Analysing impact of oxygen and water exposure on roll-coated organic solar cell performance using impedance spectroscopy

In this work we study the degradation of roll-coated flexible inverted organic solar cells in different atmospheres. We demonstrate that impedance spectroscopy is a powerful tool for elucidating degradation mechanisms; it is used here to distinguish the different degradation mechanisms due to water and oxygen. Identical cells were exposed to different accelerated degradation environments using water only, oxygen only, and both water and oxygen simultaneously, all of them enhanced with UV light. The photocurrent is dramatically reduced in the oxygen-degraded samples. Impedance measurements indicate that this phenomenon is attributed to defects introduced by absorption of oxygen, which results in an increase of the acceptor impurity (NA) at the cathode interface obtained from a Mott-Schottky analysis. Simultaneously, at the anode interface where PEDOT:PSS is not shielded by the substrate, the nature of degradation differs for the water and oxygen degraded samples. While oxygen + UV light decreases the conductivity of the PEDOT:PSS layer, water + UV light changes the PEDOT:PSS work function inducing a depletion region at the anode.
High stability of benzotriazole and benzodithiophene containing medium band-gap polymer solar cell

The improvement of polymer solar cell stability is a challenge for the scientists and has significant implications commercially. In this study, we investigated the stability of a novel P-SBTBDT active material applied in an inverted type solar cell. Detailed stability experiments comprising shelf life, laboratory weathering and outdoor testing were carried out according to ISOS testing guidelines. Shelf life showed that P-SBTBDT solar cells were very stable after 840 h with encapsulation. Although accelerated weathering aging tests are a very harsh, the devices remained stable after the burn-in phase with T50 from 700 to 840 h, with some P-SBTBDT solar cells did not reach T50 in the time span of the test. Degradation tests on the P-SBTBDT solar cells which were carried out under natural solar light indicated that T40 was reached after 840 h. The results of dark, light, damp and dry stability tests showed that most of the degradation was provoked by failure of the encapsulation. The experiments indicated that P-SBTBDT solar cells are sensitive to light and oxygen but are strikingly stable under humid conditions. Further developments for minimizing the degradation effects using UV-filters and better encapsulation are some of the necessary improvements in further research.

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Mechanical stability of roll-to-roll printed solar cells under cyclic bending and torsion

The ability of printed organic solar cells (OSCs) to survive repeated mechanical deformation is critical to large-scale implementation. This paper reports an investigation into the mechanical stability of OSCs through bending and torsion testing of whole printed modules. Two types of modules are used that differ slightly in thickness as well as on the basis of the electrode materials: silver nanowires or carbon-based inks. Each type of module is subjected to two different mechanical modes of deformation, bending and torsion, of several thousand cycles per module using a purpose-built robotic device. Analysis of the distribution of stress in the devices performed by finite-element modeling predicts the locations of failure. Failure upon bending originates at the laser-cut edges of the modules from shear at the clamp/module interface leading to crazing of the plastic barrier encapsulant foils. This crazing leads to eventual delamination due first to decohesion of the active layer at the edge of the modules and later to deadhesion between the PEDOT:PSS (electrode) and P3HT:PCBM (semiconductor) layers. The torsion mode imposes greater stresses than the bending mode and thus leads to failure at fewer strain cycles. Failure during torsion occurs through crack propagation initiated at stress concentrations on the edges of the module that were imposed by their rectangular geometry and ultimately leads to bifurcation of the entire module. Rather than the differences in electrode materials, the differences in survivability between the two types of modules are attributed mostly to the thickness of the substrate materials used, with the thinner substrate used in the carbon-based modules (~160 µm) failing at fewer strain cycles than the substrate used in the silver-nanowire-based modules (~190 µm). Taken together, the results suggest ways in which the lifetimes of devices can be extended by the layouts of modules and choices of materials.

General information
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Authors: Finn, M. (Ekstern), Martens, C. J. (Ekstern), Zaretski, A. V. (Ekstern), Roth, B. (Intern), Søndergaard, R. R. (Intern), Krebs, F. C. (Intern), Lipomi, D. J. (Ekstern)
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Web of Science (2008): Indexed yes
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METHOD AND APPARATUS FOR CHARACTERIZATION OF A SOLAR CELL

The present disclosure relates to a method for characterization of a solar cell, comprising the steps of: providing an optical probe light; modulating the optical probe light with a modulation frequency of between 100 kHz and 50 MHz, thereby obtaining a modulated probe light; scanning the modulated probe light such that said modulated probe light is incident on at least a part of the surface of the solar cell, and such that the part of the solar cell exposed to the modulated probe light converts the modulated probe light to an electrical signal; detecting and analyzing said electrical signal; and estimating variations in the solar cell, thereby electrically characterizing the solar cell.

The disclosure further relates to a solar cell characterization apparatus for characterization of a solar cell, comprising: a light source for generating an optical probe light; a modulation unit, configured to produce modulated probe light by modulating the optical probe light with a modulation frequency of between 100 kHz and 0 MHz; a light scanning unit for scanning the modulated probe light such that said modulated probe light is incident on at least a part of the surface of the solar cell; and a signal analyzer, configured to detect and analyze electrical signals produced by the solar cell as a response to exposure of the modulated probe light.
A Novel Algorithm for Lifetime Extrapolation, Prediction, and Estimation of Emerging PV Technologies

Accurate determination of the lifetime of novel hybrid and organic solar cells is often rather challenging due to the very dynamic behavior of such cells over time and ageing curves with shapes of varying nature. Therefore, in order to accurately and reproducibly determine the lifetime of photovoltaic devices with such a behavior, a novel elaboration algorithm is developed, which enables automatic smoothing, filtering, and extrapolation of the real lifetime data and reproducible determination of the lifetime parameters defined in the International Summit on OPV Stability guiding standards. The algorithm is also capable of predicting the lifetime of devices, not tested until the end of sample life, given that there is sufficient number of measured data points to perform reliable extrapolation of ageing curves (to a limited time frame). The algorithm is discussed in detail and a range of examples for different lifetime data are presented.

Application of Photocurrent Model on Polymer Solar Cells Under Forward Bias Stress

We performed a constant current stress at forward bias on organic heterojunction solar cells. We measured current voltage curves in both dark and light at each stress step to calculate the photocurrent. An existing model applied to photocurrent experimental data allows the estimation of several parameters such as generation, recombination, dissociation rate, and nearly zero field voltage within the active layer as a function of the stress time. The analysis of extrapolated parameters shows that the stress mainly affects the recombination rate of the polaron charge transfer states.
Carbazole-based copolymers via direct arylation polymerization (DArP) for Suzuki-convergent polymer solar cell performance

Although direct arylation polymerization (DArP) has recently emerged as an alternative to traditional cross-coupling methods like Suzuki polymerization, the evaluation of DArP polymers in practical applications like polymer solar cells (PSCs) is limited. Because even the presence of minute quantities of defects can dramatically influence the solar cell performance, DArP polymers offers critical insight alongside other structural and optoelectronic comparisons. Even via traditional methods, carbazole-based donors are frequently prone to homocoupling defects, which has been shown to - along with β-defects - compromise performance. Through defect minimization with the bulky and affordable neo-decanoic acid (NDA) mixture, we report the synthesis of DArP poly[(9-(heptadecan-9-yl)-9H-carbazole)-alt-(4,7-di(thiophen-2-yl)benzo[c][1,2,5]thiadiazole)] (PCDTBT) that outperforms Suzuki PCDTBT with similar molecular weights. Expanding beyond this model system, carbazole-based polymers featuring 2,5-diethylhexyl-3,6-di(thiophen-2-yl)-2,5-dihydropyrrolo[3,4-c]pyrrole-1,4-dione (DPP), 4,10-bis(diethylhexyl)-thieno[2′,3′:5,6]pyrido[3,4-g]thieno[3,2-c]isoquinoline-5,11-dione (TPTI), 5-octyl-1,3-di(thiophen-2-yl)-4H-thieno[3,4-c]pyrrole-4,6(5H)-dione (DT-TPD), and 2,5-bis(2,3-dihydrothieno[3,4-b][1,4]dioxin-5-yl)pyridine (EDOT-Pyr) are generated. Polymers are characterized by 1H NMR, cyclic voltammetry, UV-Vis, GIXRD, SCLC hole mobilities, and are implemented into polymer solar cells fabricated in air under ambient humidity. We demonstrate that DArP polymers perform comparably to Suzuki in practical applications.

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Authors: Gobalasingham, N. S. (Ekstern), Ekiz, S. (Ekstern), Pankow, R. M. (Ekstern), Livi, F. (Intern), Bundgaard, E. (Intern), Thompson, B. C. (Ekstern)
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Conjugated Polymers Via Direct Arylation Polymerization in Continuous Flow: Minimizing the Cost and Batch-to-Batch Variations for High-Throughput Energy Conversion

Continuous flow methods are utilized in conjunction with direct arylation polymerization (DArP) for the scaled synthesis of the roll-to-roll compatible polymer, poly[(2,5-bis(2-hexyldecyloxy)phenylene)-alt-(4,7-di(thiophen-2-yl)-benzo[c][1,2,5]thiadiazole)] (PPDTBT). PPDTBT is based on simple, inexpensive, and scalable monomers using thienyl-flanked benzothiadiazole as the acceptor, which is the first β-unprotected substrate to be used in continuous flow via DArP, enabling critical evaluation of the suitability of this emerging synthetic method for minimizing defects and for the scaled synthesis of high-performance materials. To demonstrate the usefulness of the method, DArP-prepared PPDTBT via continuous flow synthesis is employed for the preparation of indium tin oxide (ITO)-free and flexible roll-coated solar cells to achieve a power conversion efficiency of 3.5% for 1 cm² devices, which is comparable to the performance of PPDTBT polymerized through Stille cross coupling. These efforts demonstrate the distinct advantages of the continuous flow protocol with DArP avoiding use of toxic tin chemicals, reducing the associated costs of polymer upscaling, and minimizing batch-to-batch variations for high-quality material.

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Authors: Gobalasingham, N. S. (Ekstern), Carlé, J. E. (Intern), Krebs, F. C. (Intern), Thompson, B. C. (Ekstern), Bundgaard, E. (Intern), Helgesen, M. (Intern)
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Cost-competitiveness of organic photovoltaics for electricity self-consumption at residential buildings: A comparative study of Denmark and Greece under real market conditions

To address sustainability challenges, photovoltaics (PV) are regarded as a promising renewable energy technology. Decreasing PV module costs and increasing residential electricity prices have made self-consumption of PV-generated electricity financially more attractive than exporting to the grid. Organic photovoltaics (OPV) are an emerging thin-film PV technology that shows promise of greatly improving the environmental and economic performances of PV technologies. Previous studies have estimated the current and future costs of OPV technologies, but the attractiveness of investing in OPV systems has not been evaluated under real market conditions, especially under PV self-consumption schemes. In this study, we investigate the self-consumption of electricity generation from conventional and organic PV systems installed at residential houses in two different countries, Denmark and Greece, under current PV regulatory frameworks. We then focus on modelling and assessing the cost-competitiveness of organic PV technologies based on cost estimations for existing pilot-scale (kW-range), and projected scale-up (100MW) and industrial-scale (100GW) manufacturing capacity levels. Our generic results applying to all PV technologies show that PV systems installed at residential houses in Greece perform economically better than those in Denmark do in terms of self-sufficiency and gross electricity bill savings (i.e. excluding PV costs). Using the two country cases, which present very different settings, we characterise and discuss the influence of three key parameters of the economic performance of PV systems, namely the PV regulatory scheme, the solar irradiation level and the temporal match between the electricity consumption and solar irradiation profiles. Focusing on organic PV systems developed in an industrial-scale cost setting (1.53€/Wp), we find that they deliver significant electricity bill savings for residential houses in Greece (38%) under current conditions, while they may not be sufficiently attractive for residential houses in Denmark (6.5%) due to mainly the different PV regulatory schemes. Based on these findings, we therefore recommend investors interested in renewable energy technologies to pursue scaling up the manufacturing capacity of OPV technologies, as well as assess a large number of countries to identify and prioritise financially attractive settings for PV self-consumption.
Development of outdoor luminescence imaging for drone-based PV array inspection

This work has the goal to perform outdoor defect detection imaging that will be used in a fast, accurate and automatic drone-based survey system for PV power plants. The imaging development focuses on techniques that do not require electrical contact, permitting automatic drone inspections to be perform quicker and with less manpower. The final inspection method will combine several techniques such as, infrared (IR), electroluminescence (EL), photoluminescence (PL), and visual imaging. Solar plant inspection in the future can be restricted only by imaging speed requirements, allowing an entire new perspective in large-scale PV inspection.

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Development of outdoor luminescence imaging for drone-based PV array inspection

This work has the goal to examine experimentally PV module imaging methods under natural light conditions, that will be used in a fast, accurate and automatic drone-based inspection system for PV power plants.

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Number of pages: 1
Embedded plasmonic nanoparticles in high refractive index TiOx matrix for photovoltaics applications
Resume: More frequently high refractive index dielectric matrix are used in thin film photovoltaics as transporting layers with good optical proprieties. Doping such matrix with plasmonic resonant scatterers is a promising way to further increase energy conversion efficiencies by trapping incoming light in ultrathin solar cells. Colloidal plasmonic oligomers are obtained following a cost-effective selfassembly strategy and incorporated in organic based cells produced using spincoating techniques in ambient air conditions. An interesting increase is observed of both external quantum efficiency (EQE) and short-circuit current for solar cells loaded with plasmonic oligomers compared with reference organic cells. Theoretical calculations demonstrate that the wavelength dependent EQE enhancement is a resonant process due to the increased scattering efficiency in plasmonic antennas allowed by a chemically controlled 1 nm nanogap. The nanogap antennas are linked at a controlled distance of a few nanometers by Dithiothreitol molecules. The spacing molecules ensure a minimum distance that plays a fundamental role in the formation of intensity hot spots in the nanogap as well as large and redshifted scattering peaks. This OPV device, realized in ambient air condition, exhibited an efficiency 14% higher than the reference one showing a relevant enhancement in the red part of the EQE measurements.

Environmental impacts of electricity self-consumption from organic photovoltaic battery systems at industrial facilities in Denmark
Organic photovoltaics (OPV) show promise of greatly improving the environmental and economic performance of PV compared to conventional silicon. Life cycle assessment studies have assessed the environmental impacts of OPV, but not under a self-consumption scheme for industrial facilities. We investigate the life cycle environmental impacts of electricity self-consumption from an OPV system coupled with a sodium/nickel chloride battery at an iron/metal industry in Denmark. Results show that an OPV system without storage could decrease the carbon footprint of the industry; installation of the battery increases climate change and human toxicity impacts. We discuss sensitive modelling parameters and provide recommendations.
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<td>SJR 1.145, SNIP 1.482</td>
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<td>2003</td>
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DOIs:
High definition in-situ electro-optical characterization for Roll to Roll printed electronics
Resume: Printed electronics is emerging as a new, large scale and cost effective technology that will be disruptive in fields such as energy harvesting, consumer electronics and medical sensors. The performance of printed organic electronic devices relies principally on the carrier mobility and molecular packing of the polymer semiconductor material. Unfortunately, the analysis of such materials is generally performed with destructive techniques, which are hard to make compatible with in situ measurements, and pose a great obstacle for the mass production of printed electronics devices. A rapid, in situ, non-destructive and low-cost testing method is needed. In this study, we demonstrate that nonlinear optical microscopy is a promising technique to achieve this goal. Using ultrashort laser pulses we stimulate two-photon absorption in a roll coated polymer semiconductor and map the resulting two-photon induced photoluminescence (TPPL) and second harmonic response. We anticipate that this non-linear optical method will substantially contribute to the understanding of printed electronic devices and demonstrate it as a promising novel tool for non-destructive and facile testing of materials during printing of the device and at any moment during its lifespan. This will help the production and development of high quality printed technologies where the semiconductor material can be accessed by infrared light, such as solar cells, displays and sensors.

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Highly Conformal Ni Micromesh as a Current Collecting Front Electrode for Reduced Cost Si Solar Cell
Despite relatively high manufacturing cost, crystalline-Si solar cell continues to hold promising future due to its high energy conversion efficiency and long life. As regards cost, one pertinent issue is the top electrode metallization of textured cell surface, which typically involves screen printing of silver paste. The associated disadvantages call for alternative methods that can lower the cost without compromising the solar cell efficiency. In the present work, a highly interconnected one-dimensional (1D) metal wire network has been employed as front electrode on conventional Si wafers. Here, for the first time, we report an innovative solution based crackle templating method for conformal metal wire network patterning over large textured surfaces. Laser beam induced current mapping showed uniform photocurrent collection by the electrodes without any shadow losses. With electroless deposition of Ni wire network on corrugated solar cell, a short circuit current of 33.28 mA/cm² was obtained in comparison to 20.53 mA/cm² without the network electrode. On comparing the efficiency with the conventional cells with screen printed electrodes, a 20% increment in efficiency has been observed. Importantly, the estimated manufacturing cost is at least two orders lower.

General information
State: Published
Authors: Gupta, N. (Ekstern), Rao, K. D. M. (Ekstern), Gupta, R. (Intern), Krebs, F. C. (Intern), Kulkarni, G. U. (Ekstern)
Pages: 8634-8640
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Main Research Area: Technical/natural sciences

Publication information
Journal: A C S Applied Materials and Interfaces
Volume: 9
In situ electrical and thermal monitoring of printed electronics by two-photon mapping

Printed electronics is emerging as a new, large scale and cost effective technology that will be disruptive in fields such as energy harvesting, consumer electronics and medical sensors. The performance of printed electronic devices relies principally on the carrier mobility and molecular packing of the polymer semiconductor material. Unfortunately, the analysis of such materials is generally performed with destructive techniques, which are hard to make compatible with in situ measurements, and pose a great obstacle for the mass production of printed electronics devices. A rapid, in situ, non-destructive and low-cost testing method is needed. In this study, we demonstrate that nonlinear optical microscopy is a promising technique to achieve this goal. Using ultrashort laser pulses we stimulate two-photon absorption in a roll coated polymer semiconductor and map the resulting two-photon induced photoluminescence and second harmonic response. We show that, in our experimental conditions, it is possible to relate the total amount of photoluminescence detected to important material properties such as the charge carrier density and the molecular packing of the printed polymer material, all with a spatial resolution of 400 nm. Importantly, this technique can be extended to the real time mapping of the polymer semiconductor film, even during the printing process, in which the high printing speed poses the need for equally high acquisition rates.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials, ICFO - Institute of Photonic Sciences
Improving, characterizing and predicting the lifetime of organic photovoltaics: Topical Review

This review summarizes the recent progress in the stability and lifetime of organic photovoltaics (OPVs). In particular, recently proposed solutions to failure mechanisms in different layers of the device stack are discussed comprising both structural and chemical modifications. Upscaling is additionally discussed from the perspective of stability presenting the challenges associated with device packaging and edge protection. An important part of device stability studies is the characterization, and this review provides a short overview of the most advanced techniques for stability characterization reported recently. Lifetime testing and determination is another challenge in the field of organic solar cells and the final sections of this review discuss the testing protocols as well as the generic marker for device lifetime and the methodology for comparing all the lifetime landmarks in one common diagram. These tools were used to determine the baselines for OPV lifetime tested under different ageing conditions. Finally, the current status of lifetime for organic solar cells is presented and predictions are made for progress in the near future.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Indoor measurement of angle resolved light absorption by antireflective glass in solar panels

In this work, we present measurements of angle resolved light absorption of antireflective (AR) glass of PV samples, performed indoors using a collimated high radiance broadband light source. This indoor method proved to be viable and offered a significant simplification compared to outdoor measurements with trackers. The experimental results showed optical responses that are stable and suitable for indoor characterization of solar cells. We find the characteristic optical response of six different antireflective glasses, and based on such measurements, we perform PVsyst simulations and present the monthly DC energy production estimates across four distinct latitudinal locations with six different glass types. The results indicated that the AR glasses present different optical effects at the angles intervals between 0 – 45° and 60 – 90° and that the Diffuse AR glass can improve monthly yields by as much as 2% relatively to a bare cell.

General information
State: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Photovoltaic Materials and Systems, Organic Energy Materials, Department of Micro- and Nanotechnology, Silicon Microtechnology, Experimental Surface and Nanomaterials Physics
Number of pages: 4
Publication date: 2017

Indoor Measurement of Angle Resolved Light Absorption by Black Silicon
Angle resolved optical spectroscopy of photovoltaic (PV) samples gives crucial information on PV panels under realistic working conditions. Here, we introduce measurements of angle resolved light absorption by PV cells, performed indoors using a collimated high radiance broadband light source. Our indoor method offers a significant simplification as compared to measurements by solar trackers. As a proof-of-concept demonstration, we show characterization of black silicon solar cells. The experimental results showed stable and reliable optical responses that makes our setup suitable for indoor, angle resolved characterization of solar cells.

General information
State: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Department of Micro- and Nanotechnology, Silicon Microtechnology, Experimental Surface and Nanomaterials Physics, Photovoltaic Materials and
We present the first comparative in situ small and wide angle X-ray scattering study of two polymers that are relevant for organic photovoltaics, during coating on a flexible substrate. From the obtained measurements we identified several differences between the drying of the two polymers. The polymer optimized for roll-to-roll coating attained its final morphological packing nearly instantly after deposition, and had the shortest drying profile. We therefore conclude that fast-drying polymers which are influenced less by drying temperature or substrate inhomogeneities are better suited for roll-to-roll coating, and that fundamentally, the kinetics of drying dominate the process in the case of roll-to-roll slot-die coating.
Inside or Outside? Linking Outdoor and Indoor Lifetime Tests of ITO-Free Organic Photovoltaic Devices for Greenhouse Applications

We present results from an installation of fully roll-to-roll printed and coated polymer solar cell modules in a greenhouse environment over the course of roughly 2 years (650 days). We explored two different device architectures based on either fully carbon-based electrodes or silver nanowire (AgNW)-based electrodes and two different barrier materials. We followed the ISOS protocols while studying the devices in three different greenhouse conditions in the Netherlands and compared to reference devices mounted outdoors in Denmark tested according to ISOS-O-1 and ISOS-O-2. We studied each condition and type in multiples to obtain acceptable statistics and found that the AgNW-based devices performed best in terms of stability.

General information
State: Published
Authors: Benatto, G. A. D. R. (Intern), Corazza, M. (Intern), Roth, B. (Intern), Schütte, F. (Ekstern), Rengenstein, M. (Ekstern), Gevorgyan, S. (Intern), Krebs, F. C. (Intern)
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Life-Cycle Assessment of Solar Charger with Integrated Organic Photovoltaics

Organic photovoltaics (OPV) applied in a commercial product comprising a solar charged power bank is subjected to a life cycle assessment (LCA) study. Regular power banks harvest electricity from the grid only. The solar power bank (called HeLi-on) is however, a power bank that includes a portable OPV panel, enabling the possibility to be charged from the
sun, and not only from the grid. In this paper, two well-established power bank products using amorphous silicon solar panels (a-Si PV) and a regular power bank without any portable solar panel is compared to HeLi-on. The environmental impact of the products is quantified with the aim of indicate where eco-design improvements would make a difference and to point out performance of a portable solar panel depending on the context of use (Denmark and China), realistic disposal scenarios and the recycling relevance particularly concerning metals content.

**General information**

**State:** Published  
**Organisations:** Department of Energy Conversion and Storage, Organic Energy Materials  
**Authors:** Benatto, G. A. D. R. (Intern), Espinosa Martinez, N. (Intern), Krebs, F. C. (Intern)  
**Number of pages:** 7  
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**Publication information**

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Scopus rating (2016): CiteScore 2.07 SJR 0.826 SNIP 1.083  
Web of Science (2016): Indexed yes  
BFI (2015): BFI-level 1  
Scopus rating (2015): SJR 0.807 SNIP 1.045 CiteScore 1.82  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 1  
Scopus rating (2014): SJR 0.805 SNIP 1.089 CiteScore 1.66  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 1  
Scopus rating (2013): SJR 0.733 SNIP 0.843 CiteScore 1.59  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
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Scopus rating (2012): SJR 0.779 SNIP 0.959 CiteScore 1.46  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 1  
Scopus rating (2011): SJR 0.828 SNIP 1.035 CiteScore 1.58  
ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): SJR 1.097 SNIP 1.14  
BFI (2009): BFI-level 1  
Scopus rating (2009): SJR 1.283 SNIP 1.106  
BFI (2008): BFI-level 1  
Scopus rating (2008): SJR 1.267 SNIP 1.153  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 1.014 SNIP 1.157  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 1.051 SNIP 1.386  
Scopus rating (2005): SJR 0.875 SNIP 1.131  
Web of Science (2005): Indexed yes
The goal of this work is to develop outdoor defect detection imaging and understand fully its challenges and limitations. The imaging is based on luminescence strategies that will be used for fast and accurate UAV-based inspection system for PV power plants. We studied electroluminescence (EL) acquisition under natural light conditions during several times of the day, under high sun irradiation, to unveil the sunlight noise characteristics towards an InGaAs detector. In order to bring more freedom to a drone-based inspection, we also show the preliminary results of a laser-line based photoluminescence (PL) strategy as a viable method for an outdoor module PL imaging system.

Luminescence Imaging Strategies for Drone-Based PV Array Inspection

The imaging is based on luminescence strategies that will be used for fast and accurate UAV-based inspection system for PV power plants. We studied electroluminescence (EL) acquisition under natural light conditions during several times of the day, under high sun irradiation, to unveil the sunlight noise characteristics towards an InGaAs detector. In order to bring more freedom to a drone-based inspection, we also show the preliminary results of a laser-line based photoluminescence (PL) strategy as a viable method for an outdoor module PL imaging system.

Model of Organic Solar Cell Photocurrent Including the Effect of Charge Accumulation at Interfaces and Non-Uniform Carrier Generation

We developed an improved model to fit the photocurrent density versus voltage in organic solar cells. The model has been validated by fitting data from P3HT:PCBM solar cells. Our model quantitatively accounts for the band bending near the electrodes caused by charge accumulation in the active layer. The model explains the position of the built-in and the zero-field voltage, the value of the internal electric field, the impact of electrode materials, and the appearance of multiple inflections. In addition, the model can be used to monitor the cell condition during accelerated lifetests.
New Light Source Setup for Angle Resolved Light Absorption measurement of PV sample

Here, we introduce measurements of angle resolved light absorption by PV cells, using broadband laser driven white light source with a bright, stable, broad spectral range and well collimated light.

General information

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Publication date: 2017
Main Research Area: Technical/natural sciences
Absorption, Collimated, Reproducibility, Laser
Electronic versions:
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Relations
Projects:
New Light Source Setup for Angle Resolved Light Absorption measurement of PV sample

Overcoming the Scaling Lag for Polymer Solar Cells

There is a long stretch between a laboratory discovery and a practical demonstration. For a potentially useful energy technology, many further strides must be taken before a societally meaningful scale is reached. In this work we have, based on many past experiences, brought the fully roll-to-roll printed polymer solar cell to a realistic scale across the entire value chain. The materials synthesis, the manufacture, the installation, the failure modes, and the operation have all been covered and addressed. We demonstrate outdoor operation for 2 years through a large-scale, grid-tied, high-voltage system and show that thin plastic foil can be operated as an energy-producing technology. Critical to the demonstration was the identification of the drying method during printing, and we show how this development relates to the scaling lag (the period between the point in time for a laboratory demonstration and the point in time for scaled manufacture) and allows for closure of the scaling gap.

General information

State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials, Technical University of Cartagena
Pages: 274-289
Printed organic smart devices characterized by nonlinear optical

In this study, we demonstrate that nonlinear optical microscopy is a promising technique to characterize organic printed electronics. Using ultrashort laser pulses we stimulate two-photon absorption in a roll coated polymer semiconductor and map the resulting two-photon induced photoluminescence (TPPL) and second harmonic response. First, we show that the different nonlinear optical signals can be used to discriminate between the polymer semiconductor material and embedded metal nanoparticles which constitute the electrode in a real device. Next we demonstrate that the TPPL quenches when applying a current between source and drain; this decrease can be used to determine the electrical characteristic of the device [1]. Finally, we show that the TPPL increases with higher temperature in the 20 - 120 °C range, closely following the supported current characteristics of the semiconductor. With this technique, we can recognize different nanomaterials and we propose that the TPPL is a good indicator to map and monitor the charge carrier density and the molecular packing of the printed polymer material. Importantly, simple calculations based on the signal levels, suggest that this technique can be extended to the real time mapping of the polymer semiconductor film, even during the printing process, in which the high printing speed poses the need for equally high acquisition rates.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials, Institut de Ciències Fotòniques , Catalán Institution for Research and Advanced Studies
Authors: Pastorelli, F. (Intern), Accanto, N. (Ekstern), Jørgensen, M. (Intern), van Hulst, N. F. (Ekstern)
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Source: PublicationPreSubmission
Source-ID: 134441400
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2017

Printed organic smart devices characterized by ultra-short laser pulses

Resume: In this study, we demonstrate that nonlinear optical microscopy is a promising technique to characterize organic printed electronics. Using ultrashort laser pulses we stimulate two-photon absorption in a roll coated polymer semiconductor and map the resulting two-photon induced photoluminescence (TPPL) and second harmonic response. First, we show that the different nonlinear optical signals can be used to discriminate between the polymer semiconductor material and embedded nanoparticles which constitute the electrode in a real device. Next we demonstrate that the TPPL quenches when applying a current between source and drain; this decrease can be used to determine the electrical characteristic of the device. Finally, we show that the TPPL increases with higher temperature in the 20 - 120 °C range, closely following the supported current characteristics of the semiconductor. We propose that the TPPL is a good indicator to map and monitor the charge carrier density and the molecular packing of the printed polymer material. Importantly, simple calculations based on the signal levels, suggest that this technique can be extended to the real time mapping of the polymer semiconductor film, even during the printing process, in which the high printing speed poses the need for equally high acquisition rates.
Quantification of solar cell failure signatures based on statistical analysis of electroluminescence images

We propose a method to identify and quantify the extent of solar cell cracks, shunting, or damaged cell interconnects, present in crystalline silicon photovoltaic (PV) modules by statistical analysis of the electroluminescence (EL) intensity distributions of individual cells within the module. From the EL intensity distributions (ELID) of each cell, we calculated summary statistics such as standard deviation, median, skewness and kurtosis, and analyzed how they correlate with the type of the solar cell degradation.

We found that the dispersion of the ELID increases with the size and severity of the solar cell cracks, correlating with an increase in standard deviation and decrease in kurtosis. For shunted cells, we found that the ELID median is strongly correlated with the extent of cell shunting. Last, cells with damaged interconnect ribbons show current crowding and increased series resistance regions, characterized by increased dispersion and skewness of the ELID. These cell-level diagnostic parameters can be used to quantify the level of mismatch between the solar cells in the module, which can represent the extent of the module degradation, due to transportation, installation, or field operation. The method can be easily automated for quality control by module manufacturers or installers, or can be used as a diagnostic tool by plant operators and diagnostic service providers.

SUN HUB – ENERGY HUB FOR OUTDOOR TABLES

Solar cells integrated into products are attracting more and more attention especially due to the dramatically declining cost of solar cells. Furthermore, we are getting more dependent on portable units like mobile phones, tablets and PCs which has to be charged to be of any use. Especially on festivals where people camps for several days it can be hard to have your portable units charged. In this this work we report a solar powered hub, as an add-on to a table in the urban environment for charging mobile phones and tablets and other handheld devices through USBs, charging laptops through AC connections, providing opportunity to stream music via Bluetooth and play it from a handheld device to the table and lastly to provide LED lighting on the table during the dark hours. 3 prototypes of the system was built and tested at the Roskilde Festival 2017. Electrical logger units were built into the 3 Sun Hubs to monitor the overall energy system and the consumption of each functionality in the table.
Synthesis of conjugated polymers with complex architecture for photovoltaic applications

A common approach to bulk heterojunction solar cells involves a “trial and error” approach in finding optimal kinetically unstable morphologies. An alternative approach assumes the utilization of complex polymer architectures, such as donor–acceptor block copolymers. Because of a covalent preorganization of the donor and acceptor components, these materials may form desirable morphologies at thermodynamic equilibrium. This chapter reviews synthetic approaches to such architectures and shows the first photovoltaic results.

Toward a drone-based EL and PL inspection tool for PV power plants

On-site inspection of PV systems has been historically performed through visual inspection, infrared (IR) thermography, and electrical measurements. Recent advances and cost reductions in unmanned aerial vehicle (UAV) technology has led to adoption of UAVs equipped with thermal cameras for inspection of PV plants, which survey power plants in a fraction of the time and cost than walk through IR imaging. IR imaging, however, is limited only to detection of certain fault types that result in elevated temperatures. Techniques such as electro-(EL) and photo-(PL) luminescence imaging offer a higher level of image detail and qualitative insight compared to IR thermography. Furthermore, detection and identification of incipient or severe faults in PV panels is more straightforward. This project proposes for the first time a fast and accurate automatic drone-based inspection method for large PV plants that combines IR, EL, PL imaging, and visual images (VI), called DronEL. The overarching goal is to correlate these images with known PV failures such as hotspots, cell cracks, and potential induced degradation. The DronEL project is carried out by a number of academic and commercial partners including Denmark’s Technical University (DTU), Aalborg University (AAU), Sky-watch, SiCon and Kenergy.
Using ISOS consensus test protocols for development of quantitative life test models in ageing of organic solar cells

As Organic Photovoltaic (OPV) development matures, the demand grows for rapid characterisation of degradation and application of Quantitative Accelerated Life Tests (QALT) models to predict and improve reliability. To date, most accelerated testing on OPVs has been conducted using ISOS consensus standards. This paper identifies some of the problems in using and interpreting the results for predicting ageing based upon ISOS consensus standard test data. Design of Experiments (DOE) in conjunction with data from ISOS consensus standards are used as the basis for developing life test models for OPV modules. This is used to study their temperature-humidity and light-induced degradation, which enables failure rates during accelerated testing to be assessed against the typical outdoor operational conditions. The life test models are used to assess the relative severity of the ISOS standards and the impact of geographic and seasonal climatic changes on OPV degradation.

**General information**
State: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Department of Energy Conversion and Storage, Organic Energy Materials, Aalborg University
Authors: Riedel, N. (Intern), Benatto, G. A. D. R. (Intern), Thorsteinsson, S. (Intern), Poulsen, P. B. (Intern), Spataru, S. (Ekstern), Sera, D. (Ekstern)
Publication date: 2017

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Source: FindIt
Source-ID: 2355411147
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

**Using ISOS consensus test protocols for development of quantitative life test models in ageing of organic solar cells**

As Organic Photovoltaic (OPV) development matures, the demand grows for rapid characterisation of degradation and application of Quantitative Accelerated Life Tests (QALT) models to predict and improve reliability. To date, most accelerated testing on OPVs has been conducted using ISOS consensus standards. This paper identifies some of the problems in using and interpreting the results for predicting ageing based upon ISOS consensus standard test data. Design of Experiments (DOE) in conjunction with data from ISOS consensus standards are used as the basis for developing life test models for OPV modules. This is used to study their temperature-humidity and light-induced degradation, which enables failure rates during accelerated testing to be assessed against the typical outdoor operational conditions. The life test models are used to assess the relative severity of the ISOS standards and the impact of geographic and seasonal climatic changes on OPV degradation.

**General information**
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Organisations: Department of Energy Conversion and Storage, Organic Energy Materials, Bangor University
Authors: Kettle, J. (Ekstern), Stoichkov, V. (Ekstern), Kumar, D. (Ekstern), Corazza, M. (Intern), Gevorgyan, S. A. (Intern), Krebs, F. C. (Intern)
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Main Research Area: Technical/natural sciences

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Scopus rating (2016): CiteScore 4.97 SJR 1.587 SNIP 1.71
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.869 SNIP 1.896 CiteScore 5.16
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.204 SNIP 2.396 CiteScore 5.87
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.174 SNIP 2.582 CiteScore 5.58
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.435 SNIP 2.707 CiteScore 5.25
ISI indexed (2012): ISI indexed yes
Voltage and Thermally Driven Roll-to-Roll Organic Printed Transistor Made in Ambient Air Conditions

Resume: Organic thin film transistors offer great potential for use in flexible electronics. Much of this potential lies in the solution processability of the organic polymers enabling both roll coating and printing on flexible substrates and thus greatly reducing the material and fabrication costs. We present flexible organic power transistors prepared by fast (20 m min⁻¹) roll-to-roll flexographic printing of the drain and source electrode structures, with an interspace below 50 μm, directly on polyester foil[1]. The devices have top gate architecture and were completed by slotdie coating of the organic semiconductor poly3hexylthiophene and the dielectric material polyvinylphenol before the gate was applied by screen printing. All the processing was realized in ambient air on a PET flexible substrate. We explore the footprint and the practically accessible geometry of such devices with a special view toward being able to drive large currents while handling the thermal aspects in operation together with other organic printed electronics technologies such as large area organic photovoltaics (OPV) and large area electrochromic displays (EC). We find especially that an elevated operational temperature is beneficial with respect to both transconductance and on/off ratio. We achieve high currents of up to 45 mA at a temperature of 80 °C. Finally, we observe a significant temperature dependence of the performance, which can be explored further in sensing applications.
A stability study of polymer solar cells using conjugated polymers with different donor or acceptor side chain patterns

Improvement of the power conversion efficiency and long term stability remains to be of crucial importance for the further development of polymer solar cells (PSCs). Herein, a donor-acceptor copolymer based on 4,8-di(thiophene-2-yl)benzo[1,2-b:4,5-b′]dithiophene (DTBDT) and 4,7-di(thiophene-2-yl)benzo[c][1,2,5]thiadiazole (DTBT), specifically selected because of its suitability for roll-coating in the ambient environment, is investigated in terms of operational stability via partial exchange (5 or 10%) of the alkyl side chain on either the donor or the acceptor monomer with a 2-hydroxyethyl or 2-phenylethyl group. It is shown that the exchange of the hexyl chain on the DTBT moiety has a negative impact on the stability of the polymer as well as on the performance of the resulting PSCs. On the other hand, partial exchange of the 2-hexyldecyl side chain of the BDT unit by a 2-hydroxyethyl group results in an improved photochemical stability of the polymer film and a higher efficiency of 5.6% for the spin-coated PSC. The stability of roll-coated devices also slightly increases with the incorporation of 10% of either the 2-hydroxyethyl or 2-phenylethyl side chain.
Baselines for Lifetime of Organic Solar Cells

The process of accurately gauging lifetime improvements in organic photovoltaics (OPVs) or other similar emerging technologies, such as perovskites solar cells, is still a major challenge. The presented work is part of a larger effort of developing a worldwide database of lifetimes that can help establishing reference baselines of stability performance for OPVs and other emerging PV technologies, which can then be utilized for pass-fail testing standards and predicting tools. The study constitutes scanning of literature articles related to stability data of OPVs, reported until mid-2015 and collecting the reported data into a database. A generic lifetime marker is utilized for rating the stability of various reported devices. The collected data is combined with an earlier developed and reported database, which was based on articles reported until mid-2013. The extended database is utilized for establishing the baselines of lifetime for OPVs tested under different conditions. The work also provides the recent progress in stability of unencapsulated OPVs with different architectures, as well as presents the updated diagram of the reported record lifetimes of OPVs. The presented work is another step forward towards the development of pass-fail testing standards and lifetime prediction tools for emerging PV technologies.

General information
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Organisations: Department of Energy Conversion and Storage, Organic Energy Materials, Functional organic materials, ICFO - Institute of Photonic Sciences, University of Minho, Zurich University of Applied Sciences, CNRS, Institut Català de Nanociència i Nanotecnologia, Technische Universität Ilmenau, Cyprus University of Technology, Imperial College London
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 12.96 SJR 6.124 SNIP 2.045
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 6.254 SNIP 2.531 CiteScore 14.2
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 6.706 SNIP 2.975 CiteScore 15.27
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 5.979 SNIP 2.936 CiteScore 13.24
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 5.571 SNIP 2.216 CiteScore 9.64
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Original language: English
Characterization and modeling of organic (P3HT:PCBM) solar cells as a function of bias and illumination

We investigated the response of roll coated organic solar cells at different bias voltages and illumination levels to implement a detailed impedance model. The technique used for the investigation is based on the combination of standard DC characterization with the impedance spectroscopy at different bias and illumination intensity conditions. We analyzed both fresh and intentionally degraded cells. The impedance spectra show different peaks evolutions, depending on the degradation of the cells. Moreover, the same trend appears by measuring the cell at different illumination levels. To describe the cell impedance behaviors we suggest an electrical model based on distributed elements. By fitting the model to experimental data, we extrapolate the parameters related to electron transport, recombination and accumulation. The main differences between fresh and degraded samples are underlined. (C) 2016 Elsevier B.V. All rights reserved.
Comparison of ultramicrotomy and focused-ion-beam for the preparation of TEM and STEM cross section of organic solar cells

The challenge of preparing cross sections of organic photovoltaics (OPV) suitable for transmission electron microscopy (TEM) and scanning TEM (STEM) is addressed. The samples were polymer solar cells fabricated using roll-to-roll (R2R) processing methods on a flexible polyethylene terephthalate (PET) substrate. Focused ion beam (FIB) and ultramicrotomy were used to prepare the cross sections. The differences between the samples prepared by ultramicrotomy and FIB are addressed, focusing on the advantages and disadvantages of each technique. The sample prepared by ultramicrotomy yielded good resolution, enabling further studies of phase separation of P3HT:PCBM by means of energy filtered TEM (EFTEM). The sample prepared by FIB shows good structure preservation, but reduced resolution due to non-optimal thicknesses achieved after treatment. Degradation studies of samples prepared by ultramicrotomy are further discussed, which reveal particular effects of the ISOS-L-3 aging test (85 °C, 50% R.H., 0.7 Sun) onto the sample, especially pronounced in the silver layer.

General information
State: Published
Number of pages: 7
Pages: 462-468
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Applied Surface Science
Volume: 389
ISSN (Print): 0169-4332
Ratings:
Effects of current stress and thermal storage on polymeric heterojunction P3HT:PCBM solar cell

We subjected P3HT:PCBM solar cells to electrical constant current stress and thermal storage. We employed the impedance spectroscopy technique combined to conventional DC measurements for device characterization during all stresses. We identified and separated different contributions affecting the open circuit voltage and short circuit current. Several mechanisms are behind these changes during the stresses; in particular, we underlined the exciton recombination rate and the variation of the built-in voltage.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials, University of Padova
Number of pages: 6
Publication date: 2016

Host publication information
Title of host publication: 2016 International Reliability Physics Symposium (IRPS)
Publisher: IEEE
ISBN (Print): 978-1-4673-9138-2
ISSN: 1541-7026
Main Research Area: Technical/natural sciences
Stress, Solar cell, Heterojunctions, Current, Thermal stability
DOIs:
10.1109/IRPS.2016.7574523
Source: FindIt
Source-ID: 2346008884
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

eGOPV introduction and Printed solar cells

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Krebs, F. C. (Intern)
Publication date: 2016

Publication information
Media of output: Video
Original language: English
Publisher: DTU Energy
Main Research Area: Technical/natural sciences
Links:
https://youtu.be/-qY_3zVuA3U

Bibliographical note
Introduction
Publication: Research - peer-review › Sound/Visual production (digital) – Annual report year: 2016

Flow synthesis - the answer to reproducible high-performance conjugated polymers on the scale that R2R processing demands

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Helgesen, M. (Intern)
Publication date: 2016

Publication information
High Current Printed Transistor

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Pastorelli, F. (Intern), Schmidt, T. M. (Intern), Hösel, M. (Intern), Søndergaard, R. R. (Intern), Jørgensen, M. (Intern), Krebs, F. C. (Intern)
Number of pages: 1
Pages: 28
Publication date: 2016

Host publication information
Title of host publication: Book of Abstracts. General Assembly of the Marie Curie Alumni Association 2016
Publisher: Marie Curie Alumni Association
Main Research Area: Technical/natural sciences
Conference: General Assembly of the Marie Curie Alumni Association, Venice, Italy, 04/03/2016 - 04/03/2016
Electronic versions:
High_Current_Printed_Transistor.pdf
Source: PublicationPreSubmission
Source-ID: 127807214
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2016

High Current Printed Transistor: Roll-to-Roll Manufacture and Thermal Behavior

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Pastorelli, F. (Intern), Schmidt, T. M. (Intern), Hösel, M. (Intern), Søndergaard, R. R. (Intern), Jørgensen, M. (Intern), Krebs, F. C. (Intern)
Number of pages: 1
Publication date: 2016
Event: Abstract from EMRS Spring Meeting 2016, Lille, France.
Main Research Area: Technical/natural sciences
Electronic versions:
High_Current_Printed_Transistor_emrs.pdf
Source-ID: 127807028
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

High Current Temperature Sensitive RolltoRoll Printed Transistor

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Pastorelli, F. (Intern)
Number of pages: 1
Publication date: 2016
Event: Abstract from 2016 MRS Fall Meeting & Exhibit, Boston, MA, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
High_Current_Temperature.pdf
In situ X-ray scattering of perovskite solar cell active layers roll-to-roll coated on flexible substrates

In an effort to understand recent results showing differences between the power conversion efficiencies of lead halide (CH$_3$NH$_3$PbI$_3-x$Cl$_x$) solar cells on glass versus flexible substrates, this study investigates the influence that substrate and processing methods have on morphological and crystallographic development. Using our in situ slot-die micro roll-to-roll coater setup, we measured small and wide angle X-ray scattering in grazing incidence while the material dried, enabling us to follow the crystallization from just after the deposition and up to 25 minutes later. The data showed differing crystallographic developments between the substrates, especially seen through the behaviour of a crystalline precursor which survived longer on the flexible substrates than on glass. Additionally, the common degradation product PbI$_2$ was absent on the thickest flexible substrate. This leads us to conjecture that the flexible substrates absorb part of the solvent, thereby delaying evaporation and changing the solvent environment around the perovskite. As a further test, we produced solar cells with the same substrates and confirmed that the ones made on flexible substrates performed worse than those made on glass, but that when including an ITO layer in the stack it seemed to act as a buffer, whereby the solar cell performance was improved.
Laser beam induced current mapping (LBIG) of solar cells

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Jørgensen, M. (Intern)
Publication date: 2016

Publication information
Media of output: Video
Original language: English
Publisher: DTU Energy
Main Research Area: Technical/natural sciences
Links:
https://youtu.be/gH4vyC-CUsG

Bibliographical note
Invited talk
Publication: Research - peer-review › Sound/Visual production (digital) – Annual report year: 2016

Lifetime of organic photovoltaics: Status and predictions

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Gevorgyan, S. (Intern)
Publication date: 2016

Publication information
Media of output: Video
Original language: English
Publisher: DTU Energy
Main Research Area: Technical/natural sciences
Links:
https://youtu.be/xwyP9LtwtU

Bibliographical note
Invited talk
Publication: Research - peer-review › Sound/Visual production (digital) – Annual report year: 2016
Polymer materials for roll coated solar cells: strategies to improve performance and stability

Solar cells are among the renewable energy technologies with a large potential in terms of solar energy availability. The solar cells based on conjugated polymers belong to the third generation of this technology and their attractive features include a fast and cheap solution-processed production. At DTU Energy the focus is the roll-to-roll coating process of
these materials in order to reach large area devices, as the processability and scalability of the technology is an important factor. The process ability using roll-coating techniques and the stability of the used materials can be crucial. Therefore this project focuses on the synthesis of conjugated polymers and their application in roll-coated polymer solar cells. The first part of this project aims at using a screening strategy to find suitable polymer candidates for well performing solution processed polymer solar cells. A large number of polymers was screened by applying them in roll-coated solar cells and their performance, stability and number of synthetic steps was compared, to find promising candidates. In the end seven polymers with a sufficient efficiency were found to behave in a higher or in similar manner as poly(3-hexylthiophene). Further polymers were prepared based on well-performing benzothiadiazole and thiophene based polymers with different incorporation ratios of these monomers. The incorporation ratio has different effects on the polymer properties and the performance and stability of the corresponding roll-coated devices. The best efficiency was achieved with a polymer by using an incorporation of four thiophenes in the repeating unit. The second part of the work aims at using a known strategy to improve the solar cells stability. Three of the polymers from the polymer screening were therefore partly modified with stabilizing side chains, 2-phenyl and 2-ethanol, respectively, to influence especially the device stability but also the performance. For most modifications a decrease of the solar cell efficiency was observed. The incorporation of 10% of these side chains show improvements of the stability of devices in a minor degree with a variation in the photo- and thermal stability. In addition to the use of different side chains, the impact of different positioning of one side chain was investigated, showing that the incorporation onto the acceptor or donor unit of the polymer showed a degradation or improvement of the resulting properties. In addition, the approach of side chain removable on polythiophene was compared in terms of optical properties and morphologies of two polymers with different (thermal or acidic) cleavage processes. It was found that their properties were not the same and therefore different results from the corresponding solar cells can be expected.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Heckler, I. M. (Intern), Bundgaard, E. (Intern)
Number of pages: 234
Publication date: 2016

Publication information
Place of publication: Kgs. Lyngby
Publisher: Department of Energy Conversion and Storage, Technical University of Denmark
ISBN (Print): 978-87-92986-59-7
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Ilona_Heckler_PhD_thesis_DTU_Energy.pdf

Relations
Projects:
Polymer materials for roll coated solar cells: strategies tom improve performance and stability
Publication: Research › Ph.D. thesis – Annual report year: 2017

Roll-to-Roll Printed Electronics for Standalone Smart Windows

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Pastorelli, F. (Intern)
Number of pages: 1
Publication date: 2016
Event: Abstract from 2016 MRS Fall Meeting & Exhibit, Boston, MA, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
Roll_to_Roll_Printed_Electronics.pdf

Bibliographical note
Symposium PM5 : Hierarchical, Hybrid and Roll-to-Roll Manufacturing for Device Applications
Source: PublicationPreSubmission
Source-ID: 127807130
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Screening of materials for OPV - finding the perfect candidate(s)
General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Bundgaard, E. (Intern)
Publication date: 2016

Publication information
Media of output: Video
Original language: English
Publisher: DTU Energy
Main Research Area: Technical/natural sciences
Links:
https://youtu.be/FnCtxY5DdJo

Bibliographical note
Invited talk
Publication: Research - peer-review › Sound/Visual production (digital) – Annual report year: 2016

Self-Assembled Plasmonic Nanoparticles for Organic Photovoltaics

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Pastorelli, F. (Intern)
Number of pages: 1
Publication date: 2016
Event: Abstract from 2016 MRS Fall Meeting & Exhibit, Boston, MA, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
Self_Assembled_Plasmonic_Nanoparticles.pdf

Bibliographical note
Symposium EM7 : Functional Plasmonics
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Voltage and Thermally Driven High Current RolltoRoll Printed Transistors

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Organic Energy Materials
Authors: Pastorelli, F. (Intern)
Number of pages: 1
Publication date: 2016
Event: Abstract from 2016 MRS Fall Meeting & Exhibit, Boston, MA, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
Voltage_and_Thermally_Driven.pdf

Bibliographical note
Symposium EM6 : Thin-Film Transistors—New Materials and Device Concepts
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Projects:

DronEL
The purpose of this project is to develop and bring to market an aerial drone based automated solution (DronEL) used for a full PV plant survey for more accurate survey in less time. The automatic drone-based inspection method combines IR, EL and PL imaging, and visual images.

Department of Photonics Engineering
Diode Lasers and LED Systems
Coding and Visual Communication
Centre of Excellence for Silicon Photonics for Optical Communications
Department of Energy Conversion and Storage
Organic Energy Materials
Aalborg University
Sky Watch
SiCon
Kenergy
Skive Kommune
Period: 01/01/2017 → 31/12/2019
Number of participants: 8
Project ID: 71001
Project participant:
Thorsteinsson, Sune (Intern)
Forchhammer, Søren (Intern)
Benatto, Gisele Alves dos Reis (Intern)
Riedel, Nicholas (Intern)
Thorseth, Anders (Intern)
Dam-Hansen, Carsten (Intern)
Mantel, Claire (Intern)
Project Manager, organisational:
Poulsen, Peter Behrensdorff (Intern)

Relations
Related projects:
PV LED ENGINE
PV BALCONY FENCE – a highly esthetic cost efficient PV integrated balcony
Activities:
7th International SpectroRadiometer Comparison (ISRC 2017)
Activities in the standardisation of light sources and spectroradiometer calibration
Publications:
Optimizing sensitivity of Unmanned Aerial System optical sensors for low zenith angles and cloudy conditions
Development of outdoor luminescence imaging for drone-based PV array inspection
New Light Source Setup for Angle Resolved Light Absorption measurement of PV sample
Indoor measurement of angle resolved light absorption by antireflective glass in solar panels
Luminescence Imaging Strategies for Drone-Based PV Array Inspection
Quantification of solar cell failure signatures based on statistical analysis of electroluminescence images
New dental applications with LEDs
Project

Cost and energy effective all-black solar cell panel | Black Si BIPV | Phase 2
The objective of the EUDP project is to develop and manufacture a novel type of solar panel based on a new type of solar cell (black silicon solar cell), which – apart from a high and preferably improved efficiency and an implementable and cheaper production method – should have several significant advantages in terms of building integration. The black solar cells will be further processed to make the front conducting grid completely black through an electrochemical deposition technology. The tabbing wires interconnecting the cells in the panel will be processed into non-reflecting black strings in a scalable, inorganic electrochemical process step securing a completely black appearance of the solar panel later produced. A compatible panel production process with traditional PV panel process will be demonstrated for the total black silicon BIPV module.

Department of Photonics Engineering
Diode Lasers and LED Systems
Department of Micro- and Nanotechnology
The fast evolution of printed electronics, with the photovoltaic technology in primis, is requiring the presence of a valid transistor alternative to the traditional one. The realization of a high current roll-to-roll transistor will interconnect all the different technologies so far developed with this low cost and high throughput method. Our aim is to develop a roll-to-roll transistor capable to modulate the current to levels that have not been achieved so far. The fabrication of the transistor will be done considering the lowest environmental impact possible, and containing energy consumption with a temperature below 150 °C. This high current (~mA) transistor will be able to support and assist other technologies and will also be the base for logics and sensing application.

The optical studies on the organic material will result in a more controllable production process that for the first time will relate polymer crystallinity directly with an optical characterization technique. The realization of such kind of measurements is not trivial, but will give information on polymer nanoscale structures never investigated before. To do so this technique uses femtosecond pulse in subdiffraction-limited area. This will disclose an unprecedented tool to control the polymer morphology as soon as it is deposited, with enormous consequences in performance control and optimization.

The realization of samples and the study of real cases will produce important information regarding this new technology and its real life applications. In addition, life-time and stability studies can be performed. Then the objective of minimizing the environmental impact of the technology life time cycle will be more realistic. These kinds of studies are also important to explain science to the society and to give a technology preview to industries.
Activities:

**Advanced Concepts in Photovoltaics**  
Period: 10 Oct 2017 → 13 Oct 2017  
Peter Behrensdorff Poulsen (Organizer)  
Gisele Alves dos Reis Benatto (Organizer)  
Jørgen Schou (Organizer)  
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.

**Progress in Photovoltaic Research in Denmark 2017**  
Period: 9 Oct 2017  
Peter Behrensdorff Poulsen (Organizer)  
Gisele Alves dos Reis Benatto (Organizer)  
Department of Photonics Engineering  
Optical Microsensors and Micromaterials  
Organic Energy Materials  

**Description**  
For the conference we had assembled all the top researchers in Denmark within Photovoltaics to tell about their latest results. Furthermore, some of the highly innovative companies within photovoltaics in Denmark did elaborate on their newest achievements.  
Degree of recognition: International

**Related event**  
**Progress in Photovoltaic Research in Denmark 2017: Conference i Photovoltaics**  
09/10/2017 → …  
Roskilde, Denmark  
Activity: Attending an event › Participating in or organising a conference

**IN SITU SMALL ANGLE STUDIES OF ROLL-TO-ROLL COATED PEROVSKITE SOLAR CELLS**  
Period: 14 Sep 2015  
Lea Hildebrandt Rossander (Speaker)  
Department of Energy Conversion and Storage  
Organic Energy Materials  

**Related event**  
**16th Conference on Small Angle Scattering (SAS 2015)**  
13/09/2015 → 18/09/2015  
Berlin, Germany  
Activity: Talks and presentations › Conference presentations
In situ GISAXS/GIWAXS studies of roll-to-roll coated perovskite solar cells
Period: 10 Sep 2015
Lea Hildebrandt Rossander (Speaker)
Department of Energy Conversion and Storage
Organic Energy Materials

Related event
GISAS2015: 3rd International GISAS Conference
08/09/2015 → …
Nice, France
Activity: Talks and presentations › Conference presentations

Prizes:

Best Poster Award at the Sustain 2017
Gisele Alves dos Reis Benatto (Recipient), Nicholas Riedel (Recipient), Claire Mantel (Recipient), Sune Thorsteinsson (Recipient), Peter Behrens Dorff Poulsen (Recipient), Søren Forchhammer (Recipient), Kenn H. B. Frederiksen (Recipient), Jan Vedde (Recipient), Harsh Parikh (Recipient), Sergiu Spataru (Recipient) & Dezso Sera (Recipient)
Department of Photonics Engineering, Photovoltaic Materials and Systems, Organic Energy Materials, Coding and Visual Communication, Centre of Excellence for Silicon Photonics for Optical Communications

Description
Outdoor luminescence imaging strategies for drone-based PV array inspection

Details
Awarded date: 6 Dec 2017
Degree of recognition: International
Granting Organisations: Technical University of Denmark
event: Sustain 2017
Prize: Prizes, scholarships, distinctions