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Low temperature properties of AnFe2Si2 systems (An = Th, Np, Pu)

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The ThCr2Si2 (body centered I/4mmm) structure has long been typical of systems presenting striking physical properties. Two compounds presenting this structure, namely CeCu2Si2[1] and URu2Si2[2] are unconventional superconductors, and the nature of the coupling mechanism is still under debate 30 years after their discovery. Here we have focused on Transuranium systems (TU) with this structure and selected compounds with Fe as transition metal. The interplay between the hybridization and magnetism of 3d electrons from Fe and the 5f electrons from Actinides is in the background of exotic phenomena.

Low temperature properties have been examined (or re-examined) for ThFe2Si2, NpFe2Si2 and PuFe2Si2. Polycrystals of each system have been produced by arc melting stoichiometric amounts of the pure metals components in argon atmosphere. X-ray-diffraction patterns were collected indicating that ThFe2Si2 and NpFe2Si2 samples are single phase, while PuFe2Si2 presents a small amount (<5%) of an extra phase. All the majority phases present the ThCr2Si2 structure and the lattice parameters are very close to those previously reported in literature.

Magnetization has been performed in a MPMS-7 down to 2 K and in magnetic fields up to 7 T. Previous studies indicated that ThFe2Si2 and PuFe2Si2, order antiferromagnetically (TN˜100 K) [3] and ferromagnetically (TC˜35 K) [4], respectively. Starting from very pure thorium metal for the preparation of ThFe2Si2 and after a thermal treatment for PuFe2Si2, it appears that both are actually paramagnetic. Nevertheless, we confirm the occurrence of antiferromagnetism in NpFe2Si2 as previously reported [5], but we determine a Néel temperature TN=90 K slightly higher than the reported value (TN ˜ 87 K).

Low temperature specific heat measurements under magnetic fields have been performed in a PPMS-9 down to 1.9 K and up to 9 T. No hint of magnetic order has been observed neither in ThFe2Si2 nor PuFe2Si2 in agreement with our magnetic studies. In the case of NpFe2Si2 a clear peak is visible at TN (Fig. 1). This peak presents a shoulder that may be reminiscent of a possible double magnetic transition. This feature has not been reported before [5,6]. In addition, the specific heat of ThFe2Si2 has been used to estimate the phonon contribution in NpFe2Si2 .

Transport properties measurements (r, Dr/r, S) down to 1.8 K have been performed also for NpFe2Si2 and PuFe2Si2. Electrical resistivity measurements confirm the presence of a clear magnetic transition at 93 K for NpFe2Si2 while no signature of any magnetic transition is noticeable in PuFe2Si2. The thermo power of NpFe2Si2 is relatively small (˜-2 mV/K) at room temperature, suggesting a rather localized character of the 5f electrons and it also reverses its sign in the vicinity of TN. This indicates a large impact of the magnetic ordering on the Fermi surface and its possible reconstruction below TN.

Finally, we performed high pressure resistivity measurements on NpFe2Si2 up to 12 GPa. We observed an increase of the Néel temperature up to 130 K. This relatively strong increase indicates that the magnetic order is dominated by antiferromagnetic Np-Np interactions already suggested for this system by Mossbauer studies [5].

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