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EXCHANGE ANISOTROPY: PHENOMENOLOGICAL DESCRIPTION AND A SIMPLE MODEL

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One of the key components in GMR materials , magnetic tunnel junctions or other electromagnetic devices is often an antiferromagnetic (AF) layer which is exchangecoupled to a ferromagnetic (F) layer. The function of the AF layer is to pin the magnetization direction of the adjacent F layer to a certain direction. The most prominent manifestation of the F/AF exchange interaction is a shift of the hysteresis loop of the F layer along the field axis, as if an additional fixed external field is applied to the F layer. This effective magnetic field is called the exchange bias field, *H.* The direction of this effective field is called the exchange bias direction. In contrast to the ferromagnetocrystalline anisotropy of a homogeneous magnet, which is characterized by easy and hard axes, exchange anisotropy is characterized by a single easy direction. It is called uniaxial anisotropy.

The exchange anisotropy effect has been discovered already in 1956 by Meiklejohn and Bean, for small (10-100nm)Co particles covered with a thin skin of antiferromagnetic CoO. It has also been observed for bulk alloys in which phase separation on a nanometer scale has taken place between ferromagnetic and ferromagnetic phase. Two types of AF/F layered structure showing the effect are distinguished: top structures, bilayers that consist of a AF layer grown on the top of the F layer, and bottom structures with an inverted order of deposition.

The magnetization loops are quite different from those obtained for a single Ni80Fe20 layer. Ni-Fe alloys with compositions close to the 80-20 ratio are named fermalloys because of their high magnetic permeability. They are soft magnetic, i.e. the magnetization saturates already in a very small magnetic field. The precise value of the saturation magnetic field depends on growth conditions such as direction of a magnetic field that is applied during the growth. Growth in a magnetic field (in the film plane) leads to a uniaxial inplane magnetic anisotropy, with the easy axis parallel to the field direction. The effect is thought to be the result of the occurrence of some pair order in the position of the Ne and Fe atoms. Without the field, the atoms are distributed randomly over the sites on fcc lattice. The hysteresis loop is centered around *H=0*, and the magnetization *M* saturates then in (in-plane) fields of about 4-5 Oe and less than 1 Oe, for H parallel to the hard and easy axis, respectively. These fields are very small, so the influence of the magnetic anisotropy of the permalloy films on the magnetic curves is almost negligible.