Diluted Oxide Interfaces with Tunable Ground States

The metallic interface between two oxide insulators, such as LaAlO3/SrTiO3 (LAO/STO), provides new opportunities for electronics and spintronics. However, due to the presence of multiple orbital populations, tailoring the interfacial properties such as the ground state and metal-insulator transitions remains challenging. Here, we report an unforeseen tunability of the phase diagram of LAO/STO by alloying LAO with a ferromagnetic LaMnO3 insulator without forming lattice disorder and at the same time without changing the polarity of the system. By increasing the Mn-doping level, x, of LaAl1-xMnxO3/STO (0 ≤ x ≤ 1), the interface undergoes a Lifshitz transition at x = 0.225 across a critical carrier density of nc = 2.8×10^{13} cm^{-2}, where a peak TSC = 255 mK of superconducting transition temperature is observed. Moreover, the LaAl1-xMnxO3 turns ferromagnetic at x ≥ 0.25. Remarkably, at x = 0.3, where the metallic interface is populated by only dxy electrons and just before it becomes insulating, we achieve reproducibly a same device with both signatures of superconductivity and clear anomalous Hall effect (7.6×10^{12} cm^{-2} < ns ≤ 1.1×10^{13} cm^{-2}). This provides a unique and effective way to tailor oxide interfaces for designing on-demand electronic and spintronic devices.
The role of oxide interfaces in highly confined electronic and ionic conductors

Oxides bring not only new properties such as superconductivity, ferro-, pyro-, and piezoelectricity, ferromagnetism, and multiferroicity but also ionic and catalytic properties. Such richness arises from a strong interaction between the charge, orbital, spin, and lattice degrees of freedom. Interfacing two oxide-based materials results in broken lattice symmetry as well as electronic and/or atomic reconstructions from which a wealth of new intriguing properties can emerge. Here, we provide an overview and perspective of electronic, ionic, and ionotronic properties in oxide systems with confinement designed by broken lattice symmetry.
Tuning the stoichiometry and electrical properties of tantalum oxide thin films

Tantalum oxide has a wide range of applications and has drawn much attention especially for its useful properties in resistive random-access memories, in which the Ta oxide composition plays an important role to control the electrical properties of the TaOx thin films. In this paper, we present a way to tune the composition of TaOx thin films by varying the oxygen partial pressure during growth using pulsed laser deposition. TaOx thin films were deposited at room temperature, under oxygen partial pressures ranging from 10⁻⁶ mbar to 2×10⁻⁴ mbar. Using angle resolved X-ray photoelectron spectroscopy, we show that the composition of the film varies systematically with the oxygen partial pressure during the film growth. We then correlate the oxygen content with the electrical properties of the film and the results show that the composition has a great influence on the resistivity of the TaOx thin films. As the oxygen partial pressure during deposition increases, the percentage of tantalum pentoxide (Ta₂O₅) as well as the resistivity of the films increases. This experimental approach provides a pathway to control the TaOₓ thin film stoichiometry and its electrical properties during growth.

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Electron mobility in oxide heterostructures: Topical review

Next-generation integrated circuit devices based on transition-metal-oxides are expected to boast a variety of extraordinary properties, such as superconductivity, transparency in the visible range, thermoelectricity, giant ionic conductivity and ferromagnetism. However, the realisation of this so-called oxide electronics as well as the study of their unconventional physics is stalled by inferior carrier mobilities compared to conventional semiconductor materials. Over the past 10 years, bulk conducting oxides and oxide heterostructures with superior carrier mobilities have nonetheless seen significant progress. This progress is signifying the approaching era of oxide-based electronic circuits along with novel solid-state phenomena originating from the combination of hybridized oxygen p orbitals, transition-metal d orbitals and electronic correlations. Here, we review the recent advancements and results on high mobility oxide heterostructures based on SrTiO3 and ZnO as well as other prominent oxides.

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BFI (2011): BFI-level 1
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Electron Mobility in γ-Al₂O₃/SrTiO₃

One of the key issues in engineering oxide interfaces for electronic devices is achieving high electron mobility. SrTiO₃-based interfaces with high electron mobility have gained a lot of interest due to the possibility of combining quantum phenomena with the many functionalities exhibited by SrTiO₃. To date, the highest electron mobility (140 000 cm²/V s at 2 K) is obtained by interfacing perovskite SrTiO₃ with spinel γ-Al₂O₃. The origin of the high mobility, however, remains poorly understood. Here, we investigate the scattering mechanisms limiting the mobility in γ-Al₂O₃/SrTiO₃ at temperatures between 2 and 300 K and over a wide range of sheet carrier densities. For T>150 K, we find that the mobility is limited by longitudinal optical phonon scattering. For large sheet carrier densities (>8×10¹⁳ cm⁻²), the screened electron-phonon coupling leads to room-temperature mobilities up to μ∼12 cm²/V s. For 5 K

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Exploring magnetic and electronic properties in γ-Al$_2$O$_3$/SrTiO$_3$

The increasing impact of electronic devices on our daily lives has caused the strong market pull that has empowered the tremendous development in realizing faster, smaller and more energy efficient devices. Two routes are used to satisfy this market pull: (i) Improving existing devices or (ii) designing devices with new functionalities. The functionalities that can be achieved in devices are determined by the constituent materials. Appealing functionalities may thus be realized by using materials beyond the semiconducting materials that currently constitute the backbone of state-of-the-art electronic devices. An example is the 3D-Xpoint memory technology introduced in Intel/Micron’s next generation of memory devices, which are using new memristive functionalities in chalcogenides rather than the traditional semiconducting floating gate transistors used in solid state drives (SSD).

In 2004, a new material platform was discovered, which in the following decade remarkably turned out to exhibit a plethora of functionalities. The material platform was formed by depositing a thin film of LaAlO$_3$ (LAO) epitaxially on SrTiO$_3$ (STO). Despite both oxides were considered non-magnetic and insulating, conductivity and magnetism emerged at the interface. Numerous other functionalities were also discovered including gate-tunable superconductivity, non-volatile resistive switching, and a giant Seebeck coefficient.

In 2013, LAO was replaced with γ-Al$_2$O$_3$ (GAO) resulting in an improved epitaxial growth and electron mobility. Open questions remained, however, regarding the origin of the electron gas confined at the interface and whether GAO/STO would exhibit appealing functionalities similar or perhaps superior to LAO/STO. In this thesis, I first describe the non-isomorphic epitaxial growth of the spinel GAO on perovskite STO and how it leads a useful symmetry breaking at the interface. Second, I present how oxygen vacancies lead to the emergence of an electron gas at the GAO/STO interface. At room temperature the electron mobility is limited to 12 cm$^2$/Vs by phonon scattering. At 2 K the mobility exceeds 100,000 cm$^2$/Vs, which I propose is due to an electron-donor separation. The electron gas exhibits a colossal positive magnetoresistance of 80,000% at 2 K and 15 T with a great potential for realizing extraordinary magnetoresistance. In addition, a strain-tunable magnetic state is observed in GAO/STO. The thesis ends with my view on how the understanding and number of functionalities can be improved further.
High-temperature thermoelectric properties of Na- and W-Doped Ca₃₋₂ₓNaₓ₂Co₄₋ₓWₓO₉ system

The detailed crystal structures and high temperature thermoelectric properties of polycrystalline Ca₃₋₂ₓNaₓ₂Co₄₋ₓWₓO₉ (0 ≤ x ≤ 0.075) samples have been investigated. Powder X-ray diffraction data show that all samples are phase pure, with no detectable traces of impurity. The diffraction peaks shift to lower angle values with increase in doping (x), which is consistent with larger ionic radii of Na⁺ and W⁶⁺ ions. X-ray photoelectron spectroscopy data reveal that a mixture of Co²⁺, Co³⁺ and Co⁴⁺ valence states are present in all samples. It has been observed that electrical resistivity (ρ), Seebeck coefficient (S) and thermal conductivity (κ) are all improved with dual doping of Na and W in Ca₃Co₄O₉ system. A maximum power factor (PF) of 2.71 × 10⁻⁴ W m⁻¹ K⁻² has been obtained for x = 0.025 sample at 1000 K. The corresponding thermoelectric figure of merit (zT) for x = 0.025 sample is calculated to be 0.21 at 1000 K, which is ∼2.3 times higher than zT value of the undoped sample. These results suggest that Na and W dual doping is a promising approach for improving thermoelectric properties of Ca₃Co₄O₉ system.
Joining of Half-Heusler and Bismuth Tellurides for Segmented Thermoelectric Generators

Segmented generators where the p- or n-type legs are formed by joining materials in series enables each material to operate in their most efficient temperature range. Here, we have fabricated and characterized segmented thermoelectric p- and n-type legs based on bismuth tellurides and half-Heusler alloys p-type Hf0.5Zr0.5CoSn0.2Sb0.8 and n-type Ti0.6Hf0.4NiSn. A two-step process was introduced to join the half-Heusler to the bismuth tellurides to form a segmented structure which was then characterized for its thermoelectric and structural properties. The output power generation was characterized under various hot side temperatures up to 873 K with the cold side fixed at 323 K. The stability of the joints was also investigated under heat treatment and thermal cycling. Under working temperatures from 323 K to 873 K, the obtained p-type segmented legs could deliver a power density of 0.3 W cm\(^{-2}\) and maximum voltage of 115 mV. With the same condition, the power density and the maximum voltage generated by n-type segmented leg were 0.25 W cm\(^{-2}\) and 102 mV. The area-specific contact resistances of the p- and n-type legs were 50 \, \mu\Omega \, \text{cm}^2 and 35 \, \mu\Omega \, \text{cm}^2, respectively. The output performance of each leg was \(\sim 95\%\) after 6 cycles from 323 K to 873 K.

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Strain-tunable magnetism at ferroelastic domain walls

Applying stress to a ferroelastic material results in a nonlinear strain response as domains of different orientations mechanically switch. The ability to write, erase and move domain walls between such ferroelastic domains suggests a method for making nanoelectronics where the domain wall is the device. However, little is known about the magnetic properties of such domain walls. A fascinating model system is SrTiO$_3$, where the ferroelastic domain walls display strain-tunable polarity and enhanced conductivity. Here, we reveal a long-range magnetic order with modulations along the ferroelastic domain walls in SrTiO$_3$ and SrTiO$_3$-based heterointerfaces, which manifests itself as a striped pattern in scanning superconducting quantum interference device maps of the magnetic landscape. In conducting interfaces, the magnetism is coupled to itinerant electrons with clear signatures in magnetotransport measurements. The magnetic state is also coupled dynamically to the lattice and can be reversibly tuned by applying local external forces. This study raises the possibility of designing nanoscale devices based on domain walls where strain-tunable ferroelectric, ferroelastic and ferromagnetic orders may coexist.
Tuning the Ground State of Oxide Interfaces by an Electron Sink

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Tuning the Two-Dimensional Electron Gas at Oxide Interfaces with Ti-O Configurations: Evidence from X-ray Photoelectron Spectroscopy

Chemical redox reaction can lead to a two-dimensional electron gas (2DEG) at the interface between a TiO2-terminated SrTiO3 (STO) substrate and an amorphous LaAlO3 (a-LAO) capping layer. When replacing the STO substrate with rutile and anatase TiO2 substrates, considerable differences in interfacial conduction are observed. Based on X-ray photoelectron spectroscopy (XPS) and transport measurements, we conclude that the interfacial conduction comes from redox reactions, and that the differences among the materials systems result mainly from variations in the activation energies for the diffusion of oxygen vacancies at substrate surfaces.

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Controlling the Carrier Density of SrTiO$_3$-Based Heterostructures with Annealing

The conducting interface between the insulating oxides LaAlO$_3$ (LAO) and SrTiO$_3$ (STO) displays numerous physical phenomena that can be tuned by varying the carrier density, which is generally achieved by electrostatic gating or adjustment of growth parameters. Here, it is reported how annealing in oxygen at low temperatures ($T < 300 \, ^\circ C$) can be used as a simple route to control the carrier density by several orders of magnitude. The pathway to control the carrier density relies on donor oxidation and is thus applicable to material systems where oxygen vacancies are the dominant source of conductivity. Using STO capped with epitaxial $\gamma$-Al$_2$O$_3$ (GAO) or amorphous LAO (a-LAO), the pathways for changing the carrier density in the two STO-based cases are identified where oxygen blocking (GAO) and oxygen permeable (a-LAO) films create interface conductivity from oxygen vacancies located in STO near the interface. For a-LAO/STO, the rate limiting step ($E_a = 0.25 \, eV$) for oxidizing oxygen vacancies is the transportation of oxygen from the atmosphere through the a-LAO film, whereas GAO/STO is limited by oxygen migration inside STO ($E_a = 0.5 \, eV$). Finally, it is showed how the control of the carrier density enables writing of conducting nanostructures in $\gamma$-Al$_2$O$_3$/STO by conducting atomic force microscopy.

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Correction to Creation of High Mobility Two-Dimensional Electron Gases via Strain Induced Polarization at an Otherwise Nonpolar Complex Oxide Interface

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Scopus rating (2015): CiteScore 14.76
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 14.04
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Effect of Sr-doping of LaMnO$_3$ spacer on modulation-doped two-dimensional electron gases at oxide interfaces

Modulation-doped oxide two-dimensional electron gas formed at the LaMnO$_3$ (LMO) buffered disordered-LaAlO$_3$/SrTiO$_3$ ($d$-LAO/LMO/STO) heterointerface provides new opportunities for electronics as well as quantum physics. Herein, we studied the dependence of Sr-doping of La$_{1-x}$Sr$_x$MnO$_3$ (LSMO, $x=0$, 1/8, 1/3, ½, and 1) spacer on the transport properties of $d$-LAO/LSMO/STO in order to determine the effects of the filling of Mn eg subbands as well as the LSMO polarity on the modulation-doping. Upon increasing the LSMO film thickness from 1 unit cell (uc) to 2 uc, a sharp metal to insulator transition of interface conduction was observed, independent of $x$. The resultant electron mobility is higher than 1900 cm$^2$ V$^{-1}$ s$^{-1}$ at 2 K, which increases upon decreasing $x$. The sheet carrier density, on the other hand, is in the range of $6.9 \times 10^{12}$–$1.8 \times 10^{13}$ cm$^{-2}$ (0.01–0.03 e/uc) and is largely independent on $x$ for all the metallic $d$-LAO/LSMO (1 uc)/STO interfaces. These results are consistent with the charge transfer induced modulation doping scheme and clarify that the polarity of the buffer layer plays a trivial role on the modulation doping. The negligible tunability of the carrier density could result from the reduction of LSMO during the deposition of disordered LAO or that the energy levels of Mn 3$d$ electrons at the interface of LSMO/STO are hardly varied even when changing the LSMO composition from LMO to SrMnO$_3$.

General information

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Contributors: Chen, Y., Gan, Y., Christensen, D. V., Zhang, Y., Pryds, N.
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Giant tunability of the two-dimensional electron gas at the interface of γ-Al₂O₃/SrTiO₃

Two-dimensional electron gases (2DEGs) formed at the interface between two oxide insulators provide a rich platform for the next generation of electronic devices. However, their high carrier density makes it rather challenging to control the interface properties under a low electric field through a dielectric solid insulator, i.e. in the configuration of conventional field-effect transistors. To surpass this long-standing limit, we used ionic liquids as the dielectric layer for electrostatic gating of oxide interfaces in an electric double layer transistor (EDLT) configuration. Herein, we reported giant tunability of the physical properties of 2DEGs at the spinel/perovskite interface of γ-Al₂O₃/SrTiO₃(GAO/STO). By modulating the carrier density thus the band filling with ionic-liquid gating, the system experiences a Lifshitz transition at a critical carrier density of $3.0 \times 10^{13} \text{cm}^{-2}$, where a remarkably strong enhancement of Rashba spin-orbit interaction and an emergence of Kondo effect at low temperatures are observed. Moreover, as the carrier concentration depletes with decreasing gating voltage, the electron mobility is enhanced by more than 6 times in magnitude, leading to the observation of clear quantum oscillations. The great tunability of GAO/STO interface by EDLT gating not only shows promise for design of oxide devices with on-demand properties, but also sheds new light on the electronic structure of 2DEG at the non-isostructural spinel/perovskite interface.

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Is γ-Al2O3 polar?

Polarity in thin films and polar discontinuities across an interface plays an important role in determining electronic properties. A key example is the conductivity at the LaAlO3/SrTiO3 (LAO/STO) interface, which is proposed to originate from the polarity of LAO. As a consequence, the conductivity does not disappear when LAO/STO is subjected to highly oxidizing conditions. Substituting LAO with another nominally polar material γ-Al2O3 (GAO) results in an interface conductivity which can be destroyed by annealing in oxygen. We investigate this apparent paradox by revisiting the defect spinel atomic structure of GAO. We show that the polarity is dependent on the distribution of aluminum vacancies which
are intrinsically present in GAO to ensure charge neutrality. In particular, certain film thicknesses allow for vacancy distributions that make GAO nominally non-polar along the [001] direction. We further propose that electromigration of aluminum vacancies across atomic layers can alter the polarity, making the GAO film effectively act as a ferroelectric.

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Microscopic origin of the mobility enhancement at a spinel/perovskite oxide heterointerface revealed by photoemission spectroscopy

The spinel/perovskite heterointerface γ-Al2O3/SrTiO3 hosts a two-dimensional electron system (2DES) with electron mobilities exceeding those in its all-perovskite counterpart LaAlO3/SrTiO3 by more than an order of magnitude, despite the abundance of oxygen vacancies which act as electron donors as well as scattering sites. By means of resonant soft x-ray photoemission spectroscopy and ab initio calculations, we reveal the presence of a sharply localized type of oxygen vacancies at the very interface due to the local breaking of the perovskite symmetry. We explain the extraordinarily high mobilities by reduced scattering resulting from the preferential formation of interfacial oxygen vacancies and spatial separation of the resulting 2DES in deeper SrTiO3 layers. Our findings comply with transport studies and pave the way towards defect engineering at interfaces of oxides with different crystal structures.

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Web of Science (2014): Impact factor 3.736
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Scopus rating (2013): CiteScore 3.55 SJR 2.813 SNIP 1.326
Web of Science (2013): Impact factor 3.664
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): CiteScore 3.57 SJR 3.173 SNIP 1.378
Web of Science (2012): Impact factor 3.767
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Scopus rating (2011): CiteScore 3.61 SJR 3.326 SNIP 1.423
Web of Science (2011): Impact factor 3.691
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Scopus rating (2010): SJR 3.318 SNIP 1.447
Web of Science (2010): Impact factor 3.774
Web of Science (2010): Indexed yes
Web of Science (2009): Indexed yes
Scopus rating (2008): SJR 2.923 SNIP 1.516
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.892 SNIP 1.588
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.62 SNIP 1.468
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.126 SNIP 1.156
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.012 SNIP 1.103
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.184 SNIP 1.179
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 2.856 SNIP 1.841
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 3.132 SNIP 1.727
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 2.84 SNIP 1.603
Web of Science (2000): Indexed yes
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Bibliographical note
Suppressed carrier density for the patterned high mobility two-dimensional electron gas at γ-Al2O3/SrTiO3 heterointerfaces

The two-dimensional electron gas (2DEG) at the non-isotuctural interface between spinel γ-Al2O3 and perovskite SrTiO3 is featured by a record electron mobility among complex oxide interfaces in addition to a high carrier density up to the order of 10^{15} cm^{-2}. Herein, we report on the patterning of 2DEG at the γ-Al2O3/SrTiO3 interface grown at 650 °C by pulsed laser deposition using a hard mask of LaMnO3. The patterned 2DEG exhibits a critical thickness of 2 unit cells γ-Al2O3 for the occurrence of interface conductivity, similar to the unpatterned sample. However, its maximum carrier density is found to be approximately 3×10^{13} cm^{-2}, much lower than that of the unpatterned sample (~10^{15} cm^{-2}). Remarkably, a high electron mobility of approximately 3.600 cm^2V^{-1}s^{-1} was obtained at low temperatures for the patterned 2DEG at a carrier density of ~7×10^{12} cm^{-2}, which exhibits clear Shubnikov-de Hass quantum oscillations. The patterned high-mobility 2DEG at the γ-Al2O3/SrTiO3 interface paves the way for the design and application of spinel/perovskite interfaces for high-mobility all-oxide electronic devices.
Thermodynamic Ground States of Complex Oxide Heterointerfaces

The formation mechanism of 2-dimensional electron gases (2DEGs) at heterointerfaces between nominally insulating oxides is addressed with a thermodynamical approach. We provide a comprehensive analysis of the thermodynamic ground states of various 2DEG systems directly probed in high temperature equilibrium conductivity measurements. We unambiguously identify two distinct classes of oxide heterostructures: For epitaxial perovskite/perovskite heterointerfaces (LaAlO3/SrTiO3, NdGaO3/SrTiO3, and (La,Sr)(Al,Ta)O3/SrTiO3), we find the 2DEG formation being based on charge transfer into the interface, stabilized by the electric field in the space charge region. In contrast, for amorphous LaAlO3/SrTiO3 and epitaxial γ-Al2O3/SrTiO3 heterostructures, the 2DEG formation mainly relies on the formation and accumulation of oxygen vacancies. This class of 2DEG structures exhibits an unstable interface reconstruction associated with a quenched nonequilibrium state.
Transport and excitations in a negative-U quantum dot at the LaAlO3/SrTiO3 interface

In a solid-state host, attractive electron–electron interactions can lead to the formation of local electron pairs which play an important role in the understanding of prominent phenomena such as high Tc superconductivity and the pseudogap phase. Recently, evidence of a paired ground state without superconductivity was demonstrated at the level of single electrons in quantum dots at the interface of LaAlO3 and SrTiO3. Here, we present a detailed study of the excitation spectrum and transport processes of a gate-defined LaAlO3/SrTiO3 quantum dot exhibiting pairing at low temperatures. For weak tunneling, the spectrum agrees with calculations based on the Anderson model with a negative effective charging energy U, and exhibits an energy gap corresponding to the Zeeman energy of the magnetic pair-breaking field. In contrast, for strong coupling, low-bias conductance is enhanced with a characteristic dependence on temperature, magnetic field and chemical potential consistent with the charge Kondo effect.

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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 12.41 SJR 6.582 SNIP 2.912
Web of Science (2017): Impact factor 12.353
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 11.8 SJR 6.414 SNIP 2.855
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BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 11.23 SJR 6.287 SNIP 2.86
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 10.77 SJR 6.41 SNIP 3.034
Web of Science (2014): Impact factor 11.47
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 9.85 SJR 6.206 SNIP 2.797
Web of Science (2013): Impact factor 10.742
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): CiteScore 8.32 SJR 5.866 SNIP 2.829
Web of Science (2012): Impact factor 10.015
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Tuning the ground state of polar LaAlO$_3$/SrTiO$_3$ interface by an electron sink

Most of the intriguing properties of two-dimensional electron gases (2DEGs) at the LaAlO$_3$/SrTiO$_3$ (LAO/STO) interface are sensitive to the electrons located in 3d-orbit of Ti. However, tuning the electronic structure of the system remains challenging due to the intrinsic high carrier density. Herein, instead of using LaMnO$_3$ (LMO) as buffer layers [1], we show that Mn doping in LaAlO$_3$ (LAMO) creates an electron sink that alters the ground state of 2DEG by suppressing the carrier density at the interface, without changing the polarity of the system. By precise control of the Mn-doping level, we found that 2DEGs in our system experience a change from two-band to one-band transport with decreasing carrier density, which is accompanied by a Lifshitz transition at a critical carrier density of $2.76 \times 10^{13}$ cm$^{-2}$ at 2K. Significantly, the peak value (255.7mK) of superconducting transition temperature is observed at Lifshitz point. In addition, our experiments realize the coexistence of ferromagnetism (FM) and superconductivity (SC) by Mn doping.

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Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Technical University of Denmark, University of Copenhagen
Contributors: Gan, Y., von Soosten, M., Zhang, Y., Niu, W., Christensen, D. V., Sand Jespersen, T., Pryds, N., Chen, Y.
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Research output: Research - peer-review › Conference abstract in proceedings – Annual report year: 2017

Two-Dimensional Electron Gases at Modulation-doped Oxide Interfaces

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Contributors: Chen, Y., Gan, Y., Christensen, D. V., von Soosten, M., Zhang, Y., Niu, W., Pryds, N.
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Two-Dimensional Electron Gases at Modulation-doped Oxide Interfaces
Universality of electron mobility in LaAlO₃/SrTiO₃ and bulk SrTiO₃

Metallic LaAlO₃/SrTiO₃ (LAO/STO) interfaces attract enormous attention, but the relationship between the electron mobility and the sheet electron density, nₛ₃D, is poorly understood. Here, we derive a simple expression for the three-dimensional electron density near the interface, n₃D, as a function of nₛ and find that the mobility for LAO/STO-based interfaces depends on n₃D in the same way as it does for bulk doped STO. It is known that undoped bulk STO is strongly compensated with N similar or equal to 5 x 10¹⁸ cm⁻³ background donors and acceptors. In intentionally doped bulk STO with a concentration of electrons n₃D < N, background impurities determine the electron scattering. Thus, when n₃D < N, it is natural to see in LAO/STO the same mobility as in the bulk. On the other hand, in the bulk samples with n₃D > N, the mobility collapses because scattering happens on n₃D intentionally introduced donors. For LAO/STO, the polar catastrophe which provides electrons is not supposed to provide an equal number of random donors and thus the mobility should be larger. The fact that the mobility is still the same implies that for the LAO/STO, the polar catastrophe model should be revisited.
A high mobility two-dimensional electron gas at the CaZrO$_3$/SrTiO$_3$ heterointerface

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Electric field control of the $\gamma$-Al$_2$O$_3$/SrTiO$_3$ interface conductivity at room temperature

Controlling interfaces using electric fields is at the heart of modern electronics. The discovery of the conducting interface between the two insulating oxides LaAlO$_3$ (LAO) and SrTiO$_3$ (STO) has led to a number of interesting electric field-dependent phenomena. Recently, it was shown that replacing LAO with a spinel $\gamma$-Al$_2$O$_3$ (GAO) allows a good pseudo-epitaxial film growth and high electron mobility at low temperatures. Here, we show that the GAO/STO interface resistance, similar to LAO/STO, can be tuned by orders of magnitude at room temperature using the electric field of a backgate. The resistance change is non-volatile, bipolar, and can be tuned continuously rather than being a simple on/off switch. Exposure to light significantly changes the capabilities to tune the interface resistance. High- and low-resistive states are obtained by annihilation and creation, respectively, of free $n$-type carriers, and we speculate that electromigration of oxygen vacancies is the origin of the tunability.

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Web of Science (2017): Impact factor 3.495
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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
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.47 SJR 1.499 SNIP 1.226
Web of Science (2015): Impact factor 3.142
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Evidence of weak superconductivity at the room-temperature grown LaAlO$_3$/SrTiO$_3$ interface

The two-dimensional electron gas at the crystalline LaAlO$_3$/SrTiO$_3$ (c-LAO/STO) interface has sparked large interest due to its exotic properties, including an intriguing gate-tunable superconducting phase. While there is growing evidence of pronounced spatial inhomogeneity in the conductivity at STO-based interfaces, the consequences for superconductivity remain largely unknown. We study interfaces based on amorphous LAO top layers grown at room temperature (a-LAO/STO) and demonstrate a superconducting phase similar to c-LAO/STO, however, with a gate-tunable critical temperature of 460 mK. The dependence of the superconducting critical current on temperature, magnetic field, and back-gate-controlled doping is found to be consistently described by a model of a random array of Josephson-coupled superconducting domains.

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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.34 SJR 1.604 SNIP 1.04
Web of Science (2017): Impact factor 3.813
Web of Science (2017): Indexed yes
Scopus rating (2016): CiteScore 3.16 SJR 2.339 SNIP 1.151
Web of Science (2016): Impact factor 3.836
Web of Science (2016): Indexed yes
Scopus rating (2015): CiteScore 2.8 SJR 2.377 SNIP 1.13
Web of Science (2015): Impact factor 3.718
Web of Science (2015): Indexed yes
Scopus rating (2014): CiteScore 3.3 SJR 2.762 SNIP 1.316
Web of Science (2014): Impact factor 3.736
Web of Science (2014): Indexed yes
Scopus rating (2013): CiteScore 3.55 SJR 2.813 SNIP 1.326
Web of Science (2013): Impact factor 3.664
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): CiteScore 3.57 SJR 3.173 SNIP 1.378
Web of Science (2012): Impact factor 3.767
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Scopus rating (2011): CiteScore 3.61 SJR 3.326 SNIP 1.423
Web of Science (2011): Impact factor 3.691
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Scopus rating (2010): SJR 3.318 SNIP 1.447
Web of Science (2010): Impact factor 3.774
Web of Science (2010): Indexed yes
Web of Science (2009): Indexed yes
Scopus rating (2008): SJR 2.923 SNIP 1.516
Infrared ellipsometry study of the confined electrons in a high-mobility y-Al2O3/SrTiO3 heterostructure

With infrared ellipsometry we studied the response of the confined electrons in y-Al2O3/SrTiO3 (GAO/STO) heterostructures in which they originate predominantly from oxygen vacancies. From the analysis of a so-called Berreman mode, that develops near the highest longitudinal optical phonon mode of SrTiO3, we derive the sheet carrier density, Ns, the mobility, \( \mu \), and the depth profile of the carrier concentration. Notably, we find that Ns and the shape of the depth profile are similar as in LaAlO3/SrTiO3 (LAO/STO) heterostructures for which the itinerant carriers are believed to arise from a polar discontinuity. Despite an order of magnitude higher mobility in GAO/STO, as obtained from transport measurements, the derived mobility in the infrared range exhibits only a twofold increase. We interpret this finding in terms of the polaronic nature of the confined charge carriers in GAO/STO and LAO/STO which leads to a strong, frequency-dependent interaction with the STO phonons.

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Scopus rating (2017): CiteScore 1.24 SJR 0.498 SNIP 0.569
Web of Science (2017): Impact factor 1.834
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.18 SJR 0.549 SNIP 0.603
Web of Science (2016): Impact factor 1.957
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 1.12 SJR 0.625 SNIP 0.593
Web of Science (2015): Impact factor 1.963
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 1.04 SJR 0.555 SNIP 0.579
Web of Science (2014): Impact factor 2.095
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 1 SJR 0.542 SNIP 0.539
Web of Science (2013): Impact factor 2.269
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 1.28 SJR 0.816 SNIP 0.592
Web of Science (2012): Impact factor 2.26
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.86 SJR 1.389 SNIP 0.758
Web of Science (2011): Impact factor 2.171
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.787 SNIP 0.762
Web of Science (2010): Impact factor 2.753
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.028 SNIP 0.972
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.771 SNIP 1.021
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.968 SNIP 1.062
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.927 SNIP 1.055
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.953 SNIP 1.075
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.905 SNIP 1.141
Scopus rating (2003): SJR 1.972 SNIP 1.139
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 2.14 SNIP 1.361
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 2.153 SNIP 1.193
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 2.149 SNIP 1.121
Web of Science (2000): Indexed yes
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New Insights into the Creation of High-Mobility Two-Dimensional Electron Gas at Oxide Interfaces: Control of Interfacial Redox Reactions by an Electron Sink

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Contributors: Chen, Y., Green, R., Trier, F., Christensen, D. V., Sutarto, R., He, F., von Soosten, M., Zhang, Y., Linderoth, S., Pryds, N.
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Quantization of Hall Resistance at the Metallic Interface between an Oxide Insulator and SrTiO₃

The two-dimensional metal forming at the interface between an oxide insulator and SrTiO₃ provides new opportunities for oxide electronics. However, the quantum Hall effect, one of the most fascinating effects of electrons confined in two dimensions, remains underexplored at these complex oxide heterointerfaces. Here, we report the experimental observation of quantized Hall resistance in a SrTiO₃ heterointerface based on the modulation-doped amorphous-LaAlO₃/SrTiO₃ heterostructure, which exhibits both high electron mobility exceeding 10,000 cm²/V s and low carrier density on the order of ~10¹² cm⁻². Along with unambiguous Shubnikov-de Haas oscillations, the spacing of the quantized Hall resistance suggests that the interface is comprised of a single quantum well with ten parallel conducting two-dimensional subbands. This provides new insight into the electronic structure of conducting oxide interfaces and represents an important step towards designing and understanding advanced oxide devices.

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BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.76 SJR 4.656 SNIP 2.538
Web of Science (2015): Impact factor 7.645
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 6.62 SJR 5.232 SNIP 2.71
Web of Science (2014): Impact factor 7.512
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 7.46 SJR 5.675 SNIP 2.781
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 7.19 SJR 6.292 SNIP 2.867
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 7.02 SJR 6.314 SNIP 2.905
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 6.45 SNIP 2.757
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 6.325 SNIP 2.947
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 6.194 SNIP 2.837
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 5.95 SNIP 2.738
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 4.781 SNIP 2.443
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 4.082 SNIP 2.101
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 3.847 SNIP 2.122
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 4.661 SNIP 2.651
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 5.884 SNIP 3.375
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 5.618 SNIP 3.135
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 5.771 SNIP 2.941
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Scandium-doped zinc cadmium oxide as a new stable n-type oxide thermoelectric material

Scandium-doped zinc cadmium oxide (Sc-doped ZnCdO) is proposed as a new n-type oxide thermoelectric material. The material is sintered in air to maintain the oxygen stoichiometry and avoid instability issues. The successful alloying of CdO with ZnO at a molar ratio of 1:9 significantly reduced the thermal conductivity by up to 7-fold at room temperature. By carefully selecting the Sc-dopant concentrations, a high power factor of $7.1 \times 10^{-4}$ W m$^{-1}$ K$^{-2}$ at 1173 K could be obtained. Therefore, the highest $ZT \sim 0.3$ at 1173 K was achieved for the $Zn_{0.9}Cd_{0.1}Sc_{0.01}O_{1.015}$ sample, and it has so far one of the highest ZT values among those reported for ZnO based thermoelectric materials over the temperature range, e.g., its ZT value at 300 K, which is 0.012, is over 1 order of magnitude higher than that of the state-of-the-art nanostructured Al-doped ZnO, which is 0.0013. It suggests that this material is a good candidate for improving the overall conversion efficiencies in oxide thermoelectric modules. Meanwhile, Sc-doped ZnCdO is robust in air at high temperatures, whereas other n-type materials, such as Al-doped ZnO, will experience rapid degradation of their electrical conductivity and ZT.

General information

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Scopus rating (2017): CiteScore 9.61 SJR 3.488 SNIP 1.55
Web of Science (2017): Impact factor 9.931
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 8.46 SJR 3.075 SNIP 1.479
Web of Science (2016): Impact factor 8.867
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 8.36 SJR 2.62 SNIP 1.643
Web of Science (2015): Impact factor 8.262
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 7.27 SJR 2.331 SNIP 1.514
Web of Science (2014): Impact factor 7.443
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Web of Science (2013): Impact factor
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
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10.1039/C6TA03126A
Silicon-doped InP as an alternative plasmonic material for mid-infrared

Silicon-doped InP is grown on top of semi-insulating iron-doped and sulfur-doped InP substrates by metalorganic vapor phase epitaxy (MOVPE), and the growth parameters are adjusted to obtain various free carrier concentrations from 1.05 \times 10^{19} \text{ cm}^{-3} \text{ up to } 3.28 \times 10^{19} \text{ cm}^{-3}. \text{ Mid-infrared (IR) reflection spectra of the samples with different carrier concentrations are used to retrieve pertaining dielectric functions as the key factor for understanding plasmonic behavior of InP:Si in the mid-IR wavelength range.}

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Organisations: Department of Photonics Engineering, Plasmonics and Metamaterials, Department of Energy Conversion and Storage, Mixed Conductors, Electrofunctional materials, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications
Contributors: Panah, M. E. A., Han, L., Christensen, D. V., Pryds, N., Lavrinenko, A., Semenova, E.
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Charge transfer induced modulation doping of two-dimensional electron gas at complex oxide interfaces

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Contributors: Chen, Y., Trier, F., Christensen, D. V., Linderoth, S., Pryds, N.
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Charge_transfer_induced_modulation.pdf
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Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2015

Creation of High Mobility Two-Dimensional Electron Gases via Strain Induced Polarization at an Otherwise Nonpolar Complex Oxide Interface

The discovery of two-dimensional electron gases (2DEGs) in SrTiO$_3$-based heterostructures provides new opportunities for nanoelectronics. Herein, we create a new type of oxide 2DEG by the epitaxial-strain-induced polarization at an otherwise nonpolar perovskite-type interface of CaZrO$_3$/SrTiO$_3$. Remarkably, this heterointerface is atomically sharp and exhibits a high electron mobility exceeding 60 000 cm$^2$ V$^{-1}$ s$^{-1}$ at low temperatures. The 2DEG carrier density exhibits a critical dependence on the film thickness, in good agreement with the polarization induced 2DEG scheme.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Center for Electron Nanoscopy, Imaging and Structural Analysis, Atomic Scale Materials Modelling, University of Copenhagen
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Scopus rating (2017): CiteScore 13.07
Web of Science (2017): Impact factor 12.08
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 13.4
Web of Science (2016): Impact factor 12.712
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 14.76
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 14.04
Web of Science (2014): Impact factor 13.592
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 14.23
Web of Science (2013): Impact factor 12.94
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 13.78
Web of Science (2012): Impact factor 13.025
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 13.83
Web of Science (2011): Impact factor 13.198
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Impact factor 12.219
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Web of Science (2008): Indexed yes
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Web of Science (2005): Indexed yes
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Web of Science (2001): Indexed yes
Original language: English
Extreme mobility enhancement of two-dimensional electron gases at oxide interfaces via charge transfer induced modulation doping

The discovery of two-dimensional electron gases (2DEGs) at the interface between two insulating complex oxides, such as LaAlO3 (LAO) or gamma-Al2O3 (GAO) epitaxially grown on SrTiO3 (STO), provides an opportunity for developing all-oxide electronic devices. These 2DEGs at complex oxide interfaces involve many-body interactions and give rise to a rich set of phenomena, for example, superconductivity, magnetism, tunable metal-insulator transitions, and phase separation. However, large enhancement of the interfacial electron mobility remains a major and long-standing challenge for fundamental as well as applied research of complex oxides. Here, we inserted a single unit cell insulating layer of polar La1-xSr0.15MnO3 (x=0, 1/8, and 1/3) at the interface between disordered LaAlO3 and crystalline SrTiO3 created at room temperature. We find that the electron mobility of the interfacial 2DEG is enhanced by more than two orders of magnitude. Our in-situ and resonant x-ray spectroscopic in addition to transmission electron microscopy results indicate that the manganite layer undergoes unambiguous electronic reconstruction and leads to modulation doping of such atomically engineered complex oxide heterointerfaces. At low temperatures, the modulation-doped 2DEG exhibits clear Shubnikov-de Haas oscillations and the initial manifestation of the quantum Hall effect, demonstrating an unprecedented high-mobility and low electron density oxide 2DEG system. These findings open new avenues for oxide electronics.
Extreme mobility enhancement of two-dimensional electron gases at oxide interfaces via charge transfer induced modulation doping

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Twente, University of British Columbia, University of Antwerp, University of Saskatchewan, Weizmann Institute of Science, University of Copenhagen
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Peer-reviewed: Yes
Extreme mobility enhancement of two-dimensional electron gases at oxide interfaces via charge transfer induced modulation doping

General information
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Electronic versions:
Extreme_mobility_enhancement_poster.pdf
Research output: Research - Poster – Annual report year: 2015

Patterning of high mobility electron gases at complex oxide interfaces
Oxide interfaces provide an opportunity for electronics. However, patterning of electron gases at complex oxide interfaces is challenging. In particular, patterning of complex oxides while preserving a high electron mobility remains underexplored and inhibits the study of quantum mechanical effects where extended electron mean free paths are paramount. This letter presents an effective patterning strategy of both the amorphous-LaAlO3/SrTiO3 (a-LAO/STO) and modulation-doped amorphous-LaAlO3/La7/8Sr1/8MnO3/SrTiO3 (a-LAO/LSM/STO) oxide interfaces. Our patterning is based on selective wet etching of amorphous-LSM (a-LSM) thin films, which acts as a hard mask during subsequent depositions. Strikingly, the patterned modulation-doped interface shows electron mobilities up to ∼8 700 cm²/V s at 2 K, which is among the highest reported values for patterned conducting complex oxide interfaces that usually are ∼1 000 cm²/V s at 2K. © 2015 AIP Publishing LLC.

General information
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Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Copenhagen
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BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.25 SJR 1.382 SNIP 1.167
Web of Science (2017): Impact factor 3.495
Web of Science (2017): Indexed yes
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
BFI (2015): BFI-level 2
Analysis of the internal heat losses in a thermoelectric generator

A 3D thermoelectric numerical model is used to investigate different internal heat loss mechanisms for a thermoelectric generator with bismuth telluride p- and n-legs. The model considers all thermoelectric effects, temperature dependent material parameters and simultaneous convective, conductive and radiative heat losses, including surface to surface radiation. For radiative heat losses it is shown that for the temperatures considered here, surface to ambient radiation is a good approximation of the heat loss. For conductive heat transfer the module efficiency is shown to be comparable to the case of radiative losses. Finally, heat losses due to internal natural convection in the module is shown to be negligible for the millimetre sized modules considered here. The combined case of radiative and conductive heat transfer resulted in the lowest efficiency. The optimized load resistance is found to decrease for increased heat loss. The leg dimensions are varied for all heat losses cases and it is shown that the ideal way to construct a TEG module with minimal heat losses and maximum efficiency is to either use a good insulating material between the legs or evacuate the module completely, and use small and wide legs closely spaced. (C) 2014 Elsevier Masson SAS. All rights reserved.

General information

State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Bjørk, R., Christensen, D. V., Eriksen, D., Pryds, N.
Pages: 12-20
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Publication information

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Volume: 85
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.91 SJR 1.429 SNIP 1.903
Web of Science (2017): Impact factor 3.615
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.9 SJR 1.598 SNIP 2.077
Web of Science (2016): Impact factor 3.615
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.16 SJR 1.668 SNIP 1.981
Web of Science (2015): Impact factor 2.769
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.51 SJR 1.704 SNIP 2.216
Web of Science (2014): Impact factor 2.629
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 3.26 SJR 1.417 SNIP 2.262
Web of Science (2013): Impact factor 2.563
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.99 SJR 1.699 SNIP 2.108
Web of Science (2012): Impact factor 2.47
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Room Temperature Creation of High Mobility Two-Dimensional Electron Gases at Complex Oxide Interfaces

General Information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Center for Electron Nanoscopy
Contributors: Chen, Y., Christensen, D. V., Trier, F., Kasama, T., Yazdi, S., Linderoth, S., Pryds, N.
Number of pages: 1
Publication date: 2014
Peer-reviewed: Yes
Event: Abstract from 21st International Workshop on Oxide Electronics, Lake George, NY, United States.
Electronic versions:
Room_Temperature_Creation.pdf
Source: PublicationPreSubmission
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Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2014

Room Temperature Epitaxial Growth of Complex Oxide Interfaces with High Mobility Two-Dimensional Electron Gases

General Information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Center for Electron Nanoscopy
Contributors: Chen, Y., Christensen, D. V., Trier, F., Kasama, T., Yazdi, S., Linderoth, S., Pryds, N.
Number of pages: 1
Publication date: 2014
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Event: Poster session presented at 1st Scientific Meeting of the TOBE Action, Rome, Italy.
Electronic versions:
Room_Temperature_Epitaxial_Growth.pdf
Towards high efficiency segmented thermoelectric unicouples

Segmentation of thermoelectric (TE) materials is a widely used solution to improve the efficiency of thermoelectric generators over a wide working temperature range. However, the improvement can only be obtained with appropriate material selections. In this work, we provide an overview of the theoretical efficiency of the best performing unicouples designed from segmenting the state-of-the-art TE materials. The efficiencies are evaluated using a 1D numerical model which includes all thermoelectric effects, heat conduction, Joule effects and temperature dependent material properties, but neglects contact resistance and heat losses. The calculations are performed for a fixed cold side temperature of 300K and different hot side temperatures of 700, 900, and 1100 K. We confirm that without taking into account the compatibility of TE materials, segmentation can even decrease the total efficiency. Choosing the TE materials carefully, one is, however, rewarded by a significant improvement in the total efficiency.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, California Institute of Technology
Contributors: Pham, H. N., Christensen, D. V., Snyder, G. J., Le, T. H., Linderoth, S., Van Nong, N., Pryds, N.
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BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.77
Web of Science (2017): Impact factor 1.795
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.69
Web of Science (2016): Impact factor 1.775
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.62
Web of Science (2015): Impact factor 1.648
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.56
Web of Science (2014): Impact factor 1.616
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.6
Web of Science (2013): Impact factor 1.525
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.53
Web of Science (2012): Impact factor 1.469
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.66
Transport Properties of the γ-Al$_2$O$_3$/SrTiO$_3$ Heterostructure

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Christensen, D. V., Chen, Y., Smith, A., Pryds, N.
Number of pages: 1
Publication date: 2014
Peer-reviewed: Yes
Event: Abstract from 21st International Workshop on Oxide Electronics, Lake George, NY, United States.
Electronic versions:
Transport_Properties.pdf

Research output: Research - peer-review › Journal article – Annual report year: 2013

A high-mobility two-dimensional electron gas at the spinel/perovskite interface of γ-Al$_2$O$_3$/SrTiO$_3$

The discovery of two-dimensional electron gases at the heterointerface between two insulating perovskite-type oxides, such as LaAlO$_3$ and SrTiO$_3$, provides opportunities for a new generation of all-oxide electronic devices. Key challenges remain for achieving interfacial electron mobilities much beyond the current value of approximately 1,000 cm$^2$V$^{-1}$s$^{-1}$ (at low temperatures). Here we create a new type of two-dimensional electron gas at the heterointerface between SrTiO$_3$ and a spinel γ-Al$_2$O$_3$ epitaxial film with compatible oxygen ions sublattices. Electron mobilities more than one order of magnitude higher than those of hitherto-investigated perovskite-type interfaces are obtained. The spinel/perovskite twodimensional electron gas, where the two-dimensional conduction character is revealed by quantum magnetoresistance oscillations, is found to result from interface-stabilized oxygen vacancies confined within a layer of 0.9 nm in proximity to the interface. Our findings pave the way for studies of mesoscopic physics with complex oxides and design of high-mobility all-oxide electronic devices.

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State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Department of Physics, Neutrons and X-rays for Materials Physics, Center for Electron Nanoscopy, Imaging and Structural Analysis, Secretariat, IT, Management, Chinese Academy of Sciences, Leibniz Institute for Solid State and Materials Research Dresden (IFW), University of Copenhagen
Number of pages: 6
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Peer-reviewed: Yes

Publication information
Journal: Nature Communications
Volume: 4
Article number: 1371
ISSN (Print): 2041-1723
Ratings:
BFI (2018): BFI-level 2
A high-mobility two-dimensional electron gas at the spinel/perovskite interface of γ-Al₂O₃/SrTiO₃

The realization of high-mobility 2DEGs in epitaxially grown heterostructures made of traditional semiconductors is at the heart of present electronics, which has led to a wealth of new physical phenomena as well as new electronic and photonic devices over the past few decades. 2DEGs at the interface between insulating complex oxides not only provide a wealth of opportunities to study mesoscopic physics with strongly correlated electrons confined in nanostructures, but also show promise for multifunctional all-oxide devices with probably even richer behavior than those we experienced in semiconductor devices.

General information
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Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Department of Physics, Neutrons and X-rays for Materials Physics, Center for Electron Nanoscopy, Imaging and Structural Analysis
Contributors: Chen, Y., Trier, F., Christensen, D. V., Andersen, N. H., Kasama, T., Zhang, W., Linderoth, S., Pryds, N.
Number of pages: 1
Publication date: 2013
Peer-reviewed: Yes
Event: Poster session presented at 2nd Frontiers of Microscopy Virtual Conference, .
Electronic versions:
High_mobility_2DEGs.pdf
Source: dtu
Source-ID: u::8988
A Two-Dimensional Electron Gas at the Spinel/Perovskite Interface of γ-Al₂O₃/SrTiO₃ with Carrier Mobility Exceeding 100,000 cm²V⁻¹s⁻¹

Controlling interfacial states in amorphous/crystalline LaAlO₃/SrTiO₃ heterostructures by electric fields
The tunable metal-insulator transition in crystalline LaAlO₃/SrTiO₃ heterostructures constitutes a central element in the range of remarkable interface properties that has made this oxide system subject to extensive research. Recently, metallic interfaces have also been realized when depositing amorphous LaAlO₃ films on SrTiO₃. Here, we present a non-volatile and reversible tuning of the interface conductivity by more than 3 orders of magnitude at room temperature by applying an electric field to such amorphous/crystalline heterostructures with amorphous LaAlO₃ film thicknesses of 2 nm. We show that the tunability is strongly temperature dependent, and demonstrate a simple protocol for enhancing the tunability. © 2013 American Institute of Physics.
Controlling the conductivity of amorphous LaAlO3/SrTiO3 interfaces by in-situ application of an electric field during fabrication
Amorphous-LaAlO$_3$/SrTiO$_3$ interfaces present metallic conductivity similar to those found in their all-crystalline counterparts. Here, the conductivity of amorphous-LaAlO$_3$/SrTiO$_3$ interfaces is modified by an external electric field applied in-situ with a biased truncated cone electrode ($-10\, \text{V} \leq \text{V}_{\text{bias}} \leq 20\, \text{V}$) during film growth. By modulating the charge balance of the arriving plasma species, interfacial conduction of the amorphous-LaAlO$_3$/SrTiO$_3$ heterostructures shifts from metallic to insulating via a semiconducting-like characteristic transport mode. This remarkable behavior is explained by a modification of the Al-ion flux impinging the SrTiO$_3$ surface, which alters the amount of near-interface oxygen vacancies being formed at the SrTiO$_3$ surface.

General information
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Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Naples Federico II
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.25 SJR 1.382 SNIP 1.167
Web of Science (2017): Impact factor 3.495
Web of Science (2017): Indexed yes
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
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.47 SJR 1.499 SNIP 1.226
Web of Science (2015): Impact factor 3.142
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.25 SJR 1.861 SNIP 1.492
Web of Science (2014): Impact factor 3.302
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.77 SJR 2.146 SNIP 1.633
Web of Science (2013): Impact factor 3.515
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.76 SJR 2.57 SNIP 1.739
Web of Science (2012): Impact factor 3.794
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.04 SJR 2.814 SNIP 1.917
Web of Science (2011): Impact factor 3.844
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Degradation of the interfacial conductivity in LaAlO$_3$/SrTiO$_3$ heterostructures during storage at controlled environments

The remarkable discovery of a two-dimensional electron gas confined at the interface of the two oxide band-insulators SrTiO$_3$ (STO) and LaAlO$_3$ (LAO) has spurred a great interest in the heterostructure leading to the discovery of a plethora of other exciting properties. Recently, the formation of the interfacial electron gas has also been shown possible when LAO is deposited on STO at room temperature, which leads to the growth of amorphous LAO (a-LAO). Here, we study the development of the interfacial conductivity of LAO/STO heterostructures with crystalline and amorphous LAO top layers in different controlled environments over time. The interfacial conductivity is found to degrade with a strong dependence on the thickness, the crystallinity of the deposited layer and the storage environment. A mechanism for the degradation is proposed and is further utilized to significantly reduce the rate of degradation.

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Designing CAF-adjuvanted dry powder vaccines: Spray drying preserves the adjuvant activity of CAF01

Dry powder vaccine formulations are highly attractive due to improved storage stability and the possibility for particle engineering, as compared to liquid formulations. However, a prerequisite for formulating vaccines into dry formulations is that their physicochemical and adjuvant properties remain unchanged upon rehydration. Thus, we have identified and optimized the parameters of importance for the design of a spray dried powder formulation of the cationic liposomal adjuvant formulation 01 (CAF01) composed of dimethyl-dioctadecylammonium (DDA) bromide and trehalose 6,6'-dibehenate (TDB) via spray drying. The optimal excipient to stabilize CAF01 during spray drying and for the design of nanocomposite microparticles was identified among mannitol, lactose and trehalose. Trehalose and lactose were promising stabilizers with respect to preserving liposome size, as compared to mannitol. Trehalose and lactose were in the glassy state upon co-spray drying with the liposomes, whereas mannitol appeared crystalline, suggesting that the ability of the stabilizer to form a glassy matrix around the liposomes is one of the prerequisites for stabilization. Systematic studies on the effect of process parameters suggested that a fast drying rate is essential to avoid phase separation and lipid accumulation at the surface of the microparticles during spray drying. Finally, immunization studies in mice with CAF01 in combination with the tuberculosis antigen Ag85B-ESAT6-Rv2660c (H56) demonstrated that spray drying of CAF01 with trehalose under optimal processing conditions resulted in the preservation of the adjuvant activity in vivo. These data demonstrate the importance of liposome stabilization via optimization of formulation and processing conditions in the engineering of dry powder liposome formulations.

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Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Department of Micro- and Nanotechnology, Polymer Microsystems for Cell Processing, University of Copenhagen, University of Groningen
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Peer-reviewed: Yes

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Journal: Journal of Controlled Release
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ISSN (Print): 0168-3659
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 7.9 SJR 2.684 SNIP 1.802
Web of Science (2017): Impact factor 7.877
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.56 SJR 2.463 SNIP 1.85
Web of Science (2016): Impact factor 7.786
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 8.11 SJR 2.738 SNIP 2.074
Two-dimensional electron gases at a spinel/perovskite complex oxide heterointerface with electron mobilities exceeding 100,000 cm²V⁻¹s⁻¹

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Chen, Y., Trier, F., Christensen, D. V., Linderøth, S., Pryds, N.
Degradation of the performance of microchannel heat exchangers due to flow maldistribution

The effect of flow maldistribution on the performance of microchannel parallel plate heat exchangers is investigated using an established single blow numerical model and cyclic steady-state regenerator experiments. It is found that as the variation of the individual channel thickness in a particular stack (heat exchanger) increases the actual performance of the heat exchanger decreases significantly, deviating from the expected nominal performance. We show that this is due to both the varying fluid flow velocities in each individual channel and the thermal cross talk between the channels transverse to the direction of the flow.
On the origin of metallic conductivity at the interface of LaAlO3/SrTiO3

To determine the origin of the quasi-two-dimensional electron gas formed at the interface between the two complex oxides of LaAlO3 (LAO) and SrTiO3 (STO), various amorphous films of LAO, La2O3, Al2O3, and La7/8Sr1/8MnO3 (LSMO), were deposited on TiO2-terminated (0 0 1) STO substrates by pulsed laser deposition at room temperature. Metallic interfaces are observed when the over-layers are amorphous LAO, La2O3, or Al2O3, while insulating interfaces are observed when the over-layer is LSMO. The interfacial conductivity of these SrTiO3-based hetero-structures shows strong dependence on both film thickness and oxygen pressure during film growth. The possible origin for the occurrence of metallic interfaces in these complex oxide hetero-structures due to redox reactions at the STO substrate surface is discussed. A thermodynamic criterion for designing either metallic or insulating interfaces between complex oxides is proposed.
Plasma plume effects on the conductivity of amorphous-LaAlO$_3$/SrTiO$_3$ interfaces grown by pulsed laser deposition in O$_2$ and Ar

Amorphous-LaAlO$_3$/SrTiO$_3$ interfaces exhibit metallic conductivity similar to those found for the extensively studied crystalline-LaAlO$_3$/SrTiO$_3$ interfaces. Here, we investigate the conductivity of the amorphous-LaAlO$_3$/SrTiO$_3$ interfaces grown in different pressures of O$_2$ and Ar background gases. During the deposition, the LaAlO$_3$ ablation plume is also studied, in situ, by fast photography and space-resolved optical emission spectroscopy. An interesting correlation between interfacial conductivity and kinetic energy of the Al atoms in the plume is observed: to assure conducting interfaces of amorphous-LaAlO$_3$/SrTiO$_3$, the kinetic energy of Al should be higher than 1 eV. Our findings add further insights on mechanisms leading to interfacial conductivity in SrTiO$_3$-based oxide heterostructures.© 2012 American Institute of Physics.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Naples Federico II
Resistance switching of the interfacial conductance in amorphous SrTiO3 heterostructures

Complex oxides have attracted a lot of interest recently as this class of material exhibits a plethora of remarkable properties. In particular, a great variety of properties is observed in the heterostructure composed of lanthanum aluminate (LaAlO3) and strontium titanate (SrTiO3). For instance, at the interface between the two insulating oxides LaAlO3 and SrTiO3 a high-mobility quasi-two-dimensional electron gas is formed if the thickness of LaAlO3 exceeds a critical value of 3 unit cells. At a thickness of 3 unit cells the interface remains insulating, however, an interface conductance can be induced by an electric field. It has previously been demonstrated that SrTiO3 heterostructures with amorphous LaAlO3 top layers can display interfacial conductivity with similar critical thickness dependence. Here, we report resistance switching of the interfacial conductance for SrTiO3 heterostructures with amorphous LaAlO3 top layers below the critical thickness in various controlled environments.

The creation of two-dimensional electron gases in SrTiO3-based complex oxide heterostructures by interface redox reactions

General information
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Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Chen, Y., Trier, F., Christensen, D., Pryds, N.
Pages: 66-66
Publication date: 2012
Demagnetizing effects in stacked rectangular prisms

A numerical, magnetostatic model of the internal magnetic field of a rectangular prism is extended to the case of a stack of rectangular prisms. The model enables the calculation of the spatially resolved, three-dimensional internal field in such a stack given any magnetic state function, stack configuration, temperature distribution and applied magnetic field. In this paper the model is applied to the case of a stack of parallel, ferromagnetic rectangular prisms and the resulting internal field is found as a function of the orientation of the applied field, the number of prisms in the stack, the spacing between the prisms and the packing density of the stack. The results show that the resulting internal field is far from being equal to the applied field and that the various stack configurations investigated affect the resulting internal field significantly and non-linearly. The results have a direct impact on the design of, e.g., active magnetic regenerators made of stacked rectangular prisms in terms of optimizing the internal field.
Extraordinarily high conductivity at interfaces of ZrO2:Y2O3/SrTiO3 heterostructures: origin and perspective

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State: Published
Contributors: Chen, Y., Christensen, D., Trier, F., Pryds, N., Smith, A., Linderoth, S.
Publication date: 2011
Peer-reviewed: No
Measuring the effect of demagnetization in stacks of gadolinium plates using the magnetocaloric effect
The effect of demagnetization in a stack of gadolinium plates is determined experimentally by using spatially resolved measurements of the adiabatic temperature change due to the magnetocaloric effect. The number of plates in the stack, the spacing between them and the position of the plate on which the temperature is measured are varied. The orientation of the magnetic field is also varied. The measurements are compared to a magnetostatic model previously described. The results show that the magnetocaloric effect, due to the change in the internal field, is sensitive to the stack configuration and the orientation of the applied field. This may have significant implications for the construction of a magnetic cooling device.

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Volume: 323
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.97 SJR 0.786 SNIP 1.349
Web of Science (2017): Impact factor 3.046
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.41 SJR 0.699 SNIP 1.181
Web of Science (2016): Impact factor 2.63
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.33 SJR 0.73 SNIP 1.296
Web of Science (2015): Impact factor 2.357
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.07 SJR 0.815 SNIP 1.423
Web of Science (2014): Impact factor 1.97
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.03 SJR 0.801 SNIP 1.385
Web of Science (2013): Impact factor 2.002
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.95 SJR 0.928 SNIP 1.294
Web of Science (2012): Impact factor 1.826
ISI indexed (2012): ISI indexed yes
An optimized magnet for magnetic refrigeration

A magnet designed for use in a magnetic refrigeration device is presented. The magnet is designed by applying two general schemes for improving a magnet design to a concentric Halbach cylinder magnet design and dimensioning and segmenting this design in an optimum way followed by the construction of the actual magnet. The final design generates a peak value of 1.24 T, an average flux density of 0.9 T in a volume of 2 L using only 7.3 L of magnet, and has an average low flux density of 0.08 T also in a 2 L volume. The working point of all the permanent magnet blocks in the design is very close to the maximum energy density. The final design is characterized in terms of a performance parameter, and it is shown that it is one of the best performing magnet designs published for magnetic refrigeration.

General information

State: Published
Contributors: Bjerk, R., Bahl, C. R. H., Smith, A., Christensen, D., Pryds, N.
Spatially resolved measurements of the magnetocaloric effect and the local magnetic field using thermography

General information
State: Published
Contributors: Christensen, D., Bjørk, R., Nielsen, K. K., Bahl, C. R. H., Smith, A., Clausen, S.
Pages: 063913
Publication date: 2010
Peer-reviewed: Yes

Publication information
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Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.03 SJR 0.739 SNIP 0.953
Web of Science (2017): Impact factor 2.176
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.72 SJR 0.906 SNIP 0.977
Web of Science (2016): Impact factor 2.068
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.57 SJR 0.821 SNIP 0.996
Web of Science (2015): Impact factor 2.101
Web of Science (2015): Indexed yes
The demagnetizing field of a non-uniform rectangular prism

The effect of demagnetization on the magnetic properties of a rectangular ferromagnetic prism under non-uniform conditions is investigated. A numerical model for solving the spatially varying internal magnetic field is developed, validated and applied to relevant cases. The demagnetizing field is solved by an analytical calculation and the coupling between applied field, the demagnetization tensor field and spatially varying temperature is solved through iteration. We show that the demagnetizing field is of great importance in many cases and that it is necessary to take into account the non-uniformity of the internal field, especially for non-constant temperature distributions and composite magnetic materials.

General information
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Contributors: Smith, A., Nielsen, K. K., Christensen, D., Bahl, C. R. H., Bjørk, R., Hattel, J. H.
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Publication information
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ISSN (Print): 0021-8979
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.03 SJR 0.739 SNIP 0.953
Web of Science (2017): Impact factor 2.176
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.72 SJR 0.906 SNIP 0.977
Web of Science (2016): Impact factor 2.068
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.57 SJR 0.821 SNIP 0.996
Web of Science (2015): Impact factor 2.101
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.04 SJR 1.039 SNIP 1.197
Web of Science (2014): Impact factor 2.183
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.24 SJR 1.155 SNIP 1.286
Web of Science (2013): Impact factor 2.185
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.13 SJR 1.312 SNIP 1.291
Web of Science (2012): Impact factor 2.21
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.24 SJR 1.374 SNIP 1.3
Web of Science (2011): Impact factor 2.168
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.484 SNIP 1.204
Web of Science (2010): Impact factor 2.079
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.51 SNIP 1.237
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.644 SNIP 1.326
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.695 SNIP 1.387
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.944 SNIP 1.667
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.055 SNIP 1.605
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.128 SNIP 1.591
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.078 SNIP 1.532
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 2.184 SNIP 1.7
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 2.147 SNIP 1.554
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 2.009 SNIP 1.53
Web of Science (2000): Indexed yes
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Exploring Electronic Properties in All-oxide Heterostructures
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Smith, A., Supervisor, Department of Energy Conversion and Storage
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Nygaard, J., Examiner
Granozio, F. M., Examiner
Institut stipendie (DTU) Samf.
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