Tuning the physical properties in strontium iridate heterostructures

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Iridium based transition metal oxides (iridates) were originally anticipated to be governed by paramagnetic metallic ground states because their 5*d* electrons are more spatially extended than in their 3*d* and 4*d* counterparts, resulting in a reduced on-site Coulomb interaction. However, recent studies have revealed novel ground states in these compounds due to the interaction strength of spin-orbit coupling being comparable with both the Coulomb interaction and crystal fields. The comparable energy scales of these fundamental physical interactions results in Sr_2IrO_4, the prototypical material exhibiting such behavior, being an antiferromagnetic insulator (T_N = 240 K)[1,2] with a novel J_{eff} = 1/2 ground state[3]. This discovery has generated enormous interest recently including several theoretical efforts predicting exotic phases of matter in these compounds such as unconventional superconductivity[4] and topologically protected states[5]. Experimental studies on bulk crystals of Sr_2IrO_4 have revealed metallic states by electrochemical substitution[6,7], but the insulating state has proven to be quite robust under hydrostatic pressure as high as 40 GPa[8].

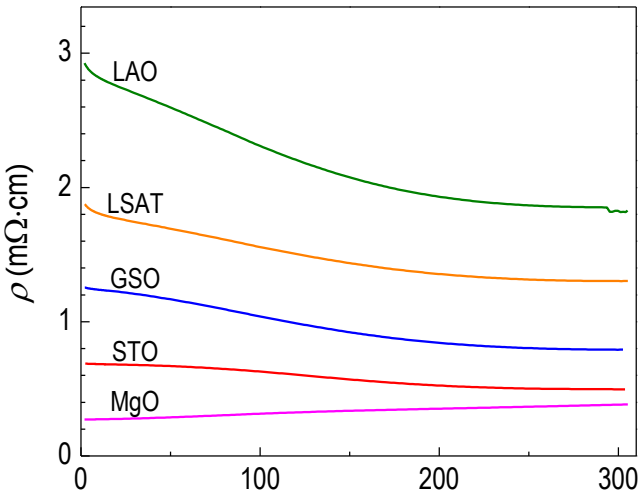

Figure 1 Temperature dependent resistivity of $SrIrO_3$ thin films grown on various substrates.

Thin films and heterostructures of iridates provide a unique playground to tune the physical properties of these materials to exhibit the predicted properties discussed above through strain, electrochemical doping, electron confinement, dimensionality, and interfacial coupling. Since strontium iridate has lattice parameters similar to many commercially available single crystal substrates, samples with various strain states can be realized. It has been shown that increasing strain in Sr_2IrO_4 enhances both the electronic bandwidth and effective correlation energy, maintaining a strain independent gap energy[9], as well as the magnetic ordering temperature[10]. Conversely, increasing strain in $SrIrO_3$ induces a metal-insulator transition (Fig. 1). Although possible to manipulate the physical properties of strontium iridate via epitaxial strain, it appears unlikely that the novel states discussed above will be realized solely through applied strain. However, heterostructuring strontium iridate with other materials creates a new platform for investigating these materials.

We have successfully synthesized thin film heterostructures, $SrIrO_3/AMO_3$ (A = Sr, La; B = Ti, Mn, Rh), that were grown layer-by-layer by a pulsed laser deposition system equipped with reflective high energy electron diffraction. We have investigated the physical properties of these samples with x-ray diffraction, *dc* transport, SQUID magnetometry, and will present that they depend strongly on epitaxial strain and spatial confinement.

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References

[1] G. Cao, J. Bolivar, S. McCall, J. E. Crow, and R. P. Guertin, *Physical Review B* **57,** 11039 (1998).

[2] B. J. Kim, H. Ohsumi, T. Komesu, S. Sakai, T. Morita, H. Takagi, and T. Arima, *Science* **323,** 1329 (2009).

[3] B. J. Kim, H. Jin, S. J. Moon, J. Y. Kim, B. G. Park, C. S. Leem, J. Yu, T. W. Noh, C. Kim, S. J. Oh, J. H. Park, V. Durairaj, G. Cao, and E. Rotenberg, *Physical Review Letters* **101,** 076402 (2008).

[4] F. Wang, and T. Senthil, *Physical Review Letters* **106,** 136402 (2011).

[5] D. Pesin, and L. Balents, *Nature Physics* **6,** 376 (2010).

[6] M. Ge, T. F. Qi, O. B. Korneta, D. E. De Long, P. Schlottmann, W. P. Crummett, and G. Cao, *Physical Review B* **84,** 100402 (2011).

[7] O. B. Korneta, T. Qi, S. Chikara, S. Parkin, L. E. De Long, P. Schlottmann, and G. Cao, *Physical Review B* **82,** 115117 (2010).

[8] D. Haskel, G. Fabbris, M. Zhernenkov, P. P. Kong, C. Q. Jin, G. Cao, and M. van Veenendaal, *Physical Review Letters* **109,** 027204 (2012).

[9] J. Nichols, J. Terzic, E. G. Bittle, O. B. Korneta, L. E. De Long, J. W. Brill, G. Cao, and S. S. A. Seo, *Applied Physics Letters* **102,** 141908 (2013).

[10] A. Lupascu, J. P. Clancy, H. Gretarsson, Z. Nie, J. Nichols, J. Terzic, G. Cao, S. S. A. Seo, Z. Islam, M. H. Upton, J. Kim, D. Casa, T. Gog, A. H. Said, V. M. Katukuri, H. Stoll, L. Hozoi, J. van den Brink, and Y.-J. Kim, *Physical Review Letters* **112,** 147201 (2014).