

TT 43: Correlated Electrons: Heavy Fermions 2

Time: Thursday 15:45–18:45

Location: HSZ 301

TT 43.1 Thu 15:45 HSZ 301

Cerium iron oxypnictides: from a heavy fermion system to the parent compound for high-Tc superconductivity — ●ANTON JESCHE, CORNELIUS KRELLNER, and CHRISTOPH GEIBEL — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Within the layered FeAs systems the CeFePnO ($Pn = As, P$) compounds offer the unique possibility to study the interplay between strong 3d correlation effects connected with peculiar features of the FeAs layers and strong 4f correlation effects due to interaction between conduction and Ce 4f electrons. Thus we recently showed that CeFePO is a paramagnetic heavy fermion system likely close to a ferromagnetic instability [1] connected with the onset of Ce long range ordering, while Fe is non magnetic. In contrast in CeFeAsO both Fe and Ce orders antiferromagnetically around 140 K and 4 K, respectively, Ce being in a magnetic stable trivalent state due to the larger unit cell volume. In this compound F-doping lead to the suppression of Fe ferromagnetic ordering and to the formation of a superconducting state with a remarkably high Tc of 41 K [2]. We report on measurements of specific heat, electric resistance and magnetization on single crystalline CeFeAsO and CeFePO, as well as on the alloy system CeFeAs_{1-x}P_xO. We shall focus on the effect of P for As substitution on the magnetic ordering of Fe and Ce as well as on the superconductivity. Further on we shall address the relation between the Fe magnetic ordering and the structural distortion in pure CeFeAsO around 150 K.

[1] Phys. Rev. Lett. 101, 117206 (2008).

[2] Phys. Rev. Lett. 100, 247002 (2008).

TT 43.2 Thu 16:00 HSZ 301

Ce and T magnetism in CeTPO compounds (T = Os, Ru, Fe, Co) - Large variety of ground states. — ●CORNELIUS KRELLNER, ANTON JESCHE, and CHRISTOPH GEIBEL — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

In the last years we have started a detailed investigation of the CeTPO compounds (T = Os, Ru, Fe, Co). These materials correspond to the family of LnTPnO systems, crystallizing in the tetragonal ZrCuSiAs structure-type, which attracts a lot of attention due the observation of high temperature superconductivity (SC) in the doped LnFeAsO compounds. Whereas the 3d-magnetism of the Fe is essentially for the occurrence of SC in LnFeAsO, the magnetism in CeTPO is dominated by the 4f-electrons of Ce³⁺.

In this contribution, we summarize our results on the single crystal growth of the CeTPO materials together with a thorough physical characterization, including magnetization, susceptibility, resistivity, specific heat, and thermopower. These measurements reveal four different magnetic ground states: (1) CeRuPO is a rare example of a ferromagnetically ordered Kondo-lattice system with $T_C = 15$ K and a Kondo scale of $T_K \sim 10$ K; (2) CeOsPO orders antiferromagnetically at $T_N = 4.5$ K; (3) CeFePO is a heavy-fermion system on the non-magnetic side of a ferromagnetic instability; (4) CeCoPO present ferromagnetic order of the Co-ions at $T_C = 75$ K and Ce-moments close to magnetism. Therefore, these new materials present a nice playground to study in detail the phenomena of strongly correlated electron systems.

TT 43.3 Thu 16:15 HSZ 301

Field induced phases in the antiferromagnet UPt₂Si₂ — ●MATTHIAS BLECKMANN¹, DIRK SCHULZE GRACHTRUP¹, STEFAN SÜLLOW¹, BRITTA WILLENBERG¹, MAREK BARTKOWIAK², HARISON RAKOTO³, and JOHN A. MYDOSH⁴ — ¹Institut für Physik der Kondensierten Materie, Braunschweig, Germany — ²Hochfeld-Magnetlabor Dresden, Germany — ³National Pulsed Magnetic Field Laboratory, Toulouse, France — ⁴Institute of Physics II, Köln, Germany

Previously, UPt₂Si₂ has been described as a moderately mass enhanced antiferromagnet with a transition temperature of $T_N = 32$ K [1]. In contrast, and more recently, it has been demonstrated that UPt₂Si₂ closely resembles the tetragonal heavy fermion superconductor/hidden order material URu₂Si₂ in various physical properties [2,3].

We present a detailed study of high field magnetization and resistivity on single crystalline UPt₂Si₂. While up to now the high field behavior of UPt₂Si₂ was discussed in terms of a crystalline electric field scheme applied to an *f* electron local moment system [4], we show

that the high field behavior is much more complex than previously thought. In particular, the magnetic phase diagrams derived from our measurements contain various field induced phases, again analogous to URu₂Si₂. We compare the phase diagrams of both systems and discuss possible scenarios accounting for such behavior in UPt₂Si₂.

[1] R. A. Steeman, *et al.*, J. Phys.: Condens. Matter **2**, 4059 (1990).[2] S. Süllow, *et al.*, J. Phys. Soc. Japan **77**, 024708 (2008).[3] N. Johannsen, *et al.*, Phys. Rev. B **78**, 121103(R) (2008).[4] G. J. Nieuwenhuys, Phys. Rev. B **35**, 5260, (1987).

TT 43.4 Thu 16:30 HSZ 301

Non-Fermi-Liquid Behaviour in CaCu₃Ru₄O₁₂ Studied by Nuclear Magnetic Resonance — ●WOLFGANG KRÄTSCHMER¹, HEIKO DEKINGER¹, NORBERT BÜTTGEN¹, ALOIS LOIDL¹, AXEL GÜNTHER¹, ALEXANDER KRIMMEL¹, and ERNST-WILHELM SCHEIDT² — ¹Experimentalphysik 5, Zentrum für elektronische Korrelationen und Magnetismus, Universität Augsburg, 86135 Augsburg, Deutschland — ²CPM, Universität Augsburg, 86135 Augsburg, Deutschland

We present a detailed study of the electronic properties of CaCu₃Ru₄O₁₂ which has perovskite structure and shows strong electron correlations. Beside magnetic susceptibility, transport and specific heat data, we focus on NMR and NQR measurements at the copper and ruthenium sites in this compound [Krimmel *et al.*, PRB **78**, 165126 (2008)]. CaCu₃Ru₄O₁₂ is a metallic system showing non-Fermi-liquid behaviour below 2K which becomes manifest in a logarithmic increase of the specific heat $C_p/T \propto -\ln(T)$ and in an NQR spin-lattice relaxation rate $1/T_1(T)$ that deviates from the Korringa law at the copper site only. Static NMR measurements were conducted to extract electric field gradients for the correction of the low-temperature specific heat data for nuclear contributions. Nuclear contributions turned out to be not sufficient to account for the Schottky-anomaly. Further investigation of the spin-lattice relaxation at the ruthenium site reveals a clearly different behaviour in comparison to the copper site and reflects the local character of the strong electron correlations.

TT 43.5 Thu 16:45 HSZ 301

Electronic Correlations and Non-Fermi-Liquid Behaviour in ACu₃Ru₄O₁₂-Perovskites — ●AXEL GÜNTHER¹, ALEXANDER KRIMMEL¹, ALOIS LOIDL¹, WOLFGANG KRÄTSCHMER¹, HEIKO DEKINGER¹, NORBERT BÜTTGEN¹, ERNST-WILHELM SCHEIDT², DENIS SHEPTYAKOV³, and HANNU MUTKA⁴ — ¹Experimentalphysik 5, Zentrum für elektronische Korrelationen und Magnetismus, Universität Augsburg, 86135 Augsburg, Deutschland — ²CPM, Institut für Physik, Universität Augsburg, 86135 Augsburg, Deutschland — ³Labor für Neutronenstreuung, ETHZ & PSI, 5232 Villigen PSI, Schweiz — ⁴Institut Laue Langevin, 38042 Grenoble Cedex 9, France

Among the large variety of AC₃B₄O₁₂-type perovskites, the copper-ruthenates (C = Cu, B = Ru) form a subclass exhibiting strongly correlated electron behaviour. A special feature of these compounds is that the ideal stoichiometry and structure is preserved for a large number of different A-site cations with different valence states. We have systematically studied the electronic properties by specific heat, magnetic susceptibility, transport, NMR/NQR and neutron scattering experiments. The compound A = Ca is a correlated metal showing non-Fermi-liquid behaviour below 2K, as indicated by a logarithmic increase of the specific heat and deviations from a Korringa behaviour of the spin lattice relaxation rate. In the case of A = Pr, an anomaly in the specific heat occurs at 0.5K whose maximum shifts to higher temperatures with increasing magnetic field. Along with data acquired from inelastic neutron scattering we obtain strong indications for a pronounced crystal field splitting.

TT 43.6 Thu 17:00 HSZ 301

Exotic Ground State of CeRu₄Sn₆ Investigated by Means of Specific-Heat and NMR — ●EVA MARIA BRÜNING¹, MANUEL BRANDO¹, MICHAEL BAENITZ¹, ANDRÉ STRYDOM², RUSSEL E. WALSTEDT³, and FRANK STEGLICH¹ — ¹Max-Planck-Institut für Chemische Physik Fester Stoffe, Dresden, Germany — ²Physics Department, University of Johannesburg, South Africa — ³Physics Department, University of Michigan, MI, USA

The tetragonal compound CeRu₄Sn₆ is a narrow-gap semi-metal and

shows no phase transition down to 50 mK. We performed field-sweep ^{119}Sn NMR measurements at different frequencies (47, 70, 100 and 119 MHz) down to 2 K as well as specific-heat measurements in magnetic fields up to 10 T and temperatures down to 65 mK. The spin-lattice-relaxation rate $1/T_1$ in the high- T range (300 K to 20 K) is field independent and could be consistently fitted with a model for a narrow gap semi-metal ($1/T_1 \propto T \exp(-\Delta/k_B T)$) with a gap of $\Delta/k_B \simeq 30$ K. This confirms the results from resistivity and thermopower measurements. Below 10 K, $1/T_1$ becomes strongly field dependent, whereas higher fields lead to a stronger reduction of $1/T_1$. The low- T range could be fitted with an activated behavior ($1/T_1 \propto \exp(-\Delta/k_B T)$), where Δ/k_B increases with increasing field. This scenario is strongly supported by specific-heat investigations. Both results can be described consistently by assuming a double Cauchy-Lorentz function for the residual in-gap density of states $N(E)$. The ground state is governed by these correlated states which show Zeeman-type splitting in magnetic fields.

15 min. break

TT 43.7 Thu 17:30 HSZ 301

Electronic structure and thermodynamic properties of CeRh_2Sn_4 — ●MONIKA GAMZA^{1,2}, WALTER SCHNELLE¹, ROMAN GUMENIUK¹, YURI PROTS¹, ANDRZEJ SLEBARSKI², HELGE ROSNER¹, and YURI GRIN¹ — ¹MPI for Chemical Physics of Solids, Dresden — ²Institute of Physics, University of Silesia, Katowice, Poland

Compounds of the system Ce–Rh–Sn have attracted a considerable attention due to a variety of strongly correlated electron phenomena, including valence fluctuations, non-Fermi liquid behavior, heavy fermion states and magnetism with reduced moments [1, 2]. Some of these systems show also evidence for spin fluctuations due to the Rh 4d electrons [2].

Here, we present a combined study of the electronic structure and thermodynamic properties of CeRh_2Sn_4 . The crystal structure has been determined from single crystal diffraction experiments. The Ce core-level XPS and Ce L_{III} XAS spectra unanimously indicate a stable $4f^1$ configuration of the Ce ions. Thermodynamic measurements show a magnetic phase transition at $T_N \approx 3.16$ K. The ground state magnetic structure is of a noncollinear antiferromagnetic type. There are clear indications for spin fluctuations in the thermodynamic data. A Fermi surface analysis reveals some parallel sections of the sheets, which could generate nesting instabilities and be responsible for the spin fluctuations.

[1] Ślebarski A *et al.* Philos. Mag. B (2002) **82** 943;

[2] Gamza M *et al.* J. Phys.: Condens. Matter (2008) **20** 025201; Ślebarski A *et al.* Phys. Rev. B (2006) **73** 2051105

TT 43.8 Thu 17:45 HSZ 301

Polarization dependent Ce- M_{45} x ray absorption spectroscopy on the giant crystal-field material CeRh_3B_2 . — ●P.O. KÖRNER¹, A. SEVERING¹, T. WILLERS¹, Z. HU¹, N. HOLLMANN¹, H. FUJIWARA¹, H.-J. LIN², C.T. CHEN², P. LEJAY³, and L.H. TJENG¹ — ¹Institute of Physics, II University of Cologne — ²NSRRC, Taiwan — ³Institut Néel, CNRS, Grenoble

The hexagonal compound CeRh_3B_2 exhibits exceptional magnetic properties ($T_C = 115$ K, $\mu_{\text{ord}} = 0.4\mu_B$) [1 and references therein]. The crystal-field splitting in this material is of the order of the spin orbit splitting so that the Steven's approximation is no longer valid. Neutron scattering combined with magnetization suggests a crystal-field level scheme where the intermixing of the higher lying multiplet contributes substantially to the ground state [1]. We have investigated the crystal-field splitting in CeRh_3B_2 with soft-x-ray absorption spectroscopy at the Ce- M_{45} edges. This technique is sensitive to the symmetry of the initial state and through the polarization dependence direct spectroscopic information about the $|J_z\rangle$ admixtures of the ground state is obtained [2]. In contrast to previous linear dichroism studies by Jo *et al.* we are taking the full crystal-field symmetry into account [3]. Our results for the ground state are consistent with [1], but we find a different level scheme providing better understanding of the anisotropies.

[1] F. Givord *et al.* J. Phys. Condens. Mater **19**, 506210 (2007).

[2] P. Hansmann *et al.*, Phys. Rev. Lett. **100**, 066405 (2008).

[3] T. Jo, Prog. Theor. Phys. Suppl. **101**, 303 (1990) and T. Jo and S. Imada, J. Phys. Soc. Jpn. **59**, 2312 (1990)

TT 43.9 Thu 18:00 HSZ 301

Investigation of the crystal-field ground state of YbInNi_4 with polarization dependent Yb-M-edge x ray absorption spectroscopy. — PETER KÖRNER¹, ●ANDREA SEVERING¹, THOMAS WILLERS¹, ZHIWEI HU¹, NILS HOLLMANN¹, DETLEF SCHMITZ², ZACHARY FISK³, ANDREA BIANCHI³, and LIU HAO TJENG¹ — ¹Institute of Physics II, University of Cologne — ²BESSY Berlin — ³University of California, Irvine, USA

YbInNi_4 serves as a stable valent reference sample for YbInCu_4 which undergoes a first order valence transition as function of temperature. Although intensively studied in the past, the crystal-field ground state of YbInNi_4 remained a matter of debate [1-4]. We will present our investigations of the crystal-field ground state of YbInNi_4 with soft-x-ray absorption spectroscopy at the Yb-M-edge. Soft-x-ray absorption spectroscopy is sensitive to the symmetry of the initial state and through the polarization dependence direct spectroscopic information about the $|J_z\rangle$ admixtures of the ground state [5] can be obtained. However, since YbInNi_4 is cubic, a polarization effect can only arise when a magnetic field is applied to split up the crystal-field states. We will show that the *induced linear dichroism* allows to distinguish between the various ground state possibilities.

[1] A. Severing *et al.*, Physica B **163**, 409 (1990).

[2] J.L. Sarrao *et al.*, Phys. Rev. B **57**, 7785 (1998).

[3] P.G. Pagiuso *et al.*, Phys. Rev. B **63**, 144430 (2001).

[4] T. Park *et al.* Phys. Rev. Lett. **96**, 046405 (2006).

[5] P. Hansmann *et al.*, Phys. Rev. Lett. **100**, 066405 (2008).

TT 43.10 Thu 18:15 HSZ 301

Narrow gap and electron correlation effects in FeSb_2 — ●PEIJIE SUN¹, NIELS OESCHLER¹, SIMON JOHNSEN², BO B. IVERSEN², and FRANK STEGLICH¹ — ¹Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — ²Department of Chemistry, University of Aarhus, Denmark

Heavy-fermion, or alternatively correlated, semiconductors are of both fundamental and practical interest due to their narrow energy gap and correlated bands at the gap edges. This talk will focus on FeSb_2 , a new d -based correlated semiconductor showing thermodynamics and band structure similar to FeSi. Correlated electrons in FeSb_2 manifest themselves in many physical properties like specific heat, magnetic susceptibility, and optical spectra. In particular, we will show a huge thermoelectric response in FeSb_2 below 50 K [1] which is also attributed to the correlated gap. Different to FeSi, a second energy gap (<100 K) was confirmed to be intrinsic to FeSb_2 by electrical, thermal transports and specific heat measurements. This largely contributes to the extraordinarily enhanced thermoelectricity at the same temperature range. Comparison of FeSb_2 to its Ru and As substituted homologues will be also presented.

[1] A. Bienten *et al.*, Europhys. Lett. **80** (2007) 17008.

TT 43.11 Thu 18:30 HSZ 301

X-ray Absorption Spectroscopy of the Narrow Gap Semiconductor FeSb_2 — ●N. HOLLMANN¹, Z. HU¹, C. CHANG¹, J. GEGNER¹, S. JOHNSEN², B.B. IVERSEN², J.C. CEZAR³, N. BROOKES³, H.H. HSIEH⁴, H.-J. LIN⁴, C.T. CHEN⁴, P. SUN⁵, N. OESCHLER⁵, F. STEGLICH⁵, and L.H. TJENG¹ — ¹II. Physikalisches Institut, University of Cologne — ²Department of Chemistry, University of Aarhus, Denmark — ³ESRF, Grenoble, France — ⁴NSRRC, Hsinchu, Taiwan — ⁵MPI for Chemical Physics of Solids, Dresden

FeSb_2 recently attracted much attention due to the observation of extremely large values of the Seebeck coefficient $S \sim -45000\mu\text{VK}^{-1}$ at 10K and the thermoelectric power $S^2\rho^{-1} = 2300\mu\text{WK}^{-2}\text{cm}^{-1}$ at 12K, the latter being a record high [1]. The material is being discussed in the framework of a Kondo insulator model with similarities to FeSi. FeSb_2 exhibits a diamagnetic to paramagnetic crossover at ≈ 100 K. The ground state was proposed to have the non-magnetic d^4 configuration. Contrary to that, band structure calculations predict a d^6 configuration for the Fe. If true, this could suggest a different scenario with similarities to that of LaCoO_3 [2]. By now, no experimental data exists to prove the valency of the Fe ion. We have performed X-ray absorption spectroscopy on FeSb_2 , as it is an ideal technique to study the valence and the spin state. The spectra directly show the valency for the Fe. Temperature-dependent linear dichroism and magnetic circular dichroism data will be discussed in the talk.

[1] A. Bienten *et al.*, Europhys. Lett. **80**, 17008 (2007).

[2] M.W. Haverkort *et al.*, Phys. Rev. Lett. **97**, 176405 (1996).