane–TiO2 composite coatings

Theoretical calculations and experimental studies were carried out on polyurethane (PU)–TiO2 composite coatings on bright and matte aluminium surfaces with an aim to understand and tailor the light scattering from particles incorporated into an anodised layer for designing the optical appearance of anodised surfaces. PU matrix was selected for its matching refractive-index (n = 1.7) with anodic alumina layer. Three different TiO2 particle size distributions were dispersed in PU and spin coated onto bright high-gloss and matte caustic-etched aluminium substrates. The reflectance spectra of coated surfaces in the visible region were analysed using an integrating sphere-spectrophotometer. Data showed that the coated surfaces have a high diffuse reflectance due to the multiple scattering from TiO2 particles and the coating–substrate interface. The diffuse reflectance spectra of the coated surfaces varied weakly with TiO2 particle concentration and reached a steady state value at 1 wt% but were dependent on the substrate type used. Using Kubelka–Munk two-stream model, the scattering and absorption coefficient of TiO2 in PU was predicted. The studies presented in this paper provide insight into generating bright white-anodised aluminium surfaces based on aluminium–TiO2 composites.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Materials and Surface Engineering, Solid Mechanics, Department of Photonics Engineering, Optical Microsensors and Micromaterials
Contributors: Gudla, V. C., Johansen, V. E., Ambat, R., Canulescu, S., Schou, J.
Number of pages: 11
Pages: 4565-4575
Publication date: 2015
Peer-reviewed: Yes
Early online date: 2015

Publication information
Journal: Journal of Materials Science
Volume: 50
Issue number: 13
ISSN (Print): 0022-2461
Ratings:
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.36 SJR 0.836 SNIP 1.052
Web of Science (2015): Impact factor 2.302
Web of Science (2015): Indexed yes
Original language: English
Keywords: Alumina, Aluminum, Interfaces (materials), Light scattering, Particle size, Polyurethanes, Reflection, Refractive index, Substrates, Surface scattering, Diffuse reflectance spectrum, Integrating spheres, Optical appearances, Particle concentrations, Reflectance spectrum, Scattering and absorption, Steady-state values, Theoretical calculations, Composite coatings
DOIs:
10.1007/s10853-015-9005-1
Source: Findit
Source-ID: 274694368
Research output: Contribution to journal › Journal article – Annual report year: 2015 › Research › peer-review


General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Micro- and Nanotechnology, Silicon Microtechnology, Experimental Surface and Nanomaterials Physics, Technical University of Denmark
Contributors: Engberg, S., Mirbagheri, N., Crovetto, A., Bosco, E., Hansen, O., Schou, J.
Number of pages: 1
Publication date: 2015

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Title of host publication: Book of Abstracts. DTU's Sustain Conference 2015
Place of publication: Lyngby
Publisher: Technical University of Denmark (DTU)
Article number: E-29
Electronic versions:
Synthesis of large CZTSe nanoparticles through a two-step hot-injection method

Grain boundaries in Cu2ZnSn(SxSe1-x)4 (CZTSSe) thin films act as a defect that reduces the mobility of the charges. Hence one way to improve the performance of these thin film solar cells is to increase the grain size in the films. Most of the synthesis methods published so far for CZTSSe colloidal nanoparticles can achieve a general size distribution range from 5-20 nm. This is where the particle size will saturate for most recipes used today. The assumption is that uniform size distribution is good for grain growth in a thin film but based on packing considerations, an optimal mixture of large and small nanoparticles that can easily be dispersed in non-polar solvents could be better. Cu2ZnSnS4 (CZTS) and Cu2ZnSnSe4 (CZTSe) nanoparticles are synthesized using the hot-injection method with oleylamine, trioctylphosphine, and hexadecane as the solvents. Selenium (Se) is introduced in the liquid phase to encourage grain growth – liquid selenization. This eliminates the need to anneal the film in a Se-containing atmosphere and allows for a more environmentally friendly process with lower temperatures and shorter annealing times. We show that a good dispersion can be achieved by choosing suitable surfactant molecules, solvents and precursors, and by controlling the initial monomer concentration. Additionally, we show how our new synthesis route can be utilized to achieve targeted ratios of CZTS and CZTSe nanoparticles to be used for mixed-phase CZTSSe thin films.

Thin film CZTS solar cells made by Pulsed Electron Deposition

General information

Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Chinese Academy of Sciences, Nanyang Technological University
Contributors: Engberg, S. L. J., Li, Z., Lek, J. Y., Lam, Y. M., Schou, J.
Pages: 96593-96600
Publication date: 2015
Peer-reviewed: Yes

Publication Information

Journal: RSC Advances
Volume: 5
ISSN (Print): 2046-2069
Ratings:
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.42 SJR 0.99 SNIP 0.812
Web of Science (2015): Impact factor 3.289
Web of Science (2015): Indexed yes
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Thin films of CZTS prepared by Pulsed Laser Deposition

Use 200x less material! Solar cells based on the Cu$_{2}$ZnSnS$_{4}$ compound

ZnS top layer for enhancement of the crystallinity of CZTS absorber during the annealing
Annealing in Sulfur of Doctor Bladed CZTS Nanoparticles

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Micro- and Nanotechnology, Silicon Microtechnology, Technical University of Denmark
Contributors: Engberg, S. L. J., Crovetto, A., Bosco, E., Rasmussen, P., Hansen, O., Schou, J.
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Anodization and Optical Appearance of Sputter Deposited Al-Zr Coatings

Anodized Al alloy components are extensively used in various applications like architectural, decorative and automobiles for corrosion protection and/or decorative optical appearance. However, tailoring the anodized layer for specific optical appearance is limited due to variation in composition and microstructure of the commercial alloys, and even more difficult with recycled alloys. Sputter coating methods promise to control the chemical composition of the Al alloy surfaces and eventually modify the microstructure of the surfaces with heat treatments thus enabling the freedom on the substrate quality. This paper evaluates the use of magnetron sputtered Al-Zr coatings on Al combined with heat treatment and anodizing for obtaining required optical properties. Metallurgical and optical characterization was carried out to investigate the effect of coating microstructure and anodizing parameters on appearance of the anodized layer. The microstructure of the coating is found to influence the appearance of anodized layer owing to the presence of completely or partially dissolved second phases during anodizing process. Oxidation status of the second phase particles in the coatings affected the light absorption and scattering phenomenon there by imparting different appearances to the anodized alloy surfaces.

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Organisations: Department of Mechanical Engineering, Materials and Surface Engineering, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Centre National de la Recherche Scientifique, Danish Technological Institute
Contributors: Gudla, V. C., Canulescu, S., Shabadi, R., Rechendorff, K., Schou, J., Ambat, R.
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Appearance of anodised aluminium: Effect of alloy composition and prior surface finish

Effect of alloy composition and prior surface finish on the optical appearance of the anodised layer on aluminium alloys was investigated. Four commercial alloys namely AA1050, Peraluman 706, AA5754, and AA6082 were used for the investigation. Microstructure and surface morphology of the substrate prior to anodising were analysed using scanning electron microscopy and atomic force microscopy. The optical appearance of the anodised surface with and without sealing was investigated using a photography setup, photospectrometry and bidirectional reflectance distribution function.

It was found that the roughness of the as-etched surface increases with the degree of alloying due to second phase particles making the reflection more diffused, and that the as-etched surface morphology is similar to the oxide–substrate interface after anodising. Proper polishing is achieved on hard alloys and the glossy appearance was kept for alloys of high purity. Sealing made the specular reflection of the mechanically polished specimens more distinct.

Band gap structure modification of amorphous anodic Al oxide film by Ti-alloying

The band structure of pure and Ti-alloyed anodic aluminum oxide has been examined as a function of Ti concentration varying from 2 to 20 at.%. The band gap energy of Ti-alloyed anodic Al oxide decreases with increasing Ti concentration. X-ray absorption spectroscopy reveals that Ti atoms are not located in a TiO2 unit in the oxide layer, but rather in a mixed Ti-Al oxide layer. The optical band gap energy of the anodic oxide layers was determined by vacuum ultraviolet spectroscopy in the energy range from 4.1 to 9.2 eV (300–135 nm). The results indicate that amorphous anodic Al2O3 has a direct band gap of 7.3 eV, which is about ~1.4 eV lower than its crystalline counterpart (single-crystal Al2O3). Upon Ti-alloying, extra bands appear within the band gap of amorphous Al2O3, mainly caused by Ti 3d orbitals localized at the Ti site.
Controlling the Ratio of CZTS to CZTSe Nanocrystals by Hot Injection of Selenium.
In this work, we present a wetchemical method to prepare CZTS and CZTSe nanoparticles in controlled proportions which will result in a film with desired Se content.

Cu2SnS3 for solar cells produced by pulsed laser deposition

CZTS - A new environmentally friendly material for thin-film solar cells
Electrical characterization of sputtered ZnO:Al films with microprobe technique

Determination of sheet resistance, carrier density and mobility in transparent conductive films is typically done with the van der Pauw technique, a rather destructive macroscopic method requiring special sample geometry or dedicated sample preparation. In this work, a miniaturized non-destructive four-point measurement system developed at CAPRES A/S is employed to evaluate the electrical properties of transparent conductive ZnO:Al films, with high spatial resolution, accuracy, and speed of measurement. n-type ZnO:Al films are deposited on fused silica substrates by DC magnetron sputtering using a ZnO/Al2O3 ceramic target (98/2 wt%). The process temperature is varied between room temperature and 250°C. Process pressure and oxygen content in the Ar-based sputtering atmosphere are varied in the range 3-8 mtorr and 0-2% respectively. Resulting film thicknesses are between 80 and 400 nm. Films deposited at room temperature are characterized before and after an additional annealing step in air, whereas films deposited at elevated temperatures are characterized as deposited. In this way the effect of deposition temperature is compared to the effect of temperature and duration of the post-deposition annealing step. We focus in particular on the determination of electrical properties by means of a semi-automatic system utilizing a microscopic Hall-probe with collinear cantilever electrodes placed parallel to, and within a few μm from a sample edge. By combination of multiple 4-point measurements obtained in one location the electrical properties are extracted and the resulting measurement errors are below 1% for sheet resistance and 4% for carrier density and Hall mobility. Such a setup eliminates the need for ad-hoc sample geometries and allows line scans along a cleaved edge of the sample for determination of the electrical properties of interest with a spatial resolution below 100 μm. This can be useful in characterizing spatial electrical non-uniformities in the films, often arising in correspondence to the erosion pattern on the sputtering target. Another advantage is that the film is only marginally affected by the contact with the micro-probes. The electrical properties measured by the microprobe system are compared to ordinary four-point probe measurements and to spectroscopic ellipsometry fits in the spectral region of free-carrier absorption. To complement the electrical analysis, optical properties are characterized by spectroscopic ellipsometry and UV-vis-NIR transmission spectroscopy; composition is evaluated by X-ray photoemission spectroscopy (XPS); grain size and morphology are characterized by scanning electron microscopy (SEM); and surface topography is characterized by atomic force microscopy (AFM). The most appropriate choice of deposition and post-deposition process parameters is discussed for application of ZnO:Al films as window layers in thin-film chalcogenide solar cells, where film resistivity should be minimized while maintaining a high transmittance in the spectral region of strong solar irradiance.

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Electrical property mapping of ZnO:Al films with micro four-point-probe technique

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Organisations: Department of Micro- and Nanotechnology, Silicon Microtechnology, Nanointegration, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Department of Physics, Experimental Surface and Nanomaterials Physics
Contributors: Crovetto, A., Kjær, D., Petersen, D. H., Schou, J., Hansen, O.
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Nanosecond laser ablation and deposition of silver, copper, zinc and tin

Nanosecond pulsed laser deposition of different metals (Ag, Cu, Sn, Zn) has been studied in high vacuum at a laser wavelength of 355 nm and pulse length of 6 ns. The deposition rate is roughly similar for Sn, Cu and Ag, which have comparable cohesive energies, and much higher for the deposition of Zn which has a low cohesive energy. The deposition rate for all metals is strongly correlated with the total ablation yield, i.e., the total mass ablated per pulse, reported in the literature except for Sn, for which the deposition rate is low, but the total ablation yield is high. This may be explained by the continuous erosion by nanoparticles during deposition of the Sn films which appear to have a much rougher surface than those of the other metals studied in the present work.

Optical properties and secondary phase identification in PLD-grown Cu2ZnSnS4 for thin-film photovoltaics

One major hurdle to production of Cu2ZnSnS4 (CZTS) thin films for photovoltaic applications is the narrow phase diagram region in which CZTS is expected as a single phase at most temperatures of interest. Unwanted secondary phases such as ZnS, CuxSnSx+1 and SnxSy are thus likely to be included in CZTS films independently of the chosen deposition technique. Identification by standard X-ray diffraction (XRD) of some of those phases is challenging since their diffraction peaks overlap with CZTS peaks. In this study we employ Raman spectroscopy to determine which secondary phases are incorporated in CZTS films grown by pulsed laser deposition (PLD) for a range of laser energies and substrate conditions.
temperatures. Film properties, such as absorption coefficient, refraction index and thickness are extracted from ellipsometry measurements. The same set of properties is evaluated for chemical-bath-deposited CdS due to its important use as a buffer layer in chalcogenide solar cells. The validity of the optical model used to derive optical constants by ellipsometry is discussed in relation to results from direct measurement methods such as UV-visible spectroscopy, Scanning Electron Microscopy (SEM) and profiling. Identification of secondary phases in CZTS films under different PLD process parameters and their effect on optical constants is an important factor in optimizing the deposition process for production of high-efficiency CZTS solar cells.

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Optical properties and surface characterization of PLD-grown Cu$_2$ZnSnS$_4$ by spectroscopic ellipsometry

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Production of top and bottom layers for CZTS-based solar cells

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Contributors: Crovetto, A., Schou, J., Hansen, O.
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Pulsed laser deposition of Cu-Sn-S for thin film solar cells
Thin films of copper tin sulfide were deposited from a target of the stoichiometry Cu:Sn:S $\sim$1:2:3 using pulsed laser deposition (PLD). Annealing with S powder resulted in films close to the desired Cu$_2$SnS$_3$ stoichiometry although the films remained Sn rich. X-ray diffraction showed that the final films contained both cubic-phase Cu$_2$SnS$_3$ and orthorhombic-phase SnS

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Pulsed laser deposition of ZnS and Cu2SnS3 multicomponent targets

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Pulsed laser deposition (PLD) of dielectrics – is femtosecond laser ablation better than nanosecond ablation

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Contributors: Schou, J., Canulescu, S.
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Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2014 › Research peer-review

Study of Grain Growth of CZTS Nanoparticles Annealed in Sulfur Atmosphere

The kesterite material, Cu2ZnSn(SxSe1-x)4 (CZTS), is very promising as absorber material in future thin filmsolar cells. The elements are abundant, the material has a high absorption coefficient, and the pure sulfide CZTS is non-toxic. These properties make CZTS a potential candidate also for large-scale applications. Here, solution processing allows for comparatively fast and inexpensive fabrication and solution processing alsoholds the record efficiency in the kesterite family, however for the selenized compound. The current challenges are, (1) that the high carbon content in nanoparticle thin films is one of the main limitations for this approach, and (2) that grain boundaries and defects are believed to be a site for recombination that limits the efficiency. Annealing in vacuum and/or a nitrogen atmosphere facilitates grain growth and improves the electronic properties. Conventionally selenization (annealing in selenium) shows the best results, however sulfurization (annealing in sulfur) has the advantage of leading to a non-toxic material. In this work, nanocrystals of CZTS with a targeted Cu-poor/Zn-rich composition are synthesized through a hot-injection method with oleylamine as the solvent. The nanocrystal inks are deposited through doctor blading in octanethiol, and annealed in a vacuum furnace using a graphite box with sulfur. The surface morphology and thus grain growth are studied for various annealing conditions in a 10-mbar nitrogen atmosphere with a varying amount of sulfur. The films are characterized with scanning electron microscopy (SEM), and an example before and after annealing is displayed in Fig. 1 (a) and (b), respectively. Compositional changes are monitored by energy dispersive X-ray spectroscopy (EDX) and the crystallinity by X-ray diffraction (XRD). A photovoltaic device of the structure soda lime glass (SLG)/Mo/CZTSSe/CdS/ZnO:Al/Ag has been built,
and our preliminary results show a power conversion efficiency of 1.41% for the nanoparticles annealed in selenium.

**Synthesis of CZTS Nanocrystals and Transformation into CZTSe**

In this work, we present an alternative route to synthesize Cu₂ZnSnS₄ (CZTS) and Cu₂ZnSnSe₄ (CZTSe) nanocrystals in controlled proportions. Initially, CZTS nanocrystals are formed through a hot-injection method with oleylamine as the solvent. Thereafter, selenium dissolved in TOP (trioctylphosphine) is injected and a transformation from CZTS to CZTSe is observed to occur. Here we present a demonstration that the transformation is possible, a first view on how the morphology of the nanoparticles changes, and our results from optimizing the conversion ratio with respect to temperature. Our X-ray diffraction pattern proves that liquid conversion from CZTS to CZTSe is possible, and from transmission electron micrographs we see that the CZTSe particles are significantly larger than the CZTS nanoparticles prepared under equivalent conditions. Finally, we find that increasing the temperature results in a larger amount of conversion from CZTS to CZTSe after a fixed amount of time.

**The minimum amount of "matrix" needed for matrix-assisted pulsed laser deposition of biomolecules**

The ability of matrix-assisted pulsed laser evaporation (MAPLE) technique to transfer and deposit high-quality thin organic, bioorganic, and composite films with minimum chemical modification of the target material has been utilized in numerous applications. One of the outstanding problems in MAPLE film deposition, however, is the presence of residual solvent (matrix) codeposited with the polymer material and adversely affecting the quality of the deposited films. In this work, we investigate the possibility of alleviating this problem by reducing the amount of matrix in the target. A series of coarse-grained molecular dynamics simulations are performed for a model lysozyme-water system, where the water serves the role of volatile "matrix" that drives the ejection of the biomolecules. The simulations reveal a remarkable ability of a small (5-10 wt %) amount of matrix to cause the ejection of intact bioorganic molecules. The results obtained for different laser fluences and water concentrations are used to establish a "processing map" of the regimes of molecular ejection in matrix-assisted pulsed laser deposition. The computational predictions are supported by the experimental observation of the ejection of intact lysozyme molecules from pressed lysozyme targets containing small amounts of residual water. The results of this study suggest a new approach for deposition of thin films of bioorganic molecules with minimum chemical modification of the molecular structure and minimum involvement of solvent into the deposition process. (Graph Presented).
Thin films of absorber material Cu2ZnSnS4 for solar cells

Pulsed Laser Deposition technique is applied to the production of thin films of CZTS (Cu2ZnSnS4). This vacuum technique has proven to be particularly successful in the production of films with a complex stoichiometry, as in the case of high temperature superconductors. The material ablated by the laser pulse is transferred to the substrate at very high kinetic energy (~ keV), thus resulting in high mobility of the adsorbed atoms yet at low substrate temperatures. Since the reaction of decomposition of CZTS via S and SnS evaporation is the main problem all vacuum techniques have to deal with, it is of interest to see how the crystallinity develops out of such high energetic, stoichiometric transfer. We investigate the optical and structural properties of thin films produced in high vacuum (p < 10^-6 mbar) with a single target made with sintered powder with stoichiometry: Cu2ZnSnS4. The films are deposited on Mo coated SLG in the temperature range from 25°C to 500°C. X-ray diffraction patterns show an increase in the intensity of main peak associated to kesterite CZTS up to a substrate temperature of 300°C, then secondary phases start to show up and the main peak associated to kesterite drops down in intensity. Optical measurements (direct and diffuse reflectance) and ellipsometry analysis are used to investigate the optical constants of the films produced and to estimate the bandgap, while AFM images are used to investigate the roughness. The same measurements are carried out on the same samples after annealing at 500°C for 20 mins in N2 + S atmosphere and the results are compared. The films produced are in the thickness range 600 – 1000 nm, the excimer laser used is a LambdaPhysik filled with KrF working at 248 nm, with pulse length of 20 ns. Pulse repetition rate was set at 10 Hz, the deposition process was lasting 1 hour.

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Anodization of sputter deposited Al-Zr coatings and microstructural issues

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Organisations: Department of Mechanical Engineering, Materials and Surface Engineering, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Danish Technological Institute
Contributors: Gudla, V. C., Canulescu, S., Schou, J., Ambat, R., Rechendorff, K., Christensen, B., Pleth Nielsen, L.
Number of pages: 8
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Deposition of matrix-free fullerene films with improved morphology by matrix-assisted pulsed laser evaporation (MAPLE)
Thin films of C60 were deposited by matrix-assisted pulsed laser evaporation (MAPLE) from a frozen target of anisole with 0.67 wt% C60. Above a fluence of 1.5 J/cm² the C60 films are strongly non-uniform and are resulting from transfer of matrix-droplets containing fullerenes. At low fluence the fullerene molecules in the films are intact, the surface morphology is substantially improved and there are no measurable traces of the matrix molecules in the film. This may indicate a regime of dominant evaporation at low fluence which merges into the MAPLE regime of liquid ejection of the host matrix at higher fluence.

Energy distribution of ions produced by laser ablation of silver in vacuum
The ion energy in a silver ablation plume for fluence in the range of 0.6–2.4Jcm⁻², typical for a pulsed laser deposition (PLD) experiment has been investigated. In this fluence range the ion fraction of the ablated particles becomes gradually dominant and can be utilized to characterize the ablation process. A silver target in vacuum was irradiated with a Nd:YAG laser at a wavelength of 355nm and detailed measurements of the time-resolved angular distribution of plume ions were made. In contrast to earlier work, the beam spot was circular such that any flip-over effect of the plume is avoided. The
angular energy distribution of ions in forward direction exceeds values of 500eV, while at large angles the ion energy tail is below 100eV. The maximum for the time-of-flight distributions agrees consistently with the prediction of Anisimov's model in the low fluence range, in which hydrodynamic motion prevails.

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Femtosecond-laser ablation dynamics of dielectrics: basics and applications for thin films

Laser ablation of dielectrics by ultrashort laser pulses is reviewed. The basic interaction between ultrashort light pulses and the dielectric material is described, and different approaches to the modeling of the femtosecond ablation dynamics are reviewed. Material excitation by ultrashort laser pulses is induced by a combination of strong-field excitation (multi-photon and tunnel excitation), collisional excitation (potentially leading to an avalanche process), and absorption in the plasma consisting of the electrons excited to the conduction band. It is discussed how these excitation processes can be described by various rate-equation models in combination with different descriptions of the excited electrons. The optical properties of the highly excited dielectric undergo a rapid change during the laser pulse, which must be included in a detailed modeling of the excitations. The material ejected from the dielectric following the femtosecond-laser excitation can potentially be used for thin-film deposition. The deposition rate is typically much smaller than that for nanosecond lasers, but film production by femtosecond lasers does possess several attractive features. First, the strong-field excitation makes it possible to produce films of materials that are transparent to the laser light. Second, the highly localized excitation reduces the emission of larger material particulates. Third, lasers with ultrashort pulses are shown to be particularly useful tools for the production of nanocluster films. The important question of the film stoichiometry relative to that of the target will be thoroughly discussed in relation to the films reported in the literature.

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Femtosecond ultraviolet laser ablation of silver and comparison with nanosecond ablation

The ablation plume dynamics arising from ablation of silver with a 500 fs, 248 nm laser at ~2 J cm^-2 has been studied using angle-resolved Langmuir ion probe and thin film deposition techniques. For the same laser fluence, the time-of-flight ion signals from femtosecond and nanosecond laser ablation are similar; both show a singly peaked time-of-flight distribution. The angular distribution of ion emission and the deposition are well described by the adiabatic and isentropic model of plume expansion, though distributions for femtosecond ablation are significantly narrower. In this laser fluence regime, the energy efficiency of mass ablation is higher for femtosecond pulses than for nanosecond pulses, but the ion production efficiency is lower.

Functionalized ormosil scaffolds processed by direct laser polymerization for application in tissue engineering

Synthesized N,N'-(methacryloyloxyethyl triethoxy silyl propyl carbamoyl-oxyhexyl)-urea hybrid methacrylate was polymerized by direct laser polymerization using femtosecond laser pulses with the aim of using it for subsequent applications in tissue engineering. The as-obtained scaffolds were modified either by low pressure argon plasma treatment or by covering the structures with two different proteins (lysozyme, fibrinogen). For improved adhesion, the proteins were deposited by matrix assisted pulsed laser evaporation technique. The functionalized structures were tested in mouse fibroblasts culture and the cells morphology, proliferation, and attachment were analyzed.
**Investigation of photocatalytic activity of titanium dioxide deposited on metallic substrates by DC magnetron sputtering**

The photocatalytic properties of titanium dioxide (TiO2) coating in the anatase crystalline structure deposited on aluminium AA1050 alloy and stainless steel S316L substrates were investigated. The coating was prepared by DC magnetron sputtering. The microstructure and surface morphology of the coating were investigated using Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Glow Discharge Optical Emission Spectroscopy (GDOES), and X-Ray Diffraction (XRD). The photocatalytic behaviour was studied using electrochemical methods such as open circuit potential measurements, linear sweep voltammetry, impedance measurements. The microstructure and surface morphology of the coating were similar irrespective of the nature of the substrate, while the photocatalytic behaviour was found to vary depending on the substrate type. In general the TiO2 coating on stainless steel was shown to be more photocatalytically active than TiO2 on aluminium. Impedance measurements show higher capacitance for the coating on stainless steel. Mott–Schottky plots indicate multiple donor states for the coating on the stainless steel substrate. The optical reflection spectrometry measurements showed a lower band gap of 0.2 eV for the coating on the stainless steel substrate.
Laser ablation of lysozyme with UV, visible and infrared femto- and nanosecond pulses

Lysozyme is an interesting molecule for laser ablation of organic materials, because the ablation has been comprehensively studied, it is a medium heavy molecule with a mass of 14305 Da, which can be detected by standard techniques, and because it is used as a bactericidal protein in the food industry. Lysozyme molecules do not absorb energy for wavelengths above 310 nm, but nevertheless there is a strong mass loss by ablation for laser irradiation in the visible regime. The total ablation yield of lysozyme at 355 nm and at 2 J/cm² is about 155 µg/pulse, possibly one of the highest ablation yields ever measured. The mass loss is mainly caused by fragmentation of the lysozyme into simple gases, such as H2S, H2O and CO2, which are rapidly pumped away in the vacuum chamber.

We have investigated the mass loss by ablation of lysozyme in all regimes to see whether a similar mechanism governs the ablation process for different wavelengths and time duration. Measurements for 6-7-ns laser ablation were carried out at DTU on Risø Campus, while measurements with pulses of 300 fs were carried out at the University of Naples in a similar setup. For all wavelengths except at nanosecond laser pulses at 355 nm, the efficiency of ablation is similar, about 0.02 g/J. Material deposited as films was investigated by MALDI (Matrix Assisted Laser Desorption) in order to check whether or not intact lysozyme molecules were transferred from target to the substrate. The experiments have confirmed that fragmentation of lysozyme into gases via photothermal processes drives the ablation at most wavelengths.

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Contributors: Schou, J., Canulescu, S., Matei, A., Cazzaniga, A. C., Constantinescu, C., Amoruso, S., Wang, X., Bruzzese, R., Dinescu, M.
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Laser deposition rates of thin films of selected metals and alloys

Thin films of Cu, Zn and Sn as well as mixtures of these elements have been produced by Pulsed Laser Deposition (PLD). The deposition rate of single and multicomponent metallic targets was determined. The strength of PLD is that the stoichiometry of complex compounds, even of complicated alloys or metal oxides, can be preserved from target to film. We apply this technique to design films of a mixture of Cu, Zn and Sn, which are constituents of the chalcogenide CZTS, which has a composition close to Cu2ZnSnS4. This compound is expected to be an important candidate for absorbers in new solar cells.

The experiments have been carried out at a laser wavelength of 355 nm in vacuum with a PLD chamber at DTU Fotonik, Risø Campus. The deposition rates have been measured by a quartz crystal microbalance. At a laser fluence of 2 J/cm² the total ablated yield of copper is about 1x1015 atoms per pulse. The film deposition rate is typically 100 times lower because not all the ablated atoms do arrive at the substrate. The deposition rate of copper is about 1x1013 atoms/cm² per pulse in a direction normal to the target surface, which is 6 times lower than that of Sn and 4 times lower than that of Zn. Results for alloys of the different elements as well as compounds with S will be presented.

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Contributors: Cazzaniga, A. C., Canulescu, S., Schou, J., Pryds, N.
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Pulsed laser deposition of lysozyme: the dependence on shot numbers and the angular distribution

The ejection of molecules from a pressed solid target of lysozyme induced by laser ablation in the UV-regime at a wavelength of 355 nm was investigated. The ablation studies were carried out in vacuum at a laser fluence of 2 J/cm² for which a significant fraction of proteins remains intact. This was verified by matrix-assisted laser desorption ionization (MALDI) spectrometry of thin films deposited on silicon substrates. The deposition rate of lysozyme was found to decrease with the number of shots and was correlated with increasing thermal damage of the lysozyme. This was monitored by measurements of the optical reflectivity of dry lysozyme. The angular distribution of the mass deposition can be fitted well by Anisimov's hydrodynamic model. The total deposited yield over the entire hemisphere from direct laser ablation of lysozyme was estimated from this model and found to be three orders of magnitude less than the ablated mass.

Reflectance spectroscopy from TiO₂ particles embedded in polyurethane

This paper presents the results of a physical simulation carried out using TiO₂-Polyurethane composite coating on bright aluminium surface to understand the light scattering effect for designing white surfaces. Polyurethane matrix is selected due to the matching refractive index (1.7) with Al₂O₃ layer on anodized aluminium surfaces. Three different TiO₂ particle distributions were dispersed in polyurethane and spin coated onto high gloss and caustic etched aluminium substrates. Reflectance spectra of TiO₂-polyurethane films of various concentrations were analysed using an integrating sphere. The results show that the TiO₂-polyurethane coatings have a high diffuse reflectance as a result of multiple scattering from TiO₂ particles. Diffuse reflectance spectra of TiO₂ containing films vary weakly with particle concentration and reach a steady state value at a concentration of 0.75 wt.%. Using the Kubelka Munk two-stream model, the scattering and absorption coefficient of the TiO₂ particles embedded in polyurethane was determined. These studies can serve on understanding the fundamental requirements for generating a bright and white decorative anodized aluminium surface.
Thin films of C\textsubscript{60} produced by matrix-assisted pulsed laser evaporation (MAPLE)

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Time-resolved and integrated angular distributions of plume ions from silver at low and medium laser fluence

Laser impact on metals in the UV regime results in a significant number of ablated plume ions even at moderate fluence (0.7–2.4 J/cm\textsuperscript{2}). The ablated particles are largely neutrals at the lowest fluence, but the fraction of ions increases strongly with fluence. The ion flow in different directions from a silver target irradiated by a laser beam at a wavelength of 355 nm in vacuum was measured with a hemispherical array of Langmuir probes. The time-of-flight spectra in all directions, as well as the total angular yield were determined. The angular distribution peaks strongly in forward direction with increasing fluence and can be well approximated by Anisimov’s model. Typically, the spectra of silver ions peak from 70 eV up to 145 eV in a direction close to the normal of the target surface with increasing fluence. With increasing observation angle, the time-of-flight spectra exhibit a peak at longer flight times, i.e., at a lower kinetic energy. At the highest fluence, the ionized fraction of the ablated particles in the plume increases up to 0.5.
A study on matrix assisted pulsed evaporation (MAPLE) of organic materials

Organic films can be produced either by MAPLE or directly by PLD (Pulsed laser deposition). For a reasonable deposition rate of ng/cm² per pulse for film production by MAPLE a fluence of 1-1.5 J/cm² is required at the laser wavelength of 355 nm, while the fluence can be considerably lower at 248 nm. At high fluence the deposition rate of proteins by MAPLE seems to decrease. The surface roughness is still an issue, but at low fluence it seems to be acceptable. The fragmentation rate increases with fluence, and seems to be less pronounced for MAPLE than for PLD. Also this issue is not yet resolved.

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, National Institute for Laser, Plasma and Radiation Physics
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Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2012 › Research › peer-review

Energy distributions of plume ions from silver at different angles ablated in vacuum.

A typical pulsed laser deposition (PLD) is carried out for a fluence between 0.5 and 2.5 J/cm². The ablated particles are largely neutrals at the lowest fluence, but the fraction of ions increases strongly with fluence and accounts for more 0.5 of the particles at 2.5 J/cm² [1,2]. Since it may be comparatively difficult to measure the energy and angular distribution of neutrals, measurements of the ionic fraction will be valuable for any modeling of PLD.

We have irradiated silver in a vacuum chamber (~ 10⁻⁷ mbar) with a Nd:YAG laser at a wavelength of 355 nm and made detailed measurements of the time-resolved angular distribution. The ion flow in different directions has been measured with a hemispherical array of Langmuir probes, by which the time-of-flight spectra the in all directions can be recorded [1,2]. In contrast to earlier work the beam spot was circular such that any flip-over effect of the plume was avoided [3]. The angular distribution of ions is strongly peaked in forward direction, and also the energy distribution peaks at much higher energy in forward direction than at oblique angles.

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Excitation of anodized alumina films with a light source

Optical properties of anodized aluminium alloys were determined by optical diffuse reflectance spectroscopy of such films. Samples with different concentrations of dopants were excited with a white-light source combined with an integrating sphere for fast determination of diffuse reflectance. The UV-VIS reflectance of Ti-doped anodized aluminium films was measured over the wavelength range of 200 nm to 900 nm. Titanium doped-anodized aluminium films with 5-15 wt% Ti
were characterized. Changes in the diffuse light scattering of doped anodized aluminium films, and thus optical appearance, with doping are discussed. Using the Kubelka-Munk model on the diffuse reflectance spectra of such films, the bandgap $E_g$ of the oxide alloys can be determined.

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Organisations: Department of Mechanical Engineering, Materials and Surface Engineering, Department of Photonics Engineering, Optical Microsensors and Micromaterials, Danish Technological Institute
Contributors: Aggerbeck, M., Canulescu, S., Rechendorff, K., Schou, J., Ambat, R.
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**Functionalized Ormosil Scaffolds Processed by Direct Laser Polymerization for Application in Tissue Engineering**
The N,N'-(methacryloyloxyethyl triethoxy silyl propyl carbamoyl-oxyhexyl)-urea hybrid methacrylate for applications in tissue engineering was synthesized and afterwards polymerized by direct laser polymerization using femtosecond laser pulses with the aim of using it for further applications in tissue engineering. The as-obtained scaffolds were modified either by low pressure argon plasma treatment or by using two different proteins (lysozyme, fibrinogen). For improved adhesion, the proteins were deposited by matrix assisted pulsed laser evaporation. The functionalized structures were tested in L929 mouse fibroblasts culture and the cells morphology, proliferation, and attachment were analyzed.

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**Growth of thin carbon-based films by laser assisted methods**

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Contributors: Canulescu, S., Schou, J., Fæster, S.
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In vitro studies of PEG thin films with different molecular weights deposited by MAPLE

In this work, polyethylene glycol (PEG) films were produced by Matrix Assisted Pulsed Laser Evaporation (MAPLE). The possibility to tailor the properties of the films by means of polymer molecular weight was explored. The films of PEG of average molecular weights 400 Da, 1450 Da, and 10000 Da (PEG400, PEG1450, and PEG10000) were investigated in vitro, in media similar with those inside the body (phosphate buffer saline PBS with pH 7.4 and blood). The mass of the polymer did not change during this treatment, but the polymer molecular weight was found to strongly influence the films properties and their behavior in vitro. Thus, immersion in PBS induced swelling of the PEG films, which was more pronounced for PEG polymers of higher molecular weight. Prior to immersion in PBS, the PEG films of higher molecular weight were more hydrophilic, the water contact angles decreasing from ∼66 grd for PEG400 to ∼41 grd for PEG 1450 and to ∼15 grd for PEG10000. The same trend was observed during immersion of the PEG films in PBS. Before immersion in PBS, the refractive index of the films increased from ∼1.43 for PEG400 to ∼1.48 for PEG1450 and to ∼1.68 for PEG10000. During immersion in PBS the refractive index decreased gradually, but remained higher for the PEG molecules of higher mass. Finally, blood compatibility tests showed that the PEG films of higher molecular weight were most compatible with blood. © 2012 Springer-Verlag.

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Laser ablation dynamics and production of thin films of lysozyme

Lysozyme is a well-known protein, which is used in food processing because of its bactericidal properties. The mass (14307 amu) is in the range in which it easily can be monitored by mass spectrometric methods, for example by MALDI (Matrix assisted laser desorption ionization). We have recently produced thin films of average thickness up to 300 nm, which not only contained a significant amount of intact molecules, but also maintained the bioactivity. These films were produced by a nanosecond laser in the UV regime at 355 nm with 2 J/cm2. The surprising fact that these molecules can be transferred to a substrate as intact molecules by the violent laser impact (~up to 50 mJ/pulse) has not yet been understood. One issue is that up to 150 ng/pulse is removed by the laser, and much of the material is ejected from the target in relatively large chunks.

We have explored as well the excitation mechanics by laser impact. Samples of pressed lysozyme prepared in the same manner as in ns-experiments have been irradiated at 527 nm with 300-fs pulses and at similar fluence as in ns ablation. Even though the pulse energy was much smaller, there was a considerable ablation weight loss of lysozyme from each shot. This is the first time the ablation by fs-lasers of a protein has been recorded quantitatively. Films of lysozyme produced by fs-laser irradiation were analyzed by MALDI and a significant number of intact molecules in the films with fs-laser deposition was found as well.

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Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Università degli Studi di Napoli Federico II, National Institute for Laser, Plasma and Radiation Physics
Laser ablation of the protein lysozyme

Lysozyme is a well-known protein, which is used in food processing because of its bactericidal properties. The mass (14307 amu) is in the range in which it easily can be monitored by mass spectrometric methods, for example by MALDI (Matrix assisted laser desorption ionization). We have recently produced thin films of average thickness up to 300 nm, which not only contained a significant amount of intact molecules, but also maintained the bioactivity. These films were produced by a nanosecond laser in the UV regime at 355 nm with 2 J/cm². The surprising fact that these molecules can be transferred to a substrate as intact molecules by the violent laser impact (up to 50 mJ/pulse) has not yet been understood. One issue is that up to 150 ng/pulse is removed by the laser, and much of the material is ejected from the target in relatively large chunks. We have explored as well the excitation mechanics by laser impact. Samples of pressed lysozyme prepared in the same manner as in ns-experiments have been irradiated at 527 nm with >>300-fs pulses and at a similar fluence as in ns ablation. Even though the pulse energy was much smaller, there was a considerable ablation weight loss of lysozyme from each shot. This is the first time the ablation by fs-lasers of a protein has been recorded quantitatively. Films of lysozyme produced by fs-laser irradiation were analyzed by MALDI and a significant number of intact

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Light Scattering of TiO₂ Nanoparticles Embedded in Polyurethane

A new approach of enhancing light scattering in polyurethane polymer through the effect of TiO₂ nanoparticles (NP) is explored. The TiO₂ NP with sizes of 360 nm, 410 nm and 500 nm were dispersed in polyurethane polymer in concentrations ranging from 0.25 wt% up to 2 wt%. Reflectivity and UV-visible absorption measurements were employed for studying the scattering and absorption properties of TiO₂ NP.

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Pulsed laser deposition of the lysozyme protein: an unexpected "Inverse MAPLE" process

Films of organic materials are commonly deposited by laser assisted methods, such as MAPLE (matrix-assisted pulsed laser evaporation), where a few percent of the film material in the target is protected by a light-absorbing volatile matrix. Another possibility is to irradiate the dry organic material directly for film production, as in PLD (pulsed laser deposition), where the film molecules may undergo strong fragmentation. In this presentation we report an alternative surprising mechanism for film deposition of the protein lysozyme in vacuum, when a small amount of residual water drives the ejection and deposition of lysozyme. This can be called an "Inverse MAPLE" process, since the ratio of "matrix" to film material in the target is 10:90, which is inverse of the typical MAPLE process where the film material is dissolved in the
Lysozyme is a well-known protein which is used in food processing and is also an important constituent of human secretions such as sweat and saliva. It has a well-defined mass (14307 u) and can easily be detected by mass spectrometric methods such as MALDI (Matrix-assisted laser desorption ionization) in contrast to many other organic materials. Also, the thermal properties of lysozyme, including the heat-induced decomposition behavior are comparatively well-known.

The ablation of lysozyme from a dry pressed target in vacuum was measured by weight loss in nanosecond laser ablation at 355 with a fluence of 0.5 to 6 J/cm². Films with a significant number of intact lysozyme molecules have been produced by direct laser irradiation of a pressed target and the number of intact molecules shows a maximum at around 2.5 J/cm². Apparently, there is a certain range of laser fluences when the transfer of intact lysozyme to the film substrate is possible. The experimental results are explained with the help of molecular-level computer simulations. The simulations show that pure lysozyme cannot ablate without complete fragmentation. However, small pockets of trapped water provide the necessary expansion of the target and the ejection of intact lysozyme molecules above a certain fluence threshold, below which no lysozyme molecules are ejected. For high fluences all molecules are ejected as fragments. For a reasonable concentration of water (10%) the fluence dependence similar to that obtained experimentally is observed in the simulations.

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**Epitaxial growth of atomically flat gadolinia-doped ceria thin films by pulsed laser deposition**
Epitaxial growth of Ce₀.₈Gd₀.₂O₂₋₂( CGO) films on (001) TiO₂-terminated SrTiO₃ substrates by pulsed laser deposition was investigated using in situ reflective high energy electron diffraction. The initial film growth shows a Stransky-Krastanov growth mode. However, this three-dimensional island formation is replaced by a two-dimensional island nucleation during further deposition, which results in atomically smooth CGO films. The obtained high-quality CGO films may be attractive for the electrolyte of solid-oxide fuel cells operating at low temperature.

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ISI indexed (2011): ISI indexed yes
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Original language: English
Growth of thin films of low molecular weight proteins by matrix assisted pulsed laser evaporation (MAPLE)
Thin films of lysozyme and myoglobin grown by matrix assisted pulsed laser evaporation (MAPLE) from a water ice matrix have been investigated. The deposition rate of these two low molecular weight proteins (lysozyme: 14307 amu and myoglobin: 17083 amu) exhibits a maximum of about 1–2 ng/cm² per pulse at a fluence of 1–2 J/cm² and decreases slowly with increasing fluence. This rate is presumably determined by the matrix rather than the proteins. A significant fraction of the proteins are intact in the film as determined by MALDI (Matrix assisted laser desorption ionization) spectrometry. The results for lysozyme demonstrate that the fragmentation rate of the proteins during the MAPLE process is not influenced by the pH of the water solution prior to freezing.

Growth of thin fullerene films by matrix assisted pulsed laser evaporation
C60 fullerene thin films of average thickness of more than 100 nm on silicon substrates can be produced in vacuum by matrix-assisted pulsed laser evaporation (MAPLE). A 355 nm Nd:YAG laser was directed onto a frozen target of anisole with a concentration of 0.67 wt% C60. At laser fluences below 1.5 J/cm² the dominant fraction of the film molecules are C60 transferred to the substrate without any fragmentation. For high fluences high-resolution SEM images of MAPLE deposited films reveal large circular features on the surface with high amount of material concentrated at edges. These features, observed over a wide range of laser fluences, are caused by ejection of large matrix-fullerene liquid droplets into the gas-phase and subsequent deposition. At similar laser energies, but using an unfocused laser beam, MAPLE favours evaporation of matrix and organic molecules, resulting in films with smooth surfaces and minimal contamination.
**Growth of thin fullerene films by Matrix Assisted Pulsed Laser Evaporation**

Metal and metal oxide films with controlled thickness from a fraction of a monolayer up more than 1000 nm and known stoichiometry can be produced by pulsed laser deposition (PLD) relatively easily, and (PLD) is now a standard technique in all major research laboratories within materials science. However, organic materials are usually not well suited for direct laser irradiation, since the organic molecules may suffer from fragmentation by the laser light. We have, therefore, explored the possible fragmentation of organic molecules by attempting to produce thin films of C60 which is a strongly bound carbon molecule with a well-defined mass (M = 720 amu) and therefore a good, organic test molecule. C60 fullerene thin films of average thickness of more than 100 nm was produced in vacuum by matrix-assisted pulsed laser evaporation (MAPLE). A 355 nm Nd:YAG laser was directed onto a frozen target of the matrix material, anisole, with a concentration of 0.67 wt% C60. At laser fluences below 1.5 J/cm², a dominant fraction of the film molecules are C60 transferred to the substrate without any fragmentation. High-resolution SEM images of MAPLE deposited films reveal large circular features on the surface with high amount of material concentrated at edges. These features, observed over a wide range of laser fluences, are caused by ejection of large matrix-fullerene liquid droplets into the gas-phase and subsequent deposition. At similar laser energies, but using an unfocused laser beam, MAPLE favours evaporation of matrix and organic molecules, resulting in production of films with smooth surfaces and minimal contamination.

**Investigation of photocatalytic activity of titanium dioxide coating deposited on aluminium alloy substrate by plasma technique**

Nowadays, there is an increased need for functionalized surfaces with self-cleaning and antibacterial properties. Titanium dioxide (TiO2) in the anatase crystalline structure is one of the most powerful photocatalytic materials available today, which can provide above functionalities. The photocatalytic process is initiated by UV-light in TiO2 which creates electron-hole pairs in the conduction band (CB) and valence band (VB) of TiO2, respectively. The electron/hole pairs generated have sufficient energy to cause reduction and oxidation on its surface providing the self-cleaning effect. Literature consists of large number of publications on titanium dioxide coating for self-cleaning applications, with glass as the main substrate. Only little work is available on TiO2 coating of metallic alloys used for engineering applications. Engineering materials, such as light-weight aluminium and steel have wide spread technological applications, where a combination of self-cleaning properties has a huge business potential. The results presented in this paper demonstrate superior photocatalytic properties of TiO2 coated aluminium compared to nano-scale TiO2 coating on glass substrate. The thickness of the coating strongly influences the photocatalytic properties. In general, the photocatalytic activity increased with thickness. Quantification of images scanned with Atomic Force Microscope (AFM) revealed that there is a linear relationship between the thickness of the coating and the average cell size of the crystals. Furthermore, it manifested that the surface area of the coating increased linearly with crystal size. The optical measurements demonstrated that the ability of the coating to absorb light was depended on the thickness of the coating. As the coating became thicker, the absorption increased up to a certain thickness where a saturation limit was reached. Overall, the results from decomposition studies and electrochemical measurements indicated that the thickness of the coating has a profound influence on the photocatalytic properties.
Laser ablation dynamics and production of thin films of lysozyme

Lysozyme is a well-known protein, which is used in food processing because of its bacteriocidal properties. The mass (14307 u) is in the range, in which it easily can be controlled by mass spectrometric methods, for example by MALDI (Matrix assisted laser desorption ionisation). We have recently at the Technical University of Denmark (DTU) produced thin films of average thickness up to 300 nm, which not only contained a significant amount of intact molecules, but also maintained the bioactivity. These films were produced by a nanosecond laser in the UV regime at 355 nm with 2 J/cm². The surprising fact that these molecules can be transferred to a substrate as intact molecules by the violent laser impact (~ up to 50 mJ/pulse) has not yet been understood. One issue is that up to 150 ng/pulse is removed by the laser, and much of the material is ejected from the target in relatively large chunks. We have continued these experiments at CNR-SPIN, Napoli, to explore the excitation mechanics by laser impact. Samples of pressed lysozyme prepared in the same manner as in DTU have been irradiated at 523 nm with 300-fs pulses and a fluence of the same order of magnitude as in DYU. Even though the pulse energy was much smaller, there was a considerable ablation weight loss of lysozyme from each shot. This is the first time the ablation by fs-lasers of a protein has been recorded quantitatively. Films of lysozyme produced by fs-laser irradiation will be analysed by MALDI in order to explore if there also is a significant amount of intact molecules in the films for fs-laser deposition.
transfer of molecules to the film substrate. The experimental results will be discussed based on the results of molecular-level modeling. In particular, the effect of the possible presence of trapped water pockets in the lysozyme targets is investigated in the simulations and the minimum amount of water required for the lift off of the intact molecules is established.

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### Laser-assisted deposition of thin C60 films

Metal and metal oxide films with controlled thickness from a fraction of a monolayer up to more than 1000 nm and known stoichiometry can be produced by pulsed laser deposition (PLD) relatively easily, and (PLD) is now a standard technique in all major research laboratories within materials science. However, organic materials are usually not well suited for direct laser irradiation, since the organic molecules may suffer from fragmentation by the laser light. We have, therefore, explored the possible fragmentation of organic molecules by attempting to produce thin films of C60 which is a strongly bound carbon molecule with a well-defined mass (M = 720 amu) and therefore a good, organic test molecule. C60 fullerene thin films of average thickness of more than 100 nm was produced in vacuum by matrix-assisted pulsed laser evaporation (MAPLE). A 355 nm Nd:YAG laser was directed onto a frozen target of the matrix material, anisole, with a concentration of 0.67 wt% C60. At laser fluences below 1.5 J/cm², a dominant fraction of the film molecules are C60 transferred to the substrate without any fragmentation. High-resolution SEM images of MAPLE deposited films reveal large circular features on the surface with high amount of material concentrated at edges.

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Contributors: Schou, J., Canulescu, S., Fæster, S.
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### Matrix Assisted Pulsed Laser Evaporation for growth of fullerene thin films

C60 fullerene thin films of average thickness of more than 100 nm can be produced in vacuum by matrix-assisted pulsed laser evaporation (MAPLE). A 355 nm Nd:YAG laser was directed onto a frozen target of anisole, with a concentration of 0.67 wt% C60. At laser fluences below 1.5 J/cm², a dominant fraction of the film molecules are C60 transferred to the substrate without any fragmentation. High-resolution SEM images of MAPLE deposited films reveal large circular droplets on the surface with high amount of material concentrated at edges (Fig. 1A). These features, observed over a wide range of laser fluences, are caused by ejection of large matrix-fullerene liquid droplets into the gas-phase and subsequent deposition. At similar laser energies, but using an unfocused laser beam, MAPLE favours evaporation of matrix and organic molecules, resulting in production of films with smooth surfaces and minimal contamination (Fig. 1B).

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Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering, Metal Structures in Four Dimensions, Materials Research Division, Risø National Laboratory for Sustainable Energy
Nanostructured PLD-grown gadolinia doped ceria: Chemical and structural characterization by transmission electron microscopy techniques

The morphology as well as the spatially resolved elemental and chemical characterization of 10 mol% gadolinia doped ceria (CGO10) structures prepared by pulsed laser deposition (PLD) technique are investigated by scanning transmission electron microscopy accompanied with electron energy loss spectroscopy and energy dispersive X-ray spectroscopy. A dense, columnar and structurally inhomogeneous CGO10 film, i.e. exhibiting grain size refinement across the film thickness, is obtained in the deposition process. The cerium M4,5 edges, used to monitor the local electronic structure of the grains, indicate apparent variation of the ceria valence state across and along the film. No element segregation to the grain boundaries is detected. These results are discussed in the context of solid oxide fuel cell applications.

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Scopus rating (2011): CiteScore 2.27 SJR 0.908 SNIP 1.414
Web of Science (2011): Impact factor 2.103
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Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review

Processing of C60 thin films by Matrix-Assisted Pulsed Laser Evaporation (MAPLE)
Thin films of fullerenes (C60) were deposited onto silicon using matrix-assisted pulsed laser evaporation (MAPLE). The deposition was carried out from a frozen homogeneous dilute solution of C60 in anisole (0.67 wt%), and over a broad range of laser fluences, from 0.15 J/cm² up to 3.9 J/cm². MAPLE has been applied for deposition of fullerenes for the first time and we have studied the growth of thin films of solid C60. The fragmentation of C60 fullerene molecules induced by ns ablation in vacuum of a frozen anisole target with C60 was investigated by matrix-assisted laser desorption/ionization (MALDI). Our findings show that intact fullerene films can be produced with laser fluences ranging from 0.15 J/cm² up to 1.5 J/cm².
Pulsed laser deposition growth of FeSb2 films for thermoelectric applications

FeSb2 films were produced in a low-pressure Ar environment by pulsed laser deposition at 355 nm. The influence of growth parameters such as substrate temperature, Ar pressure and deposition time on the growth of FeSb2 films was studied. Nearly phase-pure FeSb2 films with thicknesses of 100–400 nm were produced at 425 °C with an Ar pressure of 1.5–2 Pa. Thermal transport and Hall measurements were performed to explore the thermoelectric transport properties of the FeSb2 films. A maximum thermopower of 120 μV/K at 40 K was obtained. In general, it is highly important to understand the growth properties of FeSb2 films if they are to eventually reach thermoelectric applications at cryogenic temperatures.
The effects of thermal annealing on the structure and the electrical transport properties of ultrathin gadolinia-doped ceria films grown by pulsed laser deposition

Ultrathin crystalline films of 10 mol% gadolinia-doped ceria (CGO10) are grown on MgO (100) substrates by pulsed laser deposition at a moderate temperature of 400°C. As-deposited CGO10 layers of approximately 4 nm, 14 nm, and 22 nm thickness consist of fine grains with dimensions ≤∼11 nm. The films show high density within the thickness probed in the X-ray reflectivity experiments. Thermally activated grain growth, density decrease, and film surface roughening, which may result in the formation of incoherent CGO10 islands by dewetting below a critical film thickness, are observed upon heat treatment at 400°C and 800°C. The effect of the grain coarsening on the electrical characteristics of the layers is investigated and discussed in the context of a variation of the number density of grain boundaries. The results are evaluated with regard to the use of ultrathin CGO10 films as seeding templates for the moderate temperature growth of thick solid electrolyte films with improved oxygen transport properties.

General information
Publication status: Published
Organisations: Microstructures and Interfaces, Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy, Thermo Ceramics, Ceramic processing, Fuel Cells and Solid State Chemistry Division. Management, Optical Microsensors and Micromaterials, Department of Photonics Engineering, Paul Scherrer Institute
Pages: 845-850
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Scopus rating (2011): CiteScore 1.77 SJR 0.871 SNIP 1.136
Web of Science (2011): Impact factor 1.63
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Original language: English
Keywords: Magnetic refrigeration
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10.1007/s00339-011-6424-y
Source: orbit
Source-ID: 277048
Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review

Time-resolved angular distributions of plume ions from silver at low and medium laser fluence

Even at moderate fluence (0.6 -2.4 J/cm²) laser impact on metals in the UV regime results in a significant number of ions emitted from the surface. The ablated particles are largely neutrals at the lowest fluence, but the fraction of ions increases strongly with fluence. We have irradiated silver in a vacuum chamber (~ 10⁻⁷ mbar) with a Nd:YAG laser at a wavelength of 355 nm and made detailed measurements of the time-resolved angular distribution. The ion flow in different directions has been measured with a hemispherical array of Langmuir probes, by which the time-of-flight spectra, as well as the total angular yield, in all directions can be recorded (1). The angular distribution peaks more strongly in forward direction with increasing fluence - as also reported in the literature – and can be well approximated by the model of Anisimov et al. (1,2). Typically, the spectra of silver ions peak from 70 eV up to 145 eV in a direction normal to the target surface with increasing fluence. With increasing observation angle the time-of-flight spectra exhibit a peak at longer flight times, i.e. at a lower kinetic energy. At the highest fluence the ionized fraction of the ablated particles exceeds 0.5.

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Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Christensen, B. T., Schou, J.
Publication date: 2011
Ablation plume dynamics in a background gas: [invited]

The expansion of a plume in a background gas of pressure comparable to that used in pulsed laser deposition (PLD) has been analyzed in terms of the model of Predtechensky and Mayorov (PM). This approach gives a relatively clear and simple description of the essential hydrodynamics during the expansion. The model also leads to an insightful treatment of the stopping behavior in dimensionless units for plumes and background gases of different atomic/molecular masses. The energetics of the plume dynamics can also be treated with this model. Experimental time-of-flight data of silver ions in a neon background gas show a fair agreement with predictions from the PM-model. Finally we discuss the validity of the model, if the work done by the pressure of the background gas is neglected.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Università degli Studi di Napoli Federico II, Trinity College Dublin
Contributors: Amoruso, S., Schou, J., Lunney, J. G.
Publication date: 2010

Electrical characterization of gadolinia doped ceria films grown by pulsed laser deposition

Electrical characterization of 10 mol% gadolinia doped ceria (CGO10) films of different thicknesses prepared on MgO(100) substrates by pulsed laser deposition is presented. Dense, polycrystalline and textured films characterized by fine grains (grain sizes <18 nm and <64 nm for a 20-nm and a 435-nm film, respectively) are obtained in the deposition process. Grain growth is observed under thermal cycling between 300 and 800°C, as indicated by X-ray-based grain-size analysis. However, the conductivity is insensitive to this microstructural evolution but is found to be dependent on the sample thickness. The conductivity of the nanocrystalline films is lower (7.0×10−4 S/cm for the 20-nm film and 3.6×10−3 S/cm for the 435-nm film, both at 500°C) than that of microcrystalline, bulk samples (S/cm at 500°C). The activation energy for the conduction is found to be 0.83 eV for the bulk material, while values of 1.06 and 0.80 eV are obtained for the 20-nm film and the 435-nm film, respectively. The study shows that the ionic conductivity prevails in a broad range of oxygen partial pressures, for example down to about 10−26 atm at 500°C.

General information
Publication status: Published
Organisations: Electroceramics, Fuel Cells and Solid State Chemistry Division, Rise National Laboratory for Sustainable Energy, Thermo Ceramics, Microstructures and Interfaces, Ceramic processing, Fuel Cells and Solid State Chemistry Division, Management, Optical Microsensors and Micromaterials, Department of Photonics Engineering
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Volume: 101
Issue number: 4
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Energy balance of a laser ablation plume expanding in a background gas

The energy balance of a laser ablation plume in an ambient gas for nanosecond pulses has been investigated on the basis of the model of Predtechensky and Mayorov (PM), which provides a relatively simple and clear description of the essential hydrodynamics. This approach also leads to an insightful description in dimensionless units of how the initial kinetic energy of the plume is dissipated into kinetic and thermal energy of the background gas. Eventually when the plume has stopped, the initial kinetic energy of the plume is converted into thermal energy of the plume and background gas.

General information
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Amoruso, S., Schou, J., Lunney, J. G.
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Web of Science (2010): Impact factor 1.765
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Source: orbit
Source-ID: 268777
Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review

Epitaxial growth of atomically flat gadolinia-doped ceria thin films by pulsed laser deposition

Ceria-based thin films are often applied as key functional components in miniaturized electroceramic devices such as solid oxide fuel cells or gas sensors. Processing routes that prevent thermal degradation and yield access to the optimum microstructures are sought. Multi-step growth, involving the preparation of ultrathin seed layers in the first stage of the deposition process is often envisaged to control the growth and physical properties of the subsequent coating. This work suggests that the limitations of conventional pulsed laser deposition (PLD), performed at moderate temperature (400°C), to the growth of dense, gas impermeable 10 mol% gadolinia-doped ceria (CGO10) solid electrolyte can be overcome by the seeding process. In order to evaluate the seed layer preparation, the effects of different thermal annealing treatments on the morphology, microstructure and surface roughness of ultrathin CGO10 layers with a thickness of 4 nm, 13 nm and 22 nm, respectively, grown on Mg(100), were studied by atomic force microscopy and X-ray reflectometry.

General information
Publication status: Published
Factors controlling the microstructure of Ce0.9Gd0.1O2-δ films in pulsed laser deposition process

Films of Ce0.9Gd0.1O2-δ (CGO10) are prepared at a range of conditions by pulsed laser deposition (PLD) on a single crystal Si (100) and MgO (100), and on a polycrystalline Pt/MgO (100) substrate. The relationship between the film microstructure, crystallography, chemical composition and PLD processing parameters is studied. It is found that the laser fluence has no significant impact on the film density, whereas the substrate temperature and the oxygen pressure are of essential importance for the film microstructure development. The reduction of deposition temperature, down to 250 °C, together with a lowered oxygen pressure of 0.05 mbar, significantly inhibits the growth of columnar structures. Further decrease in oxygen pressure, to 0.005 mbar, promotes films densification, but a stress build-up is observed and leads to a lattice-parameter enlargement of the coatings. The chemical films composition is affected by the applied fluence. At a low fluence, 0.5 J/cm², a congruent transfer is obtained while a relative Gd enrichment results for substantially higher (3.5-5.5 J/cm²).

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Volume: 12
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Web of Science (2010): Impact factor 0.412
Web of Science (2010): Indexed yes
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Source: orbit
Source-ID: 259645
Research output: Contribution to journal → Journal article – Annual report year: 2010 → Research → peer-review

Growth and thermoelectric properties of FeSb2 films produced by pulsed laser deposition

FeSb2, a strongly correlated semiconductor, has promising application potential for thermoelectric cooling at cryogenic temperatures [1,2]. Single crystals of FeSb2 were found to exhibit colossal thermopower (S) values up to ~45000 μVK-1 and record high power factors up to 2300 μWK−2 cm−1 at 12 K [2]. However, the thermoelectric performance of FeSb2 is restricted by its large lattice thermal conductivity (kL). Thin film thermoelectric materials could have a much reduced kL due to surface and grain-boundary scattering of phonons. Therefore, FeSb2 thin films are expected to have remarkably enhanced thermoelectric performance. Herein, FeSb2 films were produced on silica substrates in a low-pressure Ar environment by a pulsed Nd:YAG laser at 355 nm. The effect of growth parameters, such as substrate temperature, Ar
pressure, incident fluence and growth time, on the PLD growth of FeSb2 was systematically studied. Uniform, continuous and nearly phase-pure FeSb2 films with thickness of 100-400 nm were produced. Thermal transport and Hall measurements were performed to study their thermoelectric transport properties. A maximum absolute value of S ~120 μVK-1 at 40 K was obtained. This study should serve to strengthen the interest in application of FeSb2 films in thermoelectrics. 1. P. Sun, N. Oeschler, S. Johnsen, B. B. Iversen, F. Steglich. Dalton Trans. 39 (2010) 965. 2. A. Bentien, S. Johnsen, G. K. H. Madsen, B. B. Iversen, F. Steglich, Europhys. Lett. 80 (2007) 17008.

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- **Publication status:** Published
- **Organisations:** Optical Microsensors and Micromaterials, Department of Photonics Engineering, Aarhus University
- **Contributors:** Canulescu, S., SUN, Y., Schou, J., Iversen, B. B.
- **Publication date:** 2010
- **Peer-reviewed:** Yes
- **Event:** Poster session presented at 7th International Conference on Photo-Excited Processes and Applications, Copenhagen, Denmark.

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- **bookababstracts_280910_2.pdf**

Research output: Contribution to conference › Poster – Annual report year: 2010 › Research › peer-review

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**Instantaneous monitoring of wear on a micro-nanometer scale through hard coatings by synchrotron radiation**

We have shown that wear dynamics can be monitored on a lateral micrometer scale by synchrotron radiation. We have followed the wear from the change in transmission on a system of three layers of hard coatings, TiAlN, CrN and TiAlN, of approximately one micron thickness produced by sputtering deposition. These layers were deposited on a 1 mm-thick vitreous carbon sample. The instantaneous depth was determined from transmission as well as XANES (X-ray Absorption Near Edge Spectra) measurements of the K-edge of Cr from the-CrN marker layer. The wear process is highly irregular and the local wear rate varies strongly from one position to another in the wear track. The ridges, grooves as well as the transport of debris from the track were for the first time followed on a micrometer level, confirming the stochastic nature of this type of wear. Most of the features are generated within the first 500 nm and exist over several micrometers. However, also a significant fraction of grooves and ridges disappear by wear over less than one micrometer.

### General information
- **Publication status:** Published
- **Organisations:** Optical Microsensors and Micromaterials, Department of Photonics Engineering, Ecole Centrale de Lyon, CemeCon Scandinavia A/S, University of Copenhagen
- **Contributors:** Schou, J., Rasmussen, I. L., Belin, M., Straasø, T., Feidenhans'l, R., Martin, J., Mikkelsen, N.
- **Publication date:** 2010
- **Peer-reviewed:** Yes
- **Event:** Abstract from 2010 Dansk Fysisk Selskabs Årsmøde, Nyborg, Denmark.

Electronic versions:
- **Bidrag-Dansk Fysisk Selskabs årsmøde 2010.docx**
- **URL:** [http://www.dfs.nbi.dk/aarsmoeder/scripts/viewabstracts.php?id=480](http://www.dfs.nbi.dk/aarsmoeder/scripts/viewabstracts.php?id=480)

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**Ion Production by Laser Impact on a Silver Surface**

### General information
- **Publication status:** Published
- **Organisations:** Risø National Laboratory for Sustainable Energy, Optical Microsensors and Micromaterials, Department of Photonics Engineering
- **Contributors:** Christensen, B. T., Schou, J.
- **Publication date:** 2010
- **Peer-reviewed:** Yes
- **Event:** Poster session presented at ICACS 24 (International Conference on Atomic Collisions in Solids), Krakow, Poland.

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Research output: Contribution to conference › Poster – Annual report year: 2010 › Research › peer-review
Optical detections from worn and unworn titanium compound surfaces
Wear-induced roughness in terms of grooves, sharp ridges, and edges leads to scattering of the reflected light and leads unavoidably to a reduction of the optical signals in a standard specular geometry. However, by using a double-layer system consisting of titanium aluminum nitride (TiAlN) on top of a titanium nitride (TiN) layer we obtain an increase in the reflected light as a result of wear. The relative change of reflectance of light from the tribological TiAlN coated surface to the underlying layer of TiN is similar for non-worn surfaces and for surfaces exposed to an abrasive wear process. The induced roughness reduces the signals from worn samples, in a standard specular geometry, by up to 30% compared with unworn samples. Our model system of TiAlN coatings on top of ‘optical’ signal layers of TiN deposited on a 100Cr6 steel substrate, was exposed to a reciprocating wear process with up to 105 repetitive cycles in a linear tribometer. The worn TiAlN layers of thicknesses up to 3 µm, with strongly developed grooves and ridges, were subsequently used for the reflectance measurements. The results show that optical reflectance monitoring is a potential technique for intelligent determination of a residual thickness of realistic tribological coatings prior to complete wear.

General information
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering, Laboratoire de Tribologie et Dynamique des Systèmes, CemeCon Scandinavia A/S
Contributors: Rasmussen, I. L., Guibert, M., Martin, J., Belin, M., Mikkelsen, N. J., Pedersen, H. C., Schou, J.
Pages: 15-21
Publication date: 2010
Peer-reviewed: Yes

Pulsed laser deposition of gadolinia doped ceria layers at moderate temperature – a seeding approach
Ceria-based thin films are often applied as key functional components in miniaturized electroceramic devices such as solid oxide fuel cells or gas sensors. Processing routes that prevent thermal degradation and yield access to the optimum microstructures are sought. Multi-step growth, involving the preparation of ultrathin seed layers in the first stage of the deposition process is often envisaged to control the growth and physical properties of the subsequent coating. This work suggests that the limitations of conventional pulsed laser deposition (PLD), performed at moderate temperature (400°C), to the growth of dense, gas impermeable 10 mol% gadolinia-doped ceria (CGO10) solid electrolyte can be overcome by the seeding process. In order to evaluate the seed layer preparation, the effects of different thermal annealing treatments on the morphology, microstructure and surface roughness of ultrathin CGO10 layers with a thickness of 4 nm, 13 nm and 22 nm, respectively, grown on Mg(100), were studied by atomic force microscopy and X-ray reflectometry.

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Publication date: 2010
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Event: Poster session presented at 7th International Conference on Photo-Excited Processes and Applications, Copenhagen, Denmark.
Quantitative TEM analysis of Al/Cu multilayer systems prepared by pulsed laser deposition
Thin films composed of alternating Al/Cu/Al layers were deposited on a (111) Si substrate using pulsed laser deposition (PLD). The thicknesses of the film and the individual layers, and the detailed internal structure within the layers were characterized by means of transmission electron microscopy (TEM), high-resolution TEM (HRTEM), and energy-filtered TEM (EFTEM). Each Al or Cu layer consists of a single layer of nano-sized grains of different orientations. EFTEM results revealed a layer of oxide about 2 nm thick on the surface of the Si substrate, which is considered to be the reason for the formation of the first layer of nano-sized Al grains. The results demonstrate that the PLD technique is a powerful tool to produce nano-scale multilayered metal films with controllable thickness and grain sizes.

Structural and magnetic properties of Gd/Fe multilayers grown by pulsed laser deposition
This work investigates the structural and the magnetic properties of Gd/Fe multilayered thin films grown by pulsed laser deposition onto Si (001) substrates at room temperature. The Fe layer thickness is varied from 70 to 150 nm and its effect on the structural and magnetic properties of Fe/Gd/Fe sandwich multilayers has been explored. Gd films were found to change from amorphous to polycrystalline at a critical thickness of 20 nm.
Wear monitoring of protective nitride coatings using image processing

A double-layer model system, consisting of a thin layer of tribological titanium aluminum nitride (TiAlN) on 17 top of titanium nitride (TiN), was deposited on polished 100Cr6 steel substrates. The TiAlN top-coatings were exposed to abrasive wear by a reciprocating wear process in a linear tribo-meter with up to 105 repetitive cycles, eventually leaving the embedded TiN signal layer uncovered at the bottom the wear scar. The worn surface was characterized by subsequent image processing. A color detection of the wear scar with the exposed TiN layer by a simple optical imaging system showed a significant increase up to a factor of 2 of the relative color values from the TiAlN top layers to the embedded TiN signal layers. This behavior agrees well with the results of reflectance detection experiment with a red laser optical system on the same system. Thus we have demonstrated that image processing by color detection is a potential technique for early 25 warning or determination of residual thickness of tribological tool coatings prior to complete wear.

Charging-assisted desorption of deuterium films by keV electrons

Films of solid deuterium at a temperature around 3 K have been irradiated by 1.5 or 2 keV electrons. The films were deposited on the silver electrode of a quartz crystal microbalance (QCM) suspended below a pumped liquid helium cryostat [1,2]. The thickness of the films ranged from 10 nm to up to 5 m. The initial film thickness and the mass loss as result of desorption were monitored by the QCM. The electron beam current was kept at about or below 100 nA to avoid beam-induced evaporation. Secondary electron emission was suppressed to a value below 0.01-0.03 electrons/electron by a repeller ring at a bias of ~90 V. However, for films thicker than 3-4 times the range of the bombarding electrons, the electron yield suddenly rose to a value close to 0.40. From this secondary electron yield the voltage potential could be determined unambiguously from secondary electron emission curves obtained by short pulse measurements on fresh films. For the thickest films the charging induced a surface potential of more than 1.0 kV, i.e. one-half of the energy of the bombarding electron. For these thick films the desorption yield increased from the minimum value of 6-10 D2/electron up...
to 380 D2/electron at 1.5 keV and 960 D2/electron at 2 keV. The surface potential is induced by electron charge accumulation in the film at large thicknesses from where the electrons no longer are able to migrate to the conductive substrate with a sufficiently high rate.

Factors controlling the microstructure of Ce0.9Gd0.1O2-δ films in pulsed laser deposition process

Films of Ce0.9Gd0.1O2-δ (CGO10) are prepared at a range of conditions by pulsed laser deposition (PLD) on a single crystal Si (100) and MgO (100), and on a polycrystalline Pt/MgO (100) substrate. The relationship between the film microstructure, crystallography, chemical composition and PLD processing parameters is studied. It is found that the laser fluence has no significant impact on the film density, whereas the substrate temperature and the oxygen pressure are of essential importance for the film microstructure development. The reduction of deposition temperature down to 250 oC together with a lowered oxygen pressure of 0.05 mbar, significantly inhibits the growth of columnar structures. Further decrease in oxygen pressure, to 0.005 mbar, promotes film densifications, but a stress build-up is observed and leads to a lattice-parameter enlargement of the coatings. The chemical films composition is affected by the applied fluence. At a low fluence, 0.5 J/cm², a congruent transfer is obtained while a relative Gd enrichment results for substantially higher fluences (3.5–5.5 J/cm²).

Image processing of worn and unworn protective coatings of TiAlN and TiN on 100Cr6 steel

A model system, consisting of a titanium aluminum nitride (TiAlN) coating on top of an 'optical' titanium nitride (TiN) signal layer deposited on 100Cr6 steel substrates, was exposed to an extremely abrasive wear process. The TiAlN top-coatings, of thicknesses of up to 3 μm, were removed by a reciprocating wear process in a linear tribo-meter with up to 105
repetitive cycles, leaving the embedded TiN signal layers uncovered at the bottom the wear scars. The worn surfaces were characterized by subsequent image processing. A color detection, by a simple optical imaging system, of the wear scar with the exposed TiN layer showed a significant increase of ~40% of the relative color values from the TiAlN top layers to the embedded TiN signal layers. A similar reflectance detection experiment with a red laser optical system showed a comparatively significant signal increase of ~30% from the TiAlN top-coating to the TiN signal layer. The two different methods, image processing and laser reflectance measurements, lead thus to identical results, showing that image processing by means of color detection or monitoring and laser reflectance are potential techniques for intelligent determination of residual thickness of realistic tribological coatings of tools prior to complete wear.

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Organisations: Department of Photonics Engineering, Optical Microsensors and Micromaterials, Centre National de la Recherche Scientifique, CemeCon Scandinavia A/S
Contributors: Rasmussen, I. L., Guibert, M., Martin, J., Belin, M., Mikkelsen, N., Pedersen, H. C., Schou, J.
Publication date: 2009
Peer-reviewed: Yes
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Research output: Contribution to conference › Poster – Annual report year: 2009 › Research › peer-review

It is absolutely fascinating to work with lasers

General information
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Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Schou, J.
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Publisher: DTU Fotonik
Edition: 1
ISBN (Print): 87-92062-34-2
Source: orbit
Source-ID: 255230
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2009 › Communication

Laser ablation plume expansion into an ambient gas: propagation dynamics and energetics
The use of an ambient gas is a well-established method employed in pulsed laser deposition (PLD) with nanosecond pulses and has been extensively studied in this context. Most of the existing treatments of the plume expansion are tackled by using complex numerical modeling involving specific target/background gas systems and whose results cannot be straightforwardly extended to a different situation. In the present work, we analyze the propagation dynamics of a silver ablation plume in different background gases. The starting point is the gas-dynamical model of Predtechensky and Mayorov (PM) [1], which provides a rather clear description of the essential hydrodynamics and can be used for gases of different atomic/molecular mass [2]. We also extend the model to describe the energetic of the plume from the initial stage of expansion to the complete plume halt into the background gas. The observed dynamics and energetics can be helpful for a quantitative description of the plume propagation into the surrounding, low-pressure atmosphere typically employed in PLD, thus allowing identifying the different stages of expansion for any target/background mass system.

General information
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Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering, Università degli Studi di Napoli Federico II, Trinity College Dublin
Contributors: Amoruso, S., Schou, J., Lunney, J.
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Materials through light, light through materials: Interaction of light and matter

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Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Ramanujam, P., Schou, J.
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Publication date: 2009

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Publisher: DTU Fotonik
Edition: 1
ISBN (Print): 87-92062-34-2
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Research output: Chapter in Book/Report/Conference proceeding

On the growth of gadolinia-doped ceria by pulsed laser deposition

In order to establish a new platform to manufacture micro sized solid oxide fuel cells (SOFCs) with low operating temperatures, new design concepts, new preparation methods and new materials are being explored. Our studies in this paper are focused on the electrolyte material, and in particular gadolinia doped ceria (GDC), an electrolytematerial, likely to replace the traditional yttria-stabilised zirconia (YSZ) for low temperature applications. GDC films were grown on a single crystal Si by pulsed laser deposition (PLD). The microstructure of the films as a function of growth time has been studied. We have found that the mean grain size increases with film thickness \( h \) as \( h^{2/5} \), in agreement with theoretical results.

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Contributors: Pryds, N., Rodrigo, K. A., Linderoth, S., Schou, J.
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Scopus rating (2009): SJR 0.84 SNIP 1.026
Web of Science (2009): Indexed yes
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10.1016/j.apsusc.2008.07.134
URLs:
Physical aspects of the pulsed laser deposition technique: The stoichiometric transfer of material from target to film

The physical processes of pulsed laser deposition (PLD) change strongly from the initial light absorption in a target to the final deposition and growth of a film. One of the primary advantages of PLD is the stoichiometric transfer of material from target to a film on a substrate. Even for a stoichiometric flow of material from a multicomponent target, the simultaneous arrival of the target atoms is not sufficient to ensure a stoichiometric film growth. The laser fluence has to be sufficiently high to induce ablation rather than pure evaporation from target, but a high fluence may lead to preferential (self)sputtering and possibly implantation of the light atoms in the film. A background gas of a sufficiently high pressure may reduce sputtering of the film, but may lead the preferential diffusion of the light component to the substrate. The importance of these processes during the entire PLD process will be discussed.

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Volume: 255
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Ratings:
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.84 SNIP 1.026
Web of Science (2009): Indexed yes
Original language: English
DOIs:
10.1016/j.apsusc.2008.10.101
Source: orbit
Source-ID: 250842
Research output: Contribution to journal › Journal article – Annual report year: 2009 › Research › peer-review

Quantitative TEM analysis of Al/Cu multilayer prepared by pulsed laser deposition

General information
Publication status: Published
Organisations: Metal Structures in Four Dimensions, Materials Research Division, Risø National Laboratory for Sustainable Energy, Thermo Ceramics, Fuel Cells and Solid State Chemistry Division, Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Liu, H., Pryds, N., Schou, J., Huang, X.
Publication date: 2009
Peer-reviewed: Yes
Event: Poster session presented at 10th International Conference on Laser Ablation, Singapore, Singapore.
Keywords: Materials characterization and modelling, Materials research
Source: orbit
Source-ID: 254086
Research output: Contribution to conference › Poster – Annual report year: 2009 › Research › peer-review

RHEED study of titanium dioxide with pulsed laser deposition

Reflection high-energy electron diffraction (RHEED) operated at high pressure has been used to monitor the growth of thin films of titanium dioxide (TiO2) on (1 0 0) magnesium oxide (MgO) substrates by pulsed laser deposition (PLD). The deposition is performed with a synthetic rutile TiO2 target at low fluence. The topography and structure of the deposited layers are characterized using in situ high pressure RHEED and atomic force microscope (AFM). Based on these observations the growth mode of the films is discussed. The results will be compared to earlier results obtained for the growth of TiN films on (1 0 0) MgO

General information
Sputtering of cryogenic films of hydrogen by keV ions: Thickness dependence and surface morphology

The sputtering yield induced by keV hydrogen ions measured at CERN and at Risø National Laboratory for solid H2 and D2 at temperatures below 4.2 K decreases with increasing film thickness from about 100 \times 10^{15} \text{molecules/cm}^2. For a film thickness comparable to or larger than the ion range the data from Risø show a slight increase, whereas the yield from CERN continues to decrease up to very large film thicknesses, i.e. one order of magnitude larger than the ion range. The different behavior of the yield is discussed in terms of the probable growth modes of the films. The films produced at the Risø setup are quench-condensed films, while those produced at CERN are supposed to grow with large hydrogen aggregates on top of a thin bottom layer.

Structural and magnetic properties of Gd/Fe multilayers grown by pulsed laser deposition

This work investigates structural and magnetic properties of Gd/Fe multilayered thin films grown by pulsed laser deposition onto Si (001) substrates at room temperature. The Fe layer thickness is varied from 70 to 150 nm and its effect on structural and magnetic properties of Gd/Fe multilayers has been explored. The samples have a 10 nm Ag capping layer to prevent oxidation during the processing. Two magnetization saturation plateaus were observed in the magnetization vs
field isotherm at 290 K, in parallel configuration and these plateau values correspond to that of MFe and MFe + MGd.

**General information**
Publication status: Published
Contributors: Kant, K. M., Bahl, C. R. H., Pryds, N., Smith, A., Schou, J.
Publication date: 2009
Peer-reviewed: Yes
URLs:
Source: orbit
Source-ID: 257029
Research output: Contribution to conference › Poster – Annual report year: 2009 › Research › peer-review

**Transport properties of nanocrystalline gadolinia doped ceria films grown by pulsed laser deposition**

**General information**
Publication status: Published
Publication date: 2009
Peer-reviewed: Yes
Event: Poster session presented at 10th International Conference on Laser Ablation, Singapore, Singapore.
Keywords: Solid Oxide Fuel Cells, Fuel Cells and hydrogen
Source: orbit
Source-ID: 254084
Research output: Contribution to conference › Poster – Annual report year: 2009 › Research › peer-review

**Design of optical reflectance signals for wear control by varying the thickness of thin films of Ti-compounds**

**General information**
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering, Thermo Ceramics, Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy, CemeCon Scandinavia A/S
Contributors: Rasmussen, I. L., Pryds, N., Pedersen, H. C., Schou, J., Mikkelsen, N.
Pages: 135307-135312
Publication date: 2008
Peer-reviewed: Yes

**Publication information**
Volume: 41
ISSN (Print): 0022-3727
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.465 SNIP 1.578
Web of Science (2008): Indexed yes
Original language: English
DOIs:
10.1088/0022-3727/41/13/135307
Source: orbit
Source-ID: 222872
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

**Desorption of cryogenic layers of the solid hydrogens by electron bombardment: The role of the metal substrate**
For solid hydrogenic films in the thickness range from similar to 50 ML to similar to 500 ML the desorption yield falls off inversely proportional to the thickness for both H-2 and D-2 films. This behavior is common for data obtained at CERN for solid H-2 and at Riso National Laboratory for solid D-2 at temperatures below 4.2 K. The thickness range is comparable to the range of the electrons for energies between 0.3 and 2 keV. For these energies less energy is deposited in the metal
substrate with increasing film thickness. We have explored how the behavior of the desorption yield may be explained in terms of the energy dissipated in a copper substrate or as the surface value of the energy deposited in electronic excitations in copper, but not found convincing arguments for a close correlation between the desorption yield and these quantities. The decreasing desorption yield for film thicknesses that greatly exceed the electron mean penetration depth evaluated from uniform films, may be explained by nonuniform growth of the hydrogen films on the metal substrate. (C) 2008 Elsevier B.V. All rights reserved.
**Fundamentals of laser-assisted fabrication of inorganic and organic films**

The standard method for producing films by laser-assisted methods, Pulsed Laser Deposition (PLD) will be reviewed. The films considered are usually inorganic films, but also films of organic materials have been produced. Also the deposition of organic films by MAPLE (Matrix Assisted Pulsed Laser Evaporation), in which the target is replaced by a frozen matrix containing a few per cent film material, will be reviewed.

**General information**

Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 241-256
Publication date: 2008

**Host publication information**

Title of host publication: Functionalized Nanoscale Materials, Devices and Systems
Place of publication: Dordrecht
Publisher: Springer
Editors: Vaseashta, A., Mihailescu, I.
(= NATO Science for Peace and Security Series B - Physics and Biophysics).
Keywords: Pulsed laser deposition (PLD), matrix-assisted pulsed laser evaporation (MAPLE)
DOIs: 10.1007/978-1-4020-8903-9_15
Source: orbit
Source-ID: 231373

**Growth of thin films of TiN on MgO(100) monitored by high-pressure RHEED**

Reflection high-energy electron diffraction (RHEED) operated at high pressure has been used to monitor the initial growth of titanium nitride (TiN) thin films on single-crystal (100) MgO substrates by pulsed laser deposition (PLD). This is the first RHEED study where the growth of TiN films is produced by PLD directly from a TiN target. At the initial stage of the growth (average thickness similar to 2.4 nm) the formation of islands is observed. During the continuous growth the islands merge into a smooth surface as indicated by the RHEED, atomic force microscopy and field emission scanning electron microscopy. These observations are in good agreement with the three-dimensional Volmer-Weber growth type, by which three-dimensional crystallites are formed and later cause a continuous surface roughening. This leads to an exponential decrease in the intensity of the specular spot in the RHEED pattern as well.

**General information**

Publication status: Published
Organisations: Thermo Ceramics, Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy, Electroceramics, Optical Microsensors and Micromaterials, Department of Photonics Engineering, Technical University of Denmark
Pages: 705-710
Publication date: 2008
Peer-reviewed: Yes

**Publication information**

Influence of the atomic mass of the background gas on laser ablation plume propagation
A combination of time-of-flight ion probe measurements and gas dynamical modeling has been used to investigate the propagation of a laser ablation plume in gases of different atomic/molecular weight. The pressure variation of the ion time-of-flight was found to be well described by the gas dynamical model of Predtechensky and Mayorov (Appl. Supercond. 1:2011, 1993). In particular, the model describes how the pressure required to stop the plume in a given distance depends on the atomic/molecular weight of the gas, which is a feature that cannot be explained by standard point-blast-wave descriptions of laser ablation plume expansion in gas.

Laser-induced plasma from pure and doped water-ice at high fluence by ultraviolet and infrared radiation - art. no. 70050X
Ice made of ultrapure water or water doped with 1 % polymer (polyethylene glycol, "PEG") was irradiated by laser light with fluences between 2 and 80 J/cm(2) in the ultraviolet (UV) regime at 355 nm and in the infrared (IR) regime at 1064 nm in vacuum. In the UV regime there is a threshold for plasma formation at 3.5 J/cm(2), whereas the threshold is at 8.5 J/cm(2) in the IR regime. The ions from the plasma plume were studied by a Langmuir probe. The ion yield was much higher for UV laser irradiation than for IR laser irradiation. The peak of the time-of-flight spectra comprises ions of velocity from 60 to 110 km/s. Generally, the ion yield was slightly larger for ice samples doped with PEG than for pure ones. The threshold behavior was much more pronounced in the IR regime than in the UV regime. These results indicate that the behavior of the plasma current can be understood in terms of ionization breakdown at the ice surface.
Physical Aspects of the Pulsed Laser Deposition Technique: The Stoichiometric Transfer of Material from Target to Film

General information
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Schou, J.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 224136
Research output: Contribution to conference › Paper – Annual report year: 2008 › Research

Physical aspects of the pulsed laser deposition technique: The stoichiometric transfer of material from target

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 310094
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2008 › Research

Production and fragmentation of lysozyme films at 355 nm by pulsed laser deposition (PLD)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Photonics Engineering, Optical Microsensors and Micromaterials
Contributors: Purice, A., Constantinescu, C., Mortensen, N., Schou, J., Dinescu, M.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 224140
Research output: Contribution to conference › Poster – Annual report year: 2008 › Research
Production of thin protein films by direct laser irradiation (PLD) and laser irradiation in a water ice matrix (MAPLE)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Materi, A., Constatinescu, C., Schou, J., Dinescu, M., Mortensen, N.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 310088
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2008 › Research

Production of thin protein films by direct laser irradiation (PLD) and laser irradiation in a water ice matrix (MAPLE)

General information
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Materi, A., Constatinescu, C., Schou, J., Dinescu, M., Mortensen, N.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 224168
Research output: Contribution to conference › Paper – Annual report year: 2008 › Research

Reflectance measured from worn and unworn surfaces of titanium compounds

General information
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Rasmussen, I. L., Guibert, M., Martin, J., Belin, M., Pedersen, H. C., Mikkelsen, N., Schou, J.
Publication date: 2008
Peer-reviewed: No
Event: Abstract from Danish Optical Society Annual Meeting 2008, Nyborg, Denmark.
Electronic versions: 2008_86.pdf
URLs:
Source: orbit
Source-ID: 223208
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2008 › Research

RHEED study of titanium dioxide using pulsed laser deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rasmussen, I., Pryds, N., Schou, J.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 310095
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2008 › Research

RHEED Study of Titanium Dioxide Using Pulsed Laser Deposition

General information
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering, Thermo Ceramics, Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy
Contributors: Rasmussen, I. L., Pryds, N., Schou, J.
**Sputtering of cryogenic films of hydrogen by keV ions: Thickness dependence and surface morphology**

**General information**
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Schou, J., Hilleret, N.
Publication date: 2008
Peer-reviewed: No
Electronic versions:
2008_104.pdf
Source: orbit
Source-ID: 224169

**Sputtering of cryogenic films of hydrogen by keV ions: Thickness dependence and surface morphology**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Hilleret, N.
Publication date: 2008
Peer-reviewed: No

**Thin films of proteins produced in a dry environment by laser irradiation**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Matei, A., Constatinescu, C., Dinescu, M.
Publication date: 2008
Peer-reviewed: No

**Thin films of proteins produced in a dry environment by laser irradiation**

**General information**
Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering
Contributors: Schou, J., Matei, A., Constatinescu, C., Dinescu, M.
Publication date: 2008
Peer-reviewed: No
Event: Paper presented at 12th Joint Workshop Physical and Chemical Graduate School Göttingen adn the Dahlem Research School of Molecular Science, Berlin, Germany.
A RHEED study of thin films grown on MgO samples by pulsed laser deposition

**General information**
Publication status: Published
Contributors: Pryds, N., Cockburn, D., Rodrigo, K. A., Knudsen, J., Schou, J.
Publication date: 2007
Peer-reviewed: No
Event: Abstract from Danish Optical Society annual meeting 2007, Risø, Denmark.
URLs:
Source: orbit
Source-ID: 215763
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2007 › Research

A tribological study of titanium nitrides with synchrotron radiation

**General information**
Publication status: Published
Contributors: Rasmussen, I. L., Pedersen, H. C., Pryds, N., Schou, J., Mikkelsen, N., Feidenhans’l, R., Martin, J., Guibert, M., Belin, M.
Publication date: 2007
Peer-reviewed: No
Event: Abstract from 3rd Annual meeting Danish Physical Society, Nyborg, Denmark.
URLs:
Source: orbit
Source-ID: 216248
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2007 › Research

Characterization of lysozyme films produced by matrix assisted pulsed laser evaporation (MAPLE)
Thin lysozyme films of thickness up to more than 100 nm have been produced in a dry environment by MAPLE (matrix assisted pulsed laser evaporation) from a water ice matrix. Analysis of the films demonstrates that a significant part of the lysozyme molecules is transferred to the substrate without decomposition and that the protein activity is preserved. The film deposition rate for 1 wt.% lysozyme has a maximum at 2 J/cm(2) of about 1 ng/cm(2) per laser shot. During the film production the deposition rate is constant without any sign of depletion or accumulation effects in the water ice target or in the growing film. Scanning electron microscopy (SEM) images demonstrate that the silicon substrate is completely covered by lysozyme films thicker than 100 nm. Deposition was also made from a target with pressed (100%) solid lysozyme, but the deposition was difficult to handle and with a much slower rate than that from a water ice matrix. (C) 2007 Elsevier B.V. All rights reserved.

**General information**
Publication status: Published
Contributors: Purice, A., Schou, J., Kingshott, P., Pryds, N., Dinescu, M.
Pages: 6451-6455
Publication date: 2007
Peer-reviewed: Yes

**Publication information**
Journal: Applied Surface Science
Volume: 253
Issue number: 15
ISSN (Print): 0169-4332
Ratings: Scopus rating (2007): SJR 0.791 SNIP 0.935
Characterization of yttria-stabilized zirconia thin films grown by pulsed laser deposition (PLD) on various substrates

General information
Publication status: Published
Contributors: Rodrigo, K. A., Knudsen, J., Pryds, N., Schou, J., Linderoth, S.
Pages: 1338-1342
Publication date: 2007
Peer-reviewed: Yes

Deposition and fragmentation of protein films produced by MAPLE or PLD

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Purice, A., Schou, J., Dinescu, M.
Publication date: 2007
Peer-reviewed: No
Event: Abstract from 9th International Conference on Laser Ablation, Tenerife, Spain.
URLs:
Source: orbit
Source-ID: 215930
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2007 › Research

Desorption of thin cryogenic layers by electron, ion and photon irradiation

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 216567
Electron-induced desorption of layers of the solid hydrogens on a metal substrate: The question of the energy dissipation in the substrate

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2007
Peer-reviewed: No
Event: Paper presented at Workshop in stopping, Odense, Denmark.
Source: orbit
Source-ID: 216451

Formation of thin films of yttria-stabilized zirconia thin films grown by pulse laser deposition (PLD) on various substrates

General information
Publication status: Published
Contributors: Rodrigo, K. A., Knudsen, J., Pryds, N., Schou, J., Linderoth, S.
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 216340

Fundamentals of laser-assisted fabrication of inorganic and organic films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Optics and Plasma Research Department, Laser Systems and Optical Materials
Contributors: Schou, J.
Publication date: 2007
Peer-reviewed: No
URLs:
Source: orbit
Source-ID: 216227

Growth dynamics of thin lysozyme films produced by matrix-assisted pulsed laser evaporation (MAPLE)

General information
Publication status: Published
Contributors: Purice, A., Schou, J., Pryds, N., Filipescu, M., Dinescu, M.
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 216342
Growth of thin films of TiN on MgO(100) monitored by high pressure RHEED

High fluence deposition of polyethylene glycol films at 1064 nm by matrix assisted pulsed laser evaporation (MAPLE)

Influence of the atomic mass of the background gas on laser ablation plume propagation
Large-area production of yttria-stabilized zirconia by pulsed laser deposition

General information
Publication status: Published
Contributors: Pryds, N., Schou, J., Linderoth, S.
Pages: 140-143
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Journal of Physics: Conference Series (Online)
Volume: 59
ISSN (Print): 1742-6596
Ratings:
Scopus rating (2007): SJR 0.258 SNIP 0.367
Web of Science (2007): Indexed yes
Original language: English
DOIs: 10.1088/1742-6596/59/1/030
Source: orbit
Source-ID: 215988

Laser-induced plasma from pure and doped water-ice at high fluence

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Matei, A., Rodrigo, K., Dinescu, M.
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 310158

Laser irradiation of hard and volatile solids: from laser-produced plasmas to film deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Optics and Plasma Research Department, Laser Systems and Optical Materials
Contributors: Schou, J.
Publication date: 2007
Peer-reviewed: No
URLs:
Source: orbit
Source-ID: 215969

Optical monitoring of abrasive wear of titanium compounds in tribological hard coatings

General information
Publication status: Published
Optisk kontrol af tribologiske nanotyndfilm: En laserbaseret slitagesensor

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Rasmussen, I. L., Pedersen, H. C., Schou, J.
Pages: 16-18
Publication date: 2007
Peer-reviewed: Unknown

Publication Information
Journal: DOPS-Nyt
Volume: 22
Issue number: 1
Original language: Danish
Source: orbit
Source-ID: 216503
Research output: Contribution to journal – Journal article – Annual report year: 2007 – Communication

Plume dynamics

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Amoruso, S., Lunney, J.
Pages: 67-95
Publication date: 2007

Host publication information
Title of host publication: Laser ablation and its applications
Place of publication: Berlin
Publisher: Springer
Editor: Phipps, C.
ISBN (Print): 978-0-387-30452-6
(Springer Series in Optical Sciences; No. 129).
DOIs:
10.1007/978-0-387-30453-3
URLs:

Bibliographical note
This article may be downloaded for personal use only. Any other use requires prior permission of the author and the publisher
Source: orbit
Source-ID: 216634

Production of active lysozyme films by matrix assisted pulsed laser evaporation at 355 nm
Thin lysozyme films have been produced in a dry environment by MAPLE (matrix assisted pulsed laser evaporation) from a water ice matrix irradiated by laser light at 355 nm above the absorption threshold of the protein. A significant part of the lysozyme molecules are transferred to the film without decomposition and the protein activity is preserved. The film deposition rate for 1 wt% lysozyme shows a clear maximum of about 1 ng/cm(2) per shot for a moderate fluence of 2 J/cm(2), which is about one-half of the deposition rate from a pressed (100%) lysozyme target. (c) 2007 Elsevier B.V. All rights reserved.
Slowing-down processes, energy deposition, sputtering and desorption in ion and electron interactions with solids

General information
Publication status: Published
Organisations: Laser Systems and Optical Materials, Optics and Plasma Research Department, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 169-178
Publication date: 2007

Host publication information
Title of host publication: Vacuum in accelerators : Proceedings
Volume: CERN-2007-003
Publisher: CERN
Editor: Brandt, D.
URLs:
Source: orbit
Source-ID: 215924
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2007 – Research

Surface morphology of thin lysozyme films produced by matrix-assisted pulsed laser evaporation (MAPLE)
Thin films of the protein, lysozyme, have been deposited by the matrix-assisted pulsed laser evaporation (MAPLE) technique. Frozen targets of 0.3-1.0 wt.% lysozyme dissolved in ultrapure water were irradiated by laser light at 355 nm with a fluence of 2 J/cm(2). The surface quality of the thin lysozyme films of different thickness deposited on 7 rum x 7 turn Si-(1 0 0) -wafers was investigated with scanning electron microscopy and atomic force microscopy. Already at comparatively low thickness, similar to 20 nm, the substrate is covered by intact lysozyme molecules and fragments. The concentration of lysozyme in the ice matrix apparently does not play any significant role for the morphology of the film. The morphology obtained with MAPLE has been compared with results for direct laser irradiation of a pressed lysozyme sample (i.e. pulsed laser deposition (PLD)). (C) 2007 Elsevier B.V. All rights reserved.

General information
Publication status: Published
Contributors: Purice, A., Schou, J., Pryds, N., Filipescu, M., Dinescu, M.
Pages: 1244-1248
Publication date: 2007
Peer-reviewed: Yes
The spatial thickness distribution of metal films produced by large area pulsed laser deposition
Thin films of metals have been deposited in the large-area Pulsed Laser Deposition (PLD) Facility at Risø National Laboratory. Thin films of Ag and Ni were deposited with laser pulses from an excimer laser at 248 nm with a rectangular beam spot at a fluence of 10 J/cm² on glass substrates of 127 mm diameter positioned 80 turn from the target in vacuum. We have explored the distribution of deposited material on a stationary substrate from a fixed point of impact on the target relative to the substrate. In all cases the angular distribution of the deposited metal layers shows a distinct "flip-over" of the plume. The thickness of the deposited films over the full area has been determined by energy-dispersive X-ray spectrometry in a scanning electron microscope (SEM). The measured distributions were then compared with analytical expressions. Finally, the angular distribution of the film thickness has been utilized in an algorithm for production of films over large areas. (c) 2007 Elsevier B.V. All rights reserved.

Thin films of proteins produced by laser irradiation of dry or frozen targets

General information
Publication status: Published
Contributors: Pryds, N., Schou, J., Linderoth, S.
Pages: 8231-8234
Publication date: 2007
Peer-reviewed: Yes

URLs:
**Water ice as a matrix for film production by matrix assisted pulsed laser evaporation (MAPLE)**

We have studied water ice as a matrix for the production of PEG (polyethylene glycol) films by MAPLE at 355 nm. The deposition rate is small compared with other matrices typically used in MAPLE, but the deposition of photofragments from the matrix can be avoided. At temperatures above -50 degrees C of the target holder the deposition rate increases strongly, but the evaporation pressure in the MAPLE chamber also increases drastically.

**General information**
Publication status: Published
Contributors: Rodrigo, K. A., Schou, J., Christensen, B. T., Pedrys, R.
Pages: 501-504
Publication date: 2007
Peer-reviewed: Yes

**Publication information**
Journal: Journal of Physics: Conference Series (Print)
Volume: 59
ISSN (Print): 1742-6588
Scopus rating (2007): SJR 0.258 SNIP 0.367
Web of Science (2007): Indexed yes
Original language: English
DOI: 10.1088/1742-6596/59/1/108
Source-ID: 215929

**Deposition of polyethylene glycol films (PEG) by matrix assisted pulsed laser evaporation (MAPLE) using infrared light**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Purice, A., Schou, J., Kingshott, P., Pryds, N., Dinescu, M.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from Danish Physical Society Annual Meeting 2006, Nyborg, Denmark.
Source-ID: 309478

**Publication information**
Journal: Kvant
Volume: 17
Issue number: 2
ISSN (Print): 0905-8893
High fluence deposition of polyethylene glycol films at 1064 nm by matrix assisted pulsed laser evaporation (MAPLE)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Purice, A., Schou, J., Kingshott, P., Pryds, N., Dinescu, M.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from European Materials Research Society Spring 2006 meeting, Nice, France.
Source: orbit
Source-ID: 309344
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

High-quality protein films produced by Maple (Matrix assisted pulsed laser evaporation)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Purice, A., Schou, J., Kingshott, P., Pryds, N., Dinescu, M.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from 5. International conference on photo-excited processes and applications (ICPEPA 5), Charlottesville, VA (US), 3-7 Sep.,
Source: orbit
Source-ID: 309540
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Ion, electron and photon interactions with solids: Energy deposition, sputtering and desorption

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from Vacuum in accelerators, CAS, Platja d'Aro (ES), 16-24 May, 2006
Source: orbit
Source-ID: 309627
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Large area metal films produced by pulsed laser deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pryds, N., Schou, J., Linderoth, S.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from European Materials Research Society Spring 2006 meeting, Nice, France.
Source: orbit
Source-ID: 309342
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Laser beam-solid interactions: Fundamental aspects

General information
Publication status: Published
Optical control of tribological nanofilms: A wear sensor

Particle emission from polymer-doped water ice matrices induced by non-linear absorption of laser light at 1064 nm

Plume propagation dynamics and multiple scattering effects during UV pulsed laser ablation in background gases
**Protein films produced by Maple (Matrix assisted pulsed laser evaporation)**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Purice, A., Schou, J., Kingshott, P., Pryds, N., Disnescu, M.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from International conference on advanced laser technologies (ALT ’06), Brasov (RO), 8-12 Sep, .
Source: orbit
Source-ID: 309503

**Surface morphology of polyethylene glycol films produced by matrix-assisted pulsed laser evaporation (MAPLE): Dependence on substrate temperature**

The dependence of the surface morphology on the substrate temperature during film deposition was investigated for polyethylene glycol (PEG) films by matrix-assisted pulsed laser evaporation (MAPLE). The surface structure was studied with a combined technique of optical imaging and AFM measurements. There was a clear difference between the films produced below and above the melting point of PEG. For temperatures above the melting point, the polymer material was distributed non-uniformly over the substrate with growths areas, where cluster-like structures merge into large islands of micrometer size. At these temperatures, the islands in the investigated growth areas cover most of the bottom layer which has a typical height of 50-150 nm. (c) 2005 Elsevier B.V. All rights reserved.

**Thickness determination of large-area films of yttria-stabilized zirconia produced by pulsed laser deposition**

Films of yttria-stabilized zirconia (YSZ) on a polished silicon substrate of diameter up to 125 mm have been produced in a large-area pulsed laser deposition (PLD) setup under typical PLD conditions. The film thickness over the full film area has been determined by energy-dispersive X-ray spectrometry in a scanning electron microscope (SEM) with use of a method similar to one described by Bishop and Poole. The attenuation of the electron-induced X-rays from the Si wafer by the film was monitored at a number of points along a diameter and the thickness was determined by Monte Carlo simulations of the attenuation for various values of film thickness with the program CASINO. These results have been compared with direct measurements in the SEM of the film thickness on a cross-section on one of the wafers. The results of these measurements demonstrate the ability of this technique to accurately determine the thickness of a large film, i.e. up to diameters of 125 mm, in a relatively short time, without destroying the substrate, without the need of a standard sample and without the need of a flat substrate. We have also demonstrated that by controlling the deposition parameters large-area YSZ films with uniform thickness can be produced. (c) 2005 Elsevier B.V. All rights reserved.
Broadening and attenuation of UV laser ablation plumes in background gases

The expansion of a laser-induced silver plume in a background gas has been studied in a variety of gases ranging from helium, oxygen and argon to xenon. We have measured the angular distribution of the total deposit of silver on an array of quartz crystal microbalances as well as the time-of-flight distribution with a Langmuir probe. The angular distribution broadens for all gases except for a minor pressure range for the helium background gas, in which a distinct plume narrowing occurs. The behavior of the collected, ablated silver atoms integrated over the full hemisphere is similar for all gases. This integral decreases strongly above a characteristic pressure, which depends on the specific gas. The ion time-of-flight signal shows a clear plume splitting into a fast and a slow component except for the ablation plume in a helium gas. (c) 2005 Elsevier B.V. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Amoruso, S., Toftmann, B., Schou, J.
Pages: 323-328
Publication date: 2005
Peer-reviewed: Yes

Publication information
Journal: Applied Surface Science
Volume: 248
Issue number: 1-4
ISSN (Print): 0169-4332
Ratings:
Scopus rating (2005): SJR 0.679 SNIP 0.952
Web of Science (2005): Indexed yes
Original language: English
DOIs:
Electrical and structural properties of La$_{0.8}$Sr$_{0.2}$Mn$_{0.5}$Co$_{0.5}$O$_{3+\delta}$ films produced by pulsed laser deposition

La$_{0.8}$Sr$_{0.2}$Mn$_{0.5}$Co$_{0.5}$O$_{3+\delta}$ (LSMCO) films for the use as contact layers or protective coatings in solid oxide fuel cells (SOFC) have been deposited on glass substrates by pulsed laser deposition (PLD). PLD is an obvious technique for thin film production of complex oxides, because of the ability to transfer material stoichiometrically from a multicomponent target to a growing film. In the present study, films were deposited at substrate temperatures of 473 and 573 K and in different oxygen background pressures. The influence of the process parameters, in particular of the oxygen background gas pressure, on the electrical conductivity and structure of the films is investigated. (c) 2005 Elsevier B.V. All rights reserved.

Fundamental features of UV laser ablation by ns-pulses

Matrix assisted pulsed laser evaporation (MAPLE) is a deposition technique for organic material. Water ice was used as a matrix for the biotechnologically important guest material, polyethylene glycol (PEG), for concentrations from 0.5 to 4 wt.%. The target was irradiated with 6 ns laser pulses at 355 nm at a fluence of 2.5-12 J/cm$^2$. Even at this high fluence, Fourier transform infrared spectroscopy (FTIR) indicates a chemical structure of the deposit close to that of the un-irradiated PEG. Matrix assisted laser desorption and ionization (MALDI) and gel permeation chromatography (GPC) show that the mass distribution of the deposited PEG is similar to that of the starting material. Optical pictures of the films show particle structures of PEG of a size up to 5-10 µm. The deposition rate measured with a quartz crystal microbalance is typically of the order of 1 ng/ (cm$^2$ shot). (c) 2005 Elsevier B.V. All rights reserved.
**Infrared matrix assisted pulsed laser evaporation of polymeric films (poster)**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Risø National Laboratory, National Institute for Laser, Plasma and Radiation Physics
Contributors: Purice, A., Schou, J., Kingshott, P., Dinescu, M.
Publication date: 2005
Peer-reviewed: No
Event: Poster session presented at Annual meeting of the Danish Optical Society 2005, Roskilde, Denmark.

**Electronic versions:**
opl_1_2005.pdf

Research output: Contribution to conference > Poster – Annual report year: 2005 > Research

**Ion, electron and photon interactions with solids: Sputtering and desorption (Invited lecture)**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from Seminar at Sern, Geneve (CH), 21 Sep.,

Source: orbit
Source-ID: 308744
Research output: Contribution to conference > Conference abstract for conference – Annual report year: 2005 > Research

**Large-scale production of yttria-stabilized zirconia by pulsed laser deposition**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pryds, N., Schou, J., Linderoth, S.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from 8th International Conference on Laser Ablation, Banff, Canada.

Source: orbit
Source-ID: 308366
Research output: Contribution to conference > Conference abstract for conference – Annual report year: 2005 > Research
Large-scale pulsed laser deposition (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pryds, N., Schou, J., Linderoth, S.
Publication date: 2005
Peer-reviewed: No
Event: Poster session presented at Annual meeting of the Danish Optical Society 2005, Roskilde, Denmark.
Electronic versions:
opl_2_2005.pdf
Source: orbit
Source-ID: 308549
Research output: Contribution to conference › Poster – Annual report year: 2005 › Research

Laser irradiation of polymer-doped cryogenic matrices

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rodrigo, K., Christensen, B. T., Schou, J., Pedrys, R.
Pages: 683-692
Publication date: 2005
Peer-reviewed: Yes
Publication information
Journal: Journal of Low Temperature Physics
Volume: 139
ISSN (Print): 0022-2291
Ratings:
Scopus rating (2005): SJR 0.681 SNIP 0.626
Web of Science (2005): Indexed yes
Original language: English
DOIs:
10.1007/s10909-005-5480-0
Source: orbit
Source-ID: 308186
Research output: Contribution to journal › Journal article – Annual report year: 2005 › Research › peer-review

Surface structure of polyethylene glycol films produced by matrix assisted pulsed laser evaporation (MAPLE)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rodrigo, K., Czuba, P., Toftmann, B., Schou, J., Pedrys, R.
Publication date: 2005
Peer-reviewed: No
Source: orbit
Source-ID: 308188
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

Thickness determination of large-area films of yttria-stabilized zirconia produced by pulsed laser ablation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pryds, N., Christensen, B. T., Bilde-Sørensen, J., Schou, J., Linderoth, S.
Publication date: 2005
Peer-reviewed: No
Source: orbit
Source-ID: 308093
Thin film-deposition of organic material from laser-irradiated water-ice matrices

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Rodrigo, K., Toftmann, B., Pedrys, R.
Publication date: 2005
Peer-reviewed: No
Source: orbit
Source-ID: 308072

Water ice as a matrix for film production by matrix-assisted pulsed laser evaporation (MAPLE)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rodrigo, K., Schou, J., Toftmann, B., Pedrys, R.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from 8th International Conference on Laser Ablation, Banff, Canada.
Source: orbit
Source-ID: 308743

Diagnostics of laser ablated plasma plumes
The effect of an ambient gas on the expansion dynamics of laser ablated plasmas has been studied for two systems by exploiting different diagnostic techniques. First, the dynamics of a MgB2 laser produced plasma plume in an Ar atmosphere has been investigated by space-and time-resolved optical emission spectroscopy. Second, deposition rate and fast ion probe measurements have been used to study the plume propagation dynamics during laser ablation of a silver target, over a large range of Ar background gas pressures (from high vacuum to approximate to 100 Pa). A comparative analysis of the experimental results allows us to identify different regimes of the plume expansion, going from a free plume at low pressure, through collisional and shockwave like hydrodynamic regimes at intermediate pressure, finally reaching a confined plume with subsequent thermalization of the plume particles at the largest pressure of the background gas. The experimental findings also show that a combination of complementary techniques, like optical emission spectroscopy, close to the target, and fast ion probe and deposition rate measurements at larger distances, can lead to a more detailed understanding of the laser ablated plasma plume propagation in a background gas. (C) 2003 Elsevier B.V All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Amoruso, S., Toftmann, B., Schou, J., Velotta, R., Wang, X.
Pages: 562-572
Publication date: 1 Apr 2004
Peer-reviewed: Yes

Publication information
Journal: Thin Solid Films
Volume: 453-54
ISSN (Print): 0040-6090
Ratings:
Scopus rating (2004): SJR 1.183 SNIP 1.326
Web of Science (2004): Indexed yes
Original language: English
Keywords: laser ablation, spectroscopy, electrical probe, plume dynamics
DOIs:
10.1016/j.tsf.2003.11.137
Source: orbit
Source-ID: 306748
Conductive and protective properties of $\text{La}_{0.8}\text{Sr}_{0.2}\text{Mn}_{0.5}\text{Co}_{0.5}\text{O}_3$ films produced by pulsed laser deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pryds, N., Christensen, B. T., Schou, J., Hendriksen, P., Linderoth, S.
Publication date: 2004
Peer-reviewed: No
Source: orbit
Source-ID: 307430
Research output: Contribution to journal › Conference article – Annual report year: 2004 › Research

Deposition of organic materials from ice matrices by laser irradiation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Janik, K., Toftmann, B., Schou, J., Pedrys, R.
Publication date: 2004
Peer-reviewed: No
Source: orbit
Source-ID: 307007
Research output: Contribution to journal › Conference abstract for conference – Annual report year: 2004 › Research

Dynamics of a laser-produced silver plume in an oxygen background gas

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Toftmann, B., Amoruso, S.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from High-power laser ablation 2004, Taos, NM (US), 25-30 Apr,.
Source: orbit
Source-ID: 307011
Research output: Contribution to journal › Conference abstract for conference – Annual report year: 2004 › Research

Ejection of atoms and molecules from solid argon by keV light ion bombardment

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Janik, K., Kosierb, A., Wójcik, K., Pedrys, R., Schou, J.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from International conference on atomic collisions in solids, ICACS 21, Genova (IT), 4-7 Jul,.
Source: orbit
Source-ID: 307002
Research output: Contribution to journal › Conference abstract for conference – Annual report year: 2004 › Research

Ejection of polymers from ice matrices induced by laser irradiation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rodrigo, K., Toftmann, B., Schou, J., Pedrys, R.
Publication date: 2004
Peer-reviewed: No
Expansion of a laser-produced silver plume in light background gases

The expansion of a silver ablation plume in a helium and an argon background gas has been studied over the pressure range 10^{-6} to 1 mbar. The angular distribution of silver atoms deposited on an array of quartz-crystal microbalances as well as time-of-flight signals of the plume ions in both gases were measured. There is a distinct sharpening of the angular distribution of the ablated silver atoms in the helium gas within a narrow range from 0.2 to 0.4 mbar. In contrast, the width of the angular distribution in the argon gas increases throughout the interval. The time-of-flight signals show a peak of fast ions which gradually merges into a more complex structure.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Amoroso, S., Toftmann, B., Schou, J.
Pages: 1311-1314
Publication date: 2004
Peer-reviewed: Yes

Publication information
Volume: 79
Issue number: 4-6
ISSN (Print): 0947-8396
Ratings:
Scopus rating (2004): SJR 1.091 SNIP 1.101
Web of Science (2004): Indexed yes
Original language: English
DOIs:
10.1007/s00339-004-2759-y
Source: orbit
Source-ID: 307071
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

Fundamental interactions in laser irradiation of silver in low-pressure background gases

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Toftmann, B., Amoroso, S.
Publication date: 2004
Peer-reviewed: No
Source: orbit
Source-ID: 307010
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research

Fundamental interactions in pulsed laser deposition of metals

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Amoroso, S., Toftmann, B.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from 4-ICPEPA, International conference on photo-excited processes and applications, Lecce (IT), 5-9 Sep,.
Source: orbit
Source-ID: 307162
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research
High laser-fluence deposition of organic materials in water ice matrices by "MAPLE"

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Janik, K., Schou, J., Pedrys, R.
Publication date: 2004
Peer-reviewed: No
Source: orbit
Source-ID: 307428
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research

Ions produced by laser-surface interactions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Toftmann, B.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from Topical meeting on stopping of ions, Odense (DK), 4 Oct, .
Source: orbit
Source-ID: 307190
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research

Langmuir probe measurements of silver plasma expanding in vacuum and argon atmosphere (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Nørskov, T., Toftmann, B., Schou, J.
Publication date: 2004
Peer-reviewed: No
Event: Poster session presented at Danish Physical Society Annual Meeting 2004, Nyborg, Denmark.
Source: orbit
Source-ID: 307005
Research output: Contribution to conference › Poster – Annual report year: 2004 › Research

Laser-induced ion emission during polymer deposition from a flash-frozen water ice matrix
Flash-frozen water solutions of 1% weight PEG (polyethylene glycol) at -50 degreesC were used as targets at a laser wavelength of 355 nm for polymer deposition with Matrix-Assisted Pulsed Laser Evaporation (MAPLE). For medium laser fluences the transfer of PEG material to the substrate was accompanied by a pronounced ion flow from the matrix target which increases with fluence F as F^{-1.2}. At the highest fluence the ion flow was partly attenuated, presumably due to plume shielding. Below a threshold of 3.5 J/cm(2) the PEG was deposited without any measurable ion emission from the target. (C) 2004 Elsevier B.V. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rodrigo, K., Toftmann, B., Schou, J., Pedrys, R.
Pages: 368-372
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Chemical Physics Letters
Volume: 399
Issue number: 4-6
ISSN (Print): 0009-2614
Ratings:
Scopus rating (2004): SJR 1.5 SNIP 1.133
Laser irradiation of polymer-doped water ice matrices: From fundamental processes to polymer film deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from Seminar given at University of Virginia, Charlottesville, VA (US), 23 Apr, .
Source: orbit
Source-ID: 307431
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research

Polymer film deposition and laser-plume interactions from laser irradiation of doped water ice

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Toftmann, B., Rodrigo, K., Pedrys, R.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from Seminar at Università di Napoli Federico II, Napoli (IT), 2 Sep, .
Source: orbit
Source-ID: 307003
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research

Pulsed laser deposition: From basic processes to film deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Toftmann, B., Amoruso, S.
Publication date: 2004
Peer-reviewed: No
Source: orbit
Source-ID: 307191
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research

Pulsed laser deposition of aluminum-doped ZnO films at 355 nm
Conducting, transparent films of aluminium-doped ZnO (AZO) have been produced at the laser wavelength 355 nm. The most critical property, the electric resistivity, is up to a factor of 8 above that for films produced at shorter wavelengths. In contrast, the transmission of visible light through the films is about 0.9 which is comparable to the transmission through films deposited with short-wavelength lasers. The polycrystalline structure of the films is similar to that of films produced by shorter wavelengths as well.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Physics, Risø National Laboratory, University of Southern Denmark, University of Copenhagen
Contributors: Holmelund, E., Schou, J., Thstrup Nielsen, B., Tougaard, S., Johnson, E., Nielsen, M. M.
Pages: 1137-1139
Publication date: 2004
Peer-reviewed: Yes
Pulsed laser deposition of thin films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from 1-day international conference on laser micro machining, Tåstrup (DK), 1 Sep,.
Source: orbit
Source-ID: 307070
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

The expansion of a laser-produced silver plume in background gases

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J., Amoruso, S., Lunney, J.
Publication date: 2004
Peer-reviewed: No
Source: orbit
Source-ID: 307163
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2004 › Research

Thermalization of a UV laser ablation plume in a background gas: From a directed to a diffusionlike flow

Combined diagnostic measurements of deposition rates and ion time-of-flight signals have been employed to study the expansion of a laser ablation plume into a background gas. With increasing gas pressure the angular distribution of the collected ablated atoms becomes broader, while the total collected yield decreases. The total collected yield shows three separate regimes with increasing pressure, a vacuumlike regime, a transition regime with increasing plume broadening and splitting of the ion signal, and at the highest pressure a diffusionlike regime with a broad angular distribution. In the high-pressure regime the expansion can be described by a simple model based on diffusion from a confined plume.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Amoruso, S., Toftmann, B., Schou, J.
Number of pages: 6
Pages: 056403
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Physical Review E
Volume: 69
Issue number: 5
ISSN (Print): 2470-0045
A comparative study of thin film production based on gentle laser-ablation techniques has been carried out with the luminescent polymer poly [2-methoxy-5-(2'-ethylhexyloxy)-1,4-phenylene vinylene]. Using a free-electron laser films were made by resonant infrared pulsed laser deposition (RIR-PLD). For the first time resonant infrared matrix assisted pulsed laser evaporation (RIR-MAPLE) was successfully demonstrated on a luminescent polymer system. In addition to this, an excimer laser has been used for UV-MAPLE depositions at 193 and 248-nm irradiation. Films deposited onto NaCl and quartz substrates were analyzed by Fourier transform infrared spectroscopy, UV-visible absorbance and photoluminescence. Photoluminescent material was deposited by RIR-MAPLE and 248-nm MAPLE, while the RIR-PLD and 193-nm-MAPLE depositions displayed the smoothest surfaces but did not show photoluminescence. (C) 2003 Elsevier B.V. All rights reserved.
Deposition and characterization of aluminum-doped ZnO films produced by pulsed laser deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Holmelund, E., Thestrup, B., Schou, J., Tougaard, S., Nielsen, M., Johnson, E.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from 7th International Conference on Laser Ablation, Hersonissos, Greece.
Source: orbit
Source-ID: 305412
Research output: Contribution to journal › Journal article – Annual report year: 2003 › Research › peer-review

Diagnostics of laser ablated plasma plumes

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Amoruso, S., Bruzzese, R., Velotta, R., Wang, X., Toftmann, B., Schou, J.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from E-MRS 2003 Spring meeting, Strasbourg, France.
Source: orbit
Source-ID: 305952
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Dynamics of the plume produced by nanosecond ultraviolet laser ablation of metals

The dynamics of the ablation plume of a partially ionized plasma produced by a nanosecond UV laser with different irradiation spot geometries has been explored. We have used an ensemble of quartz crystal microbalances to make the first systematic and quantitative study of how the shape of the plume varies as the aspect ratio (b/a) of the elliptical laser spot is varied by about a factor of ten. The flip-over effect can be described by the adiabatic expansion model of Anisimov using a value of the adiabatic constant of about gamma = 1.4. We have also studied the forward peaking of the ablation plume for a large number of metals at the same laser fluence. Contrary to earlier reports, we find that the more refractory metals have the broader angular distributions.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Christensen, B. T., Schou, J., Lunney, J.
Number of pages: 5
Pages: 104101
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Physical Review B Condensed Matter
Volume: 67
Issue number: 10
ISSN (Print): 0163-1829
Ratings:
Scopus rating (2003): SJR 2.75 SNIP 1.536
Web of Science (2003): Indexed yes
Original language: English
DOIs:
10.1103/PhysRevB.67.104101
Source: orbit
Source-ID: 305433
Research output: Contribution to journal › Journal article – Annual report year: 2003 › Research › peer-review
Expansion of a laser-produced silver plume in light and heavy background gases

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Amoruso, S., Toftmann, B., Schou, J.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from 7th International Conference on Laser Ablation, Hersonissos, Greece.
Source: orbit
Source-ID: 305953
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Laser ablation at 355 nm of organic materials embedded in matrices

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Janik, K., Toftmann, B., Schou, J., Pedrys, R.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from NATO Advanced Study Institute, Laser processing of biological tissues and bio-compatible materials, Hersonissos (GR), 24 Sep - 3 Oct,.
Source: orbit
Source-ID: 306180
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Matrix assisted pulsed laser evaporation (MAPLE) of polyethylene glycol (PEG)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from E-MRS 2003 Spring meeting, Strasbourg, France.
Source: orbit
Source-ID: 305776
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Plume dynamics of UV laser ablation of silver in vacuum with fs-pulses

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Budtz-Jørgensen, C., Doggett, B., Schou, J., Lunney, J.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from 7th International Conference on Laser Ablation, Hersonissos, Greece.
Source: orbit
Source-ID: 305951
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Sputtering of water ice
We present results of a range of experiments of sputtering of water ice together with a guide to the literature. We studied how sputtering depends on the projectile energy and fluence, ice growth temperature, irradiation temperature and external electric fields. We observed luminescence from the decay of H(2p) atoms sputtered by heavy ion impact, but not bulk ice luminescence. Radiolyzed ice does not sputter under 3.7 eV laser irradiation. (C) 2002 Elsevier B.V. All rights reserved.

General information
Publication status: Published
The angular distribution of plume ions from fs-laser irradiation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J., Doggett, B., Budtz-Jørgensen, C., Lunney, J.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from E-MRS 2003 Spring meeting, Strasbourg, France.
Source: orbit
Source-ID: 305774
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 2003 » Research

A study on Matrix assisted pulsed laser deposition of organic MEH-PPV films (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Christensen, B. T., Jespersen, K., Schou, J., Johansen, P.
Publication date: 2002

Host publication information
Title of host publication: Book of abstracts
Place of publication: Roskilde
Publisher: Dansk Optisk Selskab; Forskningscenter Risø
Source: orbit
Source-ID: 304819
Research output: Chapter in Book/Report/Conference proceeding » Conference abstract in proceedings – Annual report year: 2002 » Research

Deposition and characterization of ITO films produced by laser ablation at 355 nm
Indium tin oxide (ITO) films have been deposited by pulsed laser deposition (PLD) at 355 nm. Even though the absorption of laser light at the wavelength 355 nm is much smaller than that of the standard excimer lasers for PLD at 248 nm and 193 nm, high-quality films can be produced. At high fluence and at high substrate temperatures, the specific resistivity of the films, 2–3×10-4 Ω cm, is comparable to values obtained with excimer lasers, whereas the resistivities obtained at room temperature are somewhat higher than those of films produced by excimer lasers. The transmission coefficient of visible light, about 0.9, is also comparable to values for films deposited by excimer lasers. The crystalline structure of films produced at 355 nm is similar to that of samples produced by these lasers.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Micro- and Nanotechnology, Polymer Microsystems for Cell Processing, Department of Physics, Risø National Laboratory, University of Southern Denmark,
Energy requirements to cut plants with a CO₂ laser

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Heisel, T., Christensen, S., Andreasen, C., Schou, J.
Pages: 234-235
Publication date: 2002

Evolution of the plasma parameters in the expanding laser ablation plume of silver

The angular and radial variation of the ion density and electron temperature in the plasma plume produced by laser ablation of silver at fluences of 0.8-1.3 J cm⁻² at 355 nm have been studied using a time-resolving Langmuir probe. The angular dependence of the electron temperature and the magnitude of the ion flux, at the time when the ion flux is maximised, agree with the predictions of the self-similar isentropic model of the plasma expansion by Anisimov et al. (C) 2002 Elsevier Science B.V. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Christensen, B. T., Schou, J., Hansen, T., Lunney, J.
Pages: 293-297
Publication date: 2002
Peer-reviewed: Yes
Ion dynamics in laser ablation plumes from selected metals at 355 nm

The dynamics of ions in a laser ablation plume from a number of metals irradiated by a ns-second pulse at 355 nm has been studied. The time-of-flight signals peak at flight times corresponding to velocities between 30 and 10 km/s with decreasing values for increasing atomic masses. The angular distributions of the integrated ion signals are strongly peaked in forward direction, and the values for the volatile Bi are somewhat higher than those for the other metals. The distributions have been analyzed on the basis of Anisimov's expansion model. The fraction of ionized atoms can be estimated from weight loss measurements and is about 0.5 for Ag and Al and 0.15 for Bi at a fluence of 2.5 J/cm². (C) 2002 Elsevier Science B.V. All rights reserved.

Laser ablation of living plants

The initial stage of laser-induced plasma plume expansion from a solid in vacuum and the effect of the Coulomb field have been studied. We have performed a one-dimensional numerical calculation by mapping the charge on a computational grid according to the particle-in-cell (PIC) method of Birdsall et al. It is assumed that the particle ablation from a surface with a fixed temperature takes place as a pulse, i.e. within a finite period of time. A number of characteristic quantities for
the plasma plume are compared with similar data for expansion of neutrals as well as fluid models: Density profiles n(x, t), velocity distributions of ions u(x, t), distribution functions for velocities F(νu(x)) of ions or electrons as well as the time dependence of kinetic energy E-kin(t) for both type of particles. We found a significant increase in the velocities of the ions at the expense of field potential energy as well as electron energy. We have estimated the time constant for energy transfer between the electrons and the ions. The scaling of these processes is given by a single parameter determined by the Debye length obtained from the electron density in the plasma outside the surface. (C) 2002 Elsevier Science B.V All rights reserved.
Pure and Sn-doped ZnO films produced by pulsed laser deposition

A new technique, metronome doping, has been used for doping of films during pulsed laser deposition (PLD). This technique makes it possible to dope continuously during film growth with different concentrations of a dopant in one deposition sequence. Films of pure and doped ZnO have been produced with Sn concentrations up to 16%. The specific resistivity is found to increase and the transmission of visible light to decrease with increasing Sn concentration. (C) 2002 Elsevier Science B.V. All rights reserved.

Sputtering of isotopes of the solid hydrogens by ions

Thermalization of a laser produced silver plume in a background gas
Using laser to measure stem thickness and cut weed stems

Stem thickness of the weed Solanum nigrum and the crop sugarbeet was determined with a He-Ne laser using a novel non-destructive technique measuring stem shadow. Thereafter, the stems were cut close to the soil surface with a CO2 laser. Treatments were carried out on pot plants, grown in the greenhouse, at two different growth stages, and plant dry matter was measured 2-5 weeks after treatment. The relationship between plant dry weight and laser energy was analysed using two different non-linear dose-response regression models; one model included stem thickness as a variable, the other did not. A binary model was also tested. The non-linear model incorporating stem thickness described the data best, indicating that it would be possible to optimize laser cutting by measuring stem thickness before cutting. The general tendency was that more energy was needed the thicker the stem. Energy uses on a field scale are discussed.

Cutting weeds with a CO2 laser

Stems of Chenopodium album and Sinapis arvensis and leaves of Lolium perenne were cut with a CO2 laser or with a pair of scissors. Treatments were carried out on greenhouse-grown pot plants at three different growth stages and at two heights. Plant dry matter was measured 2 to 5 weeks after treatment. The relationship between dry weight and laser energy was analysed using a non-linear dose-response regression model. The regression parameters differed significantly between the weed species. At all growth stages and heights, S. arvensis was more difficult to cut with a CO2 laser than C. album. When stems were cut below the meristems, 0.9 and 2.3 J mm\(^{-1}\) of CO2 laser energy dose was sufficient to reduce by 90% the biomass of C. album and S. arvensis respectively. Regrowth appeared when dicotyledonous plant stems were cut above meristems, indicating that it is important to cut close to the soil surface to obtain a significant effect. When cutting L. perenne plants with 2-true leaves at a height of 2 cm from the soil surface with a laser, the biomass decreased significantly compared with plants cut by scissors, indicating a delay in regrowth. This delay was not observed for the dicotyledonous plants nor for the other growth stages of L. perenne.

General information

Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Heisel, T., Schou, J., Christiansen, S.
Pages: 19-29
Publication date: 2001
Peer-reviewed: Yes
Doping of thin films of optical materials by pulsed laser deposition (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Holmelund, E., Schou, J., Tougaard, S., Larsen, N.
Publication date: 2001
Peer-reviewed: No

Dynamics of the expansion plume from laser ablated silver

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Thstrup Nielsen, B., Christensen, B. T., Doggett, B., Hansen, T., Lunney, J.
Publication date: 2001

Electron temperatures and densities from laser-ablated silver at 355 nm

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J., Hansen, T., Lunney, J.
Publication date: 2001
Sputtering of carbon monoxide ice by hydrogen ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Pedrys, R.
Pages: 33309-33314
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Journal of Geophysical Research: Planets
Volume: 106
Issue number: E12
ISSN (Print): 1934-8592
Ratings:
Scopus rating (2001): SJR 2.667 SNIP 1.542
Web of Science (2001): Indexed yes
Original language: English
Source: orbit
Source-ID: 303764
Research output: Contribution to journal › Journal article – Annual report year: 2002 › Research › peer-review

Sputtering of isotopes of the solid hydrogens by light ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 57-59
Publication date: 2001

Host publication information
Title of host publication: Extended abstracts
Place of publication: Nagoya
Publisher: Nagoya University, Department of Nuclear Engineering
Source: orbit
Source-ID: 302831
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2001 › Research

Sputtering of solid deuterium by He-ions
Sputtering of solid deuterium by bombardment of $^3\text{He}^+$ and $^4\text{He}^+$ ions was studied. Some features are similar to hydrogen ion bombardment of solid deuterium, but for the He-ions a significant contribution of elastic processes to the total yield can be identified. The thin-film enhancement is more pronounced than that for hydrogen projectiles in the same energy range.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Stenum, B., Pedrys, R.
Pages: 116-120
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 182
ISSN (Print): 0168-583X
Ratings:
Scopus rating (2001): SJR 0.523 SNIP 0.886
Web of Science (2001): Indexed yes
Original language: English
Keywords: Ion impact, Sputtering, Electronic transitions, Solid hydrogen
DOIs:
Angular distribution of electron temperature and density in a laser-ablation plume

The angular distribution of electron temperature and density in a laser-ablation plume has been studied for the first time. The electron temperature ranges from 0.1 to 0.5 eV and is only weakly dependent on the angle in the low-intensity range studied here. In contrast, the typical ion energy is about 2 orders of magnitude larger, and its angular distribution is mon peaked about the target normal. The derived values of the electron density are in agreement with the measured values of ion density.

Crystallinity of ITO and AZO thin films produced by laser ablation

Dynamics of laser-plasma for selected components studied with electrical probes
'Flip-over' effect of a laser ablation plume

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J.
Publication date: 2000

Host publication information
Title of host publication: Programme. Abstracts. List of participants
Place of publication: København
Publisher: HCØ Tryk
ISBN (Print): 87-7834-385-2
Source: orbit
Source-ID: 301231
Research output: Chapter in Book/Report/Conference proceeding – Conference abstract in proceedings – Annual report year: 2000 – Research

Holographic grating formation in laser-deposited aluminium-doped zinc oxide and indium tin oxide films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Dam-Hansen, C., Schou, J., Johansen, P.
Pages: 196-199
Publication date: 2000
Peer-reviewed: Yes

Publication information
Volume: 2
ISSN (Print): 2040-8978
Ratings:
Scopus rating (2000): SJR 0.468 SNIP 0.766
Web of Science (2000): Indexed yes
Original language: English
Source: orbit
Source-ID: 301222

SmartProbe and Langmuir probe measurements, Dublin, July 2000

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J.
Number of pages: 15
Publication date: 2000

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
Original language: English
Source: orbit
Source-ID: 302038
Time-of-flight study of water ice sputtered by slow xenon ions

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pedrys, R., Krok, F., Leskiewicz, P., Schou, J., Podschaske, U., Cleff, B.
Pages: 861-867
Publication date: 2000
Peer-reviewed: Yes

**Publication information**
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 164
ISSN (Print): 0168-583X
Scopus rating (2000): SJR 0.777 SNIP 0.905
Web of Science (2000): Indexed yes
Original language: English
Source-ID: 301074

Ablation from artificial or laser-induced crater surfaces of silver by laser irradiation at 355 nm

The angular distribution of laser ablated particles from silver irradiated at 355 nm has been studied. The angular distribution from craters prepared by more than 10^4 shots exhibits only minor changes compared with that from a nonirradiated target. The distribution from artificial cylindrical craters of a depth comparable to the laser spot dimensions is about one order of magnitude smaller at large exit angles than that from a flat target.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J., Larsen, N.
Pages: S811-S814
Publication date: 1999
Peer-reviewed: Yes

**Publication information**
Volume: 69
ISSN (Print): 0947-8396
Scopus rating (1999): SJR 1.542 SNIP 1.062
Original language: English
DOI: 10.1007/s003390051536
Source-ID: 300644

Ablation from flat or crater surfaces of silver induced by laser irradiation at 355 nm

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toftmann, B., Schou, J.
Publication date: 1999
Peer-reviewed: No
Event: Abstract from 5th International Conference on Laser Ablation, Göttingen, Germany.
Source-ID: 299942

Research output: Contribution to journal › Journal article – Annual report year: 2000 › Research › peer-review

Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1999 › Research
Electrical and optical properties of thin indium tin oxide films produced by pulsed laser ablation in oxygen or rare gas atmospheres

Films of indium tin oxide (ITO) have been produced in different background gases by pulsed laser deposition (PLD). The films deposited in rare gas atmospheres on room temperature substrates were metallic, electrically conductive, but had poor transmission of visible light. For substrate temperatures at 200 degrees C, the specific resistivity was reduced and the transmission of visible light enhanced for all background gases. Films produced in oxygen turned out to be superior to films deposited in other gases at the same temperature. (C) 1999 Elsevier Science B.V. All rights reserved.

Gasflow and collision dynamics in a thermally laser ablated plume of silver atoms described by Monte Carlo simulations

Gasflow and collision dynamics in a thermally laser ablated plume of silver atoms described by Monte Carlo simulations
Holographic gratings induced in laser deposited AZO and ITO films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Dam-Hansen, C., Schou, J., Johansen, P.
Pages: 31-34
Publication date: 1999

Host publication information
Title of host publication: Post-deadline papers
Place of publication: Roskilde
Publisher: Risø National Laboratory
Source: orbit

Ion time-of-flight study of laser ablation of silver in low pressure gases
The dynamics of ions from a laser-ablated silver target in low pressure background atmospheres have been investigated in a simple geometry using an electrical probe. A simple scattering picture for the first transmitted peak of the observed plume splitting has been used to calculate cross sections of the ablated silver ions in oxygen (sigma(O(2)) = 4.8 x 10^{-16} cm^2) and in argon (sigma(Ar) = 6.7 x 10^{-16} cm^2). The dynamics of the blast wave is well described by blast wave theory. (C) 1999 Elsevier Science B.V. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Schou, J., Lunney, J.
Pages: 184-187
Publication date: 1999
Peer-reviewed: No

Publication information
Journal: Applied Surface Science
Volume: 138-139
ISSN (Print): 0169-4332
Ratings:
Scopus rating (1999): SJR 1.083 SNIP 0.909
Original language: English
Keywords: Oxygen, Electrical probe, Laser-ablated silver
DOI:
10.1016/S0169-4332(98)00398-5
Source: orbit
Source-ID: 300534
Research output: Contribution to journal › Journal article – Annual report year: 1999 › Research

Langmuir probe study of plasma expansion in pulsed laser ablation
Langmuir probes were used to monitor the asymptotic expansion of the plasma produced by the laser ablation of a silver target in a vacuum. The measured angular and temporal distributions of the ion flux and electron temperature were found to be in good agreement with the self-similar isentropic and adiabatic solution of the gas dynamics equations describing the expansion. The value of the adiabatic index gamma was about 1.25, consistent with the ablation plume being a low temperature plasma.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Schou, J., Lunney, J.
Pages: S601-S604
Publication date: 1999
Laser ablation at different angles of incidence

In the present work, we have studied ablation of a silver metal surface with a Nd:YAG laser (355 nm, 0.8 J/cm², 6 ns) on the basis of measured data. We have solved the nonlinear heat conduction equation for the laser heating of the system and calculated the varying surface temperature and evaporation rates. These realistic experimental input parameters are further combined with a direct simulation Monte Carlo (DSMC) description of collisions in the gas flow of ablated surface atoms.

With this method, new data of plume development and collision processes in the beginning of the ablation process can be extracted. It also allows us to identify important processes by comparing the computational results with experimental ones, such as density, energy, and angular distributions.

Our main results deviate only slightly from an earlier study with constant surface temperature and evaporation rate at times t much greater than τ(laser), and this demonstrates that at these later times, the collisions in the plume efficiently...
smear out the characteristics of the varying temperature at the surface during ablation. The physical properties of the gas flow are determined by the mean thermal energy in the initial plume as well as the number of monolayers emitted.

Production of films of transparent semiconductors by laser ablation

Pulsed laser deposition of transparent, conducting AZO and ITO films

Sputtering by excitonic and elastic processes from solid neon by He ion bombardment
Transparent conducting AZO and ITO films produced by pulsed laser ablation at 355 nm

Thin films of aluminium-doped zinc oxide (AZO) and indium tin oxide (ITO) were deposited on glass substrates by laser ablation in an oxygen environment. The electrical and optical properties of films grown at various oxygen pressures were compared. With no substrate heating, highly transparent and conducting films were obtained with oxygen pressures between 15 and 23 mTorr for both materials. We obtained a specific resistivity of 1.8 x 10(-3) Omega cm for AZO and 1.1 x 10(-3) Omega cm for ITO. By heating the substrate to 160 degrees C or 200 degrees C, the resistivity was further reduced to 1.1 x 10(-3) Omega cm for AZO and 3.9 x 10(-4) Omega cm for ITO. The average transmission of visible light (450-750 nm) was between 82% and 98% in most cases. The results suggest that AZO is a promising alternative to ITO.

Ablation of volatile films by laser heating of substrates
Angle-resolved energy distributions of laser ablated silver ions in vacuum

The energy distributions of ions ablated from silver in vacuum have been measured in situ for pulsed laser irradiation at 355 nm. We have determined the energy spectra for directions ranging from 5 degrees to 75 degrees with respect to the normal in the intensity range from 100 to 400 MW/cm(2). At the highest intensity and for angles close to the normal, the highest ion energy measured exceeds 500 eV. However, the energy distributions are shifted strongly toward low energies with increasing angle. (C) 1998 American Institute of Physics.

Angular distributions of emitted particles by laser ablation of silver at 355 nm

The angular distribution of laser ablated silver in vacuum has been measured in situ with an array of quartz-crystal microbalances. The silver surface was irradiated by ns pulses from a Nd:YAG laser operating at 355 nm for fluences ranging from 0.7 J/cm² to 8 J/cm². The distribution is strongly peaked in the forward direction corresponding to \( \cos \theta \), where \( \theta \) varies from 5 to 12 for the largest beam spot, but is less peaked for the smallest beam spots. The total collected yield of ablated atoms is about \( 2.2 \times 10^{15} \) Ag atoms per pulse for the highest pulse energies.

A study on indium tin oxide films produced by laser ablation in different background gases

The study has been published and is peer-reviewed.
Background gas effects on deposition of ITO films by pulsed laser deposition

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Schou, J., Nordskov, A., Larsen, N.
Number of pages: 21
Publication date: 1998

Host publication information
Title of host publication: Annual meeting of the Danish Optical Society
Place of publication: Aalborg
Publisher: Aalborg Universitet
Source: orbit
Source-ID: 298963
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1998 › Research

Electron temperatures of laser-induced plasmas

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Toffmann, B., Hansen, T., Schou, J., Lunney, J.
Publication date: 1998
Peer-reviewed: No
Event: Abstract from SASP 98. Symposium on atomic and surface physics and related topics, Going (AT), 25-30 Jan, .
Source: orbit
Source-ID: 298552
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1998 › Research

Laser ablation of silver in a background gas

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Shen, Y., Lunney, J., Schou, J.
Publication date: 1998
Peer-reviewed: No
Event: Abstract from LASER ’98, Nyborg, Denmark.
Source: orbit
Source-ID: 298553
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1998 › Research

Production of thin films of ITO by laser ablation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Thestrup, B., Nordskov, A., Larsen, N.
Publication date: 1998
Peer-reviewed: No
Event: Abstract from LASER ’98, Nyborg, Denmark.
Source: orbit
Pulsed laser deposition of ITO in different background gases

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Schou, J., Nordskov, A., Larsen, N.
Publication date: 1998
Peer-reviewed: No
Event: Abstract from Meeting of the Danish Sputtering Club, Odense, Denmark.
Source: orbit
Source-ID: 297683

Sputtering of Surfaces of the Solid Hydrogens
Sputtering of the solid hydrogens by electrons and ions exhibits features that may be related to quantum properties of these solids, i.e. a drastic enhancement of the yield for electron–bombarded thick deuterium films and a thermal peak at low ejection energies in the energy distribution of the sputtered particles.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Thestrup Nielsen, B., Svendsen, W. E., Stenum, B., Ellegaard, O., Pedrys, R., Warczak, B.
Pages: 569-576
Publication date: 1998
Peer-reviewed: Yes

Use of image-processing tools for texture analysis of high-energy X-ray synchrotron data
The introduction of synchrotron beamlines for high-energy X-ray diffraction raises new possibilities for texture determination of polycrystalline materials. The local texture can be mapped out in three dimensions and texture developments can be studied in situ in complicated environments. However, it is found that a full alignment of the two-dimensional detector used in many cases is impractical and that data-sets are often partially subject to geometric restrictions. Estimating the parameters of the traces of the Debye-Scherrer cones on the detector therefore becomes a concern. Moreover, the background may vary substantially on a local scale as a result of inhomogeneities in the sample environment etc. A set of image-processing tools has been employed to overcome these complications. An automatic procedure for estimating the parameters of the traces (taken as ellipses) is described, based on a combination of a circular Hough transform and nonlinear least-squares fitting. Using the estimated ellipses the background is subtracted and the intensity along the Debye-Scherrer cones is integrated by a combined fit of the local diffraction pattern. The corresponding algorithms are presented together with the necessary coordinate transform for pole-figure determination. The image-processing tools may be useful for the analysis of noisy or partial powder diffraction data-sets in general, provided flat two-dimensional detectors are used.

General information
Publication status: Published
Organisations: Department of Informatics and Mathematical Modeling, Risø National Laboratory for Sustainable Energy, Risø National Laboratory
Contributors: Fisker, R., Poulsen, H. F., Schou, J., Carstensen, J. M., Garbe, S.
Pages: 647-653
Ablation of solids by pulsed UV-lasers

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from Universität Kaiserslautern, Kaiserslautern (DE), 7 Nov, .
Source: orbit
Source-ID: 296620
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Ablation of volatile films from multilayer systems by laser heating of substrates

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J.
Publication date: 1997

Host publication information
Title of host publication: Danish Physical Society annual meeting. Programme
Place of publication: København
Publisher: HCØ Tryk
ISBN (Print): 87-7834-210-4
Source: orbit
Source-ID: 297027
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1997 › Research

Angular distribution and total yield of laser ablated silver

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W., Nordskov, A., Schou, J., Thestrup, B., Ellegaard, O.
Pages: 356-358
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 122
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 297191
Research output: Contribution to journal › Journal article – Annual report year: 1997 › Research › peer-review
Angular distributions and total yield of laser ablated silver

The angular distribution of laser ablated silver has been measured in situ with a newly constructed setup with an array of microbalances. The distribution is strongly peaked in the forward direction corresponding to $\cos \theta$, where $p$ varies between 5 and 9 for laser fluences from 2 to 7 J/cm$^2$ at 355 nm for a beam spot of 0.015 cm$^2$. The total deposited yield is of the order $10^{15}$ Ag-atoms per pulse.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W. E., Nordskov, A., Schou, J., Thestrup Nielsen, B., Ellegaard, O.
Pages: 356-358
Publication date: 1997
Peer-reviewed: Yes

Angular distributions of ions and neutrals from laser ablated silver

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Schou, J., Lunney, J.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from Particle-Solid Interaction Meeting, Odense, Denmark.
Source: orbit
Source-ID: 297057
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 1997 » Research

Angular distributions of ions from laser irradiated silver

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Nordskov, A., Lunney, J., Schou, J., Thestrup, B., Ellegaard, O.
Publication date: 1997

Host publication information
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Place of publication: København
Publisher: HCØ Tryk
ISBN (Print): 87-7834-210-4
Source: orbit
Source-ID: 297013
Research output: Chapter in Book/Report/Conference proceeding » Conference abstract in proceedings – Annual report year: 1997 » Research

Angular distributions of silver ions and neutrals emitted in vacuum by laser ablation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Ejection of molecules from solid deuterium excited by keV electrons

The energy distribution of sputtered D-2 from electron-bombarded solid deuterium has been studied for the first time. The spectra from this quantum solid show features that may originate from an energy release sequence of association of atoms. For ejection energies above 1 meV the gross features of the spectrum are similar to those from electronic sputtering of ether much less volatile condensed gases. Sputtered D-4 molecules have been observed for the first time as well.

Electronic sputtering of quantum solids: Solid deuterium bombarded by keV electrons
Electronic sputtering of quantum solids: Solid Deuterium bombarded by keV electrons

Electron temperatures of laser-induced plasmas

Kinetic energy distributions of atoms sputtered from electron-excited solid neon

Laser ablation: bestråling af overflade med ekstrem høj lysintensitet
Laser ablation of silver studied by angular-resolved ion probe measurements

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Nordskov, A., Schou, J., Lunney, J.
Publication date: 1997
Peer-reviewed: No
Source: orbit
Source-ID: 296447
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Laser blation of silver in a background gas

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hansen, T., Schou, J., Shen, Y., Lunney, J.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from 1997 Annual meeting of the Danish Optical Society (DOPS), Lyngby, Denmark.
Source: orbit
Source-ID: 296621
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Lattice dynamics during electronic sputtering of solid Ne

Electronic sputtering of solid neon has been studied with molecular dynamics. The cavity formation around an excited atom and particle migration in the surface region, as well as the sputtering process have been studied. A single atomic exciton has been observed to produce a desorption of up to five excited or ground state atoms. The ejection from the surface is induced by excitons formed in five outermost monolayers of the solid. Energy and angular distributions of sputtered excited and ground state atoms have been calculated and are compared with experimental data.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dutkiewicz, L., Pedrys, R., Schou, J.
Pages: 337-350
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Radiation Effects and Defects in Solids
Volume: 142
Issue number: 1-4
ISSN (Print): 1042-0150
Original language: English
Keywords: atomic excitons, cavity formation, sputtering
DOI: 10.1080/10420159708211618
Source: orbit
Source-ID: 296661
Research output: Contribution to journal › Journal article – Annual report year: 1997 › Research
Open questions in fundamental processes of laser ablation from surfaces

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Hansen, T., Svendsen, W., Ellegaard, O., Thestrup, B., Lunney, J.
Pages: 83-88
Publication date: 1997

Host publication information
Title of host publication: Proceedings of the 17. Werner Brandt workshop on the penetration of charged particles in matter
Place of publication: Charlottesville, VA
Publisher: University of Virginia Publishing
Editor: Baragiola, R.
Source: orbit
Source-ID: 296380
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1997 › Research

Resistivity measurements of ITO thin films deposited by laser ablation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Nordskov, A., Schou, J.
Publication date: 1997

Host publication information
Title of host publication: Danish Physical Society annual meeting 1997. Programme
Place of publication: København
Publisher: HCØ Tryk
ISBN (Print): 87-7834-210-4
Source: orbit
Source-ID: 297011
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1997 › Research

Sputtering of insulators

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1997
Peer-reviewed: No
Source: orbit
Source-ID: 297025
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Sputtering of quantum solids: A study on solid deuterium

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from Particle-Solid Interaction Meeting, Odense, Denmark.
Source: orbit
Source-ID: 297030
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research
Sputtering of quantum solids by electrons - a study on solid deuterium

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Thestrup, B., Svendsen, W., Ellegaard, O., Pedrys, R., Warczak, B.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from Symposium on fundamental physics, Chicago, IL (US), 11-15 May, .
Source: orbit
Source-ID: 297026
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Sputtering of surfaces of the solid hydrogens by electron and ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Thestrup, B., Svendsen, W., Stenum, B., Ellegaard, O., Pedrys, R., Warczak, B.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from 2nd International Conference on Cryocrystals and Quantum Crystals, Wroclaw, Poland.
Source: orbit
Source-ID: 296446
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Ablation from metals induced by visible and UV laser irradiation
The deposition rate of laser-ablated silver has been determined for fluences between 0.5 and 15 J/cm² at the wavelengths 532 and 355 nm for a beam spot area of around 0.01 cm². The ablated metal was collected on a quartz crystal microbalance. The rate at 5 J/cm² was about 4 × 10¹³ Ag/cm² per pulse for 532 nm, and somewhat lower for 355 nm. The initial vaporization during the ablation has been studied numerically as well.

General information
Publication status: Published
Organisations: Bioprobes, Department of Micro- and Nanotechnology, Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W. E., Schou, J., Thestrup Nielsen, B., Ellegaard, O.
Pages: 518-521
Publication date: 1996
Peer-reviewed: Yes
Publication information
Journal: Applied Surface Science
Volume: 96-98
ISSN (Print): 0169-4332
Original language: English
DOI:
10.1016/0169-4332(95)00506-4
Bibliographical note
Source: orbit
Source-ID: 295388
Research output: Contribution to journal › Conference article – Annual report year: 1996 › Research › peer-review

Angular resolved ablation from silver induced by intense UV laser irradiation

General information
Publication status: Published
Organisations: Rise National Laboratory for Sustainable Energy
Contributors: Schou, J., Svendsen, W. E., Nordskov, A., Thestrup, B., Ellegaard, O.
Publication date: 1996
Angular resolved UV laser ablation from silver

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Svendsen, W., Thestrup, B., Ellegaard, O.
Publication date: 1996
Peer-reviewed: No
Source: orbit
Source-ID: 276613
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1996 › Research

Electron emission from solids

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 177-216
Publication date: 1996

Host publication information
Title of host publication: Physical processes of the interaction of fusion plasmas with solids
Place of publication: San Diego, CA
Publisher: Academic Press
Editors: Hofer, W., Roth, J.
Source: orbit
Source-ID: 295515
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 1996 › Research

Electronic sputtering

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1996
Peer-reviewed: No
Event: Abstract from International Symposium on Particle Penetration and Collision Cascades, Odense, Denmark.
Source: orbit
Source-ID: 295474
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1996 › Research

Electronic sputtering and charge accumulation in thick deuterium films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Svendsen, W., Schou, J., Ellegaard, O.
Publication date: 1996
Peer-reviewed: No
Event: Abstract from International Symposium on Particle Penetration and Collision Cascades, Odense, Denmark.
Source: orbit
Source-ID: 295476
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1996 › Research
Holographic gratings induced in laser ablated thin films of indium tin oxide

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Nordskov, A., Dam-Hansen, C., Johansen, P., Schou, J.
Number of pages: 28
Publication date: 1996

Host publication information
Title of host publication: Annual meeting of the Danish Optical Society. Book of abstracts
Place of publication: Roskilde
Publisher: Risø National Laboratory
Editors: Petersen, P., Johansen, P., Skaarup, B.
Source: orbit
Source-ID: 294977
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 1996 › Research

Laser ablation deposition measurements from silver and nickel
The deposition rate for laser ablated metals has been studied in a standard geometry for fluences up to 20 J/cm(2). The rate for silver and nickel is a few percent of a monolayer per pulse at the laser wavelengths 532 nm and 355 nm. The rate for nickel is significantly higher than that for silver at 532 nm, whereas the rate for the two metals is similar at 355 nm. This behaviour disagrees with calculations based on the thermal properties at low intensities as well as predictions based on formation of an absorbing plasma at high intensities. The deposition rate falls strongly with increasing pressure of the ambient gases, nitrogen and argon.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W. E., Ellegaard, O., Schou, J.
Pages: 247-255
Publication date: 1996
Peer-reviewed: Yes

Publication information
Volume: 63
Issue number: 3
ISSN (Print): 0947-8396
Original language: English
DOIs: 10.1007/s003390050380
Source: orbit
Source-ID: 206837
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review

Laser induced evaporation of volatile films from a multicomponent system

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J.
Publication date: 1996
Peer-reviewed: No
Event: Abstract from Gordon Research Conference , Plymouth, NH, United States.
Source: orbit
Source-ID: 295477
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1996 › Research

Lattice dynamics during electronic sputtering of solid Ne
**Linear and nonlinear effects at low energy ion bombardment of solid xenon**

Elastic sputtering of crystalline xenon by 20-750 eV Xe ions has been studied with molecular dynamics. The nonlinear effects are dominant at 250 eV ion bombardment. They result in a partly amorphization of the impact volume as well as in a considerable reduction of the surface binding energy in this volume during the sputtering process.

**Molecular-dynamics simulation of ejection processes in electronically excited solid Ne**

**Secondary electrons from heavy-ion tracks**
**Host publication information**
Title of host publication: Radiation research 1895 - 1995. Congress proceedings. Vol. 2: Congress lectures
Place of publication: Würzburg
Publisher: ICRR Society
Editors: Hagen, U., Harder, D., Jung, H., Streffer, C.
Source: orbit
Source-ID: 294226
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1996

**Secondary electron spectra from charged particle interactions**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rudd, M., Kim, Y., Märk, T., Schou, J., Stolterfoht, N., Toburen, L.
Number of pages: 108
Publication date: 1996

**Publication Information**
Place of publication: Bethesda, MD
Publisher: International Commission on Radiation Units and Measurements
Original language: English
(ICRU-55).
Source: orbit
Source-ID: 295514
Research output: Book/Report › Book – Annual report year: 1996

**Thin films of ITO produced by pulsed laser deposition**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thetstrup, B., Nordskov, A., Schou, J., Svendsen, W., Johansen, P.
Publication date: 1996
Peer-reviewed: No
Event: Abstract from Gordon Research Conference, Plymouth, NH, United States.
Source: orbit
Source-ID: 295479
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1996

**Thin films of ITO produced by pulsed laser deposition**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thetstrup, B., Nordskov, A., Schou, J., Svendsen, W., Johansen, P.
Publication date: 1996
Peer-reviewed: No
Source: orbit
Source-ID: 295481
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1996

**Ablation from metals induced by visible and UV laser irradiation**

**General information**
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W. E., Schou, J., Thetstrup Nielsen, B., Ellegaard, O.
Publication date: 1995
Peer-reviewed: No
Event: Abstract from DFS 95. Dansk Fysisk Selskab og Astronomisk Udvalg, Odense, Denmark.
Ablation of silver and nickel induced by visible and UV laser irradiation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W., Schou, J., Thesstrup, B., Ellegaard, O.
Publication date: 1995

Host publication information
Title of host publication: Dansk Optisk Selskabs årsmøde 1995. 10-års jubilæum. Abstracts
Place of publication: Roskilde
Publisher: DOPS. Forskningscenter Risø
Source: orbit
Source-ID: 293395
Research output: Chapter in Book/Report/Conference proceeding – Conference abstract in proceedings – Annual report year: 1995 › Research

A multipurpose cluster ion source

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1995
Peer-reviewed: No
Event: Abstract from Sputtering Club. Odense Universitet, Odense (DK), 19 Sep, .
Source: orbit
Source-ID: 293552
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1995 › Research

Laser-induced evaporation of metals studied by numerical methods

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Svendsen, W.
Publication date: 1995
Peer-reviewed: No
Source: orbit
Source-ID: 293547
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1995 › Research

Linear and nonlinear effects at low energy ion bombardment of solid xenon

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dutkiewicz, L., Pedrys, R., Schou, J.
Publication date: 1995
Peer-reviewed: No
Event: Abstract from 16th International Conference on Atomic Collisions in Solids (ICACS-16), Linz, Austria.
Source: orbit
Source-ID: 293550
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1995 › Research

Particle dynamics during electronic sputtering of solid krypton
We have modeled electronic sputtering of solid krypton by excimer production with molecular dynamics. Both excimer evolution in the solid and deexcitation processes have been incorporated in the simulation. The excimer dynamics in the
lattice has been analyzed: the excimers formed near the surface shift upwards whereas those formed in the bulk contribute to long-range collision sequences directed along crystal rows. Singlet and triplet excitations showed considerable differences in their behavior. The defects introduced in the target strongly influenced the development of the phenomena. Good agreement of simulation results with experimental data has been achieved.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dutkiewicz, L., Pedrys, R., Schou, J.
Pages: 188-194
Publication date: 1995
Peer-reviewed: Yes

**Publication information**
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 101
Issue number: 1-2
ISSN (Print): 0168-583X
Original language: English
DOIs: 10.1016/0168-583X(95)00290-1
Source: orbit
Source-ID: 293802
Research output: Contribution to journal › Conference article – Annual report year: 1995 › Research › peer-review

**Particle emission induced by ionization tracks in water ice**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Shi, M., Grosjean, D., Schou, J., Baragiola, R.
Pages: 524-529
Publication date: 1995
Peer-reviewed: Yes

**Publication information**
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 96
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 293799
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research › peer-review

**Secondary electron emission from solids**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1995
Peer-reviewed: No
Event: Abstract from University of Sherbrooke, Quebec, (CA), 27 Jun, .
Source: orbit
Source-ID: 293549
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1995 › Research

**Secondary electron emission from solids: Fundamental aspects**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1995
Secondary electrons from solids

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1995
Peer-reviewed: No
Event: Abstract from Scanning microscopy meeting '95, Houston, TX (US), 6-11 May, .
Source: orbit
Source-ID: 293564
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 1995 » Research

Secondary particle emission from water ice irradiated by photons and charged particles

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Shi, M., Bahr, D., Baragiola, R., Grosjean, D., Svendsen, W., Vidal, R.
Publication date: 1995
Peer-reviewed: No
Event: Abstract from 10th International Congress of Radiation Research, Würzburg, Germany.
Source: orbit
Source-ID: 293551
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 1995 » Research

Setup for pulsed laser deposition of thin ITO films

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Nordskov, A., Schou, J., Svendsen, W., Johansen, P.
Publication date: 1995

Host publication information
Title of host publication: Dansk Optisk Selskabs årsmøde 1995. 10-års jubilæum. Abstracts
Place of publication: Roskilde
Publisher: DOPS. Forskningscenter Risø
Source: orbit
Source-ID: 293394
Research output: Chapter in Book/Report/Conference proceeding » Conference abstract in proceedings – Annual report year: 1995 » Research

Sputtering of the most volatile solids: The solid hydrogens

Electronic sputtering of the three stable hydrogenic solids, H-2, HD and D-2 by keV hydrogen and deuterium ions has been studied at the low-temperature setup at Riso. The yield of the sputtered particles has been determined for hydrogenic films of thicknesses ranging from 0.1 X 10(18) up to 10 X 10(18) molecules/cm(2) and for 4-10 keV H+, H-2(+), H-3(+) and D-3(+) ions. The yield increases with decreasing firm thickness for solid hydrogen as well as for deuterium. This behavior agrees with the trend observed for other volatile gases. For thick films the yield decreases to a constant value. This thick-film yield can be approximated fairly well by a quadratic function of the stopping power except for a somewhat steeper dependence for proton-bombarded deuterium. The yield increases strongly with decreasing sublimation energy from one isotope to another. No existing theory can account for the dependence of the yield on the electronic stopping power as well as the sublimation energy.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Sputtering of thin and intermediately thick films of solid deuterium by keV electrons

Sputtering of films of solid deuterium by keV electrons was studied in a cryogenic set-up. The sputtering yield shows a minimum yield of about 4 D2/electron for 1.5 and 2 keV electrons at a thickness slightly larger than the average projected range of the electrons. We suggest that the yield around the minimum represents the value closest to a bulk-yield induced by electron bombardment. It may also include contributions from the mechanisms that enhance the yield for thin and very thick films.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W. E., Thestrup Nielsen, B., Schou, J., Ellegaard, O.
Pages: 174-178
Publication date: 1995
Peer-reviewed: Yes

Sputtering of water ice surfaces and the production of extended neutral atmospheres

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Shi, M., Baragiola, R., Grosjean, D., Johnson, R., Jurac, S., Schou, J.
Pages: 26387-26395
Publication date: 1995
Peer-reviewed: Yes

Sputtering of thin and intermediately thick films of solid deuterium by keV electrons

Sputtering of films of solid deuterium by keV electrons was studied in a cryogenic set-up. The sputtering yield shows a minimum yield of about 4 D2/electron for 1.5 and 2 keV electrons at a thickness slightly larger than the average projected range of the electrons. We suggest that the yield around the minimum represents the value closest to a bulk-yield induced by electron bombardment. It may also include contributions from the mechanisms that enhance the yield for thin and very thick films.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W. E., Thestrup Nielsen, B., Schou, J., Ellegaard, O.
Pages: 174-178
Publication date: 1995
Peer-reviewed: Yes

Sputtering of water ice surfaces and the production of extended neutral atmospheres

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Shi, M., Baragiola, R., Grosjean, D., Johnson, R., Jurac, S., Schou, J.
Pages: 26387-26395
Publication date: 1995
Peer-reviewed: Yes
Transition from linear to nonlinear sputtering of solid xenon
Self-sputtering of solid xenon has been studied with molecular dynamics simulations as a model system for the transition from dominantly linear to strongly nonlinear effects. The simulation covered the projectile energy range from 20 to 750 eV. Within a relatively narrow range from 30 to 250 eV, nonlinear features such as high collision densities in the sputtering volume, amorphization of the crystalline structure, and an enhanced emission of low-energy atoms occur gradually.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dutkiewicz, L., Pedrys, R., Schou, J., Kremer, K.
Pages: 1407-1410
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Physical Review Letters
Volume: 75
Issue number: 7
ISSN (Print): 0031-9007
Original language: English
DOIs: 10.1103/PhysRevLett.75.1407
Source: orbit
Source-ID: 293581

Dynamics of rigid bodies

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1994
Peer-reviewed: No
Event: Abstract from Conference at University of Virginia 1994, Charlottesville, United States.
Source: orbit
Source-ID: 292158
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 1994 – Research

Erosion of solid deuterium of various film thicknesses by keV electrons

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup, B., Svendsen, W., Schou, J., Ellegaard, O.
Publication date: 1994
Peer-reviewed: No
Event: Abstract from Danish Physical Society Spring Meeting 1994, Odense, Denmark.
Source: orbit
Source-ID: 292415
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 1994 – Research

Ion-surface scattering

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1994
Peer-reviewed: No
Source: orbit
Laser ablation from metallic targets

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W., Schou, J., Ellegaard, O.
Publication date: 1994
Peer-reviewed: No
Source: orbit
Source-ID: 292748
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

Laser ablation from metals

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W., Schou, J., Thestrup, B.
Publication date: 1994
Peer-reviewed: No
Source: orbit
Source-ID: 292428
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

Laser ablation from silver targets

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W., Schou, J., Ellegaard, O.
Publication date: 1994
Peer-reviewed: No
Event: Abstract from Danish Physical Society Spring Meeting 1994, Odense, Denmark.
Source: orbit
Source-ID: 292414
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

Laser-induced evaporation yields of metallic systems evaluated by numerical methods

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Svendsen, W.
Published date: 1994
Peer-reviewed: No
Source: orbit
Source-ID: 292417
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

Particle dynamics during electronic sputtering of solid krypton

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dutkiewicz, L., Pedrys, R., Schou, J.
Publication date: 1994
Plasmon-assisted electron emission from Al and Mg surfaces

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Baragiola, R., Dukes, C., Schou, J., Ritzau, S.
Publication date: 1994
Peer-reviewed: No
Event: Abstract from 6th International Workshop on Desorption Induced by Electronic Transitions, Krakow, Poland.
Source-ID: 292102
Source: orbit
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

Satellite and ring atmospheres produced by ion, electron and photo-sputtering of icy satellites and ring particles: Laboratory measurements

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Shi, M., Westley, M., Baragiola, R., Schou, J., Johnson, R.
Publication date: 1994
Peer-reviewed: No
Source-ID: 292159
Source: orbit
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

Sputtering by excimer production from solid krypton

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dutkiewicz, L., Pedrys, R., Schou, J.
Pages: 323-328
Publication date: 1994
Peer-reviewed: Yes
Publication information
Journal: Europhysics Letters
Volume: 27
ISSN (Print): 0295-5075
Original language: English
Source-ID: 292436
Source: orbit
Research output: Contribution to journal › Journal article – Annual report year: 1994 › Research › peer-review

Sputtering of frozen gases by ion and electron bombardment

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 72-75
Publication date: 1994
Sputtering of solid nitrogen and oxygen by keV hydrogen ions

Electronic sputtering of solid nitrogen and oxygen by keV hydrogen ions has been studied at two low-temperature setups. The yield of the sputtered particles has been determined in the energy regime 4-10 keV for H+, H-2+ and H-3+ ions. The yield for oxygen is more than a factor of two larger than that for nitrogen. The energy distributions of the sputtered N2 and O2 molecules were measured for hydrogen ions in this energy regime as well. The yields from both solids turn out to depend on the sum of the stopping power of all atoms in the ion. The yield increases as a quadratic function of the stopping power for oxygen, but slightly slower for nitrogen. The energy distributions do not exhibit strong features, but are similar to those published earlier for electron sputtering.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Stenum, B., Sørensen, H., Pedrys, R., Warczak, B., Oostra, D., Haring, A., Vries, A. D.
Pages: 371-384
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Surface Science
Volume: 302
Issue number: 3
ISSN (Print): 0039-6028
Original language: English
DOIs:
10.1016/0039-6028(94)90841-9
Source: orbit
Source-ID: 292163
Research output: Contribution to journal › Journal article – Annual report year: 1994 › Research › peer-review

Sputtering of Thick Deuterium Films by KeV Electrons

Sputtering of thick films of solid deuterium up to several μm by keV electrons is reported for the first time. The sputtering yield increases within a narrow range of thicknesses around 1.6 μm by about 2 orders of magnitude for 1.5 keV electrons. A similar behavior has not been observed for ion bombardment. The yield enhancement is accompanied by an increasing electron accumulation in the film.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Thestrup Nielsen, B., Svendsen, W. E., Schou, J., Ellegaard, O.
Pages: 1444-1447
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Physical Review Letters
Volume: 73
Issue number: 10
ISSN (Print): 0031-9007
Original language: English
Electronic versions:
Winnie.pdf
DOIs:
10.1103/PhysRevLett.73.1444
Sputtering of thin and intermediately thick films of solid deuterium by keV electrons

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Svendsen, W., Thestrup, B., Schou, J., Ellegaard, O.
Publication date: 1994
Peer-reviewed: No
Event: Abstract from 6th International Workshop on Desorption Induced by Electronic Transitions, Krakow, Poland.
Source: orbit
Source-ID: 292103
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1994 › Research

UV luminescence of NeD in solid neon-deuterium mixtures
Solid samples of neon-deuterium mixtures were irradiated by keV electrons, and the luminescence was measured between 100 and 300 nm. For concentrations between 0.1% D-2 in Ne and 1% Ne in D-2 an intense emission band was observed. The maximum intensity was observed for 10% D-2 in Ne. Comparisons with results from gas phase measurements indicate that the dominant component of the band originates from a bound-free transition from the A(2) Sigma+ state of NeD to the repulsive ground state.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Stenum, B., Schou, J., Gürtler, P.
Pages: 353-356
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Chemical Physics Letters
Volume: 229
Issue number: 4-5
ISSN (Print): 0009-2614
Original language: English
DOIs: 10.1016/0009-2614(94)01042-0
Source: orbit
Source-ID: 292076
Research output: Contribution to journal › Journal article – Annual report year: 1994 › Research › peer-review

Laserablation fra faste stoffer. Et område i rivende udvikling

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 6-9
Publication date: 1993
Peer-reviewed: Unknown

Publication information
Journal: DOPS-Nyt
Volume: 8
Issue number: 3
Original language: Danish
Luminescence from pure and doped solid deuterium irradiated by keV electrons

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Stenum, B., Schou, J., Sørensen, H., Gürtler, P.
Pages: 126-134
Publication date: 1993
Peer-reviewed: Yes

Publication information
Journal: Journal of Chemical Physics
Volume: 98
ISSN (Print): 0021-9606
Original language: English
Source: orbit
Source-ID: 291054
Research output: Contribution to journal → Journal article – Annual report year: 1993 → Research → peer-review

Secondary electron emission from insulators

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 351-358
Publication date: 1993

Host publication information
Title of host publication: Ionization of solids by heavy particles
Place of publication: New York
Publisher: Plenum Publishing Corporation
Editor: Baragiola, R.
(NATO Advanced Science Institutes Series B: Physics, 306).
Source: orbit
Source-ID: 291062
Research output: Chapter in Book/Report/Conference proceeding → Article in proceedings – Annual report year: 1993 → Research

Sputtering of inorganic insulators

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Johnson, R., Schou, J.
Pages: 403-493
Publication date: 1993
Peer-reviewed: No

Publication information
Journal: Det Kongelige Danske Videnskabernes Selskab, Matematisk-Fysiske Meddelelser
Volume: 43
Original language: English
Source: orbit
Source-ID: 290571
Research output: Contribution to journal → Journal article – Annual report year: 1993 → Research

Sputtering of solid deuterium by keV electrons. Paper P53
Sputtering of solid nitrogen by keV helium ions

Solid nitrogen has become a standard material among the frozen molecular gases for electronic sputtering. We have combined measurements of sputtering yields and energy spectra from nitrogen bombarded by 4-10 keV helium ions. The data show that the erosion is electronic rather than knockon (collisional) sputtering. The sputtering yields induced by He-3+ and He-4+ ions of equal velocity are almost the same. The magnitude of the yields is about 20 N2 molecules/He+ ion. Most of the sputtered particles are molecules, but also atoms are emitted. For molecules, the energy distribution is similar to that for electron incidence, but differs considerably from that of bombardment by medium mass ions.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Sørensen, H., Pedrys, R., Warczak, B.
Pages: 192-197
Publication date: 1993
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 78
Issue number: 1-4
ISSN (Print): 0168-583X
Original language: English
DOIs: 10.1016/0168-583X(93)95798-A
Source: orbit
Source-ID: 291055
Research output: Contribution to journal › Conference article – Annual report year: 1993 › Research › peer-review

UV laser irradiation of thin films of silver and solid nitrogen

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Ellegaard, O.
Pages: 64-69
Publication date: 1993

Host publication information
Title of host publication: Laser ablation: Mechanisms and applications II
Place of publication: New York
Publisher: American Institute of Physics
Editors: Miller, J., Geohegan, D.
Source: orbit
Source-ID: 291465
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1993 › Research › peer-review
Continuum emission from irradiated solid deuterium
A new emission feature from the spectrum of irradiated solid deuterium has been observed in the very near-infrared spectral region. Experiments from three laboratories, using different excitation conditions, have confirmed the observation. Comparison of the timing and temperature dependence of the spectral feature to the information previously available from electron spin resonance studies of solid deuterium, points to atomic association as the underlying cause. We shall show the connection of this emission to the occurrence of thermal spikes and optical flashes, previously observed in solid deuterium.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Pages: 13820-13824
Publication date: 1992
Peer-reviewed: No

Publication information
Journal: Physical Review B Condensed Matter
Volume: 46
Issue number: 21
ISSN (Print): 0163-1829
Original language: English
DOI: 10.1103/PhysRevB.46.13820
Source: orbit
Source-ID: 289796
Research output: Contribution to journal » Journal article – Annual report year: 1992 » Research

Electron yields from solids: A probe for the stopping power of swift charged particles?

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rothard, H., Schou, J., Koschar, P., Groeneveld, K.
Pages: 154-157
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 69
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 289572
Research output: Contribution to journal » Journal article – Annual report year: 1992 » Research » peer-review

Energy spectra from solid rare gases sputtered by light ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pedrys, R., Warczak, B., Schou, J., Ellegaard, O.
Publication date: 1992
Peer-reviewed: No
Event: Abstract from 9th International Workshop on Inelastic Ion Surface Collisions, Aussois, France.
Source: orbit
Source-ID: 289772
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 1992 » Research
Enhanced sputtering of solid neon by molecular ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Stenum, B., Sørensen, H., Pedrys, R.
Pages: 549-553
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 67
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 290350
Research output: Contribution to journal › Journal article – Annual report year: 1992 › Research › peer-review

Evaporation yields of solid nitrogen induced by UV-laser irradiation

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Ellegaard, O.
Publication date: 1992
Peer-reviewed: No
Source: orbit
Source-ID: 289809
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1992 › Research

Iskugler af brint er brændstof til fusionsreaktorer

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 8-9
Publication date: 1992
Peer-reviewed: Unknown

Publication information
Journal: Risønyt
Issue number: 2
Original language: Danish
Source: orbit
Source-ID: 290280
Research output: Contribution to journal › Journal article – Annual report year: 1992 › Communication

Projectile- and charge-state-dependent electron yields from ion penetration of solids as a probe of preequilibrium stopping power

Kinetic electron-emission yields $\gamma$ from swift ion penetration of solids are proportional to the (electronic) stopping power $\gamma \approx \beta S^*$, if the preequilibrium evolution of the charge and excitation states of the positively charged ions is taken into account. We show that the concept of the preequilibrium near-surface stopping $S^*$ can be applied successfully to describe the dependence of the ion-induced electron yields on the projectile atomic number $Z(P)$ and on the charge states $q(i)$ of the incoming ions. We discuss the implementation of this concept into Schou’s transport theory after having presented a summary of recent results on the projectile- and charge-state dependence of forward and backward electron yields $\gamma(F)$ and $\gamma(B)$ and the Meckbach factor $R = \gamma(F)/\gamma(B)$. A simple extension of the yield equations is proposed and several assumptions are justified by investigating the “transport factor” beta, the energy spectrum of directly ejected recoil electrons and the evolution of ionic charge state inside solids. Estimates of the energy-loss fraction leading to electron emission and the effective charges of the ions near the surface allow a quantitative description of the $Z(p)$ dependence of the electron yields.
General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Rothard, H., Schou, J., Groeneveld, K.
Pages: 1701-1710
Publication date: 1992
Peer-reviewed: No

Publication information
Journal: Physical Review A
Volume: 45
Issue number: 3
ISSN (Print): 2469-9926
Original language: English
DOIs:
10.1103/PhysRevA.45.1701
Source: orbit
Source-ID: 290051
Research output: Contribution to journal › Journal article – Annual report year: 1992 › Research

Sputtering of solid hydrogenic targets by keV hydrogen ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Stenum, B., Schou, J., Pedrys, R., Sørensen, H.
Publication date: 1992
Peer-reviewed: No
Source: orbit
Source-ID: 289794
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1992 › Research

Sputtering of solid neon and argon by medium mass ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Ellegaard, O., Pedrys, R., Sørensen, H.
Pages: 173-176
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 65
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 290368
Research output: Contribution to journal › Journal article – Annual report year: 1992 › Research › peer-review

Sputtering of solid nitrogen by keV helium ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Sørensen, H., Pedrys, R., Warczak, B.
Publication date: 1992
Peer-reviewed: No
Event: Abstract from 9th International Workshop on Inelastic Ion Surface Collisions, Aussois, France.
Source: orbit
Source-ID: 289793
Sputtering of thick nitrogen and oxygen films by keV hydrogen ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Stenum, B., Sørensen, H., Pedrys, R., Oostra, D., Haring, A., deVries, A.
Number of pages: 96
Publication date: 1992

Host publication information
Title of host publication: Proceedings of the Joint Nordic Spring meeting '92. Extended abstracts
Volume: Risø-R-628(EN)
Editor: Lindgård, P.
ISBN (Print): 87-550-1810-6
URLs:
http://www.risoe.dtu.dk/rispubl/reports_INIS/RISOR628.pdf
Source: orbit
Source-ID: 290347
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1992

Sputtering yields and energy distributions from nonoverlapping subspikes in ion bombarded volatile solids

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Stenum, B., Sørensen, H., Pedrys, R.
Pages: 447-455
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 62
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 290050
Research output: Contribution to journal – Journal article – Annual report year: 1992

Erosion of Volatile Elemental Condensed Gases by keV Electron and Light-Ion Bombardment
Erosion of the most volatile elemental gases by keV electron and light-ion bombardment has been studied at the experimental setup at Risø.
The present work includes frozen neon, argon, krypton, nitrogen, oxygen and three hydrogen isotopes, deuterium, hydrogen deuteride and hydrogen. The yield of these condensed gases has been measured as a function of film thickness and primary energy for almost all combinations of primary particles (1-3 keV electrons, 5-10 keV hydrogen- and helium ions) and ices. These and other existing results show that there are substantial common features for the sputtering of frozen elemental gases. Within the two groups, the solid rare gases and the solid molecular gases, the similarity is striking. The hydrogenic solids deviate in some respects from the other elements. The processes that liberate kinetic energy for the particle ejection in sputtering are characteristic of the specific gas.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Number of pages: 162
Publication date: 1991

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
ISBN (Print): 87-550-1737-1
Fundamental electron and ion beam interactions with solids for microscopy, microanalysis and microlithography

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Kruit, P., Newbury, D.
Number of pages: 370
Publication date: 1991

Publication information
Place of publication: Chicago, IL
Publisher: Scanning Microscopy International
Original language: English
(Scanning Microscopy Supplement, 4).
Source: orbit
Source-ID: 288888
Research output: Book/Report › Book – Annual report year: 1991 › Research

Radiation in the wavelength range 120-900 nm from keV electron bombardment of solid hydrogens
The emission of light from hydrogenic pellet material has been studied in a special experimental set-up. The measurements show that the intensity of light from particle bombarded solid hydrogens is very small and that none of the well known lines for the gas phase are emitted from the solid. The solid hydrogens do not contribute to the strong H-alpha (D-alpha) signal observed from the pellet cloud during penetration into the plasma.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Stenum, B., Sørensen, H., Weisberg, K.
Pages: 589-591
Publication date: 1991
Peer-reviewed: No

Publication information
Journal: Nuclear Fusion
Volume: 31
Issue number: 3
ISSN (Print): 0029-5515
Original language: English
DOIs: 10.1088/0029-5515/31/3/017
Source: orbit
Source-ID: 289018
Research output: Contribution to journal › Journal article – Annual report year: 1991 › Research

Sputtering of frozen gases by molecular hydrogen ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Stenum, B., Elleegaard, O., Schou, J., Sørensen, H., Pedrys, R.
Pages: 399-403
Publication date: 1991
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 58
ISSN (Print): 0168-583X
Sputtering of solid hydrogenic targets by keV hydrogen ions

The first sputtering measurements of the most volatile solid hydrogenic targets are reported. Bombardment of these targets by hydrogen and deuterium ions leads to erosion predominantly via electronic transitions. The magnitude of the yield depends strongly on the particular isotope. No existing theory for this electronic sputtering can explain the large yields that range from about 100 D2/H for solid deuterium up to 800 H-2/H for solid hydrogen.

Sputtering of volatile solids from nonoverlapping subspikes

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Sørensen, H.
Pages: 459-464
Publication date: 1990
Peer-reviewed: Yes

Publication information
Journal: Europhysics Letters
Volume: 12
ISSN (Print): 0295-5075
Original language: English
Source: orbit
Source-ID: 288576

Research output: Contribution to journal › Journal article – Annual report year: 1990 › Research

Thickness dependence of the sputtering yield from solid deuterium by light keV ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Stenum, B., Ellegaard, O., Schou, J., Sørensen, H.
Pages: 530-533
Publication date: 1990
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
Volume: 48
ISSN (Print): 0168-583X
Energy Deposition of keV Electrons in Light Elements

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Valkealahti, S., Schou, J., Nieminen, R.
Pages: 2258-2266
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: Journal of Applied Physics
Volume: 65
ISSN (Print): 0021-8979
Original language: English
Source: orbit
Source-ID: 288208
Research output: Contribution to journal › Journal article – Annual report year: 1989 › Research › peer-review

Energy Distributions from Electron-Sputtered Solid Nitrogen

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pedrys, R., Oostra, D., Haring, A., Vries, A. D., Schou, J.
Pages: 239-244
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: Radiation Effects and Defects in Solids
Volume: 109
ISSN (Print): 1042-0150
Original language: English
Source: orbit
Source-ID: 288205
Research output: Contribution to journal › Journal article – Annual report year: 1989 › Research › peer-review

Erosion and Luminescence from Pure and Impure Solid Deuterium

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Stenum, B., Schou, J., Sørensen, H., Gürtler, P.
Pages: 235-238
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: Radiation Effects and Defects in Solids
Volume: 109
ISSN (Print): 1042-0150
Original language: English
Source: orbit
Source-ID: 288207
Research output: Contribution to journal › Journal article – Annual report year: 1989 › Research › peer-review
Ion Energy Dissipation and Sputtering during Bombardment of Multicomponent Materials

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 61-102
Publication date: 1989

Host publication information
Title of host publication: Structure-Property Relationships in Surface-Modified Ceramics
Place of publication: Dordrecht
Publisher: Kluwer Academic Publishers
Editors: McHargue, C., Kossowsky, R., Hofer, W.
(NATO Advanced Study Institutes Series E: Applied Sciences, 170).
Source: orbit
Source-ID: 288193
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1989 › Research › peer-review

Observation of Fluorescence from Heavy Rare-gas Hydrides and Deuterides in Electron-Irradiated Matrices of Solid Hydrogen and Deuterium

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Stenum, B., Sørensen, H., Gürtler, P.
Pages: 969-971
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: Physical Review Letters
Volume: 63
Issue number: 9
ISSN (Print): 0031-9007
Original language: English
DOIs: 10.1103/PhysRevLett.63.969
Source: orbit
Source-ID: 288206
Research output: Contribution to journal › Journal article – Annual report year: 1989 › Research › peer-review

Secondary Electron Emission: Progress and Prospects

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 429-433
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: Scanning Microscopy
Volume: 3
ISSN (Print): 0891-7035
Original language: English
Source: orbit
Source-ID: 288188
Research output: Contribution to journal › Journal article – Annual report year: 1989 › Research › peer-review

Electronic and Knock-on Sputtering of Solid Rare Gases by Light keV Ions
Erosion of Rare Gas Solids by Electron Bombardment

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pedrys, R., Oostra, D., Haring, A., Vries, A. D., Schou, J.
Publication date: 1988
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 287812
Research output: Contribution to journal › Journal article – Annual report year: 1988 › Research › peer-review

Range and Stopping Power of keV Electrons in the Solid Hydrogens

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Valkealahti, S., Schou, J., Sørensen, H., Nieminen, R.
Publication date: 1988
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 287829
Research output: Contribution to journal › Journal article – Annual report year: 1988 › Research › peer-review

Secondary-Electron Emission from Solids by Electron and Proton-Bombardment

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1988
Peer-reviewed: Yes

Publication information
Journal: Scanning Microscopy
ISSN (Print): 0891-7035
Original language: English
Source: orbit
Source-ID: 287813
Electronic Sputtering of Solid Argon and Krypton by keV Hydrogen Ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Pedrys, R., Ellegaard, O., Sørensen, H.
Publication date: 1987
Peer-reviewed: Yes

Electronic sputtering of solid nitrogen and oxygen by keV electrons
Sputtering of solid N2 and O2 has been performed with electrons in the keV regime by means of a quartz microbalance technique. Good agreement is found between the sputtering yields obtained with this and the emissivity-change method. O2 sputters more efficiently than N2, although these solids are very similar in their physical properties. The yields are almost proportional to the electronic stopping power of the primary electrons. Different models for electronic sputtering of solid condensed gases are discussed and compared with the results. For low excitation densities predictions are attempted on the basis of a simple collision-cascade model where the low-energy cascades are generated by kinetic energy release from electronic deexcitations.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Sørensen, H., Børgesen, P.
Pages: 474-492
Publication date: 1986
Peer-reviewed: Yes

Sputtering of Frozen Gases

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Publication date: 1987
Peer-reviewed: Yes

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 287253
Research output: Contribution to journal › Journal article – Annual report year: 1987 › Research › peer-review

Publication information
Journal: Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
ISSN (Print): 0168-583X
Original language: English
Source: orbit
Source-ID: 287252
Research output: Contribution to journal › Journal article – Annual report year: 1987 › Research › peer-review

Publication information
Journal: Surface Science
Volume: 167
Issue number: 2-3
ISSN (Print): 0039-6028
Original language: English
Source: orbit
Source-ID: 279827
Research output: Contribution to journal › Journal article – Annual report year: 1986 › Research › peer-review
Erosion of solid neon by keV electrons
The erosion of solid neon by keV electrons has been studied experimentally and theoretically. Electronic sputtering as well as temperature-enhanced sublimation are investigated by a frequency-change measurement on a quartz crystal or in some cases by the change in intensity of reflected electrons. The erosion yield increases with increasing temperature for substrate temperatures above 7K. Below this temperature sputtering via electronic transitions is the dominant process. The yield shows a clear minimum for film thicknesses about $(5-7) \times 10^{16}$ Ne atoms/cm$^2$ for 2-keV electrons. The sputtering yield for thick films has a maximum at 1.2-1.5 keV. The results are explained by the diffusion of excitations to the surface with subsequent decay. From this model and the experimental results one derives a characteristic diffusion length of about $1 \times 10^{17}$ Ne atoms/cm$^2$. The eventual particle ejection is driven by decay of surface-trapped excitons or by dissociative recombination. The magnitude of the yield indicates that deexciting neon particles at the surface induce further sputtering. Direct sputtering from electron-nucleus collisions does not contribute significantly to the yield.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Risø National Laboratory
Contributors: Schou, J., Børgesen, P., Ellegaard, O., Sørensen, H.
Pages: 93-106
Publication date: 1986
Peer-reviewed: Yes

Sputtering of solid neon by keV hydrogen ions
Sputtering of solid Ne with the hydrogen ions H$^+$, H$^{+2}$ and H$^{+3}$ in the energy range 1–10 keV/atom has been studied by means of a quartz microbalance technique. No enhancement in the yield per atom for molecular ions was found. The results for hydrogen ions are compared with data for keV electrons. The thickness dependence of the yield is almost the same for the two types of bombarding particles. The energy dependence as well as the absolute magnitude of the yield are discussed on the basis of mobile electronic excitations.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ellegaard, O., Schou, J., Sørensen, H.
Pages: 567-571
Publication date: 1986
Peer-reviewed: Yes

The Erosion of Condensed Gases by keV Electron Bombardment

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Ellegaard, O., Børgesen, P., Sørensen, H.
Pages: 170-176
Publication date: 1985
The Range of 1-3 keV Electrons in Solid Oxygen and Carbon Monoxide.

The range of 1-3 keV electrons in films of solid oxygen and carbon monoxide has been measured by a mirror substrate method. The technique used here is identical to the one previously used for range measurements in solid hydrogen and nitrogen. The range in oxygen is slightly shorter than that in nitrogen whereas the range in carbon monoxide is about 20% larger than that in the nitrogen.

Range Measurements of keV Hydrogen Ions in Solid Oxygen and Carbon Monoxide

Ranges of 1.3–3.5 keV/atom hydrogen and deuterium molecular ions have been measured by a thin-film reflection method. The technique, used here for range measurements in solid oxygen and carbon monoxide targets, is identical to the one used previously for range measurements in hydrogen and nitrogen. The main aim was to look for phase-effects, i.e. gas-solid differences in the stopping processes. While measured ranges in solid oxygen were in agreement with known gas data, the ranges in solid carbon monoxide were up to 50% larger than those calculated from gas-stopping data. The latter result agrees with that previously found for solid nitrogen.
The Measurement of Electron-Induced Erosion of Condensed Gases: Experimental Methods

Two experimental methods for measuring the erosion yield of condensed gases are described. One, the frequency-change method, utilizes a quartz-crystal microbalance operating at liquid-helium temperature. The other, the emissivity-change method is based on the strongly varying electron emission as a function of the condensed-gas film thickness. Satisfactory results have been obtained for both methods for solid Ne and D2 at electron energies up to 3 keV, and the mutual agreement is good as well. Accurate measurements are affected critically by the beam conditions, particularly if the erosion yield depends on the film thickness. The erosion yield has been measured for dominant electron sputtering of solid Ne (≈ 28 Ne-atoms/electron) as well as for beam-induced evaporation at 2 keV. In the latter case a clear lateral broadening of the erosion spot is observed.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Technical University of Denmark
Contributors: Schou, J., Sørensen, H., Børgesen, P.
Pages: 44-57
Publication date: 1984
Peer-reviewed: Yes

Festkörperanalysen Mittels Nachionisation Zerstäubter Neutralteilchen

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Hofer, W. O., Giber, J., Schou, J.
Pages: 220-220
Publication date: 1983
Peer-reviewed: Yes

Secondary electron emission from solid HD and a solid H2-D2 mixture

Secondary electron emission from solid HD and a solid 0.6 H2 + 0.4 D2 mixture has been studied for electron and hydrogen ion bombardment at primary energies from 0.5 to 3 keV and 2 to 10 keV/amu, respectively. The yield for solid HD is well explained by a simple stoichiometric model of the low-energy stopping power for the internal secondaries. The secondary electron yield from the mixture is somewhat larger than the expected value, but lies between the values for pure solid H2 and D2. The secondary electron emission coefficient for solid tritium may be determined from a linear extrapolation of the present data.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Sørensen, H., Børgesen, P., Hao-Ming, C., Schou, J.
Pages: 355-365
Charged Particle Erosion of Solid Rare Gases and Dilute Rare Gas Alloys

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Børgesen, P., Schou, J., Sørensen, H., Clausen, C.
Pages: 57-61
Publication date: 1982
Peer-reviewed: Yes

Publication information
Journal: Surface Science
Volume: 25
Issue number: 2
ISSN (Print): 0039-6028
Original language: English
Source: orbit
Source-ID: 280135
Research output: Contribution to journal › Journal article – Annual report year: 1983 › Research › peer-review

On the Emission of Electrons from Solid H_2 and D_2 by Bombardment with 1-3 keV Electrons up to Very Large Angles of Incidence

Electron emission, i.e. electron reflection (ER) and secondary electron emission (SEE), was studied for solid H2 and D2 for oblique incidence of 1-3 keV electrons up to an angle of incidence θ of 83°. The ER coefficient η was small at low angles, and rose rapidly with increasing θ above 60-65°. Only at large angles and low energies were the results different for H2 and D2, those for H2 being the lower ones. The angular variation of the SEE coefficient δ may be written as δ(θ)=δ(0)(cos θ)^3/2 up to an angle of 65-75°. For H2 the SEE coefficient is around 0.65 times that the D2 except at the largest angles. The results agree well with the existing qualitative tendencies described in the literature. The variation with the angle of incidence shows a fair agreement with an estimate based on data for the angular distribution of electrons ejected from ionized hydrogen molecules. In addition, an ionization cascade treatment leads to an expression for the behavior of the yield of those secondary electrons that are generated directly by the primaries. The agreement with experimental data is good

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Risø National Laboratory, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Sørensen, H.
Pages: 5231-5238
Publication date: 1982
Peer-reviewed: Yes

Publication information
Journal: Journal of Applied Physics
Volume: 53
Issue number: 7
ISSN (Print): 0021-8979
Original language: English
Source: orbit
Source-ID: 286281
Probe Measurements of the Impurity Flux at the Plasma Edge of the Stellerator Wiendelstein VII A

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Scherzer, B. M. U., Renner, H.
Pages: 162-164
Publication date: 1982
Peer-reviewed: Yes

Publication information
Journal: Journal of Nuclear Materials
Issue number: 111/112
ISSN (Print): 0022-3115
Original language: English
Source: orbit
Source-ID: 285889

Sputtered Clusters from Niobium-Vanadium Alloys
A series of Nb&zsb;& V alloys have been irradiated by 6 keV argon ions. Homonuclear and heteronuclear clusters emitted from these alloys have been studied by means of post-ionization and/or secondary ion mass spectrometry. The intensity of clusters of atomic masses up to approximately 300 amu was related to the concentrations of Nb and V in the alloys. In addition, the behaviour of polyatomic cluster yields as a function of partial oxygen pressure was studied. At partial pressures larger than approximately 10 6Torr, the yields decreased with increasing partial pressures. By inclusion of the post-ionized neutrals, the total secondary particle intensity was increased by a factor of 1.5 for clusters up to atomic masses of around 200 amu. Scanning electron microscopy revealed a varied surface topography with large differences from grain to grain for irradiated samples exposed for doses larger than 1018 atoms/cm2

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Hofer, W. O.
Pages: 383-404
Publication date: 1982
Peer-reviewed: Yes

Publication information
Journal: Applications of Surface Science
Volume: 10
Issue number: 3
ISSN (Print): 0378-5963
Original language: English
Source: orbit
Source-ID: 285888

Comments to transport theory for secondary electron emission

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Number of pages: 36
Publication date: 1980

Publication information
Original language: English
(Risø-M; No. 2218).
Keywords: Risø-M-2218
Source: orbit
Source-ID: 311136
Erosion of Thin Films of D2 by keV Light Ions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Number of pages: 920
Pages: 822-831
Publication date: 1980

Host publication information
Title of host publication: Proceedings of the Symposium on Sputtering
Place of publication: Wien
Publisher: Institut für Allgemeine Physik
Source: orbit
Source-ID: 281215
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1980 – Research

Ion-Induced Emission of Charged Particles from Solid Hydrogen and Deuterium

Measurements have been made of the emission of both positive and negative particles from solid hydrogen and deuterium for normal incidence of H+, H2+, H3+, D2H+, D3+ and He+ ions up to 10 keV. For positive particles the emission coefficient increased with increasing energy of incidence to reach a value of 0.08 per atom for 10 keV H+ onto hydrogen. Apparently the positive particles are sputtered ones. The negative particles emitted are predominantly electrons. The emission coefficient per incident atom as a function of the velocity of the incident particle agrees fairly well with results published earlier for incidence of hydrogen and deuterium ions. However, systematic differences of up to 10% are now observed between the coefficients for the different types of ions.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Børgesen, P., Schou, J., Sørensen, H.
Pages: 701-703
Publication date: 1980
Peer-reviewed: Yes

Publication information
Journal: Journal of Nuclear Materials
Volume: 93-94
Issue number: part 2
ISSN (Print): 0022-3115
Original language: English
DOIs: 10.1016/0022-3115(80)90195-6
Source: orbit
Source-ID: 281212

Transport Theory for Kinetic Emission of Secondary Electrons from Solids

Kinetic secondary electron emission from a solid target resulting from incidence of keV electrons or keV and MeV ions is treated theoretically on the basis of ionization cascade theory. The energy and angular distribution and the yield of secondary electrons are calculated for a random target. These quantities are determined from the solutions to a system of Boltzmann transport equations. Input quantities are the cross sections for collisions between the involved particles and the surface barrier of the target. A general power cross section has been utilized in the analytical procedure. It is shown that liberated electrons of low energy move isotropically inside the target in the limit of high primary energy as compared to the instantaneous energy of the liberated electrons. The connection between the spatial distribution of kinetic energy of the liberated electrons and the secondary electron current from a solid is derived. To find the former, existing computations for ion slowing down and experimental and theoretical ones for electron bombardment can be utilized. The energy and angular distribution of the secondary electrons and the secondary electron yield are both expressed as products of the deposited energy at the surface of the target and a factor which depends only on the properties of the escaping secondary electrons. Corrections for energy transport away from the surface by energetic recoil electrons are partly included. Also the contribution from recoiling target atoms at heavy-ion bombardment in the keV region is largely taken into account. The predicted energy and angular distribution agree with absolute spectra for incident electrons, whereas the agreement with
absolute spectra for incident protons is less satisfactory. Extrapolation of the energy distribution down to the vacuum level gives a spectrum which shows good agreement with experimental data. The electron- and proton-induced yields from aluminum are evaluated on the basis of existing low-energy-electron stopping-power data. The agreement with existing experimental data is good. Also, experimental yields from electrons, protons, and noble gas ions incident on copper agree within the accuracy of the treatment.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Pages: 2141-2174
Publication date: 1980
Peer-reviewed: Yes

**Publication information**
Journal: Physical Review B
Volume: 22
Issue number: 5
ISSN (Print): 2469-9950
Original language: English
DOIs:
10.1103/PhysRevB.22.2141
Source: orbit
Source-ID: 281274
Research output: Contribution to journal › Journal article – Annual report year: 1980 › Research › peer-review

**Direct and Recoil-Induced Electron Emission from Ion-Bombarded Solids**
The kinetic emission of secondary electrons from ion-bombarded solid surfaces is split into two contributions, a direct one caused by ionizing collisions between the bombarding ion and target atoms, and an indirect one originating from ionizing collisions undergone by recoil atoms with other target atoms. The direct contribution, which has been treated by several authors in previous studies, shows a behavior that is determined primarily by the electronic stopping power of the bombarding ion, while the indirect contribution is nonproportionally related to the nuclear stopping power. This latter contribution is known to be quite important for heavy-ion bombardment at keV energies, and is shown to be of crucial importance for the understanding of the energy dependence of the electron yield in such cases. The model is shown to give consistent results for copper bombarded with electrons, protons, and noble-gas ions within the accuracy of the treatment.

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Holmen, G., Svensson, B., Schou, J., Sigmund, P.
Pages: 2247-2254
Publication date: 1979
Peer-reviewed: Yes

**Publication information**
Journal: Physical Review B
Volume: 20
Issue number: 6
ISSN (Print): 2469-9950
Original language: English
DOIs:
10.1103/PhysRevB.20.2247
Source: orbit
Source-ID: 282659
Research output: Contribution to journal › Journal article – Annual report year: 1979 › Research › peer-review

**Studies on keV and eV electrons in solids**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J.
Number of pages: 88
Publication date: 1979
Energy Reflection Coefficients for 5-10 keV He Ions Incident on Au, Ag, and Cu

The calorimetric deuterium-film method was used for measurements of the energy reflection coefficient $\gamma$ for normal incidence of 5-10 keV He ions on Cu, Ag and Au. A theoretical calculation of $\gamma$ by means of transport theory gives fair agreement with the experimental results. The experimental data for all three materials lie on a single curve, if depicted as a function of the reduced energy $\varepsilon$. $\gamma$ varies from 0.14 to 0.04 with $\varepsilon$ varying from 0.2 to 1.6. The calculated data do not show similar behaviour, and the position of each curve depends on the specific beam-target combination. Both the experimental and theoretical results for the He ions are in acceptable agreement with other experimental and theoretical results. For He ions, the experimental $\gamma$-values are 20-30% above the values for hydrogen ions for the same value of $\varepsilon$.

Interaction between Solid Nitrogen and 1-3-keV Electrons

Experimental studies were made of the interaction between solid nitrogen and beams of 1-2-keV electrons. The projected range for the electrons was measured by means of the mirror-substrate method (gold substrate), giving the result $9.02 \times 10^{16} E^{1.75}$ molecules/cm$^2$ with the energy given in keV. The escape depth for secondary electrons was studied by means of the equivalent-substrate method (carbon substrate). The results varied from 280 Å at 1 keV to 400 Å at 3 keV. Measurements were also made of the secondary-electron-emission coefficient, which varied from 2.3 el/el at 1 keV to 1.2 el/el at 3 keV. At 3 keV, the SEE coefficient is 12 times that for solid deuterium. This is attributed partly to the larger production rate for low-energy electrons in nitrogen and partly to the larger escape probability for these electrons. Moreover, measurements were made of the electron-reflection coefficient, both for solid nitrogen and for the carbon substrate. For nitrogen, it varied from 0.17 el/el at 1 keV to 0.13 el/el at 3 keV, and for carbon it varied from 0.13 to 0.12. The observations are discussed and comparisons made with other theoretical and experimental results. The agreement ranges from good to fair.
On Secondary Electron Emission from Solid H₂ and D₂
The emission of secondary electrons from solid hydrogen (H₂, D₂, T₂) is often considered to be of importance for the interaction between a fusion plasma and pellets of solid hydrogens. A set-up was therefore built for studies of interactions between energetic particles and solid hydrogens. Studies of secondary electron emission (SEE) from solid H₂ and D₂ were made for incidence of electrons up to 3 keV and for incidence of ions of hydrogen, deuterium, and helium up to 10 keV. The measurements were made for normal incidence, and in some cases also for oblique incidence. The SEE coefficients for solid H₂ is always 0.65-0.70 times that for solid D₂. This difference is attributed to different losses to vibrational states in H₂ and D₂ for the low energy electrons. Measurements were also made on solid para-H₂ with both electrons and hydrogen ions. There was no difference from the results for normal H₂, which consists of 25% para-H₂ and 75% ortho-H₂.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Sørensen, H.
Pages: 634-635
Publication date: 1978
Peer-reviewed: Yes

Penetration Depth of 0.5-3-keV Electrons in Solid Hydrogen and Deuterium
The mirror-substrate method was used for measuring the penetration depth of 0.5-3-keV electrons in solid hydrogen and deuterium. The penetration depth was found to be 0.53 multiplied by 10^1×10^1×2 molecules/cm^2 with the energy given in keV. There was satisfactory agreement with other data. The measurements also showed that the escape depth for true secondary electrons from solid deuterium is less than 50 Å, which agrees well with the small values for the secondary-electron-emission coefficient found for solid deuterium. Results were furthermore obtained for the electron-reflection coefficient for the gold substrate, i.e., the number of electrons that are reflected with high energies. The electron-reflection coefficient agrees well with other results, both with respect to magnitude and energy dependence.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Sørensen, H.
Pages: 816-821
Publication date: 1978
Peer-reviewed: Yes

Projects:
New thin solar cell films makes silicon cells better
Martinho, F. M. A., PhD Student, Department of Photonics Engineering
Schou, J., Supervisor
Stamate, E., Supervisor
Canulescu, S., Main Supervisor
Forskningsrådsfinansiering
01/08/2017 → 31/07/2020
Award relations: New thin solar cell films makes silicon cells better
Project: PhD

New thin solar cell films makes silicon cells better
Gansukh, M., PhD Student, Department of Photonics Engineering
Schou, J., Supervisor
Canulescu, S., Main Supervisor
Technical University of Denmark
01/04/2017 → 31/03/2020
Award relations: New thin solar cell films makes silicon cells better
Project: PhD

Compressed sensing for material characterization and simulation
Amdemeskel, M. W., PhD Student, Department of Photonics Engineering
Dam-Hansen, C., Main Supervisor
Soreze, T. S. C., Supervisor
Thorseth, A., Supervisor
Schou, J., Examiner
Fontoyvont, M., Examiner
Martinsons, C., Examiner
Forskningsrådsfinansiering
01/04/2015 → 21/09/2018
Award relations: Compressed sensing for material characterization and simulation
Project: PhD

Reagentless dissolved Oxygen-sensor for Microfluidic Applications (water/blood analysis)
Jensen, M. F., PhD Student, Department of Micro- and Nanotechnology
Geschke, O., Main Supervisor
Hansen, H. N., Examiner
Drese, K. S., Examiner
Schou, J., Examiner
Christensen, L., Supervisor
Erhvervsforskerordningen
01/10/2001 → 02/02/2005
Award relations: Reagentless dissolved Oxygen-sensor for Microfluidic Applications (water/blood analysis)
Project: PhD

Fabrication and Characterization of Mixed Ionic Electronic Conducting Thin Films for Use in Solid Oxide Fuel Cells
Plonczak, P., PhD Student, Risø National Laboratory for Sustainable Energy
Hendriksen, P. V., Main Supervisor
Gauckler, L. J., Supervisor
Segaard, M., Supervisor
Schou, J., Examiner
López, J. S., Examiner
Bieberle-Hütter, A., Supervisor
Fleig, J., Examiner
Forskningsrådsfinansiering
01/12/2007 → 31/08/2011
Award relations: Fabrication and Characterization of Mixed Ionic Electronic Conducting Thin Films for Use in Solid Oxide Fuel Cells
Project: PhD

Thin-film Deposition and Characterization of new Solar Cell Materials
Engberg, S. L. J., PhD Student, Department of Photonics Engineering
Schou, J., Main Supervisor
Thin-film deposition and characterization of new solar cell materials
Ettlinger, R. B., PhD Student, Department of Photonics Engineering
Schou, J., Main Supervisor
Jepsen, P. U., Supervisor
Laurynenka, A., Examiner
Nistor, M. G., Examiner
Eason, R., Examiner
Forskningsrådsfinansiering
01/08/2013 → 08/02/2017
Award relations: Thin-film deposition and characterization of new solar cell materials
Project: PhD

New technology for fast localization and characterization of faults in solar cell systems
The purpose is to develop and demonstrate a new efficient and flexible technology for fault localization/diagnosis in PV systems. The technology is aimed the growing PV service market. Measurements can be carried out at the string level, and O&M costs are minimized. At the same time performance is optimized and the cost of energy is lowered.
Poulsen, P. B., Project Participant, Department of Photonics Engineering, Diode Lasers and LED Systems
Thorsteinsson, S., Project Participant, Department of Photonics Engineering, Diode Lasers and LED Systems
Schou, J., Project Participant, Department of Photonics Engineering, Optical Microsensors and Micromaterials
Hansen, O., Project Participant, Experimental Surface and Nanomaterials Physics, Department of Micro- and Nanotechnology, Silicon Microtechnology
EUDP: DKK8,209,548.00
01/01/2015 → 31/01/2016
Keywords: Solar Cells, Solar Energy, Characterization
Award relations: New technology for fast localization and characterization of faults in solar cell systems
Project: Research

Rheed
Schou, J., Project Manager
03/01/2007 → 27/03/2007
Collaborators: Ministry of Higher Education and Science
Project: Research

Large area pulsed laser deposition (PLD)
Schou, J., Project Manager, Risø National Laboratory for Sustainable Energy
03/01/2007 → 21/05/2007
Collaborators: Danish Agency for Science and Higher Education
Project: Research
Assessment of the photovoltaic properties of CZTS grown on representative Si solar cell structures for monolithic CZTS/Si tandem applications

Period: 29 Nov 2018

Filipe Mesquita Alves Martinho (Speaker)
Alireza Hajijafarassar (Other)
Simón López Mariño (Other)
Moises Espindola Rodriguez (Other)
Mungunshagai Gansukh (Other)
Stela Canulescu (Other)
Eugen Stamate (Other)
Sara Lena Josefin Engberg (Other)
Ole Hansen (Other)
Andrea Crovetto (Other)
Jørgen Schou (Other)

Department of Photonics Engineering
Silicon Microtechnology
Department of Micro- and Nanotechnology
Photovoltaic Materials and Systems
Nanophotonic Devices
Electrochemical Materials
Department of Energy Conversion and Storage
Experimental Surface and Nanomaterials Physics
Department of Physics

Description
The prospect of increasing the efficiency of pure sulfide Cu2ZnSnS4 (CZTS) opens up the possibility of using it as a high bandgap partner in tandem photovoltaics, in particular with a Si-based bottom cell. Although the growth of CZTS on monocrystalline Si has been discussed in recent years, the implications of such growth for real and representative monolithic CZTS/Si tandem structures are hardly ever discussed.

In this work, we grow CZTS by co-sputtering precursors on a representative Tunnel Oxide Passivated Contact (TOPCon) n-Si structure, and investigate how the growth conditions and bottom cell structure affect the photovoltaic properties of CZTS. In particular, CZTS is grown on two different layers: the n-type poly-Si electron selective layer, and a TiN barrier layer. The properties of the resulting CZTS films are compared to those of a baseline single junction CZTS solar cell, and it is shown that the resulting CZTS films can differ considerably. The advantages and limitations of each resulting case are then used to assess the potential of achieving high-quality CZTS absorbers without compromising the performance of the bottom Si cell. Based on this, an elementary monolithic CZTS/Si tandem device is presented, and the aspects behind its low performance are discussed based on the work conducted.

Degree of recognition: International

Related event
9th European Kesterite Workshop
29/11/2018 → 30/11/2018
Ghent, Belgium
Keywords: Solar Energy, Solar cells, Photovoltaics, tandem cells, sputtering, Silicon, Kesterite, CZTS
Activity: Talks and presentations › Conference presentations
Development of CZTS absorbers by sputter deposition for application in CZTS/Si tandem photovoltaics: The Copper problem

Period: 22 Jun 2018
Filipe Mesquita Alves Martinho (Speaker)
Alireza Hajijafarassar (Other)
Stela Canulescu (Other)
Eugen Stamate (Other)
Simón López Mariño (Other)
Moises Espindola Rodriguez (Other)
Mungunshagai Gansukh (Other)
Sara Lena Josefin Engberg (Other)
Ole Hansen (Other)
Andrea Crovetto (Other)
Jørgen Schou (Other)

Department of Photonics Engineering
Silicon Microtechnology
Department of Micro- and Nanotechnology
Nanophotonic Devices
Photovoltaic Materials and Systems
Electrochemical Materials
Department of Energy Conversion and Storage
Experimental Surface and Nanomaterials Physics
Department of Physics

Description
Kesterite solar cells based on pure sulfide CZTS (Cu2ZnSnS4) offer prospects of a cost effective and environmentally benign solution for photovoltaics. While promising on its own, CZTS is now receiving increased interest for applications in monolithic CZTS/Si tandem solar cells due to its high bandgap and low lattice mismatch with Si. However, integrating the Si and CZTS production steps to obtain an efficient monolithic cell is a challenging task.

In this work, CZTS absorbers were produced by co- or sequential sputter deposition of the binary precursors SnS and ZnS and of the metallic precursor Cu. The characterization of a baseline single junction CZTS solar cell is presented, and some of the challenges and early results on the CZTS/Si tandem cell integration are reported. CZTS was grown on a Si substrate with a TiN diffusion barrier, to prevent the diffusion of some CZTS elements into Si during annealing – particularly Cu and S – that can degrade the photovoltaic properties of Si. The effects of annealing on the resulting structure were studied as a function of the initial CZTS precursor configuration and composition. The results of this initial integration and their implications for CZTS/Si tandem devices are discussed. The ideal thickness of the CZTS layer, in order to match the Si thickness for complete light absorption, was studied experimentally, in conjunction with optical simulations on complete CZTS/Si tandem structures.

Degree of recognition: International

Related event

EMRS Spring meeting 2018
18/06/2018 → 22/06/2018
Strasbourg, France
Keywords: Solar Energy, solar cells, Photovoltaics, Kesterite, Silicon, Tandem cells, Sputtering
Activity: Talks and presentations › Conference presentations
Department of Photonics Engineering
Optical Microsensors and Micromaterials
Organic Energy Materials

Description
Top Danish Researchers within photovoltaics was lecturing in this 4 day summer school along with Professor Peter Würfel, who is one of the international leading researchers within photovoltaics and author of the book Physics of Solar Cells: From Basic Principles to Advanced Concepts. The summer school was tailored towards PhD students within photovoltaics, but other interested in the program could join.
Degree of recognition: International

Related event
Advanced Concepts in Photovoltaics: A Summer School in Photovoltaics
10/10/2017 → 13/10/2017
Roskilde, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Pulsed laser deposition (PLD) of the CZTS absorber for thin solar cells with up to 5.2-% -efficiency
Period: 26 Jun 2017 → 30 Jun 2017
Jørgen Schou (Guest lecturer)
Andrea Carlo Cazzaniga (Other)
Stela Canulescu (Other)
Andrea Crovetto (Other)
Rebecca Bolt Ettlinger (Other)
Nini Pryds (Guest lecturer)
Ole Hansen (Other)
Chang Yan (Other)
Kaiwen Sun (Other)
Xiaojing Hao (Other)
Department of Photonics Engineering
Optical Microsensors and Micromaterials
Department of Physics
Experimental Surface and Nanomaterials Physics
Silicon Microtechnology
Department of Energy Conversion and Storage
Electrofunctional materials
Department of Micro- and Nanotechnology

Description
Collaborative Conference on Materials Research (CCMR) 2017
Documents:
Abstract Korea

Related external organisation
Kwangwoon University
Korea, Republic of
Keywords: Solar cells , PLD, CZTS
Activity: Talks and presentations › Conference presentations

EMRS Spring meeting 2017
Period: 23 May 2017
Jørgen Schou (Participant)
Description
Pulsed laser deposition (PLD) of the CZTS absorber for thin solar cells with up to 5.2-% -efficiency

Degree of recognition: International
Documents:
Abstract Earth-abundant CZTS

Related event

EMRS Spring meeting 2017
22/05/2017 → 26/05/2017
Strasbourg, France
Keywords: PLD , CZTS
Activity: Attending an event › Participating in or organising a conference

High-energy deposition methods for CZTS and CTS solar cells
Period: 22 May 2017 → 23 May 2017
Jørgen Schou (Other)
Rebecca Bolt Ettlinger (Guest lecturer)
Andrea Carlo Cazzaniga (Other)
Stela Canulescu (Other)
K. Normann (Other)
F. Pattini (Other)
Stefano Rampino (Other)
Eduardo Gilioli (Other)

Department of Photonics Engineering
Optical Microsensors and Micromaterials
Degree of recognition: National
Documents:
DFS 2017 abstract R Ettlinger (3)

Related event

Dansk Fysisk Selskab annual meeting
22/05/2017 → 23/05/2017
Denmark
Pulsed laser deposition (PLD) of a CZTS-absorber for thin solar cells with up to 5.2% efficiency

Keywords: Thin films, CZTS, PLD
Activity: Talks and presentations › Conference presentations

Materials Research Society Spring Meeting 2017
Period: 17 Apr 2017 → 21 Apr 2017
Jørgen Schou (Organizer)
Andrea Carlo Cazzaniga (Participant)
Andrea Crovetto (Participant)
Rebecca Bolt Ettlinger (Participant)
Sara Lena Josefin Engberg (Participant)
Stela Canulescu (Participant)
Nini Pryds (Participant)
Ole Hansen (Participant)
Chang Yan (Participant)
Kaiwen Sun (Participant)
Xiaojing Hao (Participant)

Department of Photonics Engineering
Photovoltaic Materials and Systems
Department of Physics
Experimental Surface and Nanomaterials Physics
Optical Microsensors and Micromaterials
Technical University of Denmark
Department of Energy Conversion and Storage
Electrofunctional materials
Department of Micro- and Nanotechnology
Silicon Microtechnology

Description
Pulsed laser deposition (PLD) of a CZTS-absorber for thin solar cells with up to 5.2% efficiency

Degree of recognition: International
Documents:
MRS 2017_poster_JS_2

Related event
Materials Research Society Spring Meeting 2017
17/04/2017 → 21/04/2017
Phoenix, United States
Keywords: PLD, CZTS
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Compression of dry lysozyme targets: A new parameter in protein thin film production by PLD
Period: 1 Sep 2016
Jørgen Schou (Speaker)

Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event
10th International Conference on Photoexcited Processes and Applications
29/08/2016 → 02/09/2016
Brasov, Romania
Keywords: PLD, Lysozyme, Preesure
**Annual Meeting of the Danish Physical Society**  
*Period: 6 Jun 2016 → 7 Jun 2016*  
Jørgen Schou (Participant)  
Department of Photonics Engineering  
Optical Microsensors and Micromaterials

**Description**  
Material transfer in Pulsed Laser Deposition of the solar cell materials Cu2SnS3 and Cu2ZnSnS4

**Presentation**  
**Documents:**  
abstract DFS 2016 Andcan

**Related event**

**Annual Meeting of the Danish Physical Society: DFS årsmøde**  
06/06/2016 → 07/06/2016  
Middelfart, Denmark  
Activity: Attending an event › Participating in or organising a conference

**Annual Meeting of the Danish Physical Society**  
*Period: 6 Jun 2016 → 7 Jun 2016*  
Jørgen Schou (Participant)  
Department of Photonics Engineering  
Optical Microsensors and Micromaterials

**Description**  
Pulsed laser deposition of Cu2ZnSnS4 absorber layers assisted by a reactive sulfur beam for solar cells

**Annual Meeting of Danish Physical Society**  
**Documents:**  
Joan-Abtract Danish Physic Society

**Related event**

**Annual Meeting of the Danish Physical Society: DFS årsmøde**  
06/06/2016 → 07/06/2016  
Middelfart, Denmark  
Activity: Attending an event › Participating in or organising a conference

**Annual**  
*Period: 30 Mar 2016*  
Jørgen Schou (Participant)  
Department of Photonics Engineering  
Optical Microsensors and Micromaterials

**Description**  
Pulsed Laser Deposition (PLD) of the Solar Cell Materials CZTS and CTS

**Documents:**  
Abstract MRS 2016

**Related event**

**2016 MRS Spring Meeting & Exhibit**  
28/03/2016 → 01/04/2016  
Phoenix, United States  
Activity: Attending an event › Participating in or organising a conference
Lys revolutionerer fysikken såvel som vores dagligdag
Period: 20 Oct 2015
Jørgen Schou (Lecturer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event

Vin og Videnskab: Lys revolutionerer fysikken såvel som vores dagligdag
20/10/2015 → 20/10/2015
København, Denmark
Activity: Talks and presentations › Conference presentations

Laserens vej fra specialfysik til dagligdag: -
Period: 24 Sep 2015
Jørgen Schou (Lecturer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event

Laserens vej fra specialfysik til dagligdag: -
24/09/2015 → 24/09/2015
Lyngby, Denmark
Activity: Talks and presentations › Conference presentations

Sputtering of solid deuterium below 3 K by keV electrons: An extreme case of electronic sputtering at low temperature...
Period: 22 Sep 2015
Jørgen Schou (Lecturer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event

Eighth international Meeting on recent developments of radiation effects in matter
20/09/2015 → 23/09/2015
Kerteminde, Denmark
Activity: Talks and presentations › Conference presentations

Lys der har ændret vores verdensbillede og vort dagligliv
Period: 17 Sep 2015
Jørgen Schou (Lecturer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event

Lys der har ændret vores verdensbillede og vort dagligliv: -
17/09/2015 → 17/09/2015
Lyngby, Denmark
Activity: Talks and presentations › Conference presentations

Morphology of Copper Tin Sulfide Films Grown by Pulsed Laser Deposition at 248 and 355 nm
Period: 30 Aug 2015 → 4 Sep 2015
Jørgen Schou (Lecturer)
CZTS a new environmentally friendly material for thin film solar cells
Period: 9 Jun 2015 → 12 Jun 2015
Jørgen Schou (Speaker)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
Co-authors: Andrea Cazzaniga, Sara Engberg, Rebecca Ettlinger, Stela Canulescu, Naghmeh Mirbagheri (all from DTU Fotonik), Andrea Crovetto (DTU Nanotech)

Related event
Nordic Physics Days
09/06/2015 → 11/09/2015
Trondheim, Norway
Activity: Talks and presentations › Conference presentations

2014 MRS Spring Meeting
Jørgen Schou (Participant)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
Co-authors: Andrea Cazzaniga*, Rebecca Bolt Ettlinger1, Sara Engberg1, Stela Canulescu1, Andrea Crovetto2, Nini Pryds3, Ole Hansen2

Thin films of CZTS prepared by Pulsed Laser Deposition
Documents:
Andcan_MRS2015_poster_JS_JS2
Andcan_MRS2015_poster_JS_JS2.pdf

Related event
2014 MRS Spring Meeting
21/04/2014 → 25/04/2014
San Francisco, United States
Keywords: thin films, solar cells
Activity: Attending an event › Participating in or organising a conference

Laseren - de første 50 år: -
Period: 12 Mar 2015
Jørgen Schou (Speaker)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description

Related event

Laseren - de første 50 år.
12/03/2015 → 12/03/2015
Odense, Denmark
Keywords: Lasers
Activity: Talks and presentations › Conference presentations

10th International Conference on Cryocrystals and Quantum Crystals (invited) (CC-2014)
Period: 31 Aug 2014
Jørgen Schou (Lecturer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
Enhanced desorption from deuterium films driven by charging with keV electrons
Documents:
CC2014-abstract

Related event

10th International Conference on Cryocrystals and Quantum Crystals
31/08/2014 → 06/09/2014
Almaty, Kazakhstan
Activity: Talks and presentations › Conference presentations

Pulsed laser deposition (PLD) of dielectrics – is femtosecond laser ablation better than nanosecond ablation? (Invited Talk)
Jørgen Schou (Lecturer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
Stela Canulescu was coauthoring
Documents:
Pulsed laser deposition - santa fe 2014

Related event

High Power Laser Ablation 2014
21/04/2014 → 25/04/2014
Santa Fè, NM, United States
Activity: Talks and presentations › Conference presentations

Investigating the fragmentation of C60 by Matrix Assisted Pulsed Laser Evaporation
Jørgen Schou (Speaker)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
We study possible fragmentation effects that can occur during the transfer of C60 molecules in vacuum by matrix assisted pulsed laser evaporation (MAPLE). The MAPLE studies are performed on a frozen homogeneous dilute solution of C60 in anisole (typically 0.67 wt.%), and over a broad range of laser fluences, from 0.3 Jcm⁻² up to 2 Jcm⁻². The processing of
the C60 molecules into thin films of C60, and for other fullerenes can be of large interest not only for fundamental studies, but also for organic solar cells applications. For a given MAPLE matrix, possible fragmentation effects were monitored by measuring the deposition rate/pulse and determining the fragmentation rate with matrix assisted laser desorption ionization (MALDI). Analyses of high-resolution SEM images reveal that the surface of the MAPLE films consists of a high density area of clusters/droplets. These round shaped features are probably caused by ejection of large liquid droplets of C60 suspended in solvent upon laser irradiation, followed by the evaporation of the solvent when reaching the substrate. MALDI analyses of the C60 layers deposited onto Si wafers have shown that a significant fraction of fullerenes remain intact upon MAPLE transfer.

Documents:
bookabstracts_280910_2.pdf
Links:

Related external organisation
Unknown Organization
Keywords: Materials and energy storage, Materials characterisation and modelling
Activity: Talks and presentations › Conference presentations

International High-Power Laser Ablation Conference (HPLA): [invited]
Period: 18 Apr 2010 → 22 Apr 2010
Jørgen Schou (Speaker)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
The expansion of a plume in a background gas of pressure comparable to that used in pulsed laser deposition (PLD) has been analyzed in terms of the model of Predtechensky and Mayorov (PM). This approach gives a relatively clear and simple description of the essential hydrodynamics during the expansion. The model also leads to an insightful treatment of the stopping behavior in dimensionless units for plumes and background gases of different atomic/molecular masses. The energetics of the plume dynamics can also be treated with this model. Experimental time-of-flight data of silver ions in a neon background gas show a fair agreement with predictions from the PM-model. Finally we discuss the validity of the model, if the work done by the pressure of the background gas is neglected.
Place: Santa Fe, USA

Related external organisation
Unknown Organization
Keywords: laser ablation, laser plasma, shock wave, pulsed laser deposition, PLD
Activity: Talks and presentations › Conference presentations

NanoDay at DTU: nm-thin films produced by pulsed laser deposition - a direction for new materials
Period: 7 Dec 2009
Jørgen Schou (Speaker)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
Place: Kgs. Lyngby, Denmark
Documents:
programnanodaydec2009.pdf

Related event
NanoDay 2009
07/12/2009 → …
Kgs. Lyngby, Denmark
Activity: Talks and presentations › Conference presentations
10th International Conference on Laser Ablation
Period: 24 Nov 2009
Jørgen Schou (Chairman)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event
10th International Conference on Laser Ablation
Singapore, Singapore
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

International Conference on Laser Ablation (COLA); 10: energetics of laser ablation plume expanding in a background gas
Period: 23 Nov 2009
Jørgen Schou (Speaker)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Description
Place: Singapore

Related external organisation
Unknown Organization
Activity: Talks and presentations › Conference presentations

2010 FONDECYT - National Research Funding Competition (FONDECYT) (Journal)
Period: 12 Oct 2009
Jørgen Schou (Reviewer)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related journal
2010 FONDECYT - National Research Funding Competition (FONDECYT)
Local database
Activity: Editorial work and peer review › Peer review of manuscripts › Research

Den Nordiske Konference for de fysiske selskaber
Jørgen Schou (Chairman)
Department of Photonics Engineering
Optical Microsensors and Micromaterials

Related event
Den Nordiske Konference for de fysiske selskaber
16/06/2009 → 18/06/2009
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

The Twelfth International Workshop on Desorption Induced by Electronic Transitions (DIETXII); 12
Period: 21 Apr 2009
Jørgen Schou (Speaker)
Description
Films of solid deuterium at a temperature around 3 K have been irradiated by 1.5 or 2 keV electrons. The films were deposited on the silver electrode of a quartz crystal microbalance (QCM) suspended below a pumped liquid helium cryostat [1,2]. The thickness of the films ranged from 10 nm to up to 5 m. The initial film thickness and the mass loss as result of desorption were monitored by the QCM. The electron beam current was kept at about or below 100 nA to avoid beam-induced evaporation. Secondary electron emission was suppressed to a value below 0.01-0.03 electrons/electron by a repeller ring at a bias of –90 V. However, for films thicker than 3-4 times the range of the bombarding electrons, the electron yield suddenly rose to a value close to 0.40. From this secondary electron yield the voltage potential could be determined unambiguously from secondary electron emission curves obtained by short pulse measurements on fresh films. For the thickest films the charging induced a surface potential of more than 1.0 kV, i.e. one-half of the energy of the bombarding electron. For these thick films the desorption yield increased from the minimum value of 6-10 D2/electron up to 380 D2/electron at 1.5 keV and 960 D2/electron at 2 keV. The surface potential is induced by electron charge accumulation in the film at large thicknesses from where the electrons no longer are able to migrate to the conductive substrate with a sufficiently high rate.

Place: Callaway Gardens, Pine Mountain, GA, USA

Related external organisation

Unknown Organization

Activity: Talks and presentations › Conference presentations