Editorial

New Trends in Magnetic Exchange Bias

The study of layered magnetic structures is one of the hottest topics in magnetism due to the growing attraction of applications in magnetic sensors and magnetic storage media, such as random access memory. For almost half a century, new discoveries have driven researchers to re-investigate magnetism in thin film structures. Phenomena such as giant magnetoresistance, tunneling magnetoresistance, exchange bias and interlayer exchange coupling led to new ideas to construct devices, based not only on semiconductors but on a variety of magnetic materials

Upon cooling fine cobalt particles in a magnetic field through the Néel temperature of their outer antiferromagnetic oxide layer, Meiklejohn and Bean discovered exchange bias in 1956. The exchange bias effect through which an antiferromagnetic AF layer can cause an adjacent ferromagnetic F layer to develop a preferred direction of magnetization, is widely used in magnetoelectronics technology to pin the magnetization of a device reference layer in a desired direction. However, the origin and effects due to exchange interaction across the interface between antiferromagneic and ferromagnetic layers are still debated after about fifty years of research, due to the extreme difficulty associated with the determination of the magnetic interfacial structure in F/AF bilayers. Indeed, in an AF/F bilayer system, the AF layer acts as "the invisible man" during conventional magnetic measurements and the presence of the exchange coupling is evidenced indirectly through the unusual behavior of the adjacent F layer. Basically, the coercive field of the F layer increases in contact with the AF and, in some cases, its hysteresis loop is shifted by an amount called exchange bias field. Thus, AF/F exchange coupling generates a new source of anisotropy in the F layer. This induced anisotropy strongly depends on basic features such as the magnetocrystalline anisotropy, crystallographic and spin structures, defects, domain patterns etc of the constituant layers.

The spirit of this topical issue is, for the first time, to gather and survey recent and original developments, both experimental and theoretical, which bring new insights into the physics of exchange bias. It has been planned in relation with an international workshop exclusively devoted to exchange bias, namely IWEBMN'04 (International Workshop on Exchange Bias in Magnetic Nanostructures) that took place in Anglet, in the south west of France, from 16th to 18th September 2004. The conference gathered worldwide researchers in the area, both experimentalists and theoreticians. Several research paths are particularly active in the field of magnetic exchange coupling. The conference, as well as this topical issue, which was also open to contributions from scientists not participating in the conference, has been organized according to the following principles:

1. **Epitaxial systems:** Since the essential behavior of exchange bias critically depends on the atomic-level chemical and spin structure at the interface between the ferromagnetic and antiferromagnetic components, epitaxial AF/F systems in which the quality of the interface and the crystalline coherence are optimized and well known are ideal candidates for a better understanding of the underlying physics of exchange bias. The dependence of exchange bias on the spin configurations at the interfaces can be accomplished by selecting different crystallographic orientations. The role of interface roughness can also be understood from thin-film systems by changing the growth parameters, and correlations between the interface structure and exchange bias can be made, as reported in this issue.

2. **Out-of-plane magnetized systems:** While much important work has been devoted to the study of structures with in-plane magnetization, little has been done on the study of exchange bias and exchange coupling in samples with out-of-plane magnetization. Some systems can exhibit either in-plane or out-of-plane exchange bias, depending on the field cooling direction. This is of particular

interest since it allows probing of the three-dimensional spin structure of the AF layer. The interface magnetic configuration is extremely important in the perpendicular geometry, as the short-range exchange coupling competes with a long-range dipolar interaction; the induced uniaxial anisotropy must overcome the demagnetization energy to establish perpendicular anisotropy films. Those new studies are of primary importance for the magnetic media industry as perpendicular recording exhibits potential for strongly increased storage densities.

3. **Parameters tuning exchange bias in polycrystalline samples and magnetic configurations:** Different parameters can be used to tune the exchange bias coupling in polycrystalline samples similar to those used in devices. Particularly fascinating aspects are the questions of the appearance of exchange bias or coercivity in ferromagnet/antiferromagnet heterostructures, and its relation to magnetic configurations formed on either side of the interface. Several papers report on either growth choices or post preparation treatments that enable tuning of the exchange bias in bilayers. The additional complexity and novel features of the exchange coupled interface make the problem particularly rich.

4. **Dynamics and magnetization reversal:** Linear response experiments, such as ferromagnetic resonance, have been used with great success to identify interface, surface anisotropies and interlayer exchange in multilayer systems. The exchange bias structure is particularly well suited to study because interface driven changes in the spin wave frequencies in the ferromagnet can be readily related to interlayer exchange and anisotropy parameters associated with the antiferromagnet. Because the exchange bias is intimately connected with details of the magnetization process during reversal and the subsequent formation of hysteresis, considerations of time dependence and irreversible processes are also relevant. Thermal processes like the training effect manifesting itself in changes in the hysteretic characteristics depending on magnetic history can lead to changes in the magnetic configurations. This section contains an increasing number of investigations of dynamics in exchange bias coupled bilayers, and in particular those of the intriguing asymmetric magnetization reversal in both branches of a hysteresis loop.

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