MAR07-2006-000921

Abstract for an Invited Paper
for the MAR07 Meeting of
the American Physical Society

Understanding Thermal Activation Processes in Exchange Bias Systems

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The phenomenon of exchange bias has been of major scientific interest and technological importance since the 1980s following its discovery by Meiklejohn and Bean in 1956 [1,2]. Following initial seminal work by Fulcomer and Charap [3] it has recently become clear that a major contribution to the phenomena of exchange bias derives from the fact that the grains in the anti-ferromagnetic (AF) layer are capable of thermally activated reorientation due to the exchange field from the ferromagnetic (F) layer. In this work careful measurement protocols will be presented that enable the thermal activation process to be analysed in considerable detail. More recently Hoffman [4] has described a spin reorientation process that occurs after the AF layer is set which leads to a large shift in the forward going hysteresis loop on the first reversal of the F layer. This effect, coupled to the thermal activation process, gives rise to the phenomenon of training whereby the loop progressively shifts from its original set direction towards the origin. Lastly we have observed a spin freezing phenomena at the interface that can be induced by either temperature or applied field which results in a systematic variation of the exchange bias. We interpret this effect as being due to paramagnetic like spins at the interface whose ordering leads to a significant increase in the overall value of the exchange bias. Thus we show that exchange bias is a complex convolution of at least three distinct effects, all of which will be described in detail. This explains why single theories of how this effect arises have been so unsuccessful during the last 50 years.

[1] Meiklejohn and Bean: Physical Review vol.102 p.1413 (1956)
[2] Nogues and Schuller: Journal of Magnetism and Magnetic Materials vol.192 p.203 (1999)
[3] Fulcomer and Charap: Journal of Applied Physics vol.43 p.4190 (1972)
[4] Hoffmann: Physical Review Letters vol.93 p.097203 (2004)