# TT 6: Superconductivity: Properties and Electronic Structure

Time: Monday 10:00–13:00 Location: H19

TT 6.1 Mon 10:00 H19

**Superconductivity in intercalated topological insulator $Tl_xBi_2Te_3$** — •Zhiwei Wang[1,2], Alexey A. Taskin[1,2], and Yoichi Ando[1,2] — [1]Institute of Physics II, University of Cologne, D-50937 Cologne, Germany — [2]Institute of Scientic and Industrial Research, Osaka University, Osaka 567-0047, Japan

Bulk superconductivity has been discovered in $Tl_xBi_2Te_3$, which is derived from the topological insulator $Bi_2Te_3$ by intercalating Tl. The superconducting volume fraction of up to 95% (determined from specific heat) with $T_c$ of 2.28 K is obtained for samples with $x = 0.6$, where the carriers are $p$-type with the density of $\sim 1.8 \times 10^{20}$ cm$^{-3}$. The thermodynamic upper critical field $B_{c2}$ obtained from specific heat presents a conventional temperature dependence with the zero-temperature-limit value of 1.06 T; however, resistive transitions under magnetic fields suggests a higher $B_{c2}$, which hints at an unconventional nature of the superconductivity. The temperature dependence of the specific heat in 0 T suggests that the superconducting state is fully gapped. This material is an interesting candidate of a topological superconductor which may be realized by the strong spin-orbit coupling inherent to topological insulators.

TT 6.2 Mon 10:15 H19

**Vortex-bound zero-energy modes in the noncentrosymmetric superconductors** — •Oleksiy Kashuba[1] and Carsten Timm[2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Deutschland — [2]Institut für Theoretische Physik, TU Dresden, 01062 Dresden, Deutschland

Nodal noncentrosymmetric superconductors are known to be the candidate for the realization of the surface-bound zero-energy modes. We investigate whether the similar modes bound to the 1D defects may exist in the superconductors with unconventional pairing. The known example of such modes are the Majorana states in the half-integer vortices in the $p_x + ip_y$-wave superconductor. We showed that there is a precise mapping of the localized cylindrical solutions in the superconductor with arbitrary pairing onto the localized solutions in the superconducting Anderson chain model. We studied different superconductor pairing which depends on the crystal symmetry and found out that in some systems, like ones with cubic symmetry ($Li_2Pd_xPt_{3-x}$, $Mo_3Al_2C$), such states are forbidden, and for other, like ones with tetrahedral symmetry ($Y_2C_3$), the zero-energy states may exist.

TT 6.3 Mon 10:30 H19

**Heat Capacity Measurements of $Sr_2RuO_4$ under uni-axial Strain** — •You-sheng Li[1,2], Alexandra Gibbs[3], Clifford Hicks[1], Andrew Mackenzie[1,2], and Michael Nicklas[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany. — [2]University of St. Andrews, School of Physics and Astronomy, United Kingdom. — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany.

One of the most-discussed possible pairing symmetries of $Sr_2RuO_4$ is $p_x \pm ip_y$. By applying strain along ⟨100⟩-direction, the degeneracy of the $p_x$ and $p_y$ components is lifted, and thus there should be two critical temperatures ($T_c$). Hicks et al. [1] have observed an increase of $T_c$ of $Sr_2RuO_4$ under both compressive and tensile strains, by measuring the susceptibility, which is sensitive only to the first transition. Their results also indicate, indirectly, that any splitting of $T_c$s might be small. For a direct test of possible splitting, we measure the heat capacity of $Sr_2RuO_4$ under strain. To do so, we are developing an approach to measure heat capacity under non-adiabatic conditions. We have observed an increase of $T_c$ under compressive strain. This is the first thermodynamic evidence of the strain-induced increase in $T_c$ of $Sr_2RuO_4$.
[1] C. W. Hicks et al., Science **344**, 283 (2014).

TT 6.4 Mon 10:45 H19

**$Sr_2RuO_4$ at high uniaxial strain** — •Alexander Steppke[1], Lishan Zhao[1,2], Clifford Hicks[1], Daniel Brodsky[1,2], Mark Barber[1,2], Alexandra Gibbs[3], Yoshiteru Maeno[4], and Andrew Mackenzie[1,2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]University of St Andrews, UK — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany — [4]Kyoto University, Japan

We applied high anisotropic strains to high-quality single crystals of the superconductor $Sr_2RuO_4$, to gain information on the influence of anisotropic Fermi surface distortions on its superconductivity. Due to proximity to a van Hove singularity, one of the Fermi surfaces distorts particularly strongly in response to anisotropic strain [1]. The superconducting properties also vary strongly: we show susceptibility and resistivity data indicating that $T_c$ more than doubles as strain is applied, and passes through a sharp peak. Similarly, the upper critical field $H_{c2}$ for fields both parallel and perpendicular to the crystallographic c axis increases substantially. For fields perpendicular to the c axis, there is strongly hysteretic behaviour at low temperatures, that may be due to Pauli limiting.
[1] C. W. Hicks et al., Science **344**, 283 (2014)

TT 6.5 Mon 11:00 H19

**$Cd_2Re_2O_7$: Temperature dependence of the superconducting order parameter and the effect of quasiparticle self-energy** — F. S. Razavi[1], Y. Rohanizadegan[1], M. Hajialamdari[1], M. Reedyk[1], B. Mitrovic[1], and •R. K. Kremer[2] — [1]Department of Physics, Brock University, St. Catharines, ON L2S 3A1, Canada — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany

The temperature dependence and the magnitude of the superconducting order parameter of single crystals of $Cd_2Re_2O_7$ ($T_c = 1.02$ K) were measured using soft point-contact spectroscopy. The order parameter, $\Delta(T)$, increases steeply below the superconducting transition temperature and levels off below $\sim 0.8$ K at a value of 0.22(1) meV, about 40 % larger than the BCS value. Our findings indicate the presence of a strong electron-phonon interaction and an enhanced quasiparticle damping and may be related to a possible phase transition within the superconducting region at $\sim 0.8$ K. In order to fit the conductance spectra and to extract the order parameter at different temperatures we generalized the Blonder-Tinkham-Klapwijk theory by including the self-energy of the quasiparticles into the Bogoliubov equations. This modification enabled excellent fits of the conductance spectra.

**15 min. break**

TT 6.6 Mon 11:30 H19

**Electronic structure determination of $R_3T_4Sn_{13}$** — •Xiaoye Chen[1], HongEn Tan[1], Lina E. Klintberg[1], Swee K. Goh[1,2], Sven Friedemann[1,3], Jinhu Yang[4,5], Bin Chen[4,5], Kazuyoshi Yoshimura[5], David A. Tompsett[1], Wing Chi Yu[2], F. Malte Grosche[1], and Michael Sutherland[1] — [1]University of Cambridge, Cavendish Laboratory, Cambridge, UK — [2]The Chinese University of Hong Kong, Department of Physics, Hong Kong, China — [3]University of Bristol, HH Wills Physics Laboratory, Bristol, UK — [4]Hangzhou Normal University, Department of Physics, Hangzhou, China — [5]Kyoto University, Department of Chemistry, Kyoto, Japan

The quasi-skutterudite superconducting material family $R_3T_4Sn_{13}$ ($R$ = Ca, Sr, $T$ = Ir, Rh) was recently shown to have a composition and pressure induced structural quantum phase transition. The end member material $Sr_3Ir_4Sn_{13}$ at ambient pressure and above T* = 147 K adopts a simple cubic structure (I phase, Pm-3n). Below this temperature, the compound enters the I* phase, thought to result from a superlattice distortion of the I phase with twice the original lattice constant. We compare our quantum oscillation data for $Sr_3Ir_4Sn_{13}$, measured at a wide range of angles, with DFT calculations for the I and I* phases, as well as other proposed possibilities such as merohedral twining domains. We complement this comparison with thermal conductivity measurements of other materials in the family to provide important insights into the nature of the superlattice distortion.

TT 6.7 Mon 11:45 H19

**Correlating properties and microstructure of YBCO thin films by magnetic X-ray microscopy** — •Stephen Ruoss[1], Claudia Stahl[1], Patrick Zahn[1,2], Jonas Bayer[1,2], Markus Weigand[1], Gisela Schütz[1], and Joachim Albrecht[2] — [1]Max-Planck-Institute for Intelligent Systems, Heisenbergstraße 3, 70569 Stuttgart — [2]Research Institute for Innovative Surfaces, FINO, Aalen University, Beethovenstraße 1, 73430 Aalen

The magnetic flux distribution in high-temperature superconductors

namely YBCO has been observed using a novel high-resolution technique based on the X-ray magnetic circular dichroism (XMCD) [1,2]. Therefore, a CoFeB layer is deposited on the superconductor which exhibits a strong XMCD-effect. X-ray absorption measurements with circular polarized radiation allows the analysis of the magnetic flux distribution in the superconductor via the soft-magnetic sensor layer [3,4]. In the total electron yield (TEY) mode of the scanning X-ray microscope (SXM) the surface structure and the magnetic domains can be imaged at the same time. Having obtained such high resolution images, the correlation of magnetic flux penetration and defect structure of YBCO thin films can be analyzed.

*The measurements have been performed at the scanning X-ray microscope MAXYMUS at Bessy II, HZB Berlin.*

[1] S. Ruoß et al., APL **106**, 022601 (2015).
[2] C. Stahl et al., EPL **106**, 27002 (2014).
[3] C. Stahl et al., PRB **90**, 104515 (2014).
[4] C. Stahl et al., J. Appl. Phys. **117**, 17D109 (2015).

TT 6.8 Mon 12:00 H19

**Superconducting properties of $La_{2-x}Ba_2CuO_4$ under pressure** — •Wolf Schottenhamel[1], Markus Hücker[2], Anja Wolter-Giraud[1], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research, IFW Dresden, 01171 Dresden, Germany — [2]Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory, Upton, New York 11973, USA

$La_{2-x}Ba_2CuO_4$ displays an anomalous doping dependence associated with a deep suppression of superconductivity at the hole concentration $x$=1/8. The so-called 1/8-anomaly is accompanied by a structural transition in the average rotational symmetry of the $CuO_2$ planes coinciding with the onset of a charge stripe order [1]. It has been claimed that static stripe order destroys the superconducting phase coherence, while dynamic stripe correlations may promote superconductivity. In order to achieve more information about the relationship between superconductivity, stripe order and crystal structure we performed magnetization measurements under pressure up to 3 GPa on the single crystalline $La_{2-x}Ba_2CuO_4$ with $0.095 \leq x \leq 0.125$. Moreover, we relate the magnetization data to pressure dependent X-Ray diffraction studies. This way, we show that the specific superconducting properties as function of pressure are clearly correlated to structural changes.

[1] M. Hücker *et al.*, PRB **83**, 104506 (2011)

TT 6.9 Mon 12:15 H19

**The collapse of the columnar spatial topology of pseudogap excitations in the underdoped-overdoped transition of cuprate superconductors** — •Jürgen Röhler — Universität zu Köln, 50937 Köln, Germany

The intensity $I_{Q_0}$ of the $Q = 0$ nematic pseudogap excitations in $Bi_2Sr_2CaCu_2O_{8+x}$ was found to increase between $p \geq 0.06$ and 0.14 and to collapse at $p_{opt} = 0.16$, reaching zero at $p = 0.2$ [1]. Evidentally it maps the growth and the collapse of the bulge in the doping dependence of the basal-plane area ($ab$) of $p$-type cuprates [2]. The nematic topology of the pseudogap excitations results from the non-occupancy constraint for $nn$ ZR-holes excluding $1a$ dimerization, but favoring $3a$ pair states with inequivalent $O_{x,y}$ sites. $3a$ pair states have hard core properties [3], yield $d$-type CDW excitations, and inflate the basal-plane area by a columnar topology against covalency-driven contraction. We show that optimal delocalization of ZR-holes at $p_{opt} = 1/6 \simeq 0.17$, tantamount to maximal connectedness of $3a$ pair states, will transform the columnar nematic pattern into isotropic tweedy striations, hence collapses $I_{Q_0}$, and the bulge.

[1] K. Fujita *et al.*, Science **344**, 612 (2015).
[2] J. Röhler, J. Superconductivity **17**, 159 (2004).
[3] J. Röhler, Int. Mod. Phys. **B19**, 255 (2005).

TT 6.10 Mon 12:30 H19

**Trapped field measurements on $MgB_2$ bulk samples** — Michael Koblischka[1], •Thomas Karwoth[1], XianLin Zeng[1], Kévin Berger[2], Bruno Douine[2], and Uwe Hartmann[1] — [1]Institute of Experimental Physics, Saarland University, P. O. Box 151150, D-66041 Saarbrücken, Germany — [2]University of Lorraine, GREEN, 54506 Vandoeuvre-lès-Nancy, France

Trapped field measurements were performed on bulk, polycrystalline $MgB_2$ samples stemming from different sources with the emphasis to develop applications like superconducting permanent magnets ('supermagnets') and electric motors. We describe the setup for the trapped field measurements and the experimental procedure (field cooling, zero-field cooling, field sweep rates). The trapped field measurements were conducted using a cryocooling system to cool the bulk samples to the desired temperatures, and a low-loss cryostat equipped with a room-temperature bore and a maximum field of ±5 T was employed to provide the external magnetic field. The superconducting coil of this cryostat is operated using a bidirectional power supply. Various sweep rates of the external magnetic field ranging between 1 mT/s and 40 mT/s were used to generate the applied field. The measurements were performed with one sample and two samples stacked together. A maximum trapped field of 7 T was recorded. We discuss the results obtained and the problems arising due to flux jumping, which is often seen for the $MgB_2$ samples cooled to temperatures below 10 K.

TT 6.11 Mon 12:45 H19

**High temperature superconductivity and flat bands in graphite: state of the art** — Christian Precker[1], •Pablo Esquinazi[1], Ana Champi[2], Santiago Munoz[1], Jose Barzola-Quiquia[1], Israel Lorite[1], and Winfried Böhlmann[1] — [1]Division of Superconductivity and Magnetism, University of Leipzig, Linnéstraße 5, 04103 Leipzig, Germany — [2]Universidade Federal do ABC, Rua Santa Delia 166, 09210-170, Santo Andre, SP, Brazil

In this experimental work we studied the magneto-transport properties of natural graphite samples from a mine in Brazil. The reason for the study of these samples is the existence of well-defined, large 2D interfaces inside the samples. The observed huge magnetic field driven metal-insulator transition (MIT) is directly related to the existence of internal interfaces. Previous experimental results as well as theoretical work suggest the existence of granular superconductivity at certain interfaces between twisted Bernal stacking ordered regions or between rhombohedral and Bernal regions. We present results that indicate the existence of a transition in the electrical resistance at $T \gtrsim 320$ K. The observed irreversibility in the magnetoresistance at low magnetic fields and other transport details suggest the existence of superconducting paths at such high temperatures.