ESRF	**Experiment title:** Selective hysteresys loops in $DyFe_2/YFe_2$ superlattices	**Experiment number**: HE-625
Beamline: ID12 A	**Date of experiment**: from: 21/06/00 to: 27/06/00	**Date of report**: 25/08/00 *Received at ESRF:*
Shifts:	**Local contact(s)**: Andreï Rogalev	

Names and affiliations of applicants (* indicates experimentalists):

Karine Dumesnil*, Ph. Mangin*, C. Dufour

Laboratoire de Physique des Matériaux, Université H. Poincaré – Nancy I, BP 239

54506 Vandoeuvre les Nancy cedex

A. Rogalev*,

ESRF

Report:

$DyFe_2/YFe_2$ superlattices are composite magnetic systems constituted of two single crystalline Laves phases compounds, with very close crystal structures and different magnetic behaviours. $DyFe_2$ is a hard ferrimagnet whose net magnetisation is aligned along the dominant Dy moments, whereas YFe_2 is a soft ferromagnet. The exchange coupling at the interface between the two compounds arises via positive exchange between iron moments ; the system is therefore a kind of giant ferrimagnet where net magnetisation's in both compounds are antiparallel. Under an external magnetic field, the magnetic configuration, and thus the magnetisation reversal process, is the result of the balance between anisotropy, domain walls and Zeeman energies.

Magnetic measurements performed with a SQUID magnetometer have shown that the magnetisation reversal can be completely tailored in changing the relative thicknesses of both components. Moreover, for thin $DyFe_2$ layers, the superlattice exhibits a particularly interesting behaviour, that makes the system suitable to help in understanding open issues in exchange spring and exchange bias phenomena.

The aim of the experiment performed at ESRF was to measure separately $DyFe_2$ and YFe_2 hysteresis loops (XMCD signals at Dy and Y edges) in superlattices with typical magnetic behaviours, in order to investigate the magnetisation reversal processes and the interaction between both compounds under magnetic field.

For this purpose, the detection in fluorescence mode has been chosen because it is particularly suitable for superlattices deposited on a thick substrate (sapphire) that are thus difficult to observe in transmission mode. After a successful test performed on an unique thick $DyFe_2$ film at room temperature, two superlattices have been measured in the –7T/+7T field-range: a $[DyFe_2(100Å)/YFe_2(130Å)]_{18}$ superlattice (at the Dy L_3 edge) and a $[DyFe_2(50Å)/YFe_2(130Å)]_{21}$ superlattice (at Dy L_3 edge and Y L_3 edge). A specific sample holder has been used, so that the external magnetic field can be applied along the in-plane [110] easy magnetisation direction.

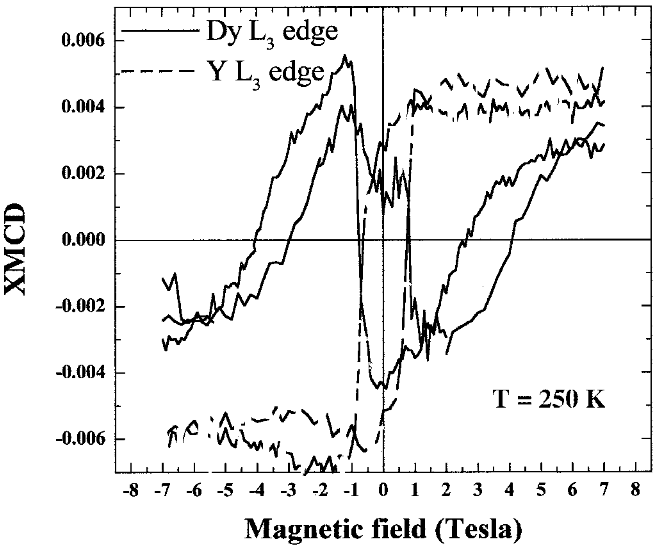
In the superlattice ***[DyFe$_2$(100Å)/YFe$_2$(130Å)]$_{18}$***, where the DyFe$_2$ layers are relatively thick, only the XMCD signal at the Dy L$_3$ edge has been measured versus magnetic field. As expected from the strong crystal field anisotropy in DyFe$_2$, the results reveal square loops at any temperature; the coercive field decreases in increasing temperature and is close to the position of the second drop in magnetization observed by SQUID. This unambiguously shows that the DyFe$_2$ magnetisation direction is not affected for fields below this coercive field, although magnetic domain walls extend at the interface between both compounds.

In the superlattice ***[DyFe$_2$(50Å)/YFe$_2$(130Å)]$_{21}$***, the XMCD signal at the Dy L$_3$ edge has been measured versus magnetic field at 10K, 100K, 150K, 200K and 250K ; the XMCD signal at the Y L$_3$ edge has been measured at 10K, 200K and 250K. The results can be discussed over three temperature ranges:

(i) At 10K, the XMCD signal measured at the Dy edge only slightly decreases for negative fields but does not change sign, even for a –7T applied field. Simultaneously, the XMCD signal from Y reveals that the YFe$_2$ magnetisation reverses. The magnetisation direction in the thin DyFe$_2$ layers is quenched at low temperature, along the positive cooling field, and the magnetisation reversal only occurs via domain walls extension in the softer YFe$_2$ layers.

(ii) For temperatures between 10K and 150K, the DyFe$_2$ behaviour is rather similar to what occurs in the previous superlattice. The magnetisation starts to reverse at negative fields but the process is smoother and extends over a larger field range. The Y signal has not been measured in this temperature range.

(iii) For temperatures above 150K, the results have revealed a rather unexpected behaviour (see figure at 250K), impossible to be deduced from classical SQUID magnetization measurements. Whereas the YFe$_2$ loop (dotted curve) becomes square with 1 Tesla coercive field, the DyFe$_2$ signal (continuous curve) decreases as soon as the positive field decreases to favour alignment between Fe moments ; it switches together with the YFe$_2$ magnetization at the coercive field of YFe$_2$, and decreases again when increasing the negative field, because of the Zeeman contribution. It is clear that, compared to other energy terms, the anisotropy is too weak at this temperature in the thin DyFe$_2$ layers to block its magnetization, that thus follows the YFe$_2$ one.



In conclusion, these first results show that, despite the relative small amount of magnetic materials in these systems and, although a grazing incidence geometry was needed to apply the external field in the sample plane, the signal was sufficient to get information on the element-specific magnetization reversal in the superlattices. These are nevertheless preliminary results that still need to be improved (signal/noise) and completed for a better understanding of the exchange bias and exchange spring phenomena.