TT 17: Superconductivity: Properties and Electronic Structure

Time: Monday 15:00–18:45 Location: H 2053

TT 17.1 Mon 15:00 H 2053

Broadband microwave response of superconducting NbN and TaN thin films — M. Maximilian Felger[1], Uwe S. Pracht[1], Martin Dressel[1], Konstantin Ilin[2], Michael Siegel[2], and •Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart, D-70669 Stuttgart, Germany — [2]Institut für Mikro- und Nanoelektronische Systeme, Karlsruher Institut für Technologie, D-76187 Karlsruhe, Germany

Ultrathin NbN and TaN films with their peculiar superconducting behavior are of interest both for fundamental physics (e.g. concerning the superconductor-insulator transition) and novel applications (e.g. for single-photon detectors). Here microwave spectroscopy is a powerful tool to characterize essential superconducting properties and to investigate the charge dynamics (Cooper pairs and quasiparticles).

We have prepared by sputtering thin films of NbN (thickness between 3 nm and 20 nm; T_c between 5 K and 13 K) and TaN (thickness 5 nm; T_c between 8.5 K and 9.5 K) on sapphire substrates. We performed broadband microwave spectroscopy on these samples using a Corbino spectrometer at temperatures down to 1.1 K and at frequencies up to 50 GHz. From these data we determine the superconducting penetration depth and we evaluate the frequency-dependent conductivity. While many of the observed features can be described within expectations of conventional BCS theory, we also find deviations that are caused by fluctuations near the superconducting transition.

TT 17.2 Mon 15:15 H 2053

Magnetic field dependence of the superconducting proximity effect in a two atomic layer thin metallic film — Michael Caminale, Augusto A. Leon Vanegas, Agniezka Stepniak, Hirofumi Oka, •Jeison A. Fischer, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle

The intriguing possibility to induce superconductivity in a metal, in direct contact with a superconductor, is under renewed interest for applications and for fundamental aspects [1]. The underlying phenomenon is commonly known as proximity effect. In this work we exploit the high spatial resolution of scanning tunneling spectroscopy at sub-K temperatures and in magnetic fields. We probe the differential conductance along a line from a superconducting 9 ML high Pb nanoisland into the surrounding two layer thin Pb/Ag wetting layer on a Si(111) substrate. A gap in the differential conductance indicates superconductivity of the Pb island. We observe an induced gap in the wetting layer, which decays with increasing distance from the Pb island. This proximity length is 21 nm at 0.38 K and 0 T. We find a non-trivial dependence of the proximity length on magnetic field. Surprisingly, we find that the magnetic field does not affect the induced superconductivity up to 0.3 T. However, larger fields of 0.6 T suppress superconductivity in the wetting layer, where the Pb island still remains superconducting. We discuss the unexpected robustness of induced superconductivity in view of the high electronic diffusivity in the metallic wetting layer.

[1] Guéron et al. Phys. Rev. Lett. 77, 3025 (1996);
Xiang et al. Nat. Nano. 1, 208 (2006);
Wang et al. Phys. Rev. Lett. 100, 197002 (2008).

TT 17.3 Mon 15:30 H 2053

Scanning tunneling spectroscopy of Co adsorbates on superconducting Pb nanostructures — •Regis Decker, Michael Caminale, Hirofumi Oka, Agneszka Stepniak, Augusto A. Leon Vanegas, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Superconductivity in low-dimensional structures has become an active research area [1,2]. In order to understand the superconducting pairing, long-standing work has been devoted to the pair breaking effect, where magnetic impurities break Cooper pair singlets [3]. We performed scanning tunneling spectroscopy at low temperature on Co adsorbates on superconducting Pb nanoislands. On the Co adsorbates, we observe spectral features in the superconductor's energy gap, which we attribute to magnetic impurity induced bound states [3], a hallmark of the pair breaking effect. We discuss the response of the superconducting islands to the presence of Co adsorbates.

[1] T. Nishio et al., Phys. Rev. Lett. 101, 167001 (2008).
[2] T. Zhang et al., Nature Phys. 6, 104 (2010).
[3] A. V. Balatsky et al., Rev. Mod. Phys. 78, 373 (2006).

TT 17.4 Mon 15:45 H 2053

Suppression of superconductivity in a single Pb layer on Ag/Si(111) — •Augusto Leon-Vanegas[1,2], Michael Caminale[1], Agnieszka Stepniak[1], Hirofumi Oka[1], Antonio Sanna[1], Andreas Linscheid[1], Dirk Sander[1], and Jürgen Kirschner[1,2] — [1]Max Plank Institüt für Mikrostukturphysik — [2]Martin Luther Univeristät, Halle-Wittenberg

Recently, superconductivity was reported in a single layer of Pb on Si(111) with a critical temperature of 1.83 K [1]. It has been proposed that the interaction of Pb with the Si substrate provides the electron phonon coupling to support superconductivity in this system [2]. We have used a ^{3}He-cooled STM with a vector magnetic field to study the effect of insertion of a Ag interlayer on the superconducting properties of a single Pb layer on Si(111). In contrast to the experiments on Pb/Si(111), the differential conductance of Pb/Ag/Si(111) does not show a gap indicative of superconductivity even at the lowest experimental temperature of 0.38 K. We ascribe this to the suppression of superconductivity [3]. This result is explained by means of ab-initio calculations, showing that the effect of a chemical hybridization between Pb and Ag/Si occurring at the Fermi level dramatically reduces the strength of the electron phonon coupling. This contrasts with the case of Pb/Si(111), where no overlap between Pb and Si electronic states at the Fermi level is found in the calculations.

[1] Zhang et al., Nat. Phys. 6, 104 (2010)
[2] Noffsinger and Cohen, Sol. State Comm. 151, 421 (2011)
[3] Stepniak, et al., J. Surface and Interface Analysis(2014)

TT 17.5 Mon 16:00 H 2053

Signatures of Unconventional Superconductivity in Granular Aluminum — •Uwe S. Pracht[1], Nimrod Bachar[2,3], Eli Farber[2], Guy Deutscher[3], Martin Dressel[1], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Laboratory for Superconductivity and Optical Spectroscopy, Ariel University, Israel — [3]Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Israel

Thin films composed of nanoscale Al grains coupled through dielectric barriers exhibit peculiar superconducting properties: As the grain coupling is decreased, the normal-state resistivity ρ increases and the critical temperature T_c is elevated from 1.1 K to 3.2 K before it is suppressed to zero at a critical ρ_c. This dome-like appearence of superconductivity together with Kondo-like normal-state transport and presence of localized spins suggest the superconducting mechanism to be of unconventional type in contrast to the BCS nature of bulk Al.

We measured the dynamical conductivity $\hat{\sigma}(\nu) = \sigma_1(\nu) + i\sigma_2(\nu)$ in the range 90 - 700 GHz of various films with different ρ by means of quasi-optical Mach-Zehnder interferometry above and below T_c. With increasing ρ we find an enhanced sub-gap absorption compared to the BCS theory for $\sigma_1(\nu)$ which we discuss in various contexts such as collective modes or magnetic impurity scattering, [1,2].

[1] N. Bachar, U. S. Pracht *et al.*, J. Low Temp. Phys (in print)
[2] D. Sherman, U. S. Pracht *et al.*, Nat. Phys (accepted)

TT 17.6 Mon 16:15 H 2053

Long-ranged interactions in thin TiN films at the superconductor-insulator transition? — •Klaus Kronfeldner[1], Tatyana Baturina[2], and Christoph Strunk[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]A. V. Rzhanov Institute of Semiconductor Physics SB RAS, Novosibirsk 630090, Russia

We measured IV-characteristics and magnetoresistance of square TiN-films in the vicinity of the disorder-tuned superconductor-insulator transition (SIT) for different sizes (5μm to 240μm). While the films are superconducting at zero magnetic field, at finite fields a SIT occurs. The resistance shows thermally activated behaviour on both sides of the SIT. Deep in the superconducting regime the activation energy grows linear with the sample size as expected for a size-independent critical current density. Closer to the SIT the activation energy becomes clearly size independent. On the insulating side the magnetoresistance maximum and the activation energy both grow logarithmically with sample size which is consistent with a size-limited charge

BKT (Berezinskii-Kosterlitz-Thouless) scenario. In order to test for the presence of long-ranged interactions in our films, we investigate the influence of a topgate. It is expected to screen the possible long-ranged interactions as the distance of the film to the gate is much shorter than the electrostatic screening length deduced from the size-dependent activation energy.

TT 17.7 Mon 16:30 H 2053

Multigap superconductivity with broken time reversal symmetry in locally noncentrosymmetric SrPtAs — •Felix Brückner[1], Hubertus Luetkens[2], Hannes Kühne[3], Pabitra Kumar Biswas[2], Titus Neupert[4], Marco Günther[1], Rajib Sarkar[1], Tobias Stürzer[5], Dirk Johrendt[5], and Hans-Henning Klauss[1] — [1]Institut für Festkörperphysik, Technische Universität Dresden, Germany — [2]Paul-Scherrer-Institut, Villigen, Switzerland — [3]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]Princeton Center for Theoretical Science, Princeton University, Princeton, USA — [5]Ludwig-Maximilians-Universität München, Germany

The recently discovered compound SrPtAs has awakened grown scientific interest, because it comprises an exceptional structural feature: it consists of non-centrosymmetric PtAs layers that are weakly coupled to each other. Thus, SrPtAs is a prime example for staggered noncentrosymmetricity. Theoretical calculations predict an unconventional chiral d-wave superconducting state which is unique in material science, but no general consent has been archieved.

The evidence for time reversal symmetry breaking was found in μSR experiments, which implies an unconventional superconducting state. Nuclear quadrupole resonance reveals multigap behavior and a fully gapped superconducting state. In particular, I present spin-lattice relaxation rate $(1/T_1)$ measurements and discuss possible pairing symmetries. These results are relevant to understand the pairing mechanism in this and similar compounds. While the fokus is on the experiment, I will discuss the theoretical point of view as well.

TT 17.8 Mon 16:45 H 2053

Light induced superconductivity in underdoped $YBa_2Cu_3O_x$ — •Stefan Kaiser[1,2,3], Daniele Nicoletti[1], Cassi Hunt[1], Wanzheng Hu[1], Roman Mankowsky[1], Michael Först[1], Isabella Gierz[1], Toshinao Loew[2], Mathieu LeTacon[2], Bernhard Keimer[2], and Andrea Cavalleri[1] — [1]Max-Planck-Institut für die Struktur und Dynamik der Materie, Hamburg — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]4. Physikalisches Institut und Research Center SCoPE, Uni Stuttgart

Photo-stimulation with femtosecond mid-infrared pulses allows us to induce an inhomogeneous non-equilibrium superconducting state in $YBa_2Cu_3O_x$ at temperatures as high as 300 K. Its transient response is probed via THz time-domain spectroscopy [1,2]. We measure and characterize its complex optical response above and below the superconducting transition temperature T_c: Below T_c, we find an enhancement of the optical signatures of superconducting coherence. Above T_c we find that the incoherent optical properties at equilibrium become highly coherent with optical signatures very similar to the ones for superconductors below T_c. In the course of understanding these observations, ultrafast x-ray experiments at LCLS allow us observing reconstructed crystal structure in the transient superconducting state and the influence of competing CDW-order to the phonon-excitation [3,4].

[1] S. Kaiser et al., PRB 89, 184516 (2014).
[2] W. Hu et al., Nat. Mat. 13, 705 (2014).
[3] R. Mankowsky et al., arXiv:1405.2266.
[4] M. Först et al., PRB 90, 184514 (2014).

15 min. break.

TT 17.9 Mon 17:15 H 2053

The evolution of microwave conductivity in $YBa_2Cu_3O_{6+x}$ across the superconducting dome — •Jordan Baglo[1], James Day[2], Pinder Dosanjh[2], Ruixing Liang[2], Walter Hardy[2], and Doug Bonn[2] — [1]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom — [2]Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, Canada

The rich phenomenology displayed in the phase diagram of the high-T_c cuprates continues to be an active arena of investigation. Recent experimental and theoretical work appears to be converging on a picture of separate spin and charge order phase transitions – well-below and near optimal doping, respectively – along with associated Fermi surface reconstruction. As sensitive probes of the low-energy electrodynamics, microwave spectroscopy techniques are well-suited for characterizing the effects of such changes in electronic structure deep within the superconducting state.

I will present the results of our survey of the complex microwave conductivity of $YBa_2Cu_3O_{6+x}$ over a wide range of oxygen contents, from 6.49 to 6.998, and discuss their implications for the evolution of electronic structure with doping. In particular, I will highlight the apparent absence of a peak in penetration depth near the proposed $p \approx 0.18$ quantum critical point (QCP), contrasting with its presence near the antiferromagnetic QCP of the pnictide superconductors. I will also discuss the surprising relationship we observed between quasiparticle scattering lifetimes and oxygen ordering, which carries important implications for quantum oscillation measurements.

TT 17.10 Mon 17:30 H 2053

Charge density wave fluctuations in $La_{2-x}Sr_xCuO_4$ and their competition with superconductivity — •Thomas Croft[1], Christopher Lester[1], Alessandro Bombardi[2], Mark Senn[2], and Stephen Hayden[1] — [1]H. H. Wills Physics Laboratory, University of Bristol, Bristol, BS8 1TL, United Kingdom — [2]Diamond Light Source Ltd., Harwell Science and Innovation Campus, Didcot, Oxfordshire OX11 0DE, United Kingdom

The recent observations of charge and stripe correlations in $YBa_2Cu_3O_{6+x}$ and $La_{2-x}Ba_xCuO_4$ has reinvigorated interest in their role in influencing the superconductivity of the cuprates. However, structural complications of these systems makes it difficult to isolate the effect the lattice has in inducing the charge order.

Here, we report hard x-ray diffraction measurements on three compositions $(x = 0.11, 0.12, 0.13)$ of the high-temperature superconductor $La_{2-x}Sr_xCuO_4$, a canonical example of HTS with $T_c \approx 35$ K and a simple crystal structure. All samples show charge-density-wave (CDW) order with onset temperatures in the range 51-80 K and ordering wavevectors close to (0.23,0,0.5). We present a phase diagram of $La_{2-x}Sr_xCuO_4$ including the pseudogap phase, CDW and magnetic order.

TT 17.11 Mon 17:45 H 2053

Microstructural characterization of Bulk MgB_2 — •Alex Wiederhold[1], Michael Koblischka[1], Kazuo Inoue[2], Miryala Muralidhar[2], Masato Murakami[2], Kévin Berger[3], Bruno Douine[3], Thomas Hauet[4], Jacques Noudem[5], and Uwe Hartmann[1] — [1]Institute of Experimental Physics, Saarland University, P. O. Box 151150, D-66123 Saarbrücken, Germany — [2]Department of Material Science and Engeneering, Shibaura Institute of Technology, 3-7-5 Toyosu, Koto-ku, Tokyo 135-8548, Japan — [3]GREEN, Université de Lorraine, Vandœuvre-les-Nancy, France — [4]Institute Jean Lamour, Université de Lorraine, Vandœuvre-les-Nancy, France — [5]CRISMAT-CNRS, Cherbourg, France

A series of disk-shaped bulk MgB_2 superconductors (sample diameter up to 4 cm) was prepared in order to improve the performance for superconducting super-magnets. Several samples were fabricated using a solid state reaction in pure Ar atmosphere from 750 to 950 °C to obtain the highest critical current density (j_c) as well as large trapped field values. Magnetization and transport measurements revealed that at the low reaction temperatures flux pinning at grain boundaries is dominant, which is decreasing on increasing temperature. At the highest reaction temperature, j_c was found to increase again indicating a change of the pinning mechanism [1]. In order to clarify this behavior the samples were characterized in detail by means of transmission electron microscopy (TEM) and transmission electron backscatter diffraction (t-EBSD).

[1] M.R.Koblischka *et al.*, IEEE Trans. Magn. (in press).

TT 17.12 Mon 18:00 H 2053

Magnetic characterization of Ag-addet Bulk MgB_2 — •Alex Wiederhold[1], Michael Koblischka[1], Kazuo Inoue[2], Miryala Muralidhar[2], Masato Murakami[2], Thomas Hauet[3], and Uwe Hartmann[1] — [1]Institute of Experimental Physics, Saarland University, P. O. Box 151150, D-66123 Saarbrücken, Germany — [2]Department of Material Science and Engeneering, Shibaura Institute of Technology, 3-7-5 Toyosu, Koto-ku, Tokyo 135-8548, Japan — [3]Institute Jean Lamour, Université de Lorraine, Vandœuvre-les-Nancy, France

n earlier studies, it was found that bulk sintered MgB_2 samples contained numerous voids which hinder the current flow. Therefore, a series of bulk MgB_2 superconductors with Ag contents of 0-10 wt% was prepared in order to improve the critical current densities and the mechanical performance. Several samples were fabricated using a solid state reaction in pure Ar atmosphere at the optimal reaction temperature of 775 °C. Thorough microstructural observations obtained from scanning electron microscopy (SEM) and atomic force microscopy (AFM) indicate that metallic Ag particles are embedded in the void regions.Furthermore, nanometer-sized $AgMg_3$ particles are also present within the MgB_2 matrix, leading to improved flux pinning. Small samples cut from the bulks were characterized by transport measurements ($R(T, B)$ and I/V characteristics) in magnetic fields up to 8 T and by magnetization loops measured using a SQUID magnetometer.

TT 17.13 Mon 18:15 H 2053

Umkehr effect observed in the magnetothermoelectric power of graphite — •Santiago Muiños-Landin, Israel Lorite Villalba, Winfried Böhlmann, and Pablo Esquinazi — Division of Superconductivity and Magnetism, Institute for experimental Physics II, Fakultät für Physik und Geowissenschaften, Linnéstrasse 5, 04103 Leipzig, Germany

In thermoelectricity, the Umkehr effect is defined as the difference between the the Seebeck coeffcient values upon reversal of an applied magnetic field. It was shown to be very large for certain samples of the semimetal bismuth. We show here that the effect is also observed in highly oriented pyrolytic graphite(HOPG Union Carbide), while it is not for a HOPG sample of a different provider. The only difference between these two samples is the amount of well deffined two-dimensional interfaces that exist inside them. The contribution to the thermoelectric power (TEP) that comes only from the graphite interfaces, makes non symmetric the response of the Seebeck effect once the sign of the magnetic field is changed. This fact provides an explanation for the Umkehr effect in graphite, in terms of the contribution of the interfaces to the TEP in our samples. Recently published work indicates that granular superconductivity is embedded in some of the interfaces. Therefore, we may now speculate that the extra entropy contribution to the magnetothermoelectric effect may be due to some kind of vortices produced by the applied magnetic field at the superconducting regions. We correlate therefore the field dependence of this contribution and its temperature dependence with that of the magnetoresistance.

TT 17.14 Mon 18:30 H 2053

Elucidating superconductivity and intermediate valence of elemental Eu under high pressure — •Jürgen Röhler — Universität zu Köln, 50937 Köln, Germany

Elemental Eu is a superconductor under high pressure, $P \geq 80$ GPa, up to $T_c = 2.75$ K at 142 GPa [1]. We elucidate the possible connection between pressure induced $4f$ configurational changes, $Eu^{2+}(4f^7, J{=}7/2) \rightleftarrows Eu^{3+}$ $(4f^6, J{=}0)$, and superconductivity. Notably high pressure L_{III} XAS [2] and more recently also ME isomer shift measurements [3] do not show the theoretically expected 2^+ - 3^+ transition, but intermediate valence states saturating at $v \simeq 2.6$ between $\sim$ 20 and 70 GPa, and undergoing between 31 and 37 GPa a transformation into a complex incommensurately modulated monoclinic structure $\sim \alpha$-U, which is followed by an other hitherto unidentified low-symmetry complex structure. We discuss how the Brillouin zone - Fermi surface interaction, driven by the non integer valence electron count, may stabilize low-symmetry complex structures, which tend to favor the occurrence of superconductivity through bandstructures with overlapping electron and hole bands.

[1] M. Debessai *et al.*, Phys. Rev. Lett. **102**, 197002 (2009).
[2] J. Röhler, Physica **144B**, 27 (1986).
[3] W. Bi *et al.*, Phys. Rev. B **85**, 205134 (2012).