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XMCD study on $AnFe_2$ Laves-phase compounds

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X-ray Magnetic Circular Dichroism (XMCD) is a powerful spectroscopic technique that offers a possibility to determine quantitatively element and shell specific spin and orbital magnetic moments in ferro-, ferri- or even paramagnetic samples. At the third generation synchrotron radiation facilities, small x-ray beam with flexible polarization sized down to few microns can be routinely achieved. This technique is thus perfectly suited for studying minute samples (a few micrograms) of transuranium materials.

We report here on XMCD experiments at the An $M_{4,5}$-edges and at the Fe *K*-edge on UFe_2, $NpFe_2$, $PuFe_2$, and $AmFe_2$. All experiments have been carried out at the ID12 beamline of the ESRF. All materials are anisotropic cubic Laves-phase ferromagnets. Results for UFe_2 are published in [1] whereas results for $NpFe_2$ and $PuFe_2$ are published in [2]. The $AmFe_2$ work is new.

As it is well known, in UFe_2 the uranium moment is small, and consists of almost cancelling spin and orbital contributions [3]. This cancellation is caused by hybridization between the U 5*f* electrons and the 3*d* states of Fe, which *reduces* both the orbital and the spin magnetic moments to ~ 0.2 μ_B . The 5*f* spin and orbital moments are much larger on the actinide atoms in $NpFe_2$ and $PuFe_2$, and the XMCD results confirm those published for $PuFe_2$ from neutron studies [4]. In addition, the XMCD studies show the importance of the <Tz> term [2], which describes anisotropy of the spin moment and its experimental value was not available for transuranium ions. The 5*f* electrons are itinerant in all materials, despite the large magnetic anisotropy present.

In $AmFe_2$ the Am – if it is assumed to have six 5*f* electrons – should be nonmagnetic with a filled j = 5/2 shell. Experimentally, this is not the case, the hybridization and strong internal field from the Fe atoms, induces a small moment (~ 0.1 μ_B) on the Am site, and it has both a spin and orbital contribution. Surprisingly, the Am M_4 XMCD signal is very narrow (~ 5 eV FWHM), whereas in all other studied Laves phase materials the actinide M_4 XMCD signal is found to be ~ 10 eV FWHM. This finding suggests a narrow (i.e. localized) j = 5/2 empty state of Am above E_F in $AmFe_2$.

We also report the systematics of the Fe *K*-edge XMCD, which provide more information on the magnetic interactions between 5f states of actinide and 3d states of Fe atoms.

References

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