XMCD Studies of Actinide Compounds with Formally Nonmagnetic 5f-Electron Ground State

R. Caciuffo

European Commission, Joint Research Centre, Karlsruhe, Germany,
roberto.caciuffo@ec.europa.eu

X-ray Magnetic Circular Dichroism (XMCD) is a very efficient tool to determine the orbital and spin components of the magnetic moment in actinide compounds. These quantities are easily obtained from two sum rules applied to the dichroic signal at the M_4 and M_5 spectral edges [1]. XMCD can be applied also to compounds where the actinide atoms have a formally nonmagnetic ground state, such as $AmFe_2$ [2] and $PuCoGa_5$ [3].

In $AmFe_2$, trivalent americium has a J = 0 ground state arising from the cancellation of the orbital and spin moments, whereas the iron sublattice orders ferromagnetically at about 700 K. Despite the nonmagnetic nature of Am^{3+}, neutron diffraction measurements suggest the presence of a non-zero 5*f* magnetic moment [4]. Taking advantage of the shell- and element-specific characteristics of XMCD, we have been able to confirm that Am in $AmFe_2$ has indeed a non-zero magnetic moment. We have found that the spin component is exactly twice as large as the orbital one and that the total Am moment is opposite to that of Fe, as expected under the assumption that the former is induced by the large molecular field arising from the latter [2].

$PuCoGa_5$ is an unconventional superconductor with a critical temperature T_c =18.7 K. SQUID measurements on single crystal samples in the normal state provide a temperature independent susceptibility, suggesting a non-magnetic character of Pu. We used XMCD to study the vortex phase below T_c and found that an external magnetic field induces a Pu 5*f* magnetic moment at 2 K equal to the temperature-independent moment measured by SQUID in the normal phase up to 300 K. This observation is in agreement with theoretical models [5] claiming that the Pu atoms have a nonmagnetic singlet ground state resulting from the hybridization of the conduction electrons with the intermediate-valence 5*f* electronic shell. Unexpectedly, the orbital component of the 5*f* magnetic moment increases significantly between 30 and 2 K; the antiparallel spin component increases as well, leaving the total moment practically constant. We suggest that this indicates a low temperature breakdown of the complete Kondo-like screening of the local 5*f* moment.

References

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