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-xMnx O3/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} \text{cm}^{-2}, where a peak TSC = 255 \text{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} \text{cm}^{-2} < n_s ≤ 1.1×10^{13} \text{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.
2D hole gas seen
A p-type metallic sheet forms between two oxide insulators, LaAlO3 and SrTiO3. Suppression of oxygen vacancies in SrTiO3 plays a critical role in forming this sheet.
Direct Demonstration of the Emergent Magnetism Resulting from the Multivalence Mn in a LaMnO$_3$ Epitaxial Thin Film System

Atomically engineered oxide heterostructures provide a fertile ground for creating novel states, for example, a 2D electron gas at the interface between two oxide insulators, giant thermoelectric Seebeck coefficient, emergent ferromagnetism from otherwise nonmagnetic components, and colossal ionic conductivity. Extensive research efforts reveal that oxygen deficiency or lattice strain play an important role in determining these unexpected properties. Herein, by studying the abrupt presence of robust ferromagnetism (up to 1.5 $\mu_B$/Mn) in LaMnO$_3$-based heterostructures, the multivalence states of Mn that play a decisive role in the emergence of ferromagnetism in the otherwise antiferromagnetic LaMnO$_3$ thin films are found. Combining spatially resolved electron energy-loss spectroscopy, X-ray absorption spectroscopy, and X-ray magnetic circular dichroism techniques, it is determined unambiguously that the ferromagnetism results from a conventional Mn$^{3+}$-$\text{O}$-$\text{Mn}^{4+}$ double-exchange mechanism rather than an interfacial effect. In contrast, the magnetic dead layer of 5 unit cell in proximity to the interface is found to be accompanied with the accumulation of Mn$^{2+}$ induced by electronic reconstruction. These findings provide a hitherto-unexplored multivalence state of Mn on the emergent magnetism in undoped manganite epitaxial thin films, such as LaMnO$_3$ and BiMnO$_3$, and shed new light on all-oxide spintronic devices.
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 (>8×10¹³ cm⁻²), the screened electron-phonon coupling leads to room-temperature mobilities up to μ~12 cm²/V s. For 5 K

Emergent ferromagnetism in an otherwise antiferromagnetic LaMnO3-based heterostructure attributable to the cation-vacancy-induced oxygen excess effect through direct observation of multivalence Mn is reported by Xuefeng Wang, Peng Wang, Yongbing Xu, Yunzhong Chen, and co-workers in article number 1800055. The ferromagnetism is mediated by the Mn3+–O–Mn4+ double-exchange mechanism. It provides a hitherto unexplored multivalence state of Mn on the emergent ferromagnetism in manganite thin films.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Nanjing University, University of London
Number of pages: 1
Publication date: 2018

Publication information
Publisher: Wiley-VCH
Year: 2018
Original language: English
Electronic versions:
Niu_et_al_2018_Advanced_Electronic_Materials_1.pdf
DOIs:
10.1002/aelm.201870030
Source: FindIt
Source-ID: 2435438042
Research output: Research - peer-review – Journal article – Annual report year: 2018

Enhanced visible light catalytic activity of MoS2/TiO2/Ti photocathode by hybrid-junction

In photoelectrochemical (PEC) water splitting systems, crucial obstacles limiting their performance are poor charge carrier dynamics and high recombination rate of photoexcited electron hole pairs. Here, we report that this issue can be alleviated by engineering a hybrid-junction that is composed of homo- and hetero- junctions. This strategy is performed by facile hand-spraying MoS2 over the surface of a anatase/rutile homo-junction TiO2 film on the Ti substrate to further form a hybrid-junction photocathode. By applying this photocathode into PEC reactor, enhanced catalytic activity is achieved under visible light (AM1.5 illumination of 300W/m²) with hydrogen evolution reaction (HER) potential of −114mV versus reversible hydrogen electrode (RHE) at 10mA/cm² and long-term stability of more than 10 times improvement comparing to ordinary electrode without the introduction of hybrid-junction. The hybrid-junction that effectively regulates charge separation and transfer pathways is proven to be responsible for the enhanced activity. As an novel exploration, this hybrid-junction system comprising of low-cost, efficient charge separation and transfer, and visible light responsivity offers a new path for relative materials to boost their PEC performance.
Extreme Reconfigurable Nanoelectronics at the CaZrO₃ /SrTiO₃ Interface

Complex oxide heterostructures have fascinating emergent properties that originate from the properties of the bulk constituents as well as from dimensional confinement. The conductive behavior of the polar/nonpolar LaAlO₃/SrTiO₃ interface can be reversibly switched using conductive atomic force microscopy (c-AFM) lithography, enabling a wide range of devices and physics to be explored. Here, extreme nanoscale control over the CaZrO₃/SrTiO₃ (CZO/STO) interface, which is formed from two materials that are both nonpolar, is reported. Nanowires with measured widths as narrow as 1.2 nm are realized at the CZO/STO interface at room temperature by c-AFM lithography. These ultrathin nanostructures have spatial dimensions at room temperature that are comparable to single-walled carbon nanotubes, and hold great promise for alternative oxide-based nanoelectronics, as well as offer new opportunities to investigate the electronic structure of the complex oxide interfaces. The cryogenic properties of devices constructed from quasi-1D channels, tunnel barriers, and planar gates exhibit gate-tunable superconductivity, quantum oscillations, electron pairing outside of the superconducting regime, and quasi-ballistic transport. This newly demonstrated ability to control the metal–insulator transition at nonpolar oxide interface greatly expands the class of materials whose behavior can be patterned and reconfigured at extreme nanoscale dimensions.

General information

State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Pittsburgh
Number of pages: 8
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Advanced Materials
Volume: 30
Issue number: 33
Article number: 1801794
ISSN (Print): 0935-9648
Ratings:
BFI (2018): BFI-level 3
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 21.1
Web of Science (2017): Impact factor 2.227
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Magnetoelastic phase diagram of TbNi$_2$B$_2$C

The magnetic phase diagram of the quaternary borocarbide TbNi$_2$B$_2$C is investigated by direct means and by studying magnetoelastically induced modifications of the crystal structure. Detailed superconducting quantum interference device measurements reveal a complex phase diagram with five distinct magnetic phases. The phase boundaries are mapped out comprehensively. Synchrotron hard x-ray measurements in applied magnetic fields are employed to probe the magnetoelastic distortions throughout the phase diagram. The determination of the wave vectors of these field-induced lattice deformations suggests a range of commensurate spin-slip-type magnetic structures at low temperatures with wave vectors of the form $(q,0,0)$ with $q = 6/11$ and $5/9$. The proposed magnetic structures yield values of magnetization well in-line with observations. The scattering intensity due to the magnetoelastic deformations exhibits a drastic jump at the phase boundary at 1.3 T and low temperatures.
Metallic Conduction and Ferromagnetism in MAI2O4/SrTiO3 Spinel/Perovskite Heterostructures (M=Fe, Co, Ni)

Recently, a high mobility quasi-two-dimensional electron gas (q-2DEG) has been reported for the heterointerface between two insulating and nonmagnetic oxides of spinel γ-Al2O3 and perovskite SrTiO3 (STO). Herein, we fabricated the epitaxial heterostructure with Al-based magnetic spinel oxide MAI2O4 (M = Fe, Co, Ni) on perovskite STO. Remarkably, all the MAI2O4(M = Fe, Co, Ni) films exhibit ferromagnetic behavior up to room temperature. Although the FeAl2O4/STO is insulating, the NiAl2O4/STO and CoAl2O4/STO heterointerfaces are found to be highly metallic and exhibit anomalous Hall effect (AHE) at temperatures below 30 K. Their Hall mobility is as high as 3 × 10⁴ cm²V⁻¹s⁻¹, comparable to that of γ-Al2O3/STO interface. There has been evidence of oxygen-vacancy-related magnetism in γ-Al2O3/STO at temperatures below 5 K, while the enhanced AHE in NiAl2O4/STO and CoAl2O4/STO likely comes from the magnetic proximity effect induced by the top ferromagnetic MAI2O4 spinel films.
Nanoscale patterning of electronic devices at the amorphous LaAlO3/SrTiO3 oxide interface using an electron sensitive polymer mask

A simple approach is presented for designing complex oxide mesoscopic electronic devices based on the conducting interfaces of room temperature grown LaAlO3/SrTiO3 heterostructures. The technique is based entirely on methods known from conventional semiconductor processing technology, and we demonstrate a lateral resolution of similar to 100 nm. We study the low temperature transport properties of nanoscale wires and demonstrate the feasibility of the technique for defining in-plane gates allowing local control of the electrostatic environment in mesoscopic devices. (C) 2018 Author(s).

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Copenhagen, Technical University of Denmark
Number of pages: 5
Publication date: 2018
Peer-reviewed: Yes

Publication information
Volume: 112
Issue number: 17
Article number: 171606
ISSN (Print): 0003-6951
Ratings:
BFI (2018): BFI-level 2
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
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

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Technical University of Denmark, University of Antwerp, Chinese Academy of Sciences, University of Copenhagen
Number of pages: 1
Publication date: 2018
Peer-reviewed: Yes
Electronic versions:
iWOE25_abstract_Yulin_Gan.pdf
Source: PublicationPreSubmission
Source-ID: 160552775
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2018

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.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Chinese Academy of Sciences, Technical University of Denmark
Contributors: Zhang, Y., Gan, Y., Niu, W., Normann, K., Yan, X., Christensen, D. V., von Soosten, M., Zhang, H., Shen, B., Pryds, N., Sun, J., Chen, Y.
Pages: 1434-1439
Publication date: 2018
Peer-reviewed: Yes

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 ($T < 300$ °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 γ-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 γ-Al$_2$O$_3$/STO by conducting atomic force microscopy.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Copenhagen
Number of pages: 7
Publication date: 2017
Peer-reviewed: Yes
Correction to Creation of High Mobility Two-Dimensional Electron Gases via Strain Induced Polarization at an Otherwise Nonpolar Complex Oxide Interface

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Center for Electron Nanoscopy, Imaging and Structural Analysis, University of Copenhagen
Pages: 2738
Publication date: 2017
Peer-reviewed: No
Effect of Sr-doping of LaMnO3 spacer on modulation-doped two-dimensional electron gases at oxide interfaces

Modulation-doped oxide two-dimensional electron gas formed at the LaMnO3 (LMO) buffered disordered-LaAlO3/SrTiO3 (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_xMnO_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 2K, which increases upon decreasing x. The sheet carrier density, on the other hand, is in the range of 6.9×10^{12} - 1.8×10^{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 3d electrons at the interface of LSMO/STO are hardly varied even when changing the LSMO composition from LMO to SrMnO_3.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Technical University of Denmark
Contributors: Chen, Y., Gan, Y., Christensen, D. V., Zhang, Y., Pryds, N.
Number of pages: 4
Publication date: 2017
Peer-reviewed: Yes
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 3.0×10^{13} 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.
Magnetic two-dimensional electron gas at the manganite-buffered LaAlO$_3$/SrTiO$_3$ interface

Fabrication of highly mobile spin-polarized two-dimensional electron gas (2DEG) is crucially important for both fundamental and applied research. Usually, spin polarization appears below 10 K for the 2DEG of LaAlO$_3$/SrTiO$_3$ interface, stemming from the magnetic ordering of Ti$^{3+}$ ions with the mediation of itinerant electrons. Herein, we report a magnetic 2DEG at a La$_{7/8}$Sr$_{1/8}$MnO$_3$-buffered LaAlO$_3$/SrTiO$_3$ interface, which simultaneously shows electrically tunable anomalous Hall effect and high conductivity. The spin-polarized temperature for the 2DEG is promoted to 30 K while the mobility remains high. The magnetism likely results from a gradient manganese interdiffusion into SrTiO$_3$. The present work demonstrates the great potential of manganite-buffered LaAlO$_3$/SrTiO$_3$ interfaces for spintronic applications.
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.
Scavenging of oxygen vacancies at modulation-doped oxide interfaces: Evidence from oxygen isotope tracing

The introduction of manganite buffer layers, La$_{7/8}$Sr$_{1/8}$MnO$_3$ (LSMO) in particular, at the metallic interface between SrTiO$_3$ (STO) and another band insulator suppresses the carrier density of the interfacial two-dimensional electron gas (2DEG) and improves significantly the electron mobility. However, the mechanisms underlying the extreme mobility enhancement remain elusive. Herein, we used $^{18}$O isotope exchanged SrTi$_{18}$O$_3$ as substrates to create 2DEG at room temperature with and without the LSMO buffer layer. By mapping the oxygen profile across the interface between STO$_{18}$ and disordered LaAlO$_3$ or yttria-stabilized zirconia (YSZ), we provide unambiguous evidence that redox reactions occur at oxide interfaces even grown at room temperature. Moreover, the manganite buffer layer not only suppresses the carrier density but also strongly suppresses the oxygen exchange dynamics of the STO substrate, which likely prevents the reduction of STO during the formation of the 2DEG. The underlying mechanism on the enhanced electron mobility at buffered oxide interfaces is also discussed.
Suppressed carrier density for the patterned high mobility two-dimensional electron gas at $\gamma$-Al$_2$O$_3$/SrTiO$_3$ heterointerfaces

The two-dimensional electron gas (2DEG) at the non-isostructural interface between spinel $\gamma$-Al$_2$O$_3$ and perovskite SrTiO$_3$ 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 $\gamma$-Al$_2$O$_3$/SrTiO$_3$ interface grown at 650 °C by pulsed laser deposition using a hard mask of LaMnO$_3$. The patterned 2DEG exhibits a critical thickness of 2 unit cells $\gamma$-Al$_2$O$_3$ for the occurrence of interface conductivity, similar to the unpatterned sample. However, its maximum carrier density is found to be approximately $3\times10^{13}$ cm$^{-2}$, much lower than that of the unpatterned sample ($\sim10^{15}$ cm$^{-2}$). Remarkably, a high electron mobility of approximately 3,600 cm$^2$V$^{-1}$s$^{-1}$ was obtained at low temperatures for the patterned 2DEG at a carrier density of $\sim7\times10^{12}$ cm$^{-2}$, which exhibits clear Shubnikov-de Hass quantum oscillations. The patterned high-mobility 2DEG at the $\gamma$-Al$_2$O$_3$/SrTiO$_3$ 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 LaAlO$_3$/SrTiO$_3$ 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 $T_c$ 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 LaAlO$_3$ and SrTiO$_3$. Here, we present a detailed study of the excitation spectrum and transport processes of a gate-defined LaAlO$_3$/SrTiO$_3$ 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.

General information

State: Published
Organisations: Electrofunctional materials, Department of Energy Conversion and Storage, University of Copenhagen
Number of pages: 7
Publication date: 2017
Peer-reviewed: Yes

Publication information

Journal: Nature Communications
Volume: 8
Issue number: 1
Article number: 395
ISSN (Print): 2041-1723
Ratings:
BFI (2018): BFI-level 2
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
Web of Science (2016): Impact factor 12.124
Web of Science (2016): Indexed yes
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
Tuning the ground state of polar LaAlO3/SrTiO3 interface by an electron sink

Most of the intriguing properties of two-dimensional electron gases (2DEGs) at the LaAlO3/SrTiO3 (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 LaMnO3 (LMO) as buffer layers [1], we show that Mn doping in LaAlO3 (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 $2.76 \times 10^{13} \text{ cm}^{-2}$ at 2K. Significantly, the peak value (255.7 mK) 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.

General information
State: Published
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.
Number of pages: 1
Pages: 72
Publication date: 2017

Tuning the two-dimensional electron liquid at oxide interfaces by buffer-layer-engineered redox reactions

Polar discontinuities and redox reactions provide alternative paths to create two-dimensional electron liquids (2DELs) at oxide interfaces. Herein, we report high mobility 2DELs at interfaces involving SrTiO3 (STO) achieved using polar La$_{7/8}$Sr$_{1/8}$MnO$_3$ (LSMO) buffer layers to manipulate both polarities and redox reactions from disordered overlayers grown at room temperature. Using resonant x-ray reflectometry experiments, we quantify redox reactions from oxide overlayers on STO as well as polarity induced electronic reconstruction at epitaxial LSMO/STO interfaces. The analysis reveals how these effects can be combined in a STO/LSMO/disordered film trilayer system to yield high mobility modulation doped 2DELs, where the buffer layer undergoes a partial transformation from perovskite to brownmillerite structure. This uncovered interplay between polar discontinuities and redox reactions via buffer layers provides a new approach for the design of functional oxide interfaces.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of British Columbia, Canadian Light Source
Contributors: Chen, Y., Green, R. J., Sutarto, R., He, F., Linderoth, S., Sawatzky, G. A., Pryds, N.
Pages: 7062–7066
Publication date: 2017
Peer-reviewed: Yes
Two-Dimensional Electron Gases at Modulation-doped Oxide Interfaces

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Technical University of Denmark
Contributors: Chen, Y., Gan, Y., Christensen, D. V., von Soosten, M., Zhang, Y., Niu, W., Pryds, N.
Number of pages: 1
Publication date: 2017
Peer-reviewed: No
Event: Abstract from 3rd Functional Oxide Thin Films for Advanced Energy and Information Technology Conference, Rome, Italy.
Electronic versions:
abstract_Yunzhong_Modulation_doped_2DEG.pdf
Source: PublicationPreSubmission
Source-ID: 140346906
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2017

Universality of electron mobility in LaAlO$_3$/SrTiO$_3$ and bulk SrTiO$_3$
Metallic LaAlO$_3$/SrTiO$_3$ (LAO/STO) interfaces attract enormous attention, but the relationship between the electron mobility and the sheet electron density, $n_s$, is poorly understood. Here, we derive a simple expression for the three-dimensional electron density near the interface, $n_{3D}$, as a function of $n_s$ and find that the mobility for LAO/STO-based interfaces depends on $n_{3D}$ in the same way as it does for bulk doped STO. It is known that undoped bulk STO is strongly compensated with $N \approx 5 \times 10^{18} \text{ cm}^{-3}$ background donors and acceptors. In intentionally doped bulk STO with a concentration of electrons $n_{3D} < N$, background impurities determine the electron scattering. Thus, when $n_{3D} < N$, it is natural to see in LAO/STO the same mobility as in the bulk. On the other hand, in the bulk samples with $n_{3D} > N$, the mobility collapses because scattering happens on $n_{3D}$ 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.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Minnesota, Massachusetts Institute of Technology
Contributors: Trier, F., Reich, K. V., Christensen, D. V., Zhang, Y., Tuller, H. L., Chen, Y., Shklovskii, B. I., Pryds, N.
A high mobility two-dimensional electron gas at the CaZrO$_3$/SrTiO$_3$ heterointerface

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Chen, Y., Trier, F., Christensen, D. V., Linderoth, S., Pryds, N.
Number of pages: 1
Publication date: 2016
Peer-reviewed: Yes
Event: Abstract from TO-BE Spring Meeting 2016, Warwick, United Kingdom.
Electronic versions: A_high_mobility.pdf
Source: PublicationPreSubmission
Source-ID: 127745436
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Effects of spark plasma sintering conditions on the anisotropic thermoelectric properties of bismuth antimony telluride
Bismuth antimony telluride (Bi$_x$Sb$_{2-x}$Te$_3$, 0.4 <x<0.6) is one of the best and most-used p-type semiconductor materials for near-room-temperature thermoelectric power generation. In this work, p-type Bi$_{0.4}$Sb$_{1.6}$Te$_3$ samples were prepared under various conditions (temperature, holding time, and ramp-rate) using spark plasma sintering (SPS). The effects of SPS conditions on the anisotropic thermoelectric properties and microstructure evolutions were systematically investigated. The change of sintering temperature showed stronger influence than other sintering parameters to the resulting thermoelectric properties. Samples sintered over the temperature range between 653 K and 773 K showed significant differences in the degrees of orientations. The change was mainly caused by grain growth and re-orientation. Despite of the anisotropy, zT value as high as 1.2 to 1.3 was achieved over the temperature range of 300 to 360 K by directly using commercial power sintered at 723 and 773 K. The sintering profiles and microstructure evolutions during SPS were illustrated and the thermoelectric properties as a function of the degree of orientations were shown and discussed in detail.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Department of Wind Energy, Materials science and characterization, Technical University of Denmark, Fraunhofer Institute for Material and Beam Technology
Contributors: Han, L., Hegelund Spangsdorf, S., Van Nong, N., Le, T. H., Zhang, Y., Pham, H. N., Chen, Y., Roch, A., Stepień, L., Pryds, N.
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 γ-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.
Evidence for lattice-polarization-enhanced field effects at the SrTiO$_3$-based heterointerface

Electrostatic gating provides a powerful approach to tune the conductivity of the two-dimensionalelectron liquid between two insulating oxides. For the LaAlO$_3$/SrTiO$_3$ (LAO/STO) interface, suchgating effect could be further enhanced by a strong lattice polarization of STO caused by simultaneousapplication of gate field and illumination light. Herein, by monitoring the discharging process uponremoving the gate field, we give firm evidence for the occurrence of this lattice polarization at theamorphous-LaAlO$_3$/SrTiO$_3$ interface. Moreover, we find that the lattice polarization is accompaniedwith a large expansion of the out-of-plane lattice of STO. Photo excitation affects the polarizationprocess by accelerating thefield-induced lattice expansion. The present work demonstrates the greatpotential of combined stimuli in exploringemergent phenomenon at complex oxide interfaces.
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.

**General information**

State: Published  
Organisations: Electrofunctional materials, Department of Energy Conversion and Storage, University of Copenhagen  
Number of pages: 5  
Publication date: 2016  
Peer-reviewed: Yes

**Publication information**

Journal: Physical Review B  
Volume: 93  
Issue number: 18  
Article number: 184504  
ISSN (Print): 2469-9950  
Ratings:  
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  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 2.892 SNIP 1.588  
Web of Science (2007): Indexed yes
Infrared ellipsometry study of the confined electrons in a high-mobility γ-Al2O3/SrTiO3 heterostructure
With infrared ellipsometry we studied the response of the confined electrons in γ-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, \( N_s \), the mobility, \( \mu \), and the depth profile of the carrier concentration. Notably, we find that \( N_s \) 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.
New Insights into the Creation of High-Mobility Two-Dimensional Electron Gas at Oxide Interfaces: Control of Interfacial Redox Reactions by an Electron Sink

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.
Quantum and field effects of oxide heterostructures

The interface between two materials can show radically different properties than either of the bulk parent materials. This is not the least true for oxide interfaces, which can display multiple physical functionalities thus making them ideal for the realisation of so-called multi-plexed devices. In these multi-plexed devices, several inputs are translated into several outputs through the multiple physical functionalities. A highly prominent example of such an oxide interface is the one between LaAlO$_3$ and SrTiO$_3$. Although both LaAlO$_3$ and SrTiO$_3$ in the bulk are electrically insulating and non-magnetic, their interface nonetheless shows attractive properties such as metallic conductivity, superconductivity and ferromagnetism. This thesis will provide an extensive review of the literature concerning the interface metal found in LaAlO$_3$/SrTiO$_3$ as well as in other SrTiO$_3$-based heterostructures. Through this review, several open questions will be revealed, which constitute the scientific aims of this thesis. These open questions will subsequently be addressed through the work presented in the articles that were published during the course of this Ph.D. study. In the review of these published articles, the important aspects of sample preparation will initially be covered. Here, the growth of amorphous-LaAlO$_3$ on SrTiO$_3$ will be addressed in a modified pulsed laser deposition setup. This is followed by an investigation of two high-electron mobility interfaces in SrTiO$_3$-based heterostructures. Specifically, these interfaces are the ones between CaZrO$_3$/SrTiO$_3$ and amorphous-LaAlO$_3$/SrTiO$_3$. The sample preparation section is ended by outlining a patterning strategy for the high-electron mobility interface at amorphous-LaAlO$_3$/SrTiO$_3$ . For γ-Al$_2$O$_3$/SrTiO$_3$ it is shown that non-volatile bipolar resistance switching is possible with a gradual tuning of the interface conductivity. Finally, the so-called quantum Hall effect is demonstrated at the interface between amorphous-LaAlO$_3$/SrTiO$_3$. The manifestation of the quantum Hall effect reveals that the interface conductivity is comprised of several subbands conducting in parallel. An outlook will be provided at the end of the thesis judging the research as well as development of oxide electronics and multi-plexed devices.

General information

State: Published
Organisations: Electrofunctional materials, Department of Energy Conversion and Storage, University of Copenhagen
Contributors: Trier, F., Pryds, N., Chen, Y., Sand Jespersen, T.
Number of pages: 175
Publication date: 2016

Publication information

Place of publication: Roskilde
Publisher: Department of Energy Conversion and Storage, Technical University of Denmark
ISBN (Print): 978-87-92986-50-4
Original language: English

Band bending and alignment at the spinel/perovskite γ-Al$_2$O$_3$/SrTiO$_3$ heterointerface

We present a comprehensive study of the band bending and alignment at the interface of γ-Al$_2$O$_3$/SrTiO$_3$ heterostructures by hard x-ray photoelectron spectroscopy. Our measurements find no signs for a potential gradient within the polar γ-Al$_2$O$_3$ film as predicted by the basic electronic reconstruction scenario. We present evidence for a band bending on the SrTiO$_3$ side of the interface, yielding a roughly 600 meV deep potential trough, which reaches below the chemical potential and has a spatial expansion of 3–5 unit cells. The band offset between the bulk valence bands is determined to be also approximately 600 meV, corresponding to aligned bands at the interface. Finally, the spatial confinement of the interfacial two-dimensional electron system is derived from the chemically shifted Ti$^{3+}$ photoemission signal in the Ti 2p core level spectra, measured at various photoelectron detection angles. It is found to be in excellent agreement with the spatial depth of the potential trough.

General information

State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Universität Würzburg, Helmholtz–Zentrum Berlin für Materialien und Energie
Contributors: Schütz, P., Pfaff, F., Scheiderer, P., Chen, Y., Pryds, N., Gorgoi, M., Sing, M., Claessen, R.
Number of pages: 9
Publication date: 2015
Peer-reviewed: Yes

Publication information

Journal: Physical Review B Condensed Matter
Volume: 91
Issue number: 16
Article number: 165118
ISSN (Print): 0163-1829
Ratings:

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
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
Scopus rating (1999): SJR 2.789 SNIP 1.541

Original language: English
Electronic versions:
Charge Transfer Induced Modulation Doping at Oxide Interfaces

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Chen, Y.
Number of pages: 1
Publication date: 2015
Peer-reviewed: Yes
Event: Abstract from Rare earth-transitional metal oxides and compounds for environment-friendly energy science and technology, Beijing, China.

Electronic versions:
Charge_Transfer.pdf

Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2015

Charge transfer induced modulation doping of two-dimensional electron gas at complex oxide interfaces

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Chen, Y., Trier, F., Christensen, D. V., Linderoth, S., Pryds, N.
Number of pages: 1
Publication date: 2015
Peer-reviewed: Yes
Event: Abstract from TO-BE Spring Meeting 2015, Aveiro, Portugal.

Electronic versions:
Charge_transfer_induced_modulation.pdf

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
Pages: 1849–1854
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Nano Letters
Volume: 15
Issue number: 3
ISSN (Print): 1530-6984
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
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
Keywords: Complex oxide interfaces, Oxide electronics, Two-dimensional electron gases, Strain induced polarization
DOIs: 10.1021/nl504622w
Source: PublicationPreSubmission
Source-ID: 106061384
Research output: Research - peer-review > Journal article – Annual report year: 2015
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 La$_{1-x}$Sr$_x$MnO$_3$ (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.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Department of Physics, University of Twente, University of British Columbia, University of Antwerp, University of Saskatchewan, Weizmann Institute of Science, University of Copenhagen
Pages: 801-806
Publication date: 2015
Peer-reviewed: Yes
Early online date: 1 Jun 2015

Publication information
Journal: Nature Materials
Volume: 14
Issue number: 8
ISSN (Print): 1476-1122
Ratings:
BFI (2018): BFI-level 3
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 25.47 SJR 18.263 SNIP 8.977
Web of Science (2017): Impact factor 39.235
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 23.67 SJR 18.013 SNIP 9.04
Web of Science (2016): Impact factor 39.737
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Web of Science (2015): Impact factor 38.891
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 23.23 SJR 14.956 SNIP 8.905
Web of Science (2014): Impact factor 36.503
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 23.3 SJR 16.726 SNIP 9.171
Web of Science (2013): Impact factor 36.425
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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
Number of pages: 2
Publication date: 2015
Peer-reviewed: Yes
Event: Abstract from 22nd International Workshop on Oxide Electronics, Paris, France.
Electronic versions:
Extreme_mobility_enhancement.pdf
DOIs: 10.1038/nmat4303
Source: PublicationPreSubmission
Source-ID: 108165813
Research output: Research - peer-review › Journal article – Annual report year: 2015

Extreme mobility enhancement of two-dimensional electron gases at oxide interfaces via charge transfer induced modulation doping
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
Number of pages: 1
Publication date: 2015
Peer-reviewed: No
Event: Poster session presented at E-MRS 2015 Fall meeting, Warsaw, Poland.
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
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Copenhagen
Number of pages: 4
Publication date: 2015
Peer-reviewed: Yes

Publication information
Volume: 107
Article number: 191604
ISSN (Print): 0003-6951
Ratings:
BFI (2018): BFI-level 2
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
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
Source-ID: 103565761
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
Peer-reviewed: Yes
Event: Poster session presented at 1st Scientific Meeting of the TOBE Action, Rome, Italy.
Electronic versions:
Room_Temperature_Epitaxial_Growth.pdf
Source: PublicationPreSubmission
Source-ID: 103565846
Research output: Research - peer-review » Poster – Annual report year: 2014

Room temperature formation of high-mobility two-dimensional electron gases at crystalline complex oxide interfaces
Well-controlled sub-unit-cell layer-by-layer epitaxial growth of spinel alumina is achieved at room temperature on a TiO2-terminated SrTiO3 single-crystalline substrate. By tailoring the interface redox reaction, 2D electron gases with mobilities exceeding 3000 cm 2 V−1 s−1 are achieved at this novel oxide interface.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Center for Electron Nanoscopy, Chinese Academy of Sciences, University of Copenhagen
Contributors: Chen, Y., Bovet, N., Kasama, T., Gao, W., Yazdi, S., Ma, C., Pryds, N., Linderoth, S.
Pages: 1462–1467
Publication date: 2014
Peer-reviewed: Yes

Publication information
Journal: Advanced Materials
Volume: 26
Issue number: 9
ISSN (Print): 0935-9648
Ratings:
BFI (2018): BFI-level 3
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 21.1
Web of Science (2017): Impact factor 2.227
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Transport Properties of the $\gamma$-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.
Visible-light-enhanced gating effect at the LaAlO$_3$/SrTiO$_3$ interface

Electrostatic gating field and light illumination are two widely used stimuli for semiconductor devices. Via capacitive effect, a gate field modifies the carrier density of the devices, while illumination generates extra carriers by exciting trapped electrons. Here we report an unusual illumination-enhanced gating effect in a two-dimensional electron gas at the LaAlO$_3$/SrTiO$_3$ interface, which has been the focus of emergent phenomena exploration. We found that light illumination decreases, rather than increases, the carrier density of the gas when the interface is negatively gated through the SrTiO$_3$ layer, and the density drop can be 20 times as large as that caused by the conventional capacitive effect. This effect is further found to stem from an illumination-accelerated interface polarization, an originally extremely slow process. This unusual effect provides a promising controlling of the correlated oxide electronics in which a much larger gating capacity is demanding due to their intrinsic larger carrier density.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Chinese Academy of Sciences, Stanford University
Number of pages: 17
Publication date: 2014
Peer-reviewed: Yes

Publication information
Journal: Nature Communications
Volume: 5
Article number: 5554
ISSN (Print): 2041-1723
Ratings:
BFI (2018): BFI-level 2
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
Web of Science (2016): Impact factor 12.124
Web of Science (2016): Indexed yes
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
A high-mobility two-dimensional electron gas at the spinel/perovskite interface of γ-Al₂O₃/SrTiO₃

The discovery of two-dimensional electron gases at the heterointerface between two insulating perovskite-type oxides, such as LaAlO₃ and SrTiO₃, 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 cm²V⁻¹ s⁻¹ (at low temperatures). Here we create a new type of two-dimensional electron gas at the heterointerface between SrTiO₃ and a spinel γ-Al₂O₃ 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.
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
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
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
Research output: Research - peer-review » Poster – Annual report year: 2013
A high-mobility two-dimensional electron gas at the spinel/perovskite interface of $\gamma$-Al$_2$O$_3$/SrTiO$_3$ grown by pulsed laser deposition

A Two-Dimensional Electron Gas at the Spinel/Perovskite Interface of $\gamma$-Al$_2$O$_3$/SrTiO$_3$ with Carrier Mobility Exceeding 100,000 cm$^2$V$^{-1}$s$^{-1}$

Controlling interfacial states in amorphous/crystalline LaAlO$_3$/SrTiO$_3$ heterostructures by electric fields
Controlling the conductivity of amorphous LaAlO3/SrTiO3 interfaces by in-situ application of an electric field during fabrication

Amorphous-LaAlO3/SrTiO3 interfaces present metallic conductivity similar to those found in their all-crystalline counterparts. Here, the conductivity of amorphous-LaAlO3/SrTiO3 interfaces is modified by an external electric field applied in-situ with a biased truncated cone electrode (−10 V ≤ Vbias ≤ 20 V) during film growth. By modulating the charge balance of the arriving plasma species, interfacial conduction of the amorphous-LaAlO3/SrTiO3 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 SrTiO3 surface, which alters the amount of near-interface oxygen vacancies being formed at the SrTiO3 surface.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, University of Naples Federico II
Number of pages: 6
Pages: 031607
Publication date: 2013
Peer-reviewed: Yes

Publication information
Volume: 103
Issue number: 3
ISSN (Print): 0003-6951
Ratings:
BFI (2018): BFI-level 2
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
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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Our recent experimental work on metallic and insulating interfaces controlled by interfacial redox reactions in SrTiO3-based heterostructures is reviewed along with a more general background of two-dimensional electron gas (2DEG) at oxide interfaces. Due to the presence of oxygen vacancies at the SrTiO3 surface, metallic conduction can be created at room temperature in perovskite-type interfaces when the overlayer oxide ABO3 has Al, Ti, Zr, or Hf elements at the B sites. Furthermore, relying on interface-stabilized oxygen vacancies, we have created a new type of 2DEG at the heterointerface between SrTiO3 and a spinel g-Al2O3 epitaxial film with compatible oxygen ion sublattices. This 2DEG exhibits an electron mobility exceeding 100 000 cm²·V⁻¹·s⁻¹, more than one order of magnitude higher than that of hitherto investigated perovskite-type interfaces. Our findings pave a way for the design of high-mobility all-oxide electronic devices and open a route toward the studies of mesoscopic physics with complex oxides.
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., Linderoth, S., Pryds, N.
Number of pages: 1
Pages: 77
Publication date: 2013
Two-dimensional electron gases in SrTiO₃-based complex oxide heterostructures 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., Pryds, N.
Number of pages: 1
Publication date: 2013
Peer-reviewed: Yes
Event: Abstract from EMN West meeting, Energy materials Nanotechnology, Houston, TX, United States.
Electronic versions:
EMN_abstract_Yunzhong_Chen.pdf
Source: dtu
Source-ID: u::8985
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2013

Atomically engineered oxide heterointerfaces: new opportunities for nanoionics and nanoelectronics

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials
Contributors: Chen, Y., Pryds, N.
Pages: 63-64
Publication date: 2012

Extraordinary high conductivity in SrTiO₃-based oxide heterostructures due to interfacial redox reactions

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Electrofunctional materials, Management
Contributors: Chen, Y., Christensen, D., Trier, F., Pryds, N., Linderoth, S.
Publication date: 2012
Peer-reviewed: No
Source: dtu
Source-ID: u::6409
Research output: Research › Poster – Annual report year: 2012

Extraordinary high conductivity in SrTiO₃-based oxide heterostructures due to interfacial redox reactions
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.
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

The creation of two-dimensional electron gases in SrTiO3-based complex oxide heterostructures by interface redox reactions
Anisotropic transport behavior of orbital-ordered Nd$_{0.48}$Sr$_{0.52}$MnO$_3$ films

Anisotropic magnetoresistance (AMR) and Hall effect have been studied for the (110)-oriented Nd$_{0.48}$Sr$_{0.52}$MnO$_3$ film. The most remarkable results are the significant enhancement of the AMR accompanying the orbital ordering and the appearance of four-fold symmetry of the AMR along the [1-10] direction. Analysis of the Hall data indicates the absence of any visible increase in spin-orbit coupling corresponding to the AMR growth. This suggests a different mechanism for the AMR of Nd$_{0.48}$Sr$_{0.52}$MnO$_3$ from that of the conventional ferromagnetic metals/alloys. © 2011 American Institute of Physics.
Charge modulated interfacial conductivity in SrTiO3-based oxide heterostructures

When depositing amorphous SrTiO3 (STO) films on crystalline STO substrates by pulsed laser deposition, metallic interfaces are observed, though both materials are band-gap insulators. The interfacial conductivity exhibits strong dependence on oxygen pressure during film growth, which is closely related to the STO plasma expansion in the background gas of oxygen. By controlling the charge balance in the STO plasma with an external bias, V-bias, of -10 V.

General information
State: Published
Pages: 232105 (3 pages)
Publication date: 2011
Peer-reviewed: Yes
Epitaxial growth of atomically flat gadolinia-doped ceria thin films by pulsed laser deposition

Epitaxial growth of Ce$_{0.8}$Gd$_{0.2}$O$_2$(CGO) films on (001) TiO$_2$-terminated SrTiO$_3$ substrates by pulsed laser deposition was investigated using in situ reflective high energy electron diffraction. The initial film growth shows a Stransky–Krastanov growth mode. However, this three-dimensional island formation is replaced by a two-dimensional island nucleation during further deposition, which results in atomically smooth CGO films. The obtained high-quality CGO films may be attractive for the electrolyte of solid-oxide fuel cells operating at low temperature.

General information
State: Published
Contributors: Chen, Y., Pryds, N., Schou, J., Linderoth, S.
Pages: 697-701
Publication date: 2011
Peer-reviewed: Yes

Publication information
Volume: 105
Issue number: 3
ISSN (Print): 0947-8396
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.62 SJR 0.481 SNIP 0.699
Web of Science (2017): Impact factor 1.604
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.52 SJR 0.508 SNIP 0.744
Web of Science (2016): Impact factor 1.455
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.38 SJR 0.519 SNIP 0.768
Web of Science (2015): Impact factor 1.444
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Extraordinarily high conductivity at interfaces of ZrO2:Y2O3/SrTiO3 heterostructures: origin and perspective

General information
State: Published

Extraordinarily high conductivity at interfaces of ZrO2:Y2O3/SrTiO3 heterostructures: origin and perspective

General information
State: Published
Imposed quasi-layer-by-layer homoepitaxial growth of SrTiO3 films by large area pulsed laser deposition

The homoepitaxial growth of SrTiO3 (STO) films was investigated by a large-area pulsed laser deposition (PLD), which was in-situ monitored by a high pressure reflective high energy electron diffraction. By combining a conventionally continuous film deposition with a followed interval relaxation, a persistent layer-by-layer (LBL) film growth of more than 100 unit cells STO films was achieved. This interrupted PLD technique could realize persistent LBL film growth at any laser frequency between 1 and 10 Hz and provides an effective way to fabricate high quality complex oxide films on unit cell scale.
Metallic and insulating interfaces of amorphous SrTiO3-based oxide heterostructures

General information
State: Published
Publication date: 2011

Host publication information
Title of host publication: Abstracts
Electronic versions:
MAMA workshop[1].pdf
Source: orbit
Source-ID: 313815
Research output: Research › Conference abstract in proceedings – Annual report year: 2011
Metallic and Insulating Interfaces of Amorphous SrTiO3-Based Oxide Heterostructures

The conductance confined at the interface of complex oxide heterostructures provides new opportunities to explore nanoelectronic as well as nanoionic devices. Herein we show that metallic interfaces can be realized in SrTiO3-based heterostructures with various insulating overlayers of amorphous LaAlO3, SrTiO3, and yttria-stabilized zirconia films. On the other hand, samples of amorphous La7/8Sr1/8MnO3 films on SrTiO3 substrates remain insulating. The interfacial conductivity results from the formation of oxygen vacancies near the interface, suggesting that the redox reactions on the surface of SrTiO3 substrates play an important role.

General information
State: Published
Pages: 3774-3778
Publication date: 2011
Peer-reviewed: Yes

Publication Information
Journal: Nano Letters
Volume: 11
Issue number: 9
ISSN (Print): 1530-6984
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
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
Electronic transport properties of the charge ordered manganite-based heterojunction

The charge ordered Bi(0.4)Ca(0.4)Sr(0.2)MnO(3) (BCSMO) film has been grown on (011) SrTiO(3): Nb (STON) (0.05 wt%) substrate. The charge ordering (CO) transition is realized at similar to 336 K. The BCSMO/STON heterojunction shows excellent rectifying behavior. Through the capacitance measure of the junction, it is found that the built-in potential of the heterojunction is affected by the CO transition. A upward shift of the built-in potential of the junction appears around the CO transition temperature, which is ascribed to the change of the Fermi level in BCSMO film. (C) 2010 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Chinese Academy of Sciences
Contributors: Liang, S., Sun, J. R., Chen, Y., Lu, W. M., Shen, B. G.
Pages: 609-612
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Solid State Communications
Volume: 150
Issue number: 13-14
ISSN (Print): 0038-1098
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.47 SJR 0.535 SNIP 0.764
Web of Science (2017): Impact factor 1.549
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.42 SJR 0.519 SNIP 0.67
Web of Science (2016): Impact factor 1.554
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.7 SJR 0.718 SNIP 0.826
Web of Science (2015): Impact factor 1.458
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.79 SJR 0.859 SNIP 0.837
Epitaxial growth of atomically flat gadolinia-doped ceria thin films by pulsed laser deposition

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

General information
State: Published
Resistance switching at the interface of LaAlO3/SrTiO3

At the interface of LaAlO3/SrTiO3 with film thickness of 3 unit cells or greater, a reproducible electric-field-induced bipolar resistance switching of the interfacial conduction is observed on nanometer scale by a biased conducting atomic force microscopy under vacuum environment. The switching behavior is suggested to be an intrinsic feature of the SrTiO3 single crystal substrates, which mainly originates from the modulation of oxygen ion transfer in SrTiO3 surface by external electric field in the vicinity of interface, whereas the LaAlO3 film acts as a barrier layer. © 2010 American Institute of Physics

General information
State: Published
Organisations: Thermo Ceramics, Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy, Chinese Academy of Sciences
Contributors: Chen, Y., Zhao, J., Sun, J., Pryds, N., Shen, B.
Pages: 123102
Publication date: 2010
Peer-reviewed: Yes

Publication information
Volume: 97
Issue number: 12
ISSN (Print): 0003-6951
Ratings:
BFI (2018): BFI-level 2
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
The influence of film thickness on photovoltaic effect for the Fe3O4/SrTiO3:Nb heterojunctions

Fe3O4 films with the thickness ranging from 5 to 160 nm have been grown on SrTiO3 : Nb (0.05wt%) substrates by the pulsed laser deposition technique. The good quality of the Fe3O4 film was confirmed by x-ray diffraction and magnetic analyses. It is found that the interfacial barrier of the resultant junctions, determined by the photovoltaic technique, decreases as film thickness increases from similar to 5 to similar to 40 nm, with a relative change of similar to 20%, and saturates at a value of similar to 1.2 eV above the thickness of 40 nm. Variation of lattice strains in the Fe3O4 film may be the reason for the thickness dependence of the interfacial barrier.

General information
State: Published
Organisations: Chinese Academy of Sciences
Contributors: Wei, A. D., Sun, J. R., Chen, Y., Lu, W. M., Shen, B. G.
Number of pages: 5
Publication date: 2010
Peer-reviewed: Yes

Publication information
Volume: 43
Issue number: 20
Article number: 205004
ISSN (Print): 0022-3727
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.38 SJR 0.717 SNIP 1.011
Web of Science (2017): Impact factor 2.373
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.07 SJR 1.135 SNIP 1.122
Web of Science (2016): Impact factor 2.588
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.1 SJR 0.886 SNIP 1.25
Web of Science (2015): Impact factor 2.772
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.53 SJR 1.096 SNIP 1.408
Web of Science (2014): Impact factor 2.721
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.6 SJR 1.194 SNIP 1.452
Web of Science (2013): Impact factor 2.521
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.31 SJR 1.279 SNIP 1.414
Web of Science (2012): Impact factor 2.528
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.36 SJR 1.266 SNIP 1.399
Web of Science (2011): Impact factor 2.544
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.292 SNIP 1.28
Buffer layer-enhanced magnetic field effect in manganite-based heterojunctions

Influence of magnetic field on the rectifying property of the La$_{0.67}$Ca$_{0.33}$MnO$_3$/LaMnO$_3$/SrTiO$_3$ : 0.05 wt.%Nb heterojunctions has been studied. In addition to an enhanced magnetic response of the current-voltage characteristics, a field-induced increase in junction resistance, which is an effect different from that in the junctions without the LaMnO$_3$ layer, is observed. The positive magnetoresistance is further found to show a systematic variation with the thickness of the LaMnO$_3$ layer ($t$), growing rapidly with the increase of layer thickness and getting a maximum of $\sim$91% at $t$=4 nm ($T$=50 K and $\Delta H$=5 T). Analysis of the current-voltage and capacitance-voltage characteristics indicates a field-induced growth of interfacial barrier, which is responsible for the abnormal effect observed here.
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
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.92 SNIP 1.775
Web of Science (2010): Impact factor 3.841
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.826 SNIP 1.834
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.894 SNIP 1.82
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.012 SNIP 1.916
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 3.755 SNIP 2.353
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 3.992 SNIP 2.367
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 3.897 SNIP 2.275
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 4.018 SNIP 2.414
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 4.281 SNIP 2.22
Web of Science (2001): Indexed yes
Buffer layer-induced unusual rectifying behavior in La$_{0.67}$Ca$_{0.33}$MnO$_3$/LaMnO$_3$/SrTiO$_3$:Nb junctions

Rectifying behavior has been studied for the La$_{0.67}$Ca$_{0.33}$MnO$_3$/LaMnO$_3$/SrTiO$_3$:Nb junctions with a LaMnO$_3$ layer between 0 and 12 nm. Different from the single-process behavior in the junction with a thin intermediate layer, the junction buffered by the LaMnO$_3$ layer of 6 or 8 nm shows two distinctive processes with the character of thermionic emission. Based on the analyses of current-voltage characteristics, a spikelike and notchlike band structures in the two sides of the junctions are derived, with respectively, the interfacial barriers of $\sim$0.75 and $\sim$0.57 eV. The complex band structure is believed to be responsible for the two-process feature observed.

General information
State: Published
Organisations: Chinese Academy of Sciences
Contributors: Lu, W. M., Sun, J. R., Chen, Y., Shen, B. G.
Number of pages: 3
Publication date: 2009
Peer-reviewed: Yes
Control of the charge-ordering-insulating phase in epitaxial La$_{1-x}$Ca$_x$MnO$_3$ (x=0.30-0.45) thin films under the anisotropic strain

The control of charge-ordering-insulating (COI) phase in epitaxial La$_{1-x}$Ca$_x$MnO$_3$/NdGaO$_3$ (001) (x=0.30–0.45) thin films with essentially the ferromagnetic metal ground state as observed for the bulk counterparts has been realized via the anisotropic strain relaxation. This epitaxial system is special in that there is a negligible average lattice mismatch but a large anisotropic strain in between the film and the substrate. By changing the film thickness, postannealing temperature, along with the doping level for strain relaxation, the COI phase in the films can be tuned to either melt completely under 1 T, producing a huge low-field magnetoresistance (MR) in a wide temperature range (e.g., for the 20 nm film with x=0.33 and annealed at 780°C, the MR can be over 70% at 0.2 T and 97% at 0.5 T in 10–200 K), or survive under a high magnetic field of 6 T. The results demonstrate the crucial role of anisotropic strain relaxation in inducing the inhomogeneity in manganites films, thus providing a forward understanding of the strain field in manganite physics.
Crossover of angular dependent magnetoresistance with the metal-insulator transition in colossal magnetoresistive manganite films

The temperature and magnetic field dependence of angular dependent magnetoresistance (AMR) along two orthogonal directions (\{100\} and \{01\}) was investigated in a charge-orbital-ordered Sm0.5Ca0.5MnO3 (SCMO) film grown on (011)-oriented SrTiO3 substrates. A dramatic decrease of AMR magnitude in both directions was observed with the appearance of magnetic-field-induced metal-insulator transition, which further led to a sign crossover in the AMR effect. The AMR crossover may give a direct evidence of the drastic modification of electronic structure or possible orbital reconstruction with the magnetic-destruction of charge/orbital ordering in SCMO films. ©2009 American Institute of Physics
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
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.92 SNIP 1.775
Web of Science (2010): Impact factor 3.841
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.826 SNIP 1.834
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.894 SNIP 1.82
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.012 SNIP 1.916
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 3.755 SNIP 2.353
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 3.992 SNIP 2.367
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 3.897 SNIP 2.275
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 4.018 SNIP 2.414
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 4.281 SNIP 2.22
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 4.178 SNIP 2.017
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 4.173 SNIP 2.066

Original language: English
Keywords: Magnetic refrigeration, Fuel Cells and hydrogen
Electronic versions:
Effects of film thickness on manganite film-based heterjunctions

Effects of film thickness on interfacial barrier have been studied for the La$_{0.67}$Ca$_{0.33}$MnO$_3$/SrTiO$_3$: Nb and La$_{0.67}$Sr$_{0.33}$MnO$_3$/SrTiO$_3$: Nb junctions. In addition to the evolution of the transport behavior from electron tunneling to thermionic emission, increase in film thickness from \(\sim 5\) to \(\sim 50\) nm causes a significant growth of interfacial barrier as revealed by photoresponse experiments, and the maximum change in interfacial barrier is \(\sim 13\%\) for La$_{0.67}$Ca$_{0.33}$MnO$_3$/SrTiO$_3$: Nb and \(\sim 45\%\) for La$_{0.67}$Sr$_{0.33}$MnO$_3$/SrTiO$_3$: Nb. A linear relation between interfacial barrier and lattice constant of the films is further found, which suggests the influence of lattice strains on interfacial barrier. Qualitative explanations are given.

General information
State: Published
Organisations: Chinese Academy of Sciences
Contributors: Lu, W. M., Wei, A. D., Sun, J. R., Chen, Y., Shen, B. G.
Number of pages: 3
Publication date: 2009
Peer-reviewed: Yes

Publication information
Volume: 94
Issue number: 8
Article number: 082506
ISSN (Print): 0003-6951
Ratings:
BFI (2018): BFI-level 2
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
We investigated the structure and magnetotransport properties of Sm0.5Ca0.5MnO3 (SCMO) films epitaxially grown on (011)-oriented SrTiO3 substrates, which exhibited clear charge/orbital ordering transition. A significant anisotropy of ~1000 in the colossal magnetoresistance (CMR) effect was observed in the films with a thickness between 50 and 80 nm, which was distinctly different from the basically isotropic CMR effect in bulk SCMO. The large anisotropy in the CMR can be ascribed to the intrinsic asymmetric strain in the film, which plays an important role in tuning the spin–orbit coupling in manganite films. The origin of the peculiar CMR effect is discussed.
Bias-dependent rectifying properties of n-n manganite heterojunctions La_{1-x}Ca_xMnO_3/SrTiO_3 : Nb (x=0.65-1)

The transport property of n-n type manganite heterojunctions, composed of La_{1-x}Ca_xMnO_3 films (x=0.6, 0.75, 0.85, and 1) and 0.05 wt% Nb-doped SrTiO_3, has been experimentally studied. Different from p-n junctions, the rectifying behavior of which is either thermionic emission/diffusion-dominated or tunneling-dominated; the electronic process in the n-n junction undergoes a nonthermal to thermal transition as bias voltage increases, which is a feature emerging when Ca content exceeds x=0.75 and developing with the increase in x. The two processes can be well described by the Shockley equation and the Newman equation, respectively. Possible mechanisms for this phenomenon are discussed.
Charge ordering transition near the interface of La$_{1-x}$Sr$_x$MnO$_3$ (x~1/8) films

Two clear phase transitions, an insulator to metal transition followed by a metal to insulator transition on cooling, were realized in La$_{1-x}$Sr$_x$MnO$_3$ (x~1/8) (LSMO) thin films grown on (011) SrTiO$_3$ substrates due to the substrate-imposed anisotropic strain. Effects of phase transitions on the rectifying behavior of the corresponding junction LSMO/Nb:SrTiO$_3$ were further investigated. The paramagnetic/insulator to ferromagnetic/metal transition led to a decrease in built-in potential of the junction, while the metallic to charge/orbital ordering transition results in a growth of interfacial barrier, which could be explained by Fermi-level shifts and the gap opening/closing in LSMO films. These results indicate the occurrence of clear phase transitions in the vicinity of interface in (011)-LSMO films. © 2008 American Institute of Physics.
Effect of anisotropic strain on the charge ordering transition in manganite films

The substrate induced anisotropic strain was found to have a significant effect on the charge ordering (CO) transition and surface morphology in Bi$_{0.4}$Ca$_{0.6}$MnO$_3$ films deposited on (110)- and (111)-oriented SrTiO$_3$ substrates. Effects of film thickness $t$ on the CO transition were further studied. The CO transition appears at $T_{CO}$ when $t$ exceeds 50 nm, and develops rapidly to an excellent state as $t$ reaches 100 nm. The distinctive thickness-dependent CO transition has a close relation with the anisotropic strain relaxation process. © 2008 American Institute of Physics.
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
Interfacial potential in La$_{1-x}$Ca$_x$MnO$_3$/SrTiO$_3$:Nb junctions with different Ca contents

Manganite-based heterojunctions La$_{1-x}$Ca$_x$MnO$_3$/SrTiO$_3$:Nb (0.05 wt %) with x=0.1, 0.2, 0.33, 0.65, 0.75, and 1 have been fabricated, and the effects of Ca content on the interfacial potential are experimentally studied. Rectifying behavior well described by the Shockley equation is observed, and the interfacial potential ($V_D$) is obtained for all of the junctions based on an analysis of the current-voltage characteristics. The most remarkable result of the present work is the strong dependence of the interfacial potential on the carrier content of La$_{1-x}$Ca$_x$MnO$_3$ films: $V_D$ increases monotonously from $\sim$0.6 to $\sim$1.1 V as x sweeps from 0.1 to 1. Influence on $V_D$ of the Fermi energy and Jahn–Teller effect in La$_{1-x}$Ca$_x$MnO$_3$ films are discussed. © 2008 American Institute of Physics.
The effect of Nd and Co substitution on magnetic entropy changes and hysteresis losses has been investigated for the cubic NaZn13-type LaFe13−xSix compounds. Partially replacing La with Nd leads to a decrease of the Curie temperature $T_C$ and an increase of the magnetic entropy change $\Delta S$. Substitution of Co for Fe in La0.7Nd0.3Fe10.7Si1.5 can adjust $T_C$ to around room temperature. A large $\Delta S$ of 15J/KgK at $T_C=280K$ for a field change from 0 to 5T and a small hysteresis loss close to zero near $T_C$ have been obtained in La0.7Nd0.3Fe10.7Co0.8Si1.5. The Co-doped NaZn13-type LaNdFeSi compounds may be a suitable candidate for magnetic refrigerant near room temperature.
Microstructure and magnetic properties of strained Fe$_3$O$_4$ films

A comparable study of the microstructure and magnetic properties was performed for magnetite films deposited on (100)-oriented MgO and SrTiO$_3$ (STO) substrates. The growth of strained high quality Fe$_3$O$_4$ films was confirmed by x-ray diffraction analysis and Raman spectroscopy measurements. The surface morphology and magnetic properties of the two films were found to be obviously different. Moreover, a stripelike magnetic domain structure was observed in the film on STO. Substrate-induced strain is believed to be responsible for these observations, which significantly affects the magnetic anisotropy and the magnetic coupling at the antiphase boundaries in the films. © 2008 American Institute of Physics.
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
Scopus rating (1999): SJR 1.973 SNIP 1.486

Original language: English
Electronic versions:
Microstructure_and_magnetic_properties.pdf
Pressure effects on the charge ordering in Bi$_{0.4}$Ca$_{0.6}$MnO$_3$ films of different orientation

Effects of hydrostatic pressure on the charge ordering (CO) transition in the Bi$_{0.4}$Ca$_{0.6}$MnO$_3$ films respectively grown on (110) and (111) SrTiO$_3$ substrates have been experimentally studied. X-ray diffraction analysis indicates the occurrence of very differently deformed structures of the two films. Linear decrease of the CO temperature (T$_{CO}$) at different rates, ~12 K/GPa for the (110)-film and ~19 K/GPa for the (111)-film, is observed. Accompanying the depression of T$_{CO}$, partial melting of the charge-ordered phase occurs above a threshold pressure, ~0.8/1.2 GPa for the (111)/(110)-film. Analysis of the relative volume fraction of the CO phase, obtained based on the effective medium theory, shows that the CO collapsing occurs in a wide pressure range, typically ~1.2 GPa in width, and there will be no long-range CO phase above the pressure of ~2/2.3 GPa for the (111)/(110)-film. There is an exact correspondence between the CO melting and the pressure-driven upturn of resistivity above T$_{CO}$, suggesting the simultaneous occurrence of CO melting and shear-type lattice distortion. Different lattice strains are believed to be the reason for the dissimilar behaviors of the two films.

General information
State: Published
Organisations: Chinese Academy of Sciences, University of Science and Technology of China
Number of pages: 6
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Europhysics Letters
Volume: 82
Issue number: 1
Article number: 16002
ISSN (Print): 0295-5075
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
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
Strain-controlled anisotropic electronic transport in Bi$_{0.4}$Ca$_{0.6}$MnO$_3$ films

Structural and resistive anisotropy has been studied for the Bi$_{0.4}$Ca$_{0.6}$MnO$_3$ films grown on (011)-oriented SrTiO$_3$ substrates. Strong anisotropic transport behaviors are observed when significant lattice strains exist. The ratio of the two resistivities along the a and c axes of the films can be tuned between ~1 and ~13 by adjusting the a/c ratio between ~1.01 and ~1.04, which can be conducted simply by decreasing film thickness from 100 to 10 nm. Considerable anisotropy emerges and develops when film thickness drops below ~60 nm. With the decrease in film thickness, a change in preferred growth direction of the films is also observed. These features of the lattice effects could be useful for the design of artificial materials and devices. © 2008 American Institute of Physics.

General information
State: Published
Organisations: Chinese Academy of Sciences
Contributors: Chen, Y., Sun, J. R., Liang, S., Lu, W. M., Shen, B. G.
Number of pages: 4
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Journal of Applied Physics
Volume: 104
Current-processing-induced anisotropic conduction in manganite films

Current-processing–induced anisotropic conduction (CIAC) has been observed recently in La$_{1-x}$Ca$_x$MnO$_3$ (x = 0.2, 0.33) films. Here we report a more applicable and simple method, applying processing current at room temperature, to produce such anisotropic conduction. Using this method, we have examined La$_{1-x}$Ca$_x$MnO$_3$ (x = 0.2, 0.33), La$_{0.67}$Sr$_{0.33}$MnO$_3$, Pr$_{0.7}$Ca$_{0.3}$MnO$_3$, La$_{0.35}$Pr$_{0.32}$Ca$_{0.33}$MnO$_3$ and La$_{0.7}$Ce$_{0.3}$MnO$_3$ films grown on SrTiO$_3$ substrates, and found CIAC in all these films, showing CIAC is a fairly universal phenomenon for manganites. The method exhibits good ability to process samples of large resistance/size. We even got remarkable anisotropic conduction in a manganite film as long as 3 mm. Our effort provides a very simple method to prepare such samples, which will help to further researches in this field.

General information
State: Published
Organisations: Chinese Academy of Sciences
Contributors: Xie, Y. W., Sun, J. R., Wang, D. J., Liang, S., Chen, Y., Lu, W. M., Shen, B. G.
Number of pages: 4
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Europhysics Letters
Volume: 79
Issue number: 2
Article number: 27005
ISSN (Print): 0295-5075
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
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
We experimentally studied the transport properties and magnetoresistance behavior of a La$_{0.7}$Ce$_{0.3}$MnO$_3$/SrTiO$_3$ (doped by 1 wt% Nb) junction. Based on the analyses of the current–voltage relations and the depletion width, we conclude that the dominant transport mechanism of the junction is tunneling. The magnetoresistance of the junction is negative throughout the whole bias voltage range (from −1 V to 0.4 V) and the whole temperature range (below 300 K). It is believed that the magnetic field depresses the junction resistance by reducing the depletion width of the junction.
The electronic transport properties of charge-ordered Bi$_{0.4}$Ca$_{0.6}$MnO$_3$ films grown on a (110) SrTiO$_3$ substrate are experimentally studied. Special attention has been paid to the Hall effect around the charge-ordering (CO) transition. The charge carriers are found to be electron-like, and the carrier density $n$ exhibits a significant change upon the CO transition: it is nearly constant above the transition temperature $T_{\text{CO}}$, $\sim$0.36 electrons/Mn, and reduces with decrease of the temperature below $T_{\text{CO}}$ following the formula $n \propto \exp(-E_H/k_B T)$, with an activation energy $E_H$ of $\sim$0.13 eV. In contrast, no obvious signatures of thermal activation for Hall mobility were observed. Meanwhile, it is revealed that magnetic field affects the resistivity by enhancing the carrier mobility of the film in the course of the CO transition.
Rectifying properties of magnetite-based Schottky diode and the effects of magnetic field

Rectifying properties, with and without magnetic field, of a high quality Fe3O4/SrTiO3:Nb Schottky diode have been experimentally studied. The junction exhibits an excellent rectifying behavior both below and above the Verwey temperature (TV) of Fe3O4. Magnetic field has a weak but visible effect on the transport process of the junction, producing a negative magnetoresistance for T<TV and a positive magnetoresistance for T>TV. Based on an analysis of the current-voltage characteristics, the spin polarization of Fe3O4 has been deduced. It is a strong function of temperature, varying between −78% and 18%. © 2007 American Institute of Physics.

General information
State: Published
Organisations: Chinese Academy of Sciences
Magnetic properties of nanocomposite Pr$_2$(FeCo)$_{14}$B/α-(FeCo) with addition of Sn

Ribbons of nanocomposite Pr$_2$(FeCo)$_{14}$B/α-(FeCo) with an additive of low melting point metals, such as Al, Zn, Sn or In, were prepared by melt spinning. It was found that the remanence could be obviously improved at the expense of coercivity by the addition of Sn. The remanence $J_r$ about 1.30 T and maximum energy product ($BH$)$_{max}$ about 20.5 MG Oe were obtained in Pr$_9$Fe$_{74}$Co$_{12}$B$_5$ doped with 0.5% Sn, while $J_r$ and ($BH$)$_{max}$ in the ribbons without the additive were about 1.17 T and 17.9 MG Oe, respectively. The additive Sn is located at the grain boundaries rather than in grain interior in the ribbons. The obvious improvement of the remanence originates from the refinement of the microstructure and the increase of soft phase content by the addition of Sn. The effect of additive Sn on the coercivity was also discussed. By increasing the content of the magnetically hard phase, the intrinsic coercivity $H_c$ can be elevated. Thus, the optimum magnetic properties, such as $J_r = 1.27$ T, $H_c = 5.7$ kOe and ($BH$)$_{max} = 22.5$ MG Oe, were obtained in Pr$_{9.5}$Fe$_{73.57}$Co$_{11.93}$B$_5$ ribbons doped with 0.5% Sn.

General information
State: Published
Organisations: Chinese Academy of Sciences, Beijing Normal University
Contributors: Chen, Y., He, S. L., Zhang, H., Chen, R., Rong, C. B., Sun, J., Shen, B.
Pages: 605–609
Publication date: 2006
Peer-reviewed: Yes
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.1 SJR 0.886 SNIP 1.25
Web of Science (2015): Impact factor 2.772
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.53 SJR 1.096 SNIP 1.408
Web of Science (2014): Impact factor 2.721
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.6 SJR 1.194 SNIP 1.452
Web of Science (2013): Impact factor 2.521
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.31 SJR 1.279 SNIP 1.414
Web of Science (2012): Impact factor 2.528
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.36 SJR 1.266 SNIP 1.399
Web of Science (2011): Impact factor 2.544
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.292 SNIP 1.28
Web of Science (2010): Impact factor 2.109
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.269 SNIP 1.327
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.427 SNIP 1.549
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.38 SNIP 1.612
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.406 SNIP 1.742
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.216 SNIP 1.455
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.133 SNIP 1.438
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.912 SNIP 1.221
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.033 SNIP 1.233
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.925 SNIP 1.212
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.842 SNIP 1.125
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.89 SNIP 1.264

Original language: English
DOIs:
Magnetization behavior and magnetic viscosity in nanocomposite Pr$_9$Fe$_{74}$Co$_{12}$B$_5$Sn$_x$ (x=0, 0.5) ribbons

Nanocomposite Pr$_9$Fe$_{74}$Co$_{12}$B$_5$ and Pr$_9$Fe$_{74}$Co$_{12}$BSn$_{0.5}$ ribbons were directly prepared by melt-spinning. Measurements of reversible and irreversible magnetization and magnetic viscosity were performed on the ribbons. It is found that the demagnetization curves of the both samples show a single hard phase behavior at room temperature, while a two-phase behavior at low temperature. The sample with Sn addition, because of its more homogeneous microstructure, shows a more obvious two-phase behavior than the Sn free one at low temperature. Furthermore, the increase of the volume fraction and grain sizes of the soft phase, in the Sn-doped ribbons, increases the portions of reversible magnetization and decreases the nucleation field $H_n^*$. The investigation of the magnetic viscosity shows that the activation volume is related to the grain sizes of the soft phase.

General information
State: Published
Organisations: Capital Normal University, Chinese Academy of Sciences
Contributors: Chen, Y., Shu-Li, H., Zhang, H., Ren-Jie, C., Rong, C., Sun, J., Shen, B.
Number of pages: 5
Pages: 5890-5894
Publication date: 2005
Peer-reviewed: Yes

Publication Information
Journal: Chinese Physics B
Volume: 54
Issue number: 12
ISSN (Print): 1674-1056
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 0.8 SJR 0.263 SNIP 0.406
Web of Science (2017): Impact factor 1.321
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.57 SJR 0.339 SNIP 0.526
Web of Science (2016): Impact factor 1.223
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 0.59 SJR 0.411 SNIP 0.678
Web of Science (2015): Impact factor 1.436
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 0.74 SJR 0.495 SNIP 0.872
Web of Science (2014): Impact factor 1.603
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 0.52 SJR 0.399 SNIP 0.781
Web of Science (2013): Impact factor 1.392
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 0.6 SJR 0.312 SNIP 0.577
Web of Science (2012): Impact factor 1.148
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.05 SJR 0.403 SNIP 0.731
Projects:

**Fabrication and electrical properties of correlated electron systems at the interfaces of complex oxides**
Gan, Y., PhD Student, Department of Energy Conversion and Storage
Chen, Y., Main Supervisor, Department of Energy Conversion and Storage
Pryds, N., Supervisor, Department of Energy Conversion and Storage
Institut stipendie (DTU)
01/10/2016 → 30/09/2019
Award relations: Fabrication and electrical properties of correlated electron systems at the interfaces of complex oxides
Project: PhD

**Electrical Properties of Correlated Electron Systems at the Interfaces of Complex Oxides**
von Soosten, M., PhD Student, Department of Energy Conversion and Storage
Pryds, N., Main Supervisor, Department of Energy Conversion and Storage
Chen, Y., Supervisor, Department of Energy Conversion and Storage
Jespersen, T. S., Supervisor
Institut stipendie (DTU)
01/12/2015 → 30/06/2019
Award relations: Electrical Properties of Correlated Electron Systems at the Interfaces of Complex Oxides
Project: PhD

**Studies of doping effects on the superconducting properties of DyBa2Cu2O7-d and its possible manufacture as thin film for power applications**
Opata, Y. A., PhD Student, Department of Energy Conversion and Storage
Grivel, J., Main Supervisor, Department of Energy Conversion and Storage
Yue, Z., Supervisor, Department of Energy Conversion and Storage
Chen, Y., Examiner, Department of Energy Conversion and Storage
Crisan, I. A., Examiner
Obradors, X., Examiner
Science Without Borders, Brasi
01/09/2014 → 18/04/2018
Award relations: Studies of doping effects on the superconducting properties of DyBa2Cu2O7-d and its possible manufacture as thin film for power applications
Project: PhD

**Exploring Electronic Properties in All-oxide Heterostructures**
Christensen, D. V., PhD Student, Department of Energy Conversion and Storage
Pryds, N., Main Supervisor, Department of Energy Conversion and Storage
Chen, Y., Supervisor, Department of Energy Conversion and Storage
Smith, A., Supervisor, Department of Energy Conversion and Storage
Nygård, J., Examiner
Eom, C., Examiner, Department of Energy Conversion and Storage
Granizio, F. M., Examiner
Nygaard, J., Examiner
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Quantum and field effects of oxide heterostructures
Trier, F., PhD Student, Department of Energy Conversion and Storage
Pryds, N., Main Supervisor, Department of Energy Conversion and Storage
Chen, Y., Supervisor, Department of Energy Conversion and Storage
Jespersen, T. S., Supervisor
Thygesen, K. S., Examiner
Gabay, M., Examiner
Granozio, F. M., Examiner
Institut/centerfinansieret
01/03/2013 → 30/09/2016
Award relations: Quantum and field effects of oxide heterostructures
Project: PhD

Rare-earth/transition-metal oxides and compounds for environment-friendly energy science and technology
This network programme is to setup win-win scientific collaborations between the DTU Energy Conversion and the State Key Laboratory of Magnetism (SKLM), Institute of Physics (IOP), Chinese Academy of Sciences (CAS) in Beijing, China. This is expected to improve largely the core competences for both the Danish and the Chinese partners, known for advanced energy conversion technology and excellent fundamental research, respectively.
Chen, Y., Project Participant, Department of Energy Conversion and Storage, Electrofunctional materials
01/01/2015 → 31/12/2015
Keywords: Magnetic Cooling, Oxide Interfaces
Project: Research