TT 2: Superconductivity: Sample Preparation, Characterization, Properties and Electronic Structure

Time: Monday 9:30–12:45 Location: HSZ 103

TT 2.1 Mon 9:30 HSZ 103

Magnetic proximity effect in Nb/Gd superlattices seen by neutron reflectometry — •Yury Khaydukov[1,2,3], Evgeny Kravstov[4,5], Vladimir Zhaketov[6], Vyacheslav Progliado[4], Gideok Kim[1], Yury Nikitenko[6], Thomas Keller[1,2], Vladimir Ustinov[4,5], Viktor Aksenov[6], and Bernhard Keimer[1] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart, Germany — [2]Max Planck Society Outstation at the Heinz Maier-Leibnitz Zentrum (MLZ), D-85748 Garching, Germany — [3]Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow 119991, Russia — [4]Institute of Metal Physics, Ekaterinburg 620180, Russia — [5]Ural Federal University, Ekaterinburg 620002, Russia — [6]Joint Institute for Nuclear Research, Dubna 141980, Russia

We used polarized neutron reflectometry to investigate the magnetization profile of superlattices composed of ferromagnetic Gd and superconducting Nb layers [1]. Below the superconducting (S) transition of the Nb layers we observed a partial suppression of ferromagnetic (F) order of Gd layers in $[\mathrm{Gd}(d_F)/\mathrm{Nb}(25\mathrm{nm})]_{12}$ superlattices. The amplitude of the suppression decreases with increasing d_F. By analyzing the neutron data we conclude that the observed effect has an electromagnetic origin - the proximity-coupled S layers screen out the external magnetic field and thus suppress the F response of the Gd layers. Our investigation demonstrates significance of electromagnetic effects, and potential of elemental S/F multilayers as simple model systems for ferromagnetic superconductors.

[1] Khaydukov et al., Phys. Rev. B 99, 140503 (R) (2019)

TT 2.2 Mon 9:45 HSZ 103

Interface effects in magnetic and superconducting heterostructures — •Sebastian Kölsch and Michael Huth — Institute of Physics, Goethe University, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

Niobium-based thin films in combination with non-collinear ferromagnetic layers offer the potential for applications in superconducting spintronics, especially in superconducting spin valves (SSV) [1]. Regarding the interface between these two different layers, a gapless and odd-infrequency superconducting ground state may be stabilized, where the Cooper-pairs remain in a spin-triplett configuration.

Considering potential applications, a reduction of complexity in terms of a single magnetic layer in SVVs is mandatory. In this case the binary compounds of manganese-silicon appear as an ideal partner due to their rich magnetic phase diagram [2]. Here we present recent results on the successful growth of manganese-silicon thin films on a superconducting niobium layer.

[1] N.G. Pugachet al. Appl. Phys. Lett. 111, 162601 (2017)
[2] I. I. Lobanova et al. Scientific Reports 6, 22101 (2016)

TT 2.3 Mon 10:00 HSZ 103

Investigating the proximity effects in chiral molecules on conventional superconductors — Hen Alpern[1], •Roman Hartmann[2], Nir Sukenik[1], Shira Yochelis[1], Itai Keren[1], Hadar Steinberg[1], Zaher Salman[3], Elke Scheer[2], Yossi Paltiel[1], Oded Milo[1], and Angelo Di Bernardo[2] — [1]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel — [2]Fachbereich Physik, Universität Konstanz, 78464 Konstanz, Germany — [3]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland

Superconducting spintronics is emerging as an alternative technology that can overcome the main limitations of conventional spintronic devices related to their high current dissipations. It has developed after the recent discovery that Cooper pairs with parallel-aligned spins (spin-triplets) can be generated at the interface between a conventional superconductor (S) and a magnetically inhomogeneous ferromagnet (F). More recently, by performing low-temperature STM measurements of the density of states of chiral molecules (ChMs) adsorbed on the surface of a Nb (S) thin film, we have observed subgap features due to spin-triplet states in such system, without an F layer. Based on these results, we have carried out low-energy muon spectroscopy on ChMs/Nb demonstrating evidence for an inverse (paramagnetic) Meissner state meaning an increase in the local field above the applied field in the superconducting state, with an amplitude variation depending on the Nb thickness. This provides spectroscopic evidence for spin-triplet pairing in ChMs/Nb and paves the way for novel superconducting devices.

TT 2.4 Mon 10:15 HSZ 103

STM and STS studies of superconducting 1T-TaSeS — •Marion A. van Midden[1], Yaroslav Gerasimenko[1,2], Petra Šutar[1], Erik Zupanič[1], and Dragan Mihailovic[1,2] — [1]Jožef Stefan Institute, Ljubljana, Slovenia — [2]Center of Excellence in Nanoscience and Nanotechnology, Ljubljana, Slovenia

In 1T-TaS_2, similarly to many high-temperature superconductors, superconductivity, charge density waves (CDW) and Mott insulating (MI) states coexist. The MI state is suppressed upon doping [1], substitution [2] or pressure [3]. Until recently, it has been believed that this, together with the formation of CDW domain walls, is crucial for the onset of superconductivity. However, recent studies at $T > T_{SC}$ have challenged this hypothesis in 1T-TaS_2 and 1T-$TaSe_xS_{2-x}$ [4]. We study superconducting 1T-TaSeS close to optimal $T_{SC} = 3.5$ K using high-resolution scanning tunneling spectroscopy (STS) both below and above T_{SC}. In contrast to pure 1T-TaS_2 we observe a finite density of states inside the Mott gap both inside the domains and at the domain walls. STS at T = 1.2 K shows a small 1-2 meV gap at the Fermi level that vanishes at T > 5K, strongly suggesting it is related to SC. It is clearly uncorrelated with the CDW domain walls of any kind in clear contrast with the simple domain wall picture. This suggest a different, correlated picture of SC onset.

[1] L. J. Li et al., European Physics Letters 97, 67005 (2012).
[2] Y. Liu et al., Applie Physics Letters. 102, 192602 (2013).
[3] B. Sipos et al., Nature Materials 7, 960 (2008).
[4] J. Skolimowski, Y. Gerasimenko and R. Žitko, PRL, 122 (2019).

TT 2.5 Mon 10:30 HSZ 103

Detection and control of phase slip lines in plain superconducting $NbSe_2$ devices — •Nicola Paradiso[1], Michaela Eichinger[1], Christian Bäuml[1], Kenji Watanabe[2], Takashi Taniguchi[2], and Christoph Strunk[1] — [1]University of Regensburg — [2]National Institute for Materials Science, Tsukuba, Japan

In ordinary superconductors the dissipationless state is destroyed when the current density reaches a critical value, known as depairing current. On the other hand, it was recently found [1,2] that in superconducting 2D materials as $NbSe_2$, dissipation emerges as a sequential nucleation of so-called phase slip lines (PSL). Such nucleation occurs for current densities well below the depairing value. Here we study PSLs on plain few-layer $NbSe_2$ crystals. By transport measurements we can observe the repulsive interaction between PSLs. Moreover, by using a carbon nanotube as a local heater, we can locally tune the critical current for the nucleation of one individual PSL. Our observations show that PSLs are localized and interacting objects, whose nucleation can be locally controlled.

[1] N. Paradiso *et al.*, 2D Materials, **6**, 025039 (2019);
[2] S. Tran *et al.*, arXiv:1903.00453v3 (2019).

TT 2.6 Mon 10:45 HSZ 103

Transport measurements on microstructured samples of neodymium doped $CeCoIn_5$ — •J. Stirnat[1,2], S. Hamann[1,3], M. Winter[1,2], M. König[3], L. Bischoff[4], C. Petrovic[5], T. Helm[1,3], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden (TUD), Germany — [3]Max-Planck-Institut für Chemische Physik fester Stoffe (MPI CPfS), Dresden, Germany — [4]Ionenstrahlzentrum (IBC), HZDR, Dresden, Germany — [5]Brookhaven National Laboratory, Upton, USA

$CeCoIn_5$ is known to host d-wave heavy-fermion superconductivity and also a high-field superconducting phase, the Q phase. In neodymium the $4f$-electrons do not hybridize with the conduction electrons. Therefore, substituting a certain amount of the cerium atoms in $CeCoIn_5$ with neodymium, spin density waves and antiferromagnetic order can be induced. Previous de Haas-van Alphen measurements show that with increasing Nd doping the Fermi surfaces of $CeCoIn_5$ are reconstructed from a quasi-two-dimensional to a three-dimensional topology. Such a dramatic change may also be reflected by the electrical transport anisotropy. In order to gain access to different conduction-channel directions, we fabricated micrustructures of Nd-doped $CeCoIn_5$ using focused ion beam (FIB) microfabrication. Our goal is to study the effect of Nd doping on the resistivity anisotropy in high magnetic fields. In this talk I will present first preliminary results in fields of up to 16 T and at ^{3}He temperatures.

TT 2.7 Mon 11:00 HSZ 103

Crystal structure and superconducting properties of $Sc_5Ir_6Sn_{18}$ — •Manuel Feig[1,2], Volodymyr Levytskyi[1,3], Lev Akselrud[2,3], Walter Schnelle[2], Andreas Leithe-Jasper[2], Vadim Dyadkin[4], Dmitry Chernyshov[4], and Roman Gumeniuk[1,2] — [1]Institut für Experimentelle Physik, TU Bergakademie Freiberg, Leipziger Str. 23, 09596 Freiberg, Germany — [2]Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany — [3]Ivan Franko National University of Lviv. Kyrala and Mefodiya Str. 6, UA-79005, Lviv, Ukraine — [4]Swiss-Norwegian Beamline at ESRF, CS 40220, 38043 Grenoble Cedex 9, France

High quality single crystals of $Sc_5Ir_6Sn_{18}$ were grown from Sn melt. A split variant of the $Tb_5Rh_6Sn_{18}$ structure type (SG: $I4_1/acd$, $a \approx 13.6$ Å, $c \approx 27.2$ Å) was obtained from both single crystal and powder X-ray diffraction. The instability of the crystal structure without splits could be confirmed by DFT calculations. Measurements of the magnetic susceptibility, specific heat capacity and electrical resistivity revealed $Sc_5Ir_6Sn_{18}$ to be a metallic diamagnet with a superconducting transition temperature $T_c = 2.64$ K. The obtained values for the second critical field $B_{c2} = 3.2$ T, the specific heat jump $\Delta c_p/\gamma_N T_c = 1.73$ and the energy-gap ratio $\Delta(0)/k_B T_c = 1.85$ indicate this compound to be a weakly coupled s-wave BCS superconductor.

15 min. break.

TT 2.8 Mon 11:30 HSZ 103

The electronic structure of infinite-layer nickelates — •Matthias Hepting[1,8], Danfeng Li[1], Chunjing Jia[1], Haiyu Lu[1], Eugenio Paris[2], Yi Tseng[2], Xiao Feng[1], Motoki Osada[1], Emily Been[1], Yasuyuki Hikita[1], Yi-De Chuang[3], Zahid Hussain[3], Ke-Jin Zhou[4], Abhishek Nag[4], Mirian Garcia-Fernandez[4], Matteo Rossi[1], Hsiao-Yu Huang[5], Di-Jing Huang[5], Zhi-Xun Shen[1,6], Thorsten Schmitt[2], Harold Hwang[1], Brian Moritz[1], Jan Zaanen[7], Thomas Devereaux[1], and Wei-Sheng Lee[1] — [1]Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, USA — [2]PSI, Switzerland — [3]ALS, LBNL, USA — [4]Diamond Light Source, United Kingdom — [5]NSRRC, Hsinchu Science Park, Taiwan — [6]Geballe Lab, Stanford University, USA — [7]Instituut-Lorentz for Theoretical Physics, Leiden University, Netherlands — [8]Max Planck Institute for Solid State Research, Germany

The recent discovery of superconductivity in the Sr-doped infinite-layer nickelate $NdNiO_2$ has revived the search for materials with physical properties similar to cuprate high-temperature superconductors. We have used x-ray spectroscopy and density functional theory to show that the electronic structure of the undoped parent compound RNiO2 (R = La, Nd), while similar to the cuprates, includes significant distinctions [1]. The material can be regarded as a Kondo- or Anderson-lattice-like oxide-intermetallic, replacing the Mott insulator as the reference state from which superconductivity emerges upon doping.

[1] M. Hepting *et al.*, arXiv:1909.02678 (2019).

TT 2.9 Mon 11:45 HSZ 103

Properties of sputtered films of the electron-doped $Nd_{2-x}Ce_xCuO_{4-d}$ superconductor — •Angela Nigro[1], Anita Guarino[2], Pasquale Marra[3,4], Antonio Leo[1], and Gaia Grimaldi[2] — [1]Dipartimento di Fisica E. R. Caianiello, Università degli Studi di Salerno, 84084 Fisciano (Salerno), Italy — [2]CNR-SPIN, c/o Dipartimento di Fisica E. R. Caianiello, Università degli Studi di Salerno, 84084 Fisciano (Salerno), Italy — [3]Graduate School of Mathematical Sciences, The University of Tokyo, Tokyo,Japan — [4]Department of Physics, Keio University, 4-1-1 Hiyoshi, Yokohama, Kanagawa 223-8521, Japan,Japan

In $RE_{2-x}Ce_xCuO_{4-d}$ (RE =rare earth) electron-doped cuprates, the superconductivity is harder to achieve since as-grown samples are antiferromagnetic up to high doping levels, and become superconducting only after a special annealing process. The role of the annealing treatment still constitutes an open question for n-type superconductors. We investigate the electrical and structural properties of $Nd_{2-x}Ce_xCuO_4$ films grown by a sputtering technique in an oxygen deficient environment, in order to obtain information on the complete oxygen-phase diagram. The as-grown samples are non-superconducting and the structural properties are consistent with a deficiency of the oxygen content. Unexpectedly, a reducing thermal treatment at high temperature is able to induce superconductivity in these films. Our data seem to support the picture that the high-temperature annealing procedure induces a peculiar oxygen atoms distribution triggering the superconducting transition in these compounds.

TT 2.10 Mon 12:00 HSZ 103

Evidence for an orbital dependent Mott transition in the ladders of (La, Ca)$_x$Sr$_{14-x}$Cu$_{24}$O$_{41}$ derived by electron energy-loss spectroscopy — •Friedrich Roth[1], Udo Ammerahl[2], Alexandre Revcolevschi[2], Bernd Büchner[3], Martin Knupfer[3], and Jörg Fink[3,4,5] — [1]Institute of Experimental Physics, TU Bergakademie Freiberg, Leipziger Straße 23, D-09599 Freiberg, Germany — [2]Laboratoire de Physico-Chimie de l'État Solide, Université Paris-Sud, 91405 Orsay, France — [3]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [4]Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden, Germany — [5]Institute for Solid-State and Material Physics, Technical University Dresden, D-01062 Dresden, Germany

The knowledge of the charge carrier distribution among the different orbitals of Cu and O is a precondition for the understanding of the physical properties of various Cu-O frameworks. We employ electron energy-loss spectroscopy to elucidate the charge carrier plasmon dispersion in (La, Ca)$_x$Sr$_{14-x}$Cu$_{24}$O$_{41}$ in dependency of x as well as temperature. We observe that the energy of the plasmon increases upon increasing Ca content, which signals an internal charge redistribution between the two Cu-O subsystems. Moreover, a comparison of the experimental plasmon excitations with RPA-like calculations indicates that the holes which are transferred to the Cu_2O_3 ladders are mainly located on O orbitals in the rungs and to a much lesser extent in those in the legs. This is related to a different filling of the bonding and antibonding band leading to an orbital dependent Mott transition.

TT 2.11 Mon 12:15 HSZ 103

Combinatorial Laser Molecular Beam Epitaxy System Integrated with Specialized Low-temperature Scanning Tunneling Microscopy — •Ge He[1,2], Zhongxu Wei[1,2], Zhongpei Feng[1,2], Xiaodong Yu[1,2], Beiyi Zhu[1], Li Liu[1], Kui Jin[1,2,3,4], Jie Yuan[1,3,4], and Qing Huan[1,3,4,5] — [1]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China — [2]School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China — [3]Songshan Lake Materials Laboratory, Dongguan, Guangdong 523808, China — [4]Key Laboratory for Vacuum Physics, University of Chinese Academy of Sciences, Beijing 100190, China — [5]CAS Center for Excellence in Topological Quantum Computation, University of Chinese Academy of Sciences, Beijing 100190, China

We describe the setting-up and the performance of a newly developed combined system of combinatorial laser molecular beam epitaxy and low-temperature ultra-high vacuum scanning tunneling microscopy. This facility aims at accelerating the materials research in a highly efficient way, by advanced high-throughput film synthesis techniques and subsequent fast characterization of surface morphology and electronic states. During five years efforts, the system has exhibited good stability on both combi-film deposition and STM measurements, and decidedly appreciated advantages in both exploring new materials and investigating novel physical phenomenon.

TT 2.12 Mon 12:30 HSZ 103

Raman signatures of the Higgs mode in d-wave superconductors — •Matteo Puviani and Dirk Manske — Max Planck Institute for Solid State Research, Stuttgart, Germany

The amplitude mode (so called "Higgs" mode) in superconductors originates from the Anderson-Higgs mechanism in the symmetry-broken phase and consists of the oscillation of the order parameter with twice the gap energy[1]. Electronic Raman scattering in superconductors probes charge excitations across the superconducting gap, and thus is a valid candidate to provide information about the modes of the order parameter[2,3].

We investigated the role of the Higgs oscillations in d-wave superconductivity with the theoretical simulation of the Raman response for different light polarizations. In particular, we calculated the full Raman vertices' corrections in the amplitude channel: our results show the presence of a relevant Higgs contribution for the A1g spectrum which could solve the A1g problem[4].

Moreover, with the same theoretical approach, we are able to explain the very last experimental results of the current-assisted activation of the Higgs mode in superconductors[5].

[1] P.B. Littlewood and C.M. Varma, Phys. Rev. B 26, 4883 (1982)
[2] M.V. Klein and S.B. Dierker, Phys. Rev. B 29, 4976 (1984)
[3] T. Cea and L. Benfatto, Phys. Rev. B 90, 224515 (2014)
[4] T.P. Devereaux et al., Phys. Rev. Lett. 72, 396 (1994)
[5] S. Nakamura et al., Phys. Rev. Lett. 122, 257001 (2019)