TT 10: Superconductivity - Properties, Electronic Structure, Order Parameter

Time: Tuesday 9:30–13:00 Location: H18

TT 10.1 Tue 9:30 H18

Opening of the Superconducting Energy Gap observed with Neutron Spectroscopy — •Frank Weber[1,2], Andreas Kreyssig[3,4], Lothar Pintschovius[1], Winfried Reichardt[1], Oliver Stockert[5], Rolf Heid[1], Dmitry Reznik[1], and Klaudia Hradil[6] — [1]FZ Karlsruhe, IFP, Karlsruhe — [2]PI, Uni Karlsruhe (TH), Karlsruhe — [3]IFP, TU Dresden, Dresden — [4]Ames Laboratory, Ames, USA — [5]MPI-cpfs, Dresden — [6]IPC, Uni Göttingen, Aussenstelle FRM II, Garching

We present inelastic neutron scattering data on YNi_2B_2C ($T_c = 15$ K). We made a systematic study of the already known phonon anomaly in the (100)-direction [1] as well as of a so far unexplored anomaly at the zone boundary in the (110)-direction (M-point). Our data unambiguously show that the superconductivity-induced changes of the spectral function of phonons with a strong electron-phonon coupling can extremely well be understood in the framework of a theory proposed by Allen et al. [2]. The analysis yields the temperature dependent SC energy gap with high accuracy. As a consequence, even deviations from BCS like behavior can be assessed with confidence. Further, we found that the SC gap extracted from the phonon data for q=(0.5,0,0) and q=(0.5,0.5,0), respectively, differs by a factor 1.4. This is a direct proof for the long discussed anisotropy of the SC energy gap in borocarbides.

[1] Kawano et al., PRL. 77, 4628 (1996), [2] Allen et al., PRB 56, 5552 (1997)

TT 10.2 Tue 9:45 H18

Electron Spin Dynamics of the Novel Superconductor CaC_6 probed by ESR — •Ferenc Murányi, Grzegorz Urbanik, Vladislav Kataev, and Bernd Büchner — Leibniz Institute for Solid State and Materials Research Dresden, 01171 Dresden, PO BOX 270116, Germany

The Conduction Electron Spin Resonance (CESR) was measured on a thick slab of polycrystalline CaC_6 in the normal and superconducting state. The measurements characterize the metallic properties in the normal state and indicates the description of superconductivity in the dirty limit. Magnetic field dependent nonlinear absorption in the superconducting state evidenced the anisotropy of H_{c2}. Superconducting state measurements revealed the increase of effective skin depth below T_c.

TT 10.3 Tue 10:00 H18

Phonon anomalies in detwinned $YBa_2Cu_3O_{7-x}$: Strong *ab*-anisotropy in the phonon vibrations — •M. Bakr, C. Ulrich, J. Unterhinninghofen, D. Manske, C. Lin, and B. Keimer — Max-Planck-Institute for Solid State Research, Stuttgart, Germany

We have used Raman light scattering to investigate the electronic signal and phonon anomalies in detwinned optimally doped $YBa_2Cu_3O_{7-x}$ single crystals. Within the experimental error bar, no changes in the electronic gaps was observed with respect to the *a* and *b* axes. This is in contrast to previous experimental results observed by ARPES data and Josephson current measurements. All phonons show a pronounced asymmetry, i.e. Fano-profile, which indicates a strong electron-phonon interaction. A pronounced anisotropy in the asymmetry is observed with respect to the crystallographic *a* and *b* axes. This anisotropy appears for example for the 340 cm^{-1} phonon, but the 501 cm^{-1} phonon shows the largest difference. It is interesting to note that this phonon is right at the energy of the $2\Delta_{max}$ gap. The anisotropy of the asymmetry parameter, 1/q, is already present in the normal state. Below T_c, the 1/q changes drastically and in a characteristic way for the *a* and *b* axes. Finally, we compare our results with Fermi-liquid based calculations. Our results provide further insight into the electron-phonon interaction and therefore the electronic system of high T_c superconductors.

TT 10.4 Tue 10:15 H18

Theory for ultrafast dynamics in cuprates: Role of electron-phonon coupling — •Julia Unterhinninghofen[1], Dirk Manske[1], and Andreas Knorr[2] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart — [2]Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

We present a theory for ultrafast nonequilibrium dynamics in cuprate superconductors. In a typical time-resolved spectroscopy experiment, the sample is exited with an intense laser pulse, creating nonequilibrium quasiparticles which subsequently can relax via various scattering processes, restoring the superconducting state. We use the method of density matrix theory to study the optical excitation and relaxation dynamics in cuprates from a microscopical viewpoint. In particular, we consider scattering with optical phonons, looking at the interplay between relaxation of the excited quasiparticles and the creation of nonequilibrium phonon distributions; the superconducting state is restored on a 10 picosecond timescale, while the phonons have longer relaxation times. Time-resolved pump-probe spectra are calculated and compared both to quasi-equilibrium models and experimental results.

TT 10.5 Tue 10:30 H18

Charge(re)distribution at YBCO/metal interfaces: screened band bending — •Cosima Schuster and Udo Schwingenschlögl — Institut für Physik, Universität Augsburg, 86135 Augsburg

The functionality of nanoscale devices depends crucially on the transport properties across the interfaces. Especially, the transport mechanism in electronic devices based on high-T_c-superconductors is of special interest, in particular the charge density within the superconducting CuO_2 planes in the vicinity of an interface or grain boundary. Main questions in this context are interface charging, band bending, or contact resistivity. We calculate the local electronic structure of an YBCO/metal interface using density functional theory (using the Wien2k code) in two different geometries (where the interface is either parallel or perpendicular to the CuO_2 planes), including an optimization of the atomic positions near the interface. We consider supercells with 4 metal and 2 YBCO or 6 metal and 3 YBCO units, respectively. For the parallel contact we find a transfer of holes out of the CuO_2 planes resulting in shift to the underdoped regime of the high-T_c phase diagram. Thus, this geometry reflects the properties of a grain boundary. The results are neither dependent on contact geometry, nor the contact metal, or interface plane.

TT 10.6 Tue 10:45 H18

First principles Thermodynamics of $YBa_2Cu_3O_7$ — Volker Pankoke[1,2], •Rolf Heid[1], and Klaus-Peter Bohnen[1] — [1]Forschungszentrum Karlsruhe, Institut für Festkörperphysik — [2]Forschungszentrum Karlsruhe, Institut für Wissenschaftliches Rechnen

Modern density-functional based methods nowadays allow for an accurate calculation of phonon spectra and their dependence on structural parameters, which is a prerequisite for the study of finite temperature properties based on the free energy. Due to the large numerical costs, however, ab initio studies of thermodynamic properties have been restricted in most cases to crystals with simple lattice structures.

We will present an application of this ab initio approach to the cuprate superconductor $YBa_2Cu_3O_7$ with its rather complex crystal structure. Thermodynamical properties are calculated within the quasiharmonic approximation using phonon spectra obtained by density functional perturbation theory. We will discuss results for the anisotropic thermal expansion and specific heat in comparison with experiment to assess the accuracy of this approach.

TT 10.7 Tue 11:00 H18

Terahertz spectroscopy of electron-doped superconductors in magnetic field — •Artem V. Pronin[1], Andrei Pimenov[2,3], Alois Loidl[2], Akio Tsukada[4,5], and Micho Naito[4] — [1]Hochfeld-Magnetlabor Dresden (HLD), Forschungszentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Experimentalphysik V, EKM, Universität Augsburg, 86135 Augsburg, Germany — [3]Experimentelle Physik 4, Universität Würzburg, 97074 Würzburg, Germany — [4]Department of Applied Physics, Tokyo University of Agriculture and Technology, 2-24-16, Naka-cho, Koganei, Tokyo 184-8588, Japan — [5]NTT Basic Research Laboratories, NTT Corporation, 3-1 Morinosato-Wakamiya, Atsugi, Kanagawa 243-0198, Japan

In the terahertz and infrared regions we measured the optical conductivity and penetration depth of the electron-doped cuprate superconductor $La_{2-x}Ce_xCuO_4$. In the frequency-temperature behavior of conductivity we observe remarkable differences between the samples with different Ce content, suggesting the gap anisotropy to be a func-

tion of the doping level.

At terahertz frequencies, we performed measurements in high magnetic fields to suppress superconductivity below Tc. From the conductivity spectra we extract the quasiparticle scattering rate as a function of temperature, and compare its behavior in the superconducting and normal states below T_c. We find a small but measurable optical magnetoresistance at all doping levels, and no signatures for the pseudogap. We also discuss the applicability of "universal scaling laws"to our data on conductivity and penetration depth.

15 min. break

TT 10.8 Tue 11:30 H18

Charge modulation driven Fermi surface of Pb-Bi2201 — •Lenart Dudy, Beate Müller, Alica Krapf, Helmut Dwelk, Ralf-Peter Blum, Christoph Janowitz, and Recardo Manzke — Institut f. Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin

Due to doping with lead it is well known that the about (1x5) superstructure of Bi cuprate superconductors will be suppressed. Nevertheless, a Fermi surface map of $Bi_{2-y}Pb_ySr_{2-x}La_xCuO_{6+\delta}$ with x = 0.4 and y = 0.4 determined by angular resolved photoemission (ARPES) revealed additional Fermi surface (FS) features. Here a La content of x = 0.4 means optimum hole doping for a maximum value of Tc and for a Pb amount of y = 0.4 one commonly expect complete suppression of the superstructure. Low energy electron diffraction of these samples showed no sign of a superstructure. Scanning tunnelling microscopy, on the other hand, revealed directly two modulations of the electron density of much weaker amplitude, one long-range modulation of about (1x32) periodicity and a second of about (12x12). By taking into account the wave vectors and intensities of these two modulations the corresponding Fermi surface has been simulated, which agrees strikingly good with the experimental one. The occurrence of modulations in these high-Tc superconductors will be further discussed.

TT 10.9 Tue 11:45 H18

Energy dependence of excitations near the Fermi surface in Bi(Pb)-2212 and Bi(Pb)-2201 — •B. Müller, L. Dudy, H. Dwelk, A. Krapf, C. Janowitz, and R. Manzke — Humboldt Universität Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin

In Bi derived HT_c-cuprates the question of how many excitations occur near the Fermi surface is not yet completely answered. There are hints that more than the two peaks derived from bilayer-splitting are hidden in the well-known peak-dip-hump structure [1,2]. In our group it was previously argued that an additional polarisation dependent double-peak structure arises in the one- and two-layer Bi-cuprate [2]. In Bi(Pb)-2201 this can be traced unequivocally since there are no superstructure or bilayer effects possibly concealing this excitation. In Bi(Pb)-2212 the intensity ratio of the peak-dip-hump structure is energy dependent which could be a tool to uncover split excitations [1]. In this contribution the photon energy dependence of the excitations near the Fermi energy of Bi(Pb)-2212 and Bi(Pb)-2201 is studied.

[1] A.A. Kordyuk, S.V. Borisenko, T.K. Kim, K.A. Nenkov, M. Knupfer, J. Fink, M.S. Golden, H. Berger, R. Follath, Phys. Rev. Lett. 89 (2002) 077003

[2] R. Manzke, R. Müller, C. Janowitz, C. Ast, H. Höchst, Phys. Rev. B 63 (2001)R 100504; C. Janowitz, R. Müller, L. Dudy, A. Krapf, R. Manzke, C. Ast, H. Höchst, Europhys. Lett. 60 (2002) 615

TT 10.10 Tue 12:00 H18

STM local strucuture analysis of Pb-Bi2201 depending on the lead content — •Olaf Lübben, Ralf-Peter Blum, Lenart Dudy, Alica Krapf, Helmut Dwelk, Christoph Janowitz, and Recardo Manzke — Institut f. Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin

With scanning tunneling microscopy (STM) we have performed a detailed and systematic structural analysis of optimally lanthanum doped single-layered bismuth cuprates, $Bi_{2-y}Pb_ySr_{2-x}La_xCuO_{6+\delta}$ ($x = 0.4$), as a function of the Pb content. As expected, the periodicity of the well-known (5×1) superstructure varies with increasing the amount of Pb. For about $y = 0.4$ the superstructure is almost suppressed but, unexpectedly, new modulations occur in the electron density which might influence the electronic properties of these cuprates. In addition, this could affect the charge transfer between the carrier reservoir (BiO-SrO) and the CuO_2 plane as suggested for Pb-Bi2212 by Shi et al.[1].

[1] L. Shi et al., J. Phys.: Condens. Matter 13, 5195 (2001)

TT 10.11 Tue 12:15 H18

Magnetic field dependence of the superconducting gap node topology in non-centrosymmetric $CePt_3Si$ — •Ilya Eremin[1,2] and James Annett[3] — [1]Max-Planck-Institut für Physik Komplexer Systeme,D-01187, Dresden, Germany — [2]Institute für Mathematische und Theoretische Physik, Technische Universität Carlo-Wilhelmina zu Braunschweig, 38106 Braunschweig, Germany — [3]H.H. Wills Physics Laboratory, University of Bristol, Tyndall

Non-centrosymmetric superconductors, such as $CePt_3Si$ and Li_2PtB_2, are believed to have a line node in the energy gap arising from coexistence of s-wave and p-wave pairing. Using as an example $CePt_3Si$ we show that a weak c-axis magnetic field will remove this line node, since it has no topological stability against time-reversal symmetry breaking perturbations. Conversely a field in the $a-b$ plane is shown to remove the line node on some regions of the Fermi surface, while bifurcating the line node in other directions, resulting in two 'boomerang'-like shapes. These line node topological changes are predicted to be observable experimentally in the low temperature heat capacity.

TT 10.12 Tue 12:30 H18

Thermodynamic and Transport Properties of the Noncentrosymmetric Superconductor LaBiPt — •Gernot Goll[1], Michael Marz[1], Andreas Hamann[1], Tihomir Tomanic[1], Kai Grube[2], T. Yoshino[3], and T. Takabatake[3] — [1]Physikalisches Institut, Universität Karlsruhe, 76128 Karlsruhe — [2]Forschungszentrum Karlsruhe, Institut für Festkörperphysik, 76021 Karlsruhe — [3]Hiroshima University, Higashi-Hiroshima, Japan

Noncentrosymmetric superconductors have attracted considerable interest in recent years. The lack of an inversion center of the crystal lattice makes unconventional pairing symmetries feasible. Even mixed superconducting states consisting of singlet and triplet states are possible. We report on the observation of superconductivity in the half-Heusler compound LaBiPt which crystallizes in the noncentrosymmetric cubic space group $F\bar{4}3m$. The crystal structure is composed of three fcc sublattices for Pt, Bi, and La with the relative atomic coordinates (0,0,0), (1/4,1/4,1/4), and (3/4,3/4,3/4), respectively. LaBiPt becomes superconducting below $T_c \approx 0.9\,\mathrm{K}$ as evidenced from measurements of the resistivity, magnetisation and specific heat. In view of a simplified BCS model $T_c \sim T_\mathrm{D} \exp\left(-(N(0)V)^{-1}\right)$ where $N(0) \sim m^* n^{1/3}$ is the electronic density of states at the E_F, T_D is the Debye temperature, and V is the effective, attractive potential, is surprisingly high because LaBiPt is a semimetal with very low charge-carrier concentrations $n = 6 \cdot 10^{18}\,\mathrm{cm}^{-3}$. The carrier concentration is still 1-2 orders of magnitude lower than in the classical low-carrier-density superconductors GeTe and SnTe and comparable to that found in $SrTiO_3$.

TT 10.13 Tue 12:45 H18

Ginzburg-Landau theory of superconducting surfaces under electric fields — Pavel Lipavsky[1], •Klaus Morawetz[2,3], Jan Kolacek[4], Ernst Helmut Brandt[5], and Tzong Jer Yang[6] — [1]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague 2, Czech Republic — [2]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [3]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, 01187 Dresden, Germany — [4]Institute of Physics, Academy of Sciences, Cukrovarnická 10, 16253 Prague 6, Czech Republic — [5]Max Planck Institute for Metals Research, D-70506 Stuttgart, Germany — [6]Department of Electrophysics, National Chiao-Tung University, Hsinchu 300, Taiwan

A boundary condition for the Ginzburg-Landau wave function at surfaces biased by a strong electric field is derived within the de Gennes approach. This condition provides a simple theory of the field effect on the critical temperature of superconducting layers. [Phys. Rev. B 73 (2006) 052505-1-5]