TT 29: Unconventional Superconductors

Time: Tuesday 9:30–12:45 Location: CHE/0091

TT 29.1 Tue 9:30 CHE/0091

Investigation of the field-dependent phase diagram of UTe_2 — •F. Husstedt[1,2], M. Kimata[3], S. Naduvile Thadathil[1,2], M. König[5], G. Lapertot[4], J.-P. Brison[4], G. Knebel[4], J. Wosnitza[1,2], and T. Helm[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL) and Würzburg-Dresden Cluster of Excellence ctd.qmat, HZDR, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Institute for Materials Research, Tohoku University, Japan — [4]Centre CEA de Grenoble, France — [5]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

While the general shape of the UTe_2 superconducting (SC) phase diagram is already known, there are still investigations ongoing regarding the details of the SC states. This includes, for example, the shape and nature of the high-field reentrant SC phase near the crystallographic b axis as well as multiple superconducting phases at lower fields. Especially interesting is the case for field applied parallel to the b axis. The phase diagram proposed by Rosuel *et al.* [1] contains two second-order phase transition lines meeting, which is thermodynamically forbidden [2]. This problem could be resolved by a fourth line emerging from this point. The first indication of such a line was proposed by Sakai *et al.* [3]. We performed transport studies on a microfabricated sample to get deeper insight in the phase diagram for both the a axis and b axis as well as the angle-dependent behavior of the emergent phases.

[1] Rosuel *et al.*, PRX **13**, 011022 (2023)
[2] Yip *et al.*, PRB **43**, 2742 (1991)
[3] Sakai *et al.*, PRL **130**, 196002 (2023)

TT 29.2 Tue 9:45 CHE/0091

Determining the superconducting order parameter of UPt_3 using scanning tunneling microscopy — •Rebecca Bisset[1], Luke C. Rhodes[1], Hugo Decitre[1], Matthew Neat[1], Ana Maldonado[1], Andrew Huxley[2], Carolina A. Marques[1], and Peter Wahl[1,3] — [1]SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, United Kingdom — [2]SUPA, School of Physics and Astronomy, University of Edinburgh, Kings Buildings, Edinburgh, EH9 3FD, United Kingdom — [3]Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany

The hunt for spin-triplet superconductors has excited researchers for decades, with new candidates regularly being proposed as others are ruled out. This pairing of electrons into a Cooper pair state with total spin of one is allowed theoretically but has yet to be confirmed in a material. A system with these characteristics would have profound fundamental and technological implications. Here, we use ultra-low temperature scanning tunneling microscopy to measure the superconducting gap of UPt_3, which reveals a zero-bias Andreev bound state in the surface perpendicular to the c-axis. The superconducting origin of the gap is confirmed via observation of a vortex lattice, as well as by suppression of the gap above the expected critical field and temperature. For triplet pairing, such an Andreev state is fragile against Rashba spin-splitting, whereas for singlet pairing it remains robust, strongly suggesting that UPt_3 is a spin-singlet superconductor.

TT 29.3 Tue 10:00 CHE/0091

Study of tri-layer Bismuth-based Cuprates through ARPES measurement — •Elisa Auffray[1,2], Lenart Dudy[2], and Siham Benhabib[1] — [1]Laboratoire de Physique des Solides, CNRS, Orsay, France — [2]Synchrotron Soleil, CEA, CNRS, St Aubin, France

It is now well established that three-layer cuprates exhibit the highest critical temperature within each family, making them particularly interesting systems for studying superconductivity. Due to the presence of an underdoped inner CuO_2 plane, the magnetic environment is expected to differ from that of two-layer cuprates, a feature that has indeed been demonstrated by nuclear magnetic resonance measurements. This doping imbalance has also been revealed by ARPES measurements on the three-layer compound Bi2223. The bismuth-based three-layer cuprate is one of the most accessible in terms of synthesis and experimental investigation, and together with Hg1223 it belongs to the cuprates with the highest critical temperatures across the entire family. This makes it an excellent candidate for understanding three-layer physics, as highlighted by the number of recent publications devoted to it. Among these ARPES studies, only a few focus on the antinodal region where superconductivity truly emerges, so systematic comparisons between nodal and antinodal behavior are still lacking. In this presentation, we report our ARPES measurements on Bi2223. We present the momentum dependence of the 70 meV kink, which has previously been studied in the nodal region in superconducting state, as well as a comparison between the normal and superconducting phases.

TT 29.4 Tue 10:15 CHE/0091

Boundary critical temperature in unconventional superconductors and effects of impurities — •David Haink[1,2] and Benedikt Fauseweh[1,2] — [1]High-performance Computing, Institute of Software Technology, German Aerospace Center (DLR), 51147 Cologne, Germany — [2]Condensed Matter Theory, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany

In BCS theory, s-wave superconductors have a higher critical temperature at their boundaries than in their bulk [PRB 101, 134512 (2020)]. We show that this boundary behavior does not hold for p-wave, but for d-wave superconductors and for coexisting phases. We further investigate the effects of randomly distributed impurities in the chemical potential on the critical temperature of the edge.

TT 29.5 Tue 10:30 CHE/0091

Weak competition between magnetism and superconductivity in the heavy-fermion compound $CeRh_2As_2$ — •Pavlo Khanenko[1,2], Javier F. Landaeta[2], Simon Ruet[2], Thomas Lühmann[2], Konstantin Semeniuk[2,3,6], Max Pelly[4], Andreas W. Rost[4], Grzegorz Chajewski[5], Dariusz Kaczorowski[5], Christoph Geibel[2], Seunghyun Khim[2], Elena Hassinger[3,6], and Manuel Brando[2] — [1]Helmholtz Zentrum Dresden Rossendorf, Germany — [2]MPI CPfS, Germany — [3]TUD, Germany — [4]University of St. Andrews, United Kingdom — [5]Institute of Low Temperature and Structure Research, Poland — [6]KIT Karlsruhe, Germany

The heavy-fermion superconductor $CeRh_2As_2$ shows superconductivity at $T_c = 0.35\,K$, which is preceded by another phase (phase I) at $T_0 = 0.54\,K$. Recent μSR studies detected an internal magnetic field within phase I and suggested its coexistence with superconductivity. When a magnetic field is applied parallel to the c axis of its tetragonal unit cell, a second superconducting (SC) phase is observed at $\mu_0 H^* \approx 4\,T$. An earlier study has shown that phase I persists up to $\mu_0 H_0 \approx 6\,T$, larger than H^*. However, the phase transition disappeared upon entering the SC dome, contradicting thermodynamic considerations. Here, we report magnetic field-dependent ac-susceptibility and magnetostriction measurements on high-quality single crystals. We observed clear evidence of the singularity at H_0 in fields up to $7\,T$ and inside the SC dome. Analysis of the phase boundaries in terms of the Ginzburg-Landau theory of coupled order parameters shows a weak competition between phase I and superconductivity.

TT 29.6 Tue 10:45 CHE/0091

Entropy-rich superconductivity and unconventional vortex dynamics in $CeRh_2As_2$ — •Shuai Zhang, Xinyang Liu, Enke Liu, and Peijie Sun — Institute of Physics and Beijing National Laboratory for Condensed Matter Physics, Chinese Academy of Sciences, Beijing 100190, China

We investigate the multiple superconducting (SC) phases SC1 and SC2 of $CeRh_2As_2$ using high-resolution magnetocaloric-effect (MCE) measurements. Pronounced temperature hysteresis observed during quasiadiabatic field sweeps provides direct thermodynamic evidence that both the SC1-normal (NS) and SC2-NS transitions are first order. In contrast, a continuous yet asymmetric entropy evolution across the SC1-SC2 boundary reveals a change in the superconducting order parameter, consistent with a second-order transition. The observed temperature dips in field-sweep traces identify SC2 as a higher-entropy phase compared with SC1 and NS. Furthermore, the two-step resistive transitions and enhanced ΔT near the SC2-NS boundary highlight the unconventional and current-sensitive nature of SC2. These results establish a comprehensive thermodynamic phase diagram for $CeRh_2As_2$ and demonstrate that MCE is a powerful probe of entropy discontinuities and symmetry reconstruction in locally noncentrosymmetric superconductors.

TT 29.7 Tue 11:00 CHE/0091

Chiral topological superconductivity in hole-doped Sn/Si(111) — •Matthew Bunney[1,2], Lucca Marchetti[1], Domenico Di Sante[3], Carsten Honerkamp[2], and Stephan Rachel[1] — [1]School of Physics, University of Melbourne, Australia — [2]Institute for Theoretical Solid State Physics, RWTH Aachen University, Germany — [3]Department of Physics and Astronomy, University of Bologna, Italy

A third monolayer of tin atoms on the semiconductor substrate Si(111) has been shown to become superconducting upon six to ten percent hole doping. Experiments have reported promising results hinting at a superconducting chiral d-wave order parameter. Here we examine Sn/Si(111) by combining most recent ab initio results, quasi-particle interference calculations, state-of-the-art truncated-unity functional renormalization group simulations and Bogoliubov-de Gennes analysis. We show remarkable agreement between experimental and theoretical quasi-particle interference data both in the metallic and superconducting regimes. The interacting phase diagram reveals that the superconductivity is indeed chiral d-wave with Chern number $C = 4$. Surprisingly, magnetically ordered phases are absent, instead we find charge density wave order, as observed in related compounds, as a competing phase. Our results substantiate further that Sn/Si(111) is a promising candidate material for chiral topological superconductivity.

15 min. break

TT 29.8 Tue 11:30 CHE/0091

Point-contact spectroscopy of atomic contacts from the non-centrosymmetric superconductor $Nb_{18}Re_{82}$ — •Tiark Tiwary, Elias Hadzic, Marcel Strohmeier, and Elke Scheer — University of Konstanz, 78457 Konstanz, Germany

Revealing various properties of unconventional superconductivity, the non-centrosymmetric superconductor $Nb_{18}Re_{82}$ (Nb-Re) has become of great interest in the recent years. A key feature is the absence of inversion symmetry which is causing a Rashba-type spin-orbit coupling. Theoretically, this lack of symmetry allows for an admixture of spin-singlet and spin-triplet states. While previous measurements [1] on point contacts with Nb-Re single crystals stated the existance of two distinct BCS-like superconducting energy gaps, measurements on Nb-Re thin films [2] are showing a single s-wave gap. To address these inconsistencies, we utilised the mechanically controlled break junction technique to characterise Nb-Re atomic contacts. We observe the typical features of Andreev refelctions for atomic contacts with high transmission as well as tunneling spectra for contacts with low transmission. As a result the two distinct gaps observed in [1] can be reproduced. While the temperature dependencies of both gaps follow an BCS-like behaviour, the magnetic field dependent measurements shows a non-BCS-like behaviour.

[1] Cirillo et al., Phys. Rev. B, **91**, 134508 (2015)
[2] Cirillo et al., Phys. Rev. B, **94**, 104512 (2016)

TT 29.9 Tue 11:45 CHE/0091

Unconventional superconductivity in monolayer transition metal dichalcogenides — •Subhojit Roy[1], Andreas Kreisel[2], Brian Andersen[3], and Shantanu Mukherjee[4] — [1]University of Regensburg, Regensburg, Germany — [2]Niels Bohr Institute, University of Copenhagen, Denmark — [3]Niels Bohr Institute, University of Copenhagen, Denmark — [4]Indian Institute of Technology Madras, Chennai, India

The observation of a Leggett mode, nodal superconducting gaps in STM measurements, unusually large in-plane upper critical fields far exceeding the Pauli limit, and a two-fold gap anisotropy in magnetoresistance experiments all point toward an unconventional pairing mechanism. Ab-initio calculations have further revealed a strongly anisotropic Eliashberg electron-phonon spectral function in monolayer $NbSe_2$, with a significant contribution arising from same-spin K-K$'$ scattering. In this work [1], we consider the interplay of electron-electron and electron-phonon interactions. Starting from the ab-initio phonon spectrum, we compute the effective phonon-mediated interaction and incorporate it into an RPA-based description of the screened Coulomb interaction. Our framework captures the full lattice structure, the multi-orbital character of the relevant d-band states, and phonon retardation effects within a unified microscopic model. Using this model, we address key magnetic-field-dependent phenomena in Ising superconductors, including the enhanced Pauli limit and the two-fold magnetoresistance anisotropy.

[1] S. Roy et al., arXiv:2509.03907 (2025).

TT 29.10 Tue 12:00 CHE/0091

Effects of YIG exchange field on TMDC superconductor $NbSe_2$ — •Alfredo Spuri[1], Marcin Faitsch[1], Christian Wiedemann[1], Wolfgang Belzig[1], Elke Scheer[1], and Angelo Di Bernardo[1,2] — [1]Universität Konstanz, Konstanz, Germany — [2]Univeristà degli studi di Salerno, Fisciano, Italy

Yttrium iron garnet (YIG) [1] is a heavily investigated material for application in spintronic devices as a ferromagnet with high critical temperature ($T_C \sim 560$ °C), insulating properties due to a large bandgap of ~ 2.85 eV, and a strong local in-plane exchange field ($H_{ex} \sim 10^2$ T). Coupling YIG with a natural 2D Ising superconductor like $NbSe_2$, with a very high in-plane critical field ($H_C \sim 40$ T in the monolayer limit) [2], offers the possibility of novel unconventional superconducting states.

We have assembled YIG/$NbSe_2$ heterostructures and investigated their superconducting properties. $NbSe_2$ with a YIG flake on top reveals features in the T_C(B) curve that are not found on bare $NbSe_2$, We tentatively attribute the features in the heterostructures to scattering between two different energy bands in $NbSe_2$, enhanced by the strong exchange field of the YIG.

[1] R. Hartmann et al., APL Mater. 12, 031121 (2024).
[2] X. Xi et al., Nature Phys. 12, 139 (2016).

TT 29.11 Tue 12:15 CHE/0091

Effects of disorder on the superconducting properties of YFe_2Ge_2 — •Mads Hansen[1], Han Zong[1], Jiasheng Chen[1], Romian Grasset[2], Siham Benhabib[3], and Malte Grosche[1] — [1]University of Cambridge, Cambridge, United Kingdom — [2]Laboratoire des Solides Irradies, École Polytechnique, CNRS, Institut Polytechnique de Paris, Palaiseau, France — [3]Laboratoire de Physique des Solides, Orsay, France

YFe_2Ge_2 has been reported as an unconventional superconductor [1-3]. The non-Fermi liquid behavior observed in the normal state, as well as enhanced magnetic fluctuations [4,5] evidence the strongly correlated nature of the electron system. The pairing mechanism remains unknown, however, theoretical proposals hypothesize two different scenarios: an $s^{+/-}$ [6] or a triplet pairing wavefunction [7]. We have grown high quality crystals and induced point-like defects at various concentrations, using the electron irradiation facility SIRIUS. Here, we present a study on the effect of disorder on the Sommerfeld coefficient and the transport properties of YFe_2Ge_2 to address the outstanding question of the pairing mechanism.

[1] Y. Zou et al., Phys. Status Solidi RRL 8, 928 (2014)
[2] J. Chen et al., Phys. Rev. Lett. 116, 127001 (2016)
[3] J. Chen et al., Phys. Rev. Lett. 125, 237002 (2020)
[4] N. Sirica et al., Phys. Rev. B 91, 121102 (2015)
[5] H. Wo et al., Phys. Rev. Lett. 122, 217003 (2019)
[6] A. Subedi, Phys. Rev. 89, 024504 (2014)
[7] D. J. Singh, Phys. Rev. B 89, 024505 (2014)

TT 29.12 Tue 12:30 CHE/0091

Inverse proximity effect and unconventional superconductivity in the Pb/CrTe hybrid thin films — •Lichen Ji[1,2], Wei Chen[2], Xinyu Zhou[2], Xusheng Wang[2], Yi Hu[2], Xiaopeng Hu[2], Qinghua Zhang[3], Ding Zhang[2], Qi-kun Xue[2], and Shuai-Hua Ji[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden 01187, Germany — [2]State Key Laboratory of Low-Dimensional Quantum Physics, Department of Physics, Tsinghua University, Beijing 100084, China — [3]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

Two-dimensional (2D) heterostructures provide an important platform for exploring unconventional quantum states. Here, we investigate molecular-beam-epitaxial 2D vertical superconductor (S)/ferromagnet (F) hybrids composed of superconducting Pb and ferromagnetic CrTe using in situ scanning tunneling microscopy and ex situ transport measurements. We observe an unconventional superconducting gap structure accompanied by a pronounced inverse proximity effect. Transport data further show strong suppression of both the critical temperature and upper critical field. Importantly, the critical temperature exhibits an oscillatory dependence on the CrTe thickness, and re-entrant superconductivity emerges within a finite magnetic-field window. These results offer new insights into the unconventional superconducting properties of Pb/CrTe hybrids, underscoring the crucial role of interfacial effect and inverse proximity effect.