TT 3: Superconductivity: Properties and Electronic Structure I

Time: Monday 9:30–13:00 Location: H 0110

TT 3.1 Mon 9:30 H 0110

Paramagnetic Meissner effect in Nb: 20 years after — •Michael Koblischka[1], Crosby Chang[2], Thomas Hauet[2], and Ladislav Pust[3] — [1]Institute of Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany — [2]Institut Jean Lamour, UMR CNRS-Université de Lorraine, 54506 Vandœvre-lès-Nancy, France — [3]ELI Beamlines, Institute of Physics AS CR, Za Radnici 835, 25241 Dolni Brezany, Czech Republic

The paramagnetic Meissner effect (PME) was investigated in Nb samples which showed the PME already 20 years ago [1]. Magnetization measurements ($M(T)$ and $M(H)$)were performed using different magnetometers (QD SQUID MPMS3 and PPMS). We could reproduce the same PME behavior of the samples, despite the long storage time. In this contribution, we compare the old results from 1997 to the new data. The $M(T)$-data reveal the same principal features at the superconducting transition, and the $M(H)$-data measured close to the superconducting transition exhibit a change of the shape of the magnetization loops as in the original experiments. Furthermore, we also observe the features of the PME transition to much higher fields as reported previously. The measurements proof that the sample surfaces were not altered due to storage.

[1] L. Pust, L. E. Wenger, M. R. Koblischka, PRB 58, 14191 (1998)

TT 3.2 Mon 9:45 H 0110

Strong coupling superconductivity in the aperiodic high-pressure phase of bismuth — •Konstantin Semeniuk[1], Philip Brown[1], Stephen Hodgson[1], Diandian Wang[1], Bartomeu Monserrat[2,1], Chris Pickard[3,4], and Malte Grosche[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Dept. of Physics and Astronomy, Rutgers University, Piscataway, USA — [3]Dept. of Materials Science, University of Cambridge, UK — [4]Advanced Institute for Materials Research, Tohoku University, Japan

Application of hydrostatic pressure to elemental materials surprisingly often leads to the emergence of structurally complex phases [1]. Examples include aperiodic structures consisting of two incommensurate sublattices, seen in high pressure phases of bismuth, antimony, barium and other elemental metals. Aside from crystallographic characterisation, not many experiments have been conducted to explore the electronic and vibrational properties of these systems. We examine the incommensurate host-guest structure of high pressure bismuth, Bi-III, which superconducts below 7 K and has an anomalously large gradient of resistivity against temperature below 50 K. We attribute its properties to the existence of sliding modes, or phasons, which cause enhanced electron-phonon scattering at low temperature and boost electron-phonon coupling constant to $\lambda \simeq 2.8$, indicating unusually strong coupling superconductivity for an element.

[1] M. I. McMahon, R. J. Nelmes, Chem. Soc. Rev. 35(2006)943.

TT 3.3 Mon 10:00 H 0110

Nonequilibrium transport in ultrathin aluminium films near the vortex-unbinding transition — •Klaus Kronfeldner, Lorenz Fuchs, and Christoph Strunk — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

We analyze $I(V)$-characteristics and ac-susceptibility of epitaxial aluminium films with thicknesses below 8 nm. The Berezinskii-Kosterlitz-Thouless transition temperature T_{BKT} is determined from the superfluid stiffnesses that are extracted from both measurement techniques. For the dc-measurement the power-law criterion with slope 3 in $\log(V)$ vs. $\log(I)$ is used to determine T_{BKT}. While the two independently identified values for T_{BKT} are in good agreement for the lowest voltages V, at higher V a pronounced concave curvature is visible in the $\log(V)$ vs. $\log(I)$ plot. This curvature is traced back to both changes in the superfluid stiffness and self-heating in presence of a driving current.

TT 3.4 Mon 10:15 H 0110

Superfluid stiffness vs. electric resistance in the vicinity of the Berezinskii-Kosterlitz-Thouless transition in ultrathin aluminum films — •Lorenz Fuchs, Klaus Kronfeldner, Imke Gronwald, Dieter Schuh, Dominique Bougeard, and Christoph Strunk — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

We present superconducting properties of ultrathin aluminum films with thicknesses below 8 nm. Transport measurements are carried out in a low-noise DC configuration with IV curves spanning a voltage range of 6 orders of magnitude. Resistances are extracted from the linear parts of the curves in the zero-bias limit. Discontinuous jumps by a factor of up to 10^5 are observed above a critical current $I_c(T)$ at low temperature T. For moderate voltages we find a power-law dependence $V \propto I^{\alpha(T)} = I^{1+\pi J_s(T)/T}$. Superfluid stiffness $J_s(T) \propto 1/\lambda^2$, which is directly related to the magnetic penetration depth λ, is measured by a two-coil mutual inductance setup. We see clear signatures of a Berezinskii-Kosterlitz-Thouless transition in the low-resistance tail of the transition curve. Critical temperatures agree within a few mK for the different methods. $\alpha(T)$ extracted from IV curves and independently calculated from $J_s(T)$ are compared.

TT 3.5 Mon 10:30 H 0110

Unconventional superconductivity in Mo_8Ga_{41} — •Valeriy Verchenko[1], Rustem Khasanov[2], Zurab Guguchia[2], Alexander Tsirlin[3], Miroslav Marcin[4], and Andrei Shevelkov[1] — [1]Department of Chemistry, Lomonosov Moscow State University, Moscow, Russia — [2]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, Villigen PSI, Switzerland — [3]Experimental Physics VI, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Augsburg, Germany — [4]Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovakia

Among intermetallics, gallium cluster phases - the compounds, which crystal structures are built by gallium-based polyhedra with high coordination numbers - are promising candidates for unconventional superconductivity. In this class of compounds, $ReGa_5$, Mo_8Ga_{41}, Mo_6Ga_{31}, Rh_2Ga_9 and Ir_2Ga_9 are known to superconduct at low temperatures. Among the series, Mo_8Ga_{41} exhibits the largest superconducting transition temperature of $T_C = 9.7$ K in zero magnetic field. In our study, we focused on Mo_8Ga_{41}, aiming at the investigation of its macro- and microscopic properties. For this purpose, thermodynamic measurements as well as muon spin spectroscopy technique were employed. According to the specific heat measurements and transverse-field muon spin rotation/relaxation experiments, we classify Mo_8Ga_{41} as a strong-coupled superconductor with two s-wave superconducting gaps.

TT 3.6 Mon 10:45 H 0110

Two-gap superconductivity in the $Ag_xMo_6S_8$ Chevrel Phase — •Manuel Feig[1,2], Matej Bobnar[2], Christoph Hennig[3], Igor Veremchuk[2], Andreas Leithe-Jasper[2], and Roman Gumeniuk[1,2] — [1]Institut für Experimentelle Physik, TU Bergakademie Freiberg, Leipziger Straße 23, 09599 Freiberg, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany — [3]European Synchrotron Radiation Facility, 71, Avenue des Martyrs, Grenoble, France

The Rietveld refinement of HR-PXRD data on the superconducting $Ag_{0.92}Mo_6S_8$ confirmed the Chevrel-like structure: SG $R\overline{3}$, a = 9.3065 Å and c = 10.8310 Å. Magnetization measurements revealed a superconducting transition at $T_c = 7.9$ K. The lower and upper critical magnetic fields $B_{c1} = 12$ mT and $B_{c2} = 3.5$ T were deduced from the hysteresis. In contrast, measurements of the electrical resistivity in different magnetic fields resulted in $B_{c2} = 7.4$ T as well as the GL-coherence length $\xi_{GL} = 67$ Å, the GL-parameter $\kappa = 33$ and the London penetration depth $\lambda_L = 2204$ Å. The specific heat jump at the superconducting transition $\Delta c_p/\gamma T_c = 1.77$ is well above the value predicted by BCS theory (1.43), whereas the energy gap ratio $\Delta(0)/k_BT_c$ = 1.55 obtained from an exponential fit of the electronic specific heat c_{el} from 0.35 K to 4 K is smaller than the theoretically predicted value of 1.76. In agreement with the isostructural $SnMo_6S_8$ and $PbMo_6S_8$ Chevrel phases [1], $Ag_{0.92}Mo_6S_8$ is a two-band superconductor with the gap ratios $\Delta_1/k_BT_c = 2.39$ (95%) and $\Delta_2/k_BT_c = 1.03$ (5%).

[1] A.P. Petrović et al., Phys. Rev. Lett., 106, 017003 (2011)

TT 3.7 Mon 11:00 H 0110

Strain-enhanced three-gap superconductivity in monolayer MgB_2 — •Alex Aperis[1], Jonas Bekaert[2], Bart Partoens[2], Milorad V. Milošević[2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]University of Antwerp, Antwerp, Bel-

gium

Starting from first principles, we show the formation and evolution of superconducting gaps in MgB_2 at its ultrathin limit. Atomically thin MgB_2 is distinctly different from bulk MgB_2 in that surface states become comparable in electronic density to the bulk like σ and π bands. Solving the anisotropic Eliashberg equations with *ab initio* calculated input for electrons, phonons and the electron-phonon coupling, we show that monolayer MgB_2 develops three distinct superconducting gaps, on completely separate parts of the Fermi surface due to the emergent surface contribution. These gaps hybridise nontrivially with every extra monolayer added to the film owing to the opening of additional coupling channels. Furthermore, we reveal that the three-gap superconductivity in monolayer MgB_2 is robust over the entire temperature range that stretches up to a considerably high critical temperature of 20 K. The latter can be boosted to T_c>50 K under biaxial tensile strain of $\sim 4\%$, which is an enhancement that is stronger than in any other graphene-related superconductor known to date.

15 min. break.

TT 3.8 Mon 11:30 H 0110

Hidden nesting as the origin of strong electron-phonon coupling — •Philipp Kurzhals, Frank Weber, Rolf Heid, and John-Paul Castellan — Institute for Solid-State Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

We report a combined inelastic neutron scattering and density-functional theory investigation of a phonon anomaly in the superconductor YNi_2B_2C assigned to strong electron-phonon coupling.

Band structure calculations indicate that the Fermi surface in the material is not nested in the sense that there is no singularity in the electronic joint density of states at the wavevector $\boldsymbol{q}_{\mathbf{anom}} = (0.55, 0, 0)$ that could define the phonon anomaly.

We measured the evolution of the strong-coupling phonon mode in a volume of reciprocal space around $\boldsymbol{q}_{\mathbf{anom}}$ to unravel the momentum dependence of electron-phonon coupling expressed in the softening and broadening of single phonon modes and compared it to predictions of *ab-initio* lattice dynamical calculations.

Our combined results hint at a hybrid approach, in which a small enhancement of the nesting properties is boosted by a concomitant increase of the electron-phonon coupling matrix elements at the same wavevector $\boldsymbol{q}$.

TT 3.9 Mon 11:45 H 0110

Is there a relation between $T_{c,max}$ and the superexchange strength J? — •Silvia Müllner[1], Dirk Wulferding[1,2], Peter Lemmens[1,2], Meny Shay[3], Gil Drachuck[3], Wayne Crump[4], Jeff Tallon[4], and Amit Keren[3] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany — [3]Phys. Dep., Technion Haifa, Israel — [4]RRI, Victoria Univ., New Zealand

Using Raman scattering the magnetic superexchange strength J can be directly determined via two-magnon scattering. Two earlier Raman scattering investigations on HTSC have shown contradicting relations between J and $T_{c,max}$. We present new Raman scattering results of various RE123 HTSC with different J and their relation with $T_{c,max}$.
Work supported by GIF 1171-486 189.14/2011.
[1] Wulferding, et al., PRB 90, 104511 (2014).
[2] Tallon, PRB 90, 214523 (2014).
[3] Ellis, et al., PRB 92, 104507 (2015).

TT 3.10 Mon 12:00 H 0110

Why T_c is so low in high-T_c cuprates: importance of the dynamical vertex structure — •Motoharu Kitatani[1], Thomas Schäfer[2,3], Hideo Aoki[4], and Karsten Held[1] — [1]Vienna University of Technology, Vienna, Austria — [2]Collège de France, Paris, France — [3]École Polytechnique, Palaiseau, France — [4]Advanced Industrial Science and Technology (AIST), Ibaraki, Japan

We have applied the dynamical vertex approximation (DΓA), one of the diagrammatic extensions of the dynamical mean field theory (DMFT), for studying d-wave superconductivity in the repulsive Hubbard model on a square lattice. The result well reproduces the cuprate superconducting phase diagram, with a reasonable T_c and a superconducting dome. We have also decomposed the vertex correction contributions to T_c and traced back the dominant scattering processes, and found that local particle-particle diagrams strongly screen the bare interaction near the Fermi level, which act to suppress the pairing interaction. We shall discuss in detail how the dynamical vertex structure passes from the local vertex to the magnetic vertex (spin-fluctuations) to the pairing interaction.

TT 3.11 Mon 12:15 H 0110

Terahertz and infrared spectroscopic study of in-gap excitations in epitaxial $DyBa_2Cu_3O_7$ superconducting films — •Robert Dawson, Timofei Larkin, Daniel Putzky, Georg Christiani, Gennady Logvenov, Alexander Boris, and Bernhard Keimer — Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany

Investigations of the electronic ground state properties of high-temperature cuprate superconductors have revealed a complex array of competing forms of order, suggesting the existence of dipole-active excitations at low energies which evolve across a wide range of doping levels. Unfortunately, the strong optical response of the superconducting condensate below T_c masks low energy spectral features and makes their direct measurement challenging. To address this issue we have combined the three complementary phase-sensitive techniques of millimeter-wave interferometry, high-resolution time domain terahertz spectroscopy, and infrared ellipsometry to sensitively probe the in-gap states of $DyBa_2Cu_3O_7$ epitaxial films grown by atomic-layer-by-layer oxide MBE. We have obtained the continuous complex dielectric function in the spectral range of 0.5meV to 0.5eV and have observed its evolution as a function of temperature between 7K and 300K. We observe significant spectral weight accumulation at frequencies below 500GHz in the superconducting state, with 30% of the total charge carrier density remaining uncondensed even at temperatures below $T_c/10$. We will discuss this result and its implications for the evolution of the spectral weight distribution in the DBCO-1237 compound.

TT 3.12 Mon 12:30 H 0110

Transmission x-ray microscopy at low temperatures: watching superconductors at work — •Julian Simmendinger[1], Stephen Ruoss[1], Joachim Albrecht[2], and Gisela Schütz[1] — [1]Max Planck Institute for Intelligent Systems, Heisenbergstr. 1, D-70569 Stuttgart, Germany — [2]Research Institute for Innovative Surfaces FINO, Beethovenstr. 1, D-73430 Aalen, Germany

Scanning transmission x-ray microscopy has been used to image electric currents in superconducting films at temperatures down to 20 K. The magnetic stray field of supercurrents in a thin YBaCuO film is mapped into a soft-magnetic coating of permalloy. The so created local magnetization of the ferromagnetic film can be detected by dichroic absorption of polarized x-rays. To enable high-quality measurements in transmission geometry the whole heterostructure of ferromagnet, superconductor and single-crystalline substrate has been thinned to an overall thickness of less than 1 micron. With this novel technique local supercurrents can be analyzed in a wide range of temperatures and magnetic fields. A magnetic resolution of less than 100nm together with simultaneuosly obtained nanostructural data allow the correlation of local supercurrents with the micro- and nanostructure of the superconducting film.

TT 3.13 Mon 12:45 H 0110

Single-gap superconductivity in Nb-doped $SrTiO_3$ and superconducting dome probed by microwave spectroscopy — Markus Thiemann[1], Manfred H. Beutel[1], Martin Dressel[1], Nicholas R. Lee-Hone[2], David M. Broun[2,3], Evangelos Fillis-Tsirakis[4], Hans Boschker[4], Jochen Mannhart[4], and •Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Department of Physics, Simon Fraser University, Burnaby, Canada — [3]Canadian Institute for Advance Research, Toronto, Canada — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany

$SrTiO_3$ exhibits a superconducting dome (critical temperature T_c up to 0.4 K) upon doping with Nb, which successively fills multiple bands at the Fermi level. Using superconducting microwave stripline resonators at frequencies 2 to 23 GHz and temperatures down to 0.02 K, we probe the low-energy optical response of superconducting $SrTiO_3$ with charge carrier concentration from 0.3 to 2.2×10^{20} cm^{-3} across the superconducting dome. We find single-gap behavior [1] although several electronic bands are superconducting in $SrTiO_3$, and this presence of a single energy gap 2Δ due to gap homogenization over the Fermi surface is consistent with the amount of defect scattering observed in Nb-doped $SrTiO_3$. Furthermore, we determine T_c, 2Δ, and the superfluid density throughout the superconducting regime of Nb-doped $SrTiO_3$, and all three quantities exhibit the characteristic dome shape as a function of Nb concentration.
[1] M. Thiemann *et al.*, arXiv:1703.04716