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Report:

$DyFe_2$/YFe_2 superlattices are single crystalline composite systems that combine a hard ferrimagnet ($DyFe_2$) and a soft ferromagnet (YFe_2), the net magnetization of which are antiferromagneticaly coupled at the interfaces, mainly via the strong coupling between the iron moments. These exchange coupled superlattices are exciting systems that exhibit a wide variety of magnetic behaviours, depending on the relative thicknesses of the two compounds, on temperature and on the external magnetic field.

From previous experiments, we have shown that XMCD experiments constitute an unique tool to unravel the complex magnetic configurations and the magnetization reversal process, due to the possibility to measure element selective hysteresis loops and thus to extract independently the magnetic behaviour in each compound. We have especially proved that in certain circumstances, the magnetization reversal could affect first the harder $DyFe_2$ layers in contrast to the classical scenario generally proposed in these hard/soft heterostructures. This has been observed in the case of relative thin $DyFe_2$ layers (5-7 nm range).

In this experiment, the main interest was to investigate the extreme situation where the $DyFe_2$ layers are thinner than 5 nm to elucidate both the magnetic configurations and the magnetization reversal process. High quality [$DyFe_2$(3 nm)/YFe_2(12 nm)] and [$DyFe_2$(1 nm)/YFe_2(4 nm)] superlattices have been fabricated by Molecular Beam Epitaxy, following the process we developed for the epitaxial growth of the Laves phases $REFe_2$ compounds. The XMCD experiments have been performed both at the Dy and Y L_3 edges in choosing the fluorescence detection mode and in applying the magnetic field in a direction close to the in-plane easy axis of the samples. Figure 1 presents the results obtained at different temperatures after a +7T field-cooling process and at both edges for the two superlattices.

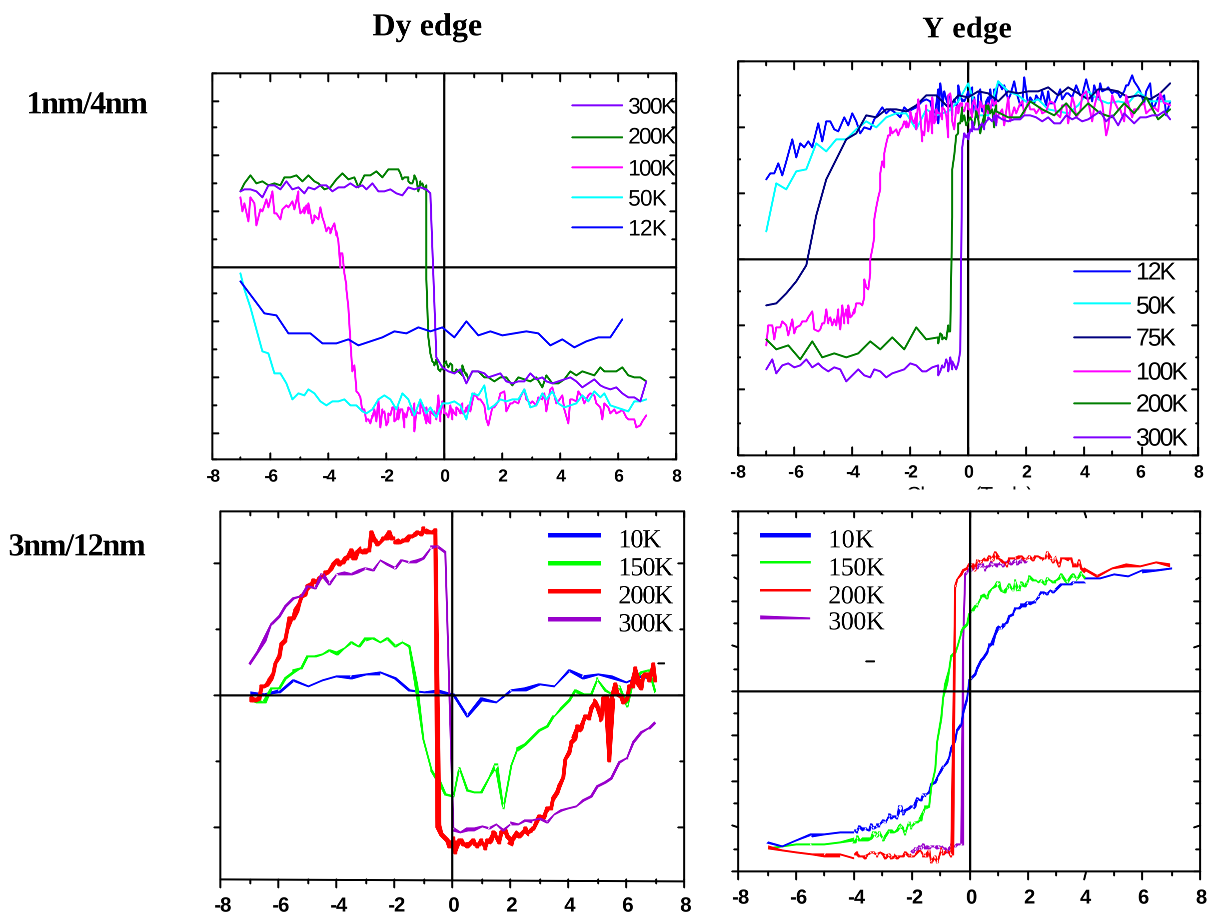

Fig.1: XMCD signal measured versus the applied field (from +7T to –7T) at the Dy and Y L_3 edges and at different temperatures for two superlattices after a +7T field cooling process from 300K.

In the [$DyFe_2$(1 nm)/YFe_2(4 nm)] superlattice, the results unambiguoulsy show that the Dy and Y signals are of opposite signs whatever the magnetic field and temperature. This reveals that the antiferromagnetic coupling between the net magnetization in each compound is not destroyed, even for the maximum applied magnetic field. The thicknesses of individual layers are likely too small for interface domain walls to develop. As a consequence, the net magnetization of the sample reverses as a block, in keeping the giant ferrimagnetic structure between both compounds.

The [$DyFe_2$(3 nm)/YFe_2(12 nm)] superlattice exhibits a completely different behaviour. First of all, the magnetization reversal amazingly affects first the harder $DyFe_2$ layers (reduction of the Dy signal under positive field) when the temperature increases. This confirms the results we obtained for the [$DyFe_2$(5 nm)/YFe_2(20 nm)] in a previous experiment. Moreover two new interesting features have been observed in this system:

(i) under the ±7T maximum external field, the Dy XMCD signal is close to zero

(ii) at 10K, the Dy XMCD signal is close to zero and almost constant over the whole field range.

We can thus conclude that the magnetic configuration for ±7T is neither the ferrimagnetic one favoured by exchange (as in the previous sample), nor the ferromagnetic one favoured by the Zeeman energy. Further experiments are necessary to clarify this magnetic configuration. At 10K, the magnetization in the $DyFe_2$ layers is completely frozen, probably due to the large anisotropy, and this specific structure remains also to be elucidated.