Ultra-thin MnPt layer on Pt(001) studied by surface X-ray diffraction and magneto-optical Kerr effect : structural order and exchange coupling

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Antiferromagnetic (AF) MnPt alloys in the ordered $L1_0$ phase are interesting materials for spin valve based technology owing to their large exchange coupling, good resistance to corrosion and good thermal stability. The total spin valve thickness must significantly decrease and the AF layer would be, by far, the thickest one in the device. However, high exchange bias (EB) and thermal stability are difficult to maintain when reducing the thickness. The EB vanishes at room temperature in sputtered spin valves when the MnPt layer is thinner than 6 nm [1]. It has been suggested that below such a critical thickness the AF coupling becomes thermally unstable, as observed for CoO/NiFe [2], where the coupling decrease was associated to the finite-size scaling of the Néel temperature. An alternative explanation related the lack of exchange coupling with the lack of chemical order [3]. Further studies on thick films confirmed the close relationship between the degree of chemical order and strength of exchange coupling [4]. With a few exceptions, all these studies were performed on polycrystalline films grown by sputtering and showing different degrees of texture. As a consequence, the latter conclusions cannot be generalized. Epitaxial growth by molecular beam epitaxy (MBE) allows a perfect control of the structure and may lead to a better comprehension of the relationship between exchange coupling and chemical ordering.

We have grown by alternating MBE deposition, ultra thin layers of MnPt on a Pt(100) single-crystal. The *a* and *c* unit cell parameters of tetragonal MnPt are 3.998 Å and 3.669 Å respectively, i.e. about 2% larger and 6.5% smaller than the Pt fcc lattice constant (3.924 Å). This is expected to promote the growth of the MnPt $L1_0$ phase with *c* perpendicular to the surface. Surface X-ray diffraction was used to follow the alternate layer-by-layer deposition of Mn and Pt, up to a thickness of about 3 nm (14 ML). The diffraction pattern for the sample grown at room temperature did not show peaks corresponding to the chemically ordered phase. After thermal annealing, at 500°C for about 1 hour, a broad scattering showed up around the expected position, indicating the emergency of short-range $L1_0$ ordering. The coherence length was estimated to be 1.6 nm. In a further step, a ferromagnetic Fe layer (15 ML) was grown on top of the MnPt slab and, finally, the sample was capped with 8 ML Pt layer. Even if no long-range $L1_0$ ordering was observed, an *ex-situ* MOKE study demonstrated that such short-range ordered system develops AF exchange coupling at low temperature. A Néel temperature of 75 K was found. An interesting outcome of this system is that, below 25K, the exchange bias is negative, while above, it becomes positive. This probably derives from an AF ordering transition, similar to that of bulk MnPt [5], which modifies the exchange coupling at the F/AF interface.

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