ESRF	**Experiment title:** **Exchange bias in magnetic systems with zero-magnetization ferromagnets**	**Experiment number**: HE 2545
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Names and affiliations of applicants (* indicates experimentalists):

C. DUFOUR*, M. UNGUREANU*, N. GONZALEZ*, K. DUMESNIL, Laboratoire de Physique des Matériaux, Université H. Poincaré Nancy I, BP 239, 54506 Vandoeuvre les Nancy cedex

F. WILHELM*, A. ROGALEV*, A. SMEKHOVA*, ESRF

For small Gd contents, the ferromagnetic compound $Sm_{1-x}Gd_xAl_2$ (SGA) presents exciting magnetic properties. It exhibits at a specific compensation temperature (T_{comp}) a large spin polarization and in the same time a zero magnetization [1]. We recently succeeded to grow single crystalline films of SGA and previous XMCD experiments (HE 1770) have proved the existence of this compensated magnetic state with long range ferromagnetic order in the epitaxial films [2-3].

During this experiment, our focus was on exchange bias phenomena in $Sm_{1-x}Gd_xAl_2$-based bilayers, where the hard-magnetic SGA layer is used as the biasing layer and a softer ferromagnetic $SmAl_2$ (SA) layer is biased. At the compensation point T_{comp}, where the SGA magnetization has vanished, the bilayers may be compared to conventional antiferromagnetic (AFM) / ferromagnetic (FM) exchange bias systems. The main difference is that the interface exchange coupling results from the ferromagnetic spin order in SGA, while it results only from the uncompensated spins in AF materials. The strong interest in our system is that the remaining ferromagnetic long range order makes the specific investigation of the biasing layer possible, in particular via XMCD measurements at the Gd absorption edges.

For this experiment, two samples have been grown simultaneously: a (111)$Sm_{0.972}Gd_{0.028}Al_2$/$SmAl_2$ bilayer layer where both layers are 300nm thick, and a single 300nm thick $Sm_{0.972}Gd_{0.028}Al_2$ layer which has not been covered with $SmAl_2$. Preliminary SQUID experiments have shown that the compensation temperature for the SGA layer is 64K. The aim was to compare the magnetic behaviour of the SGA layer as single layer and in the SGA/SA bilayer, especially during the SA magnetization reversal. The XMCD signal has been recorded in total fluorescence detection mode, at the Sm L_2 and L_3 edges and at the Gd L_3 edge. The sample was fixed in a helium pumped cryostat, which was inserted in a 6T superconducting magnet. The magnetic field was applied along the (111) easy magnetisation direction.

Hysteresis loops recorded at the Sm L_2 edge for the bilayer exhibit strong horizontal and vertical shifts (fig. 1 left, filled symbols). The vertical shift is attributed to the pinned SGA layer while the horizontal shift comes from the interface exchange coupling between both compounds. This coupling biases the SA reversal towards positive fields, the magnitude of the bias field being of 0.6T at the SGA compensation (64K). The measurements performed at the Sm L_2 edge for the single 300nm thick SGA layer (fig. 1 left, open symbols) proves that its magnetization does not reverse in this -7T/+7T field range and is pinned with the spin contribution pointing towards the direction of the cooling field (i.e. opposite to the SA spin component).

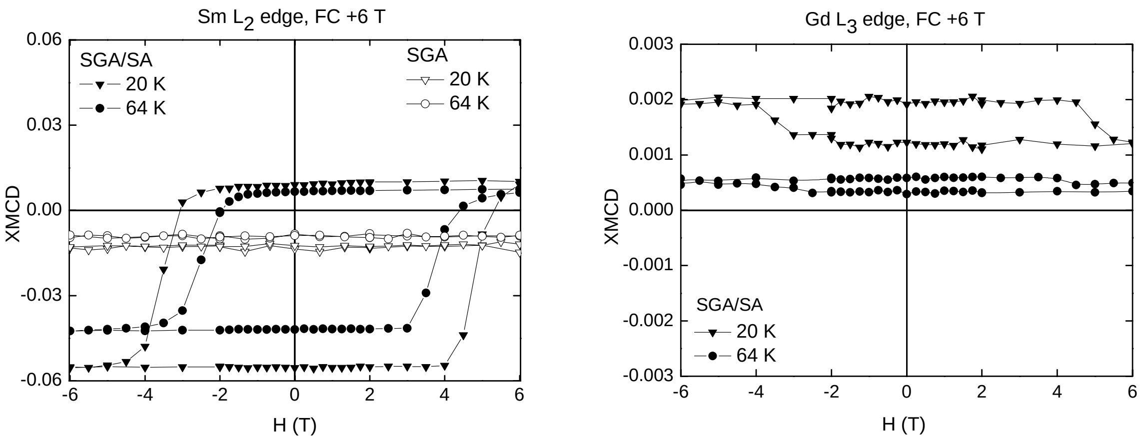

Figure 1 : Hysteresis loops measured after +6T field cooling at the Sm L_2 edge (left figure) and at the Gd L_3 edge (right figure) for the SGA single layer (open symbols) and for the SGA/SA bilayer (filled symbols)

The measurements performed at the Gd L_3 edge for the bilayer (fig. 1 right) have permitted to investigate the influence of the SA reversal on the SGA magnetization. It appears that part of the SGA layer is pinned as in the single layer, while a certain proportion is rotatable. The observation of a hysteresis loop with a coercive field similar to the one observed at the Sm edges shows that some of the SGA magnetization is driven to reverse by the exchange coupling to SA. This is also the case at the SGA compensation (64K), where the external field has no effect on the zero magnetization. From the vertical shift of the hysteresis loops, the ratio between the pinned and rotatable moments can be determined. At 20K and 64K, approximately 18% of the SGA layer is able to reverse, leading to a nominal thickness of 54nm. If this nominal thickness is attributed to the presence of an interfacial domain wall in SGA (108nm thick), we can estimate the amplitude of the corresponding bias field via the Mauri formulation [4], which gives a value of 0.57T at 64 K, in relatively good agreement with the experimental value of 0.61T. However, the DW thickness is very large, given the exchange and anisotropy constants expected in this material, which could be rather an indication of the presence of lateral domains in SGA.

A more detailed and quantitative investigation now requires the systematic measurements for different thermo-magnetic preparation of *both the bilayer and the single layer at the Gd edge*. This was not possible by lack of time and because of some technical problems occurring during our last two days of measurements.

[1] H. Adachi, H. Ino, Nature **401**, 148 (1999)
[2] A. Avisou et al , J. of Crystal Growth **297**, 239 (2006)   [3] A. Avisou et al., J. of Appl. Phys.: Cond. Matter. **20**, 265001 (2008)
[4] D. Mauri, H. C. Siegmann, P. S. Bagus, and E. Kay, J. Appl. Phys. **62**, 3047 (1987)