ESRF	**Experiment title:** **XMCD measurements in epitaxial films of the zero-moment ferromagnet SmGdAl2**	**Experiment number**: HE 1770
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Report :

Exciting magnetic properties have been recently observed in the ferromagnetic compound $Sm_{1-x}Gd_xAl_2$, in which some of the magnetic Sm ions have been substituted with another rare earth element Gd: the resulting ternary alloy amazingly exhibits, at a specific compensation temperature (T_{comp}), together a large spin polarization but no net magnetization [1].

We achieved, for the first time, the epitaxial growth of (111) $Sm_{1-x}Gd_xAl_2$ thin films, deposited onto a $(11\bar{2}0)$ sapphire substrate covered with a (110) Nb buffer layer. In-situ RHEED analysis and large angle X ray scattering experiments have confirmed the high crystal quality of the samples. From macroscopic magnetization measurements, we have observed that the films exhibit a compensation temperature that depends on the composition x, as the bulk compounds. Moreover, the magnetic moments are aligned along the [111] direction perpendicular to the film plane and the coercive fields are large (around 6T).

During this experiment, the thermo-magnetic behaviour of a 1000nm (111)$Sm_{0.994}Gd_{0.006}Al_2$ film (T_{comp}=107.4K) was studied, by recording the XMCD signal in total fluorescence detection mode at both Sm L_{II} and L_{III} edges and Gd L_{II} and L_{III} edges. For this purpose, the sample was put into a helium pumped cryostat, which was inserted in a 6T superconducting magnet. The magnetic field was applied along the (111) easy magnetisation direction.

The first important result obtained during this experiment is that we could verify the existence of a ferromagnetic order of the Sm and Gd 5d conduction electrons moments at the compensation temperature. The XMCD spectra measured at this temperature at Sm L_{II} L_{III} edges (figure 1) clearly evidence the long range order of the 5d electrons.

Moreover, selective hysteresis loops have been measured at the Sm L_{II} edge below, above and at the compensation temperature (Figure 2) after cooling the sample under 6 Tesla. Above (114K) and below (79K) T_{comp}, the results show that the applied magnetic field reverses the Sm 5d magnetisation. On the contrary, no reversal was achieved at T_{comp} (figure 2). This behaviour is related to the fact that the macroscopic total magnetization is zero at this temperature and thus the application of an external field has no effect on the 5d magnetization.

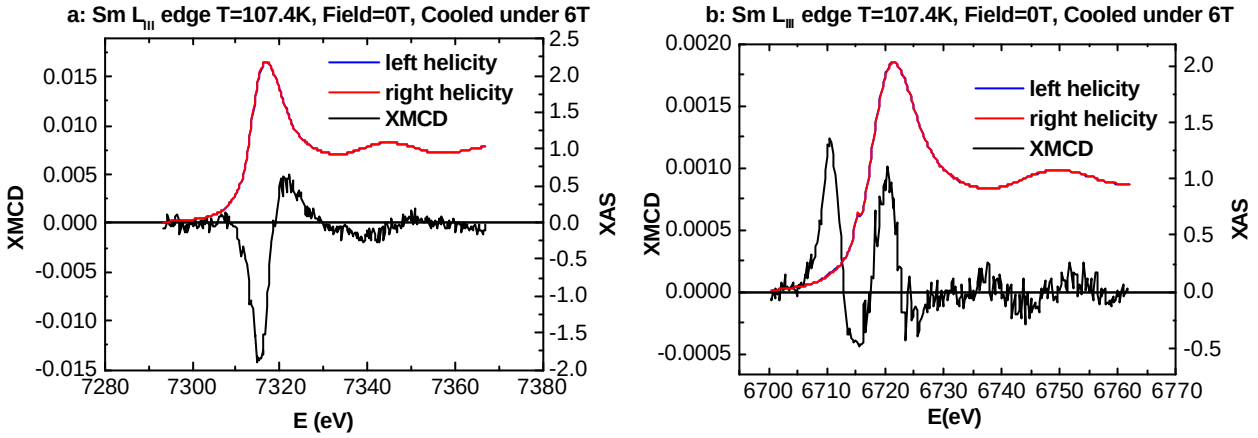

Figure 1 : XMCD and XAS spectra at a) Sm L_{II} edge and b) L_{III} edge

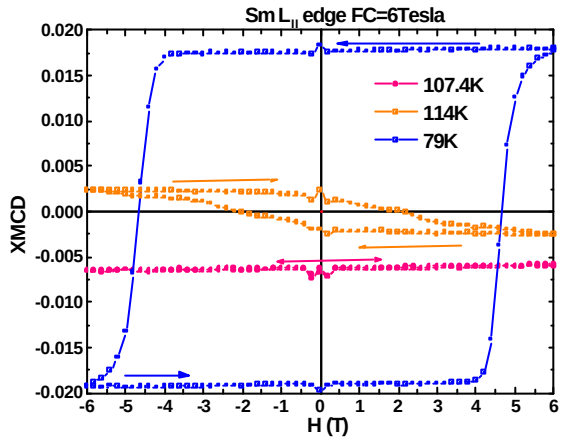

Figure 2 : Hysteresis loops at Sm L_{II} edge for three temperatures

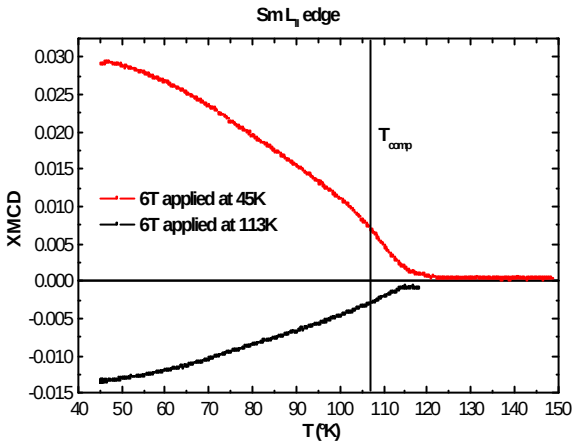

Figure 3 : XMCD signal at the Sm L_{II} edge measured versus temperature for two magnetic preparations

Finally, the XMCD signal at the Sm L_{II} edge was measured versus temperature and under zero external field, after the sample has been 'magnetically prepared' in two different ways :

i) the sample was first magnetized under a 6T field applied at 45K (below T_{comp}),

ii) the sample was first magnetized under a 6T field applied at 113K (above T_{comp})

Figure 3 gathers these two measurements and show that i) magnetizing the sample below T_{comp} results in a positive signal over the whole temperature range and ii) magnetizing the sample above T_{comp} results in a negative signal over the whole temperature range. Note that the signal does not drop to zero at T_{comp}, proving again the non vanishing ferromagnetic order at this temperature.

These results actually show that the dominant contribution to the magnetization, which aligns with the field during the magnetization process, is different below and above T_{comp}. Assuming that a *negative* XMCD signal at the Sm L_{II} edge reveals that the 5d spin magnetic moments are aligned *parallel* to the field [2], it appears that the 5d spin magnetisation is opposite to the total magnetisation below T_{comp} but is in the direction of the total magnetization above T_{comp}. Since the 5d spin moments are anti parallel to the 4f orbital moment, the orbital contribution to the magnetization is dominant below T_{comp} and the spin contribution is dominant above T_{comp}. Magnetizing the sample above or below T_{comp} thus 'prepares' the 5d magnetization in two opposite directions and this magnetization then does not change direction with temperature, because the temperature dependence has been then recorded for zero applied field.

[1] H. Adachi, H. Ino, Nature **401**, 148 (1999)
[2] C. Neumann, B.W. Hoogenboom, A. Rogalev, J.B. Goedkoop, Sol. Sta. Comm. **110**, 375-379 (1999)