SYNF 2: Ferroic materials and novel functionalities II

Time: Tuesday 14:30–17:30 Location: A 151

Invited Talk SYNF 2.1 Tue 14:30 A 151

Tunable two-dimensional electron gases in correlated electronic systems — •J. Mannhart[1], G. Hammerl[1], T. Kopp[1], C. Richter[1], C.W. Schneider[1], S. Thiel[1], N. Reyren[2], A.D. Caviglia[2], S. Gariglio[2], D. Jaccard[2], J.-M. Triscone[2], L. Fitting-Kourkoutis[3], D. Muller[3], C. Cheng[4], and J. Levy[4] — [1]Center for Electronic Correlations and Magnetism, Augsburg University, Germany — [2]University of Geneva, Switzerland — [3]Cornell University, USA — [4]University of Pittsburgh, USA

The unique properties of two-dimensional electron gases in semiconductor heterostructures provide the basis for a variety of high-performance devices, such as high electron mobility transistors or quantum well lasers, and for fundamental phenomena, such as the integer and fractional quantum Hall effects. Because standard semiconductors are mean-field systems it is intriguing that recent progress in heterostructure growth of oxides offers now the possibility to fabricate two-dimensional gases of materials with interacting electrons. These electronic correlations shape the properties of the electron gas, which, for example, may develop a ferromagnetic or a superconducting ground state. In field-effect transistor configurations these electron gases can be tuned [1], so that for example switchable, transparent superconductors are obtained [2]. In the presentation I will provide an overview of our experiments with such electron systems.

[1] S. Thiel et al., Science 313, 1942 (2006)
[2] N. Reyren et al., Science 317, 1196 (2007)

Invited Talk SYNF 2.2 Tue 15:00 A 151

New physics from electron correlations at oxide interfaces — •Warren E. Pickett[1] and Rossitza Pentcheva[2] — [1]Department of Physics, University of California, Davis, California 95616, USA — [2]Department of Earth and Environmental Sciences, University of Munich, Theresienstrasse 41, 80333 Munich, Germany

Disruption of periodic order in ionic materials (simplest examples are flat surfaces and abrupt heterointerfaces) often entail "charge mismatch" and polar layers. The strength of Coulomb forces dictates that the mismatch be accommodated within a few atomic distances. A mechanism in which the mismatch can be neutralized within a single atomic layer – strong intra-atomic repulsion resulting in charge order – will be discussed, with examples taken from ab initio calculations of abrutp LAO/STO and LTO/STO (001) heterointerfaces. The properties (conductivity, magnetism) of the interface can be dependent on atomic relaxation and of defects (oxygen vacancies, cation exchange, etc.). The "new materials " aspects of short-period multilayers will also be discussed.

Invited Talk SYNF 2.3 Tue 15:30 A 151

Gigantic magnetoelectic responses in hellimagnets — •Y. Tokura — Department of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan

Multiferroics, the materials in which both (anti)ferromagnetism and ferroelectricity can coexist, are the prospective candidate which can potentially host the gigantic magnetoelectric (ME) effect. A useful hint to designing of the strong magnetoelectric coupling has been gained by the recent discovery of the ferroelectricity in the transverse-spiral magnets, such as perovskite manganites. The multiferroics based on the spin-current (or inverse Dzyaloshinskiy-Moriya interaction) mechanism has recently been realized also in the conical spin state of chromite spinels where the transverse spiral component coexists with the uniform magnetization component along the cone axis. In those compounds, the clamping between the magnetic and ferroelectric domains can show up, perhaps enabling the magnetic (electric) control of the ferroelectric (ferromagnetic) domains. Multiferroics with the strong ME correlation may also provide a unique arena to test new optical effects. This includes the so-called magnetization-induced second harmonic generation (MSHG) and the nonreciprocal dichroism dependent on the light propagation direction (but not on the light polarization), termed the optical magnetoelectric (OME) effect as well as the electrically driven spin excitations like electromagnons. We present the late advances in our study of exploring such hellimagnets (screw, cycloidal, and conical magnets) as showing strong ME coupling and novel optical responses.

Invited Talk SYNF 2.4 Tue 16:00 A 151

Electrical field control of ferromagnets using multiferroics — •Ramamoorthy Ramesh — Dept. of Materials Science and Engineering and Dept. of Physics, University of California, Berkeley, CA 94720

Complex perovskite oxides exhibit a rich spectrum of functional responses, including magnetism, ferroelectricity, highly correlated electron behavior, superconductivity, etc. The basic materials physics of such materials provide the ideal playground for interdisciplinary scientific exploration. Over the past decade we have been exploring the science of such materials (for example, colossal magnetoresistance, ferroelectricity, etc) in thin film form by creating epitaxial heterostructures and nanostructures. Among the large number of materials systems, there exists a small set of materials which exhibit multiple order parameters; these are known as multiferroics. Our goal is to be able to deterministically control the state of a ferromagnet with the application of an electric field, by using heterostructures that include multiferroic perovskites. Our model multiferroic is BiFeO3, which ahs ferroelectric and antiferromagnetic order well about room temperature. Our work so far has shown that the AFM order can be controlled through coupling with the ferroelectricity. The next step is to explore the coupling of a ferromagnet to this antiferromagnet through the exchange biasing concept. Ultimately, this will give us the opportunity to switch the state of a ferromagnet (and therefore the spin polarization direction) by simply applying an electric field to the underlying antiferromagnetic ferroelectric. In this talk, I will describe our progress to date on this exciting possibility.

Invited Talk SYNF 2.5 Tue 16:30 A 151

Spintronics with multiferroic materials — •Agnes Barthelemy — Unite Mixte de Physique CNRS/Thales and Universite Paris-Sud, Route de partementale 128, 91767 Palaiseau, France

Multiferroics are singular materials that can exhibit simultaneously electric and magnetic orders. Some are ferroelectric and ferromagnetic and provide the opportunity to encode information in electric polarization and magnetization to obtain four logic states. However, such materials are rare and schemes allowing a simple electrical readout of these states have not been demonstrated in the same device. Here, we show that films of La0.1Bi0.9MnO3 (LBMO) are ferromagnetic and ferroelectric, and retain both ferroic properties down to a thickness of 2 nm. We have integrated such ultrathin multiferroic films as barriers in spin-filter-type tunnel junctions that exploit the magnetic and ferroelectric degrees of freedom of LBMO.Whereas ferromagnetism permits read operations reminiscent of magnetic random access memories (MRAM), the electrical switching evokes a ferroelectric RAM write operation. Significantly, our device does not require the destructive ferroelectric readout, and therefore represents an advance over the original four-statememory concept based on multiferroics.

Invited Talk SYNF 2.6 Tue 17:00 A 151

Magnetoelectric effects at multiferroic interfaces — •Evgeny Tsymbal — Department of Physics and Astronomy, University of Nebraska, Lincoln, NE 68588, USA

Multiferroic materials have recently attracted significant interest due to the coupling between different order parameters that can lead to new functionalities. One of the promising ways to achieve a strong coupling is to use heterogeneous interfaces, producing lattice strain, chemical bonding, and charge transfer effects, not existing in the bulk phase. For example, magnetoelectric effects may strongly be enhanced at the ferromagnetic/ferroelectric interfaces where the influence of ferroelectric displacements on the interface electronic structure may lead to a change in the magnetic moment and magnetic anisotropy. Ferromagnet/ferroelectric interfaces are also promising for application in ferroelectric tunnel junctions where a thin-film ferroelectric is used as a barrier layer. In these junctions, ferroelectric polarization reversal may lead to a sizable change in the conductance and the spin polarization. This talk will address our recent progress in the theoretical studies of these multiferroic interfaces and tunnel junctions which are interesting for application in multifunctional electronic devices.