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Inelastic neutron diffraction on the heavy fermion $CeCu_4Si$ compound

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Abstract – The crystal electric field levels' scheme of the heavy fermion (HF) $CeCu_4Si$ compound has been studied employing inelastic neutron diffraction (INS) and specific heat measurements. INS spectra reveal the presence of the excitation peaks at about 8.9 meV and 13 meV. The resulting levels' sequence consists of three doublets of energy 0 K-103 K-152 K and describes well the Schottky contribution to the specific heat. In the analysis of the magnetic part of the specific heat the Kondo effect has been included providing the Kondo temperature T_K=9 K.

The $CeCu_4Si$ compound is characterized by a significant electronic specific heat coefficient γ= 2 J mol^{-1}K^{-2}, which together with a maximum in the temperature dependence of the electrical resistivity classifies this material as heavy fermion (HF). It belongs to the series $CeCu_4M$ (M= Al, Ga, In, Si). A knowledge of the crystal electric field levels (CEF) scheme is crucial to describe correctly the magnetic and transport properties of $CeCu_4Si$. The inelastic neutron scattering (INS) is a unique technique, which can provide a very reliable information on the crystal field excitations. We have prepared the samples by induction melting of the stoichiometric amounts of the high purity Ce(Y), Cu and Si elements in the argon atmosphere. The YCu_4Si compound has been prepared additionally to serve as the nonmagnetic reference sample. Assuming that both the Ce- and Y-based compounds have similar phonon contributions, one can estimate the magnetic part in the INS spectra or in the specific heat. For the INS experiment the samples of the mass of about 6g were wrapped in an aluminum foil. Additionally, Vanadium has been measured to enable the correction for background. Heat capacity measurements were carried out on the PPMS commercial device (Quantum Design) in the temperature range 1.9-300 K. The INS experiments were carried out on IN4 time-of-flight instrument at the Institut Laue Langevin (ILL) in Grenoble for the incident neutrons wavelength of 1.1 Å and 1.8 Å and for several temperatures from the 2-300 K range.

Fig. 1 shows an example of the INS spectra measured for $CeCu_4Si$ and YCu_4Si at 2 K. Arrows indicate the CEF excitations at about 8.9 meV and 13 meV, which do not appear in the non-magnetic reference compound. In temperature units these positions correspond to 103 K and 152 K, which are assumed to be the distances of two CEF doublets in respect to the ground state doublet (0 K). Fig. 2 reveals that similar levels scheme (0 K-90 K-152 K) describes correctly the position of the Schottky peak contributing to the specific heat. However, apart from the CEF peak an additional increase of C_p/T at low temperatures is visible, which is approximated by the resonance level model [1] and provides $T_K \approx 9$ K.

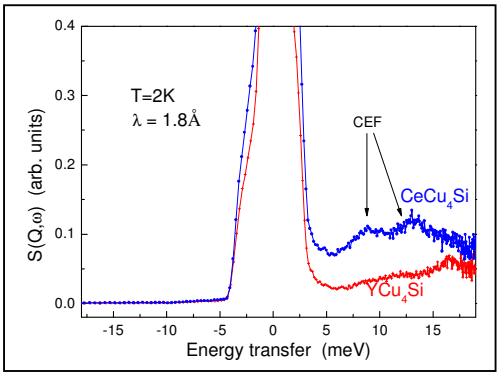

Figure 1: Neutron time-of-flight spectra for $CeCu_4Si$ and the reference compound YCu_4Si.

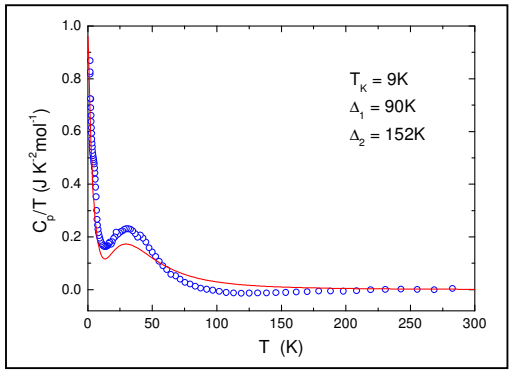

Figure 2: Magnetic part of the specific heat for $CeCu_4Si$.

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References

[1] K. D. Schotte and U. Schotte, Phys. Lett. A **55**, 38 (1975).