

Electronic Materials and Processing

Room: Dona Ana - Session EM+MI-MoA

Semiconducting and Highly Correlated Oxides

Moderator: L.J. Brillson, The Ohio State University

2:00pm **EM+MI-MoA1 Oxide Superconducting Semiconductors, H.Y. Hwang**, University of Tokyo, Japan **INVITED**

SrTiO₃ is the lowest density known bulk superconductor [1]. In addition, it is a dielectric material which is well-known for its very large low-temperature dielectric constant, arising due to the proximity of a ferroelectric instability [2]. With recent advances in complex oxide heteroepitaxy, these physical properties provide a unique opportunity to apply concepts of band structure engineering to this superconducting semiconductor.

At the conducting LaAlO₃/SrTiO₃ interface, the superconducting state can be back-gate modulated to induce a 2D superconductor-insulator transition [3]. Using magnetotransport studies in the normal state, we find that the mobility variation is five times as large as the change in sheet carrier density [4]. These results indicate that the relative disorder strength increases across the superconductor-insulator transition, which can be understood to be driven by localization as in previous examples of ultra-thin quenched amorphous superconductors such as Bi [5].

Using heterostructures of Nb:SrTiO₃ embedded in undoped SrTiO₃, we have studied the crossover from 3D to 2D superconductivity as the thickness of the doped layer is decreased. A notable feature is that the mobility increases in the 2D limit to over 6 times the highest bulk value at comparable doping, in analogy to delta-doping in semiconductors. This aspect suggests that a new regime of 2D superconducting phase transitions can be accessed approaching the clean limit, in contrast to the dirty limit seen at the back-gated LaAlO₃/SrTiO₃ interface [6].

This work was done in collaboration with Y. Kozuka, C. Bell, M. Kim, S. Harashima, Y. Hikita, and B. G. Kim.

[1] J. F. Schooley *et al.*, Phys. Rev. Lett. **12** (1964) 474.

[2] K. A. Mueller and H. Burkard, Phys. Rev. B **19** (1979) 3593.

[3] A. D. Caviglia *et al.*, Nature **456** (2008) 624.

[4] C. Bell *et al.*, Phys. Rev. Lett. **103** (2009) 226802.

[5] A. M. Goldman and N. Markovic, Physics Today **226** (1998) 39.

[6] Y. Kozuka *et al.*, Nature **462** (2009) 487.

3:00pm **EM+MI-MoA4 X-ray Photoemission Spectroscopy of Sr₂FeMoO₆ Film Stoichiometry and Valence State, M.M. Rutkowski, A.J. Hauser, F.Y. Yang, R. Ricciardo, T. Meyer, P.M. Woodward, A. Holcombe, P.A. Morris, L.J. Brillson**, The Ohio State University

We have used a combination of monochromatized X-ray photoemission spectroscopy and Rutherford backscattering spectrometry to determine bulk compound stoichiometry and charge state of Sr₂FeMoO₆ epitaxial films. Complex oxides are an attractive class of materials for the creation of novel electronic devices due to their diverse properties. Sr₂FeMoO₆ (SFMO) is one such material due to the discovery of low field colossal magnetoresistance at room temperature and its half metallic character making it suitable in applications from magnetic read heads and nonvolatile magnetic random access memory to spin injectors in spintronic devices. But in order to create functional devices from such materials, it is necessary to have complete control over the crystal stoichiometry and ordering. Complicating this is that many of these materials, SFMO included, are not point compounds and small changes in stoichiometry can lead to the formation of other material phases which would strongly influence the materials properties.

Using standard samples with known stoichiometries of Fe₂O₃ and SrMoO₃ we were able to obtain sensitivity factors relative to oxygen for Sr, Fe, and Mo. In conjunction with RBS measurements, these sensitivities allowed us to determine sensitivity factors specific to SFMO for measuring stoichiometry. These studies also identify an optimum ion sputtering process for removing surface contaminants and an SrMoO₄ overlayer while avoiding preferential sputtering of film constituents or alteration of their characteristic valence states. For Sr₂FeMoO₆, low energy (500 eV), glancing incidence Ar⁺ sputtering for short (tens of seconds) periods is successful in achieving stoichiometric compositions and characteristic charge states of the film constituents. Furthermore, the adventitious surface carbon content dropped from 10% to less than 2% in the first 15s of sputtering. With longer sputtering times we observed the oxygen content to

fall below its stoichiometric value (60%) and continue to fall with further sputtering indicating the preferential removal of oxygen from the film. We also observed the emergence of a metallic component to the iron and molybdenum valence states after 120s of sputtering indicating damage to the crystal lattice. Thus XPS reveals both a different surface overlayer stoichiometry as well as a 'window' of sputter time that provides bulk stoichiometry. The evolution of composition and valence state with sputtering provides a guide to measure stoichiometry and charge state of SFMO and complex oxide thin films in general.

4:00pm **EM+MI-MoA7 Electronic Structure of Ferrimagnetic Co_{1-x}Fe_{2+x}O₄ Determined by Soft X-ray and Ultraviolet Spectroscopies, J.A. Moyer, C.A.F. Vaz, Yale University, D.A. Arena, Brookhaven National Laboratory, V.E. Henrich, Yale University**

Developing new materials with large spin polarizations, high Curie temperatures and resistivities similar to those of semiconductors would greatly benefit the field of spintronics. Cobalt ferrite (CoFe₂O₄), like its parent compound magnetite (Fe₃O₄), is a promising material for spintronic applications due to its high Curie temperature ($T_c=793$ K) and large predicted spin polarization; however, CoFe₂O₄ is an insulator. Cobalt ferrite becomes an *n*-type conductor when doped with excess iron – Co_{1-x}Fe_{2+x}O₄; the origin of the conduction is electron hopping between Fe²⁺ cations in octahedral sites. The strong localization of electrons on the Fe²⁺ cations in this highly correlated oxide keeps the conductivity in the semiconducting range. In this work, heteroepitaxial Co_{1-x}Fe_{2+x}O₄ thin films have been grown on MgO (100) and MgAl₂O₄ (100) and (110) with *x* ranging from 0 to 0.5. The electronic band structure near the Fermi energy is measured with ultraviolet photoelectron spectroscopy (UPS), and the results are correlated with resistivities determined from transport measurements. This range of doping allows for the resistivity to be tailored over two orders of magnitude. The cation valence states and occupation sites are determined with x-ray photoelectron spectroscopy (XPS) and x-ray absorption spectroscopy (XAS). Bulk magnetic moments are obtained with SQUID magnetometry, while bulk and site specific orbital and spin magnetic moments are obtained using x-ray magnetic circular dichroism (XMCD). The XMCD measurements provide a view of the spin polarization of the Fe²⁺ octahedral cations responsible for conduction. The wide variety of measurements enables us to determine the electronic structure of Co_{1-x}Fe_{2+x}O₄, an important development for the goal of determining the viability of Co_{1-x}Fe_{2+x}O₄ as a spin-polarized source or detector in spintronic devices.

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4:20pm **EM+MI-MoA8 Effects on the Electronic Band Structure of EuO Films upon Gd Doping, J.A. Colón, J. An, K.D. Belashchenko, University of Nebraska - Lincoln, Y.B. Losovyj, Louisiana State University, P. Liu, X.J. Wang, J. Tang, University of Wyoming, P.A. Dowben, University of Nebraska - Lincoln**

High quality films of EuO and Gd doped EuO were successfully grown on Si (100) via pulse laser deposition (PLD). The addition of 4% Gd introduces considerable effects the texture growth direction, although the crystal structure remains intact. This Gd doping also have a strong influence in the electronic structure of these films, in particular the apparent band offsets, making the material appear considerably more *n*-type in combined photoemission and inverse photoemission studies. There are also concomitant changes to the conductivity properties. To further elucidate the influence of Gd doping on the electronic band structure of the EuO films, heterojunction devices were constructed resulting in diodes with very distinct properties a negative differential current that depends on magnetic field.

4:40pm **EM+MI-MoA9 Catalytic Performance for Soot Combustion of Lanthanum-Based Cobalt-Iron Perovskite Materials, L.M. Petkovic, S.N. Rashkeev, Idaho National Laboratory, V. Utgikar, University of Idaho**
Perovskite-type oxide materials with a general formula La_{0.8}A_{0.2}Fe(1-y)Co(y)O(3- δ), where A is Sr or Ba and y=0.4 or 0.5, were prepared and tested in the combustion of carbon black, which can be regarded as a conservative soot model. Maximum combustion rates under temperature programmed combustion conditions were found at temperatures about 150°C lower than blank combustion experiments. A combination of density-functional-theory (DFT) calculations and characterization analyses such as surface area, infrared spectroscopy, X-ray diffraction, and temperature programmed oxidation and reduction were applied to elucidate the main processes that contribute to the activity of these catalysts for soot combustion. The results suggest the importance of the kinetics of oxygen adsorption and reaction at the surface and oxygen migration in the bulk.

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