TT 62: Superconductivity: Properties, Electronic Structure, Order Parameter

Time: Thursday 15:00–18:15 Location: H19

TT 62.1 Thu 15:00 H19

$Y_3Pt_4Ge_{13}$: a superconductor with non-centrosymmetric crystal structure — •Roman Gumeniuk, Michael Nicklas, Lev Akselrud, Walter Schnelle, Ulrich Schwarz, Alexander Tsirlin, Ulrich Burkhardt, Yuri Grin, and Andreas Leithe-Jasper — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The intermetallic compound $Y_3Pt_4Ge_{13}$ has been synthesized by high-pressure and high-temperature technique (p = 8 GPa, T = 1070 K). It crystalizes with non-centrosymmetric type-of-structure in the monoclinic space group Cc (a = 12.8781(2) Å, b = 12.8384(2) Å, c = 9.1080(1) Å, β = 90.042(2) °, V = 1505.9(1) Å^3) and is stable in the temperature range 4 K - 380 K. At 383 K structural phase transition for $Y_3Pt_4Ge_{13}$ was observed. Above the transition temperature, the crystal structure becomes rhombohedral (space group $R3c$, a = 12.7423(1) Å, c = 15.6888(1) Å, V = 2206.0(1) Å^3). The low-temperature monoclinic modification of $Y_3Pt_4Ge_{13}$ becomes superconducting below T_c = 4.5 K. Thermodynamic properties as well as transport measurements were conducted down to 0.4 K. The upper critical field $\mu_0 H_{c2}$ is 3.8 T. The data are consistent with a single energy gap with s-wave symmetry for the superconducting phase.

TT 62.2 Thu 15:15 H19

Superconducting properties of the filled skutterudite $LaPt_4Ge_{12}$ probed by thermal conductivity — •Heike Pfau, Ulrike Stockert, Roman Gumeniuk, Walter Schnelle, Helge Rosner, Michael Nicklas, Andreas Leithe-Jasper, Yuri Grin, and Frank Steglich — MPI for Chemical Physics of Solids, 01187 Dresden, Germany

Filled skutterudites have attracted much interest due to a remarkable variety of physical properties and ground states. Particular interest has been paid to the superconductors, which range from conventional BCS over multiband to unconventional types.

In this contribution we present results on the filled skutterudite $LaPt_4Ge_{12}$, which becomes superconducting below T_c = 8.3 K with a critical field of H^0_{c2} = 1.6 T. While for its Pr-counterpart an unconventional and/or a multiband coupling mechanism is discussed, NMR and photoemission measurements on the La-compound suggest conventional s-wave superconductivity. However, results on the series $La_xPr_{1-x}Pt_4Ge_{12}$ indicate compatible order parameters for the two stoichiometric end-compounds. As a complementary and very sensitive probe of the order parameter, we performed temperature and field dependent thermal conductivity measurements on $LaPt_4Ge_{12}$ down to temperatures below 100 mK. Our results do not show a typical s-wave behaviour, but point towards a more complex gap structure, which will be discussed in the context of previous results on both, $LaPt_4Ge_{12}$ and $PrPt_4Ge_{12}$.

TT 62.3 Thu 15:30 H19

Direct observation of the superconducting gap in thin films of titanium nitride using terahertz spectroscopy — •Uwe Santiago Pracht[1], Marc Scheffler[1], Martin Dressel[1], Tatyana Baturina[2], David Kalok[3], and Christoph Strunk[3] — [1]1. Physikalisches Institut, University of Stuttgart, Germany — [2]A. V. Rzhanov Institute of Semiconductor Physics SB RAS, Russia — [3]Institute of Experimental and Applied Physics, University of Regensburg, Germany

Thin films of superconducting titantium nitride (TiN) have recently gained attention for both applications (such as single-photon detectors) and fundamental reseach (as model system for the superconductor-insulator transition which is accompanied by uncommon superconducting properties). TiN has been studied comprehensively with (magneto-)transport studies, but only little is known about it's electrodynamical properties.

We report on the charge carrier dynamics of TiN thin films with critical temperatures of 3.4 K and below, which we study with THz spectroscopy in the frequency range 90-510 GHz. Our analysis provides access to superconducting properties like the real and imaginary parts of the complex conductivity, energy gap and penetration depth. These findings as well as the normal-state properties strongly suggest conventional weak-coupling BCS superconductivity [1].

[1] U. S. Pracht et al. Phys. Rev. B 86, 184503 (2012)

TT 62.4 Thu 15:45 H19

Soft-mode enhanced superconductivity in the antiperovskite APt_3P, A=Sr, Ca, La — •Rolf Heid and Klaus-Peter Bohnen — Institut für Festkörperphysik, Karlsruher Institut für Technologie

The surprising discovery of superconductivity in iron pnictides initiated an increased search for superconductivity in other unconventional compounds. Recently, a new class of P-based antiperovskites was synthesized, and superconductivity with a T_c of 8.4 K was observed for $SrPt_3P$ [1]. Specific heat measurements indicated a strong-coupling scenario and the presence of low-energy phonon modes. Replacing Sr by Ca or La resulted in lower T_c's and a progressive loss of strong-coupling signatures.

Here we present results of a first principles study of lattice dynamics and electron-phonon coupling properties of APt_3P, A=Sr, Ca, La, with full consideration of spin-orbit interaction. For $SrPt_3P$, the coupling is carried almost totally by a single low-frequency branch consisting of planar Pt vibrations, which result in a coupling constant of $\lambda \approx 2$. In $CaPt_3P$ this mode stiffens significantly thereby reducing λ to about 1, while in $LaPt_3P$ the coupling is further reduced to 0.5 because of a shift of the electronic bands. In contrast to previous work [2,3], our ab initio results provide a consistent quantitative description of the key features of superconductivity in this new class of materials within the framework of the strong-coupling Eliashberg theory.

[1] Takayama et al. PRL **108**, 27001 (2012)
[2] Chen et al., PRB **86**, 125116 (2012)
[3] Kang et al., arXiv:1207.6196

Topical Talk TT 62.5 Thu 16:00 H19

Condensation Energy of $CeCu_2Si_2$ and Theoretical Implications — •Stefan Kirchner — Max Planck Institute, Dresden, Germany

Unconventional superconductivity occurs in a broad range of strongly correlated electron systems. These systems are not only of varying effective dimensionality but their parent compounds out of which superconductivity emerges ranges from metals to bad metals and Mott insulators. The only unifying characteristic features seems that unconventional superconductivity occurs in close vicinity of zero-temperature instabilities which are most often magnetic in nature. Heavy fermion compounds represent prototype systems to address the interplay between quantum criticality and unconventional superconductivity. In $CeCu_2Si_2$, the magnetic quantum phase transition and superconductivity occur at ambient pressure which allows for a detailed study of the energetics across the superconducting transition. Based on an in-depth study of the magnetic excitation spectrum of $CeCu_2Si_2$ in the normal and superconducting state we obtain a lower bound for the change in exchange energy. The comparison with the superconducting condensation energy demonstrates that the built-up of magnetic correlations near the quantum critical point does drive superconductivity in $CeCu_2Si_2$. In addition, our comparison establishes a huge kinetic energy loss which we relate to the competition of Kondo screening and superconductivity as the opening of the gap weakens the Kondo effect. We discuss the relation between kinetic energy loss and the nature of the underlying quantum critical point.

15 min. break

TT 62.6 Thu 16:45 H19

Magnetic and Superconducting Phases in RE-doped Chrysene — •Franziska Hammerath, Pietro Carretta, Gianluca A. Artioli, and Lorenzo Malavasi — University of Pavia - CNISM, 27100 Pavia, Italy

We present the first magnetic susceptibility, nuclear magnetic resonance (NMR) and muon spin rotation (μSR) investigations of rare earth (RE) doped Chrysene, (RE = Sm, Eu and La), a promising candidate for a new superconducting (SC) hydrocarbon material. The magnetic susceptibility of pure Chrysene is only weakly temperature dependent, its zero-field μSR measurements indicate a high fraction of Muonium formation and its ^{1}H-NMR spectra and relaxation rates are determined by the dominant nuclear dipolar interactions. The NMR, μSR and susceptibility measurements on the RE-doped compounds show different behaviors, thus confirming the formation of REChrysene phases. Indications of superconductivity are present in La- and

Sm-doped Chrysene with SC transition temperatures of 6 K and 4-7 K, respectively. While LaChrysene exhibits a rather high SC volume fraction (≈ 30 %), the one of SmChrysene is always very small. The pressure and magnetic field dependence of T_c of LaChrysene is very similar to the one of LaPhenanthrene [1], but has to be discussed in the context of a possible spurious fcc La phase, which shows similar SC properties. Such an effect can be excluded for SmChrysene. Susceptibility, NMR and μSR measurements on EuChrysene on the other hand evidence the onset of a magnetic order involving Eu ions.

[1] X. F. Wang *et al.*, J. Phys. Condens. Matter **24**, 345701 (2012)

TT 62.7 Thu 17:00 H19

Imaging the Anisotropic Nonlinear Meissner Effect in Unconventional Superconductors — Alexander P. Zhuravel[1], Behnood G. Ghamsari[2], Cihan Kurter[2], •Philipp Jung[3], Stephen Remillard[4], John Abrahams[2], Alexander Lukashenko[3], Alexey V. Ustinov[3], and Steven M. Anlage[2,3] — [1]B. Verkin Institute for Low Temperature Physics and Engineering, National Academy of Sciences of Ukraine, 61103 Kharkov, Ukraine — [2]CNAM, Physics Department, University of Maryland, College Park, ML 20742-4111, USA — [3]Physikalisches Institut and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [4]Physics Department, 27 Graves Place, Hope College, Holland, MI 49422, USA

We present measurements on the anisotropic nonlinear Meissner effect (aNLME). Using a laser scanning microscope we have directly imaged this effect in a self-resonant spiral patterned from a thin film of the $d_{x^2-y^2}$ superconductor $YBa_2Cu_3O_{7-\delta}$. The spiral is excited at one of its resonant frequencies while a focused laser spot is scanned across its surface. The local illumination by the laser gives rise to a detectable change in the resonant properties. At low temperatures, the aNLME causes a direction dependent contribution to the critical current density. This makes it possible to image the directions of nodes and antinodes of the superconducting order parameter and the contribution of Andreev bound states associated with them. These two contributions to the photoresponse can be distinguished by their temperature dependence, which is consistent with theoretical predictions.

TT 62.8 Thu 17:15 H19

Effect of photo-induced hole doping on the Meissner screening in underdoped $YBa_2Cu_3O_{7-\delta}$ — •Evelyn Stilp[1,2], Andreas Suter[2], Elvezio Morenzoni[2], Thomas Prokscha[2], Zaher Salman[2], Hugo Keller[1], Patrick Pahlke[3,4], Ruben Hühne[4], Jordan C. Baglo[5], Ruixing Liang[5], and Robert F. Kiefl[5] — [1]Physik-Institut, University of Zurich, CH-8057 Zurich, Switzerland — [2]Laboratory for Muonspin Spectroscopy, PSI, CH-5232 Villigen PSI, Switzerland — [3]Inst. für Festkörperphysik,TU Dresden, D-01069 Dresden, Germany — [4]IFW Dresden, D-01069 Dresden, Germany — [5]Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, Canada, V6T

For classical superconductors the interaction with light results in a reduction of the energy gap due to excess of quasiparticles. Surprisingly, this is very different for cuprate superconductors where it was found that illumination with light increases the charge carrier density. Systematic investigations in $YBa_2Cu_3O_{7-\delta}$ showed that T_c is increased by this effect which is most pronounced at the heavily underdoped side of the phase diagram. Up to now studies of photo-induced processes have been restricted to investigations of transport properties and critical temperatures. Using low energy μSR changes in the Meissner screening profile caused by illumination were directly investigated. We will show that the photo-persistent effect in underdoped $YBa_2Cu_3O_{7-\delta}$ is related to an increase of the superfluid density close to the surface. We are also able to show that the oxygen ordering is a crucial ingredient of the photo-induced effect.

TT 62.9 Thu 17:30 H19

Is there a magnetic analogon of the isotope effect in HTSC? — •Dirk Wulferding[1], Peter Lemmens[1], Gil Drachuck[2], Meni Shay[2], Galina Bazalitsky[2], Rinat Ofer[2], Zaher Salman[3], Alex Amato[3], Christof Niedermayer[3], and Amit Keren[2] — [1]IPKM, TU-BS, Braunschweig — [2]Technion, Haifa, Israel — [3]PSI, Villigen, Switzerland

The successful growth of large $(Ca_xLa_{1-x})(Ba_{1.75-x}La_{0.25+x})Cu_3O_y$ (CLBLCO) allows now a systematic investigation of correlations between material properties and T_c. In particular, the parameter x varies the magnetic super-exchange coupling J by controlling the Cu-O-Cu buckling angle. Using Raman scattering (and μSR) we determine J for a series of samples, and show that T_c monotonically increases with increasing J. Our results are in contrast to recent Raman data (B. Mallett, arXiv:1202.5078) showing the opposite behavior in other systems. The origin of the contradiction will be discussed. Work supported by DFG, GIF and the ESF.

TT 62.10 Thu 17:45 H19

Gold nanocrystals in high-temperature superconducting films: Creation of pinning patterns of choice — •Christian Katzer[1], Claudia Stahl[2], Peter Michalowski[1], Sebastian Treiber[2], Georg Christiani[3], Frank Schmidl[1], Paul Seidel[1], Gisela Schütz[2], and Joachim Albrecht[4] — [1]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, 07743 Jena — [2]Max-Planck-Institut für Intelligente Systeme, Heisenbergstraße 3, 70569 Stuttgart — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart — [4]Hochschule Aalen, Beethovenstraße 1, 73430 Aalen

Many superconducting thin film devices require a spatially resolved current carrying capability due to different boundary conditions. On the one hand, the critical current density and the pinning of flux lines respectively should be high to reduce flux noise in the antenna regions of gradiometers; on the other hand, the critical current density of the Josephson junctions itself must not be too high to ensure a proper functionality. We report that adding gold nanoparticles during the preparation process of epitaxial $YBa_2Cu_3O_{7-\delta}$ thin films offers the possibility of creating spatially varying flux pinning properties, thus allowing to locally enhance the critical current density up to a factor of two. Magneto-optical investigations as well as transport measurements will be presented, indicating that an Au particle induced modification of the YBCO pinning properties allows the engineering of the critical current landscape on the sub-micrometre scale.

TT 62.11 Thu 18:00 H19

Temperature dependence of band gaps in semiconductors: electron-phonon interaction — •Reinhard K. Kremer[1], M. Cardona[1], R. Lauck[1], J. Bhosale[2], A. K. Ramdas[2], A. Burger[3], A. Muñoz[4], and A. H. Romero[5] — [1]MPI for Solid State Research, Stuttgart, Germany — [2]Physics Dep., Purdue University, West Lafayette, IN — [3]Fisk University, Dep. of Life and Physical Sciences, Nashville, TN, USA — [4]MALTA Consolider Team, Dep. de Física Fundamental II, and Instituto de Materiales y Nanotecnología, Universidad de La Laguna, La Laguna, Tenerife, Spain — [5]CINVESTAV, Dep. de Materiales, Unidad Querétaro, Querétaro, Mexico and MPI für Mikrostrukturphysik, Weinberg 2, Halle, Germany

We investigate the temperature dependence of the energy gap of several semiconductors with chalcopyrite structure and re-examine literature data and analyze own high-resolution reflectivity spectra in view of our new *ab initio* calculations of their phonon properties. This analysis leads us to distinguish between materials with *d*-electrons in the valence band (e.g. $CuGaS_2$, $AgGaS_2$) and those without *d*-electrons (e.g. $ZnSnAs_2$). The former exhibit a rather peculiar non-monotonic temperature dependence of the energy gap which, so far, has resisted cogent theoretical description. We demonstrate it can well be fitted by including two Bose-Einstein oscillators with weights of opposite sign leading to an increase at low-T and a decrease at higher T's. We find that the energy of the former correlates well with characteristic peaks in the phonon density of states associated with low-energy vibrations of the *d*-electron constituents.