Stuttgarter Physikalisches Kolloquium

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Tuning the Band Structure of Ruthenates with Strain and Dimensionality

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Abstract

Molecular-beam epitaxy (MBE) is renowned for preparing semiconductor heterostructures with high purity, high mobility, and exquisite control of layer thickness at the atomic-layer level. In recent decades it has become the definitive method for the preparation of oxide quantum materials as well. In this talk I will describe the use of MBE to tune the band structure of ruthenates. Ruthenates with perovskite and perovskite-related structures host a remarkably diverse class of exotic quantum phases ranging from spin-triplet superconductivity, ferromagnetism, metamagnetism, spin-density waves, antiferromagnetism, and quantum criticality – all with the same basic building block of corner-sharing RuO_6 octahedra containing Ru^{4+} ions. Using thermodynamics we identify appropriate conditions for the growth of ruthenate films[1] and then exploit strain engineering and dimensionality to tune the band structure and properties of $SrRuO_3$[1,2] and $BaRuO_3$[3] with the perovskite structure as well as their two-dimensional counterparts Sr_2RuO_4[4,5] and Ba_2RuO_4.[4] The misfit strain is imposed by underlying substrates to strain these ruthenate thin films to percent levels. The band structure is revealed by high-resolution angle-resolved photoemission (ARPES) on pristine as-grown surfaces of these complex oxides made possible by a direct ultra-high vacuum connection between the MBE and ARPES.[6] Our work demonstrates the possibilities for utilizing strain engineering as a disorder-free means to manipulate emergent properties and many-body interactions in correlated materials.

1. H.P. Nair, Y. Liu, J.P. Ruf, N.J. Schreiber, S-L. Shang, D.J. Baek, B.H. Goodge, L.F. Kourkoutis, Z.K. Liu, K.M. Shen, and D.G. Schlom, "Synthesis Science of $SrRuO_3$ and $CaRuO_3$ Epitaxial Films with High Residual Resistivity Ratios," *APL Materials* **6** (2018) 046101.
2. D.E. Shai, C. Adamo, D.W. Shen, C.M. Brooks, J.W. Harter, E.J. Monkman, B. Burganov, D.G. Schlom, and K.M. Shen, "Quasiparticle Mass Enhancement and Temperature Dependence of the Electronic Structure of Ferromagnetic $SrRuO_3$ Thin Films," *Physical Review Letters* **110** (2013) 087004.
3. B. Burganov, H. Paik, J.P.C. Ruff, D.G. Schlom, and K.M. Shen (unpublished).
4. B. Burganov, C. Adamo, A. Mulder, M. Uchida, P.D.C. King, J.W. Harter, D.E. Shai, A.S. Gibbs, A.P. Mackenzie, R. Uecker, M. Bruetzam, M.R. Beasley, C.J. Fennie, D.G. Schlom, and K.M. Shen, "Strain Control of Fermiology and Many-Body Interactions in Two-Dimensional Ruthenates," *Physical Review Letters* **116** (2016) 197003.
5. H.P. Nair, J.P. Ruf, N.J. Schreiber, L. Miao, M.L. Grandon, D.J. Baek, B.H. Goodge, J.P.C. Ruff, L.F. Kourkoutis, K.M. Shen, and D.G. Schlom, "Demystifying the Growth of Superconducting Sr_2RuO_4 Thin Films," *APL Materials* (in press).
6. D.G. Schlom and K.M. Shen, "Oxide MBE and the Path to Creating and Comprehending Artificial Quantum Materials," *Applied Surface Science* (in press).