The Effect of Solution pH on the Magnetic Anisotropy of Thin Ni and Co Films Grown on N-GaAs

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Ferromagnetic films on semiconductors are essential components of magnetic sensors, memories, and novel devices based on spin-dependent transport phenomena. Electrochemical deposition offers some advantages with respect to UHV techniques for the growth of these structures, such as the dependence of film growth, structure and properties on the electronic properties of substrate. We have studied the electrochemical growth and magnetic anisotropy of Ni and Co on (001)- and (011)-oriented n-GaAs. In particular, we shall present here results on the effect of solution pH on the magnetic anisotropy of the films.

Ni films were grown under galvanostatic control from a 0.1M $NiSO_4$ solution, the pH of which was adjusted using 10% H_2SO_4. All samples were grown at a current density of 4 $mAcm^{-2}$ to a nominal thickness of 72nm. The thickness calculated from magnetization gave current efficiencies between 75% (pH 2.72) and 38% (pH2.25). Figure 1 shows results for a 55nm thick (calculated from the magnetic moment) Ni film grown on GaAs (001) from a solution of pH 2.72. Figure 1(a) shows the variation in squareness of the hysteresis loops as a function of the in-plane direction. A uniaxial anisotropy is observed with the easy and hard axis at 90° to each other along the [110] and $\left[\bar{1}10\right]$ directions of the GaAs. Figure 1 (b) shows the corresponding hysteresis loops along these directions. The coercivity is smaller in the hard direction, but the field required to saturate the film in the hard direction is very large (>2000 Oe), indicating a relevant magnetoelastic contribution to the anisotropy.

Figure 2(a) shows the variation of squareness with field angle for a Ni film grown under the same condition from a solution of pH 2.5. The thickness calculated from sample moment is 44nm. The anisotropy is much smaller than in the case pH=2.72, and it is no longer uniaxial but shows a four-fold symmetry with the easy axis at 60° to the [110] direction Figure 2(b) shows the hysteresis loops along the hard and easy axis for this film. The coercivity is smaller for the hard direction than the easy direction as before, however the saturation field for the hard direction is now less than 500 Oe, indicating a much smaller magnetoelastic contribution. Films grown at pH 2.25 have similar magnetic properties, although the current efficiency is smaller.

Ni films grown on GaAs (011) show a very definite uniaxial anisotropy. Figure 3 shows the magnetic properties for a 54nm film grown from the solution with pH 2.72. Small values for the coercivity and anisotropy field are observed in the hard direction. The properties of the film are unchanged in the pH range 2.25-2.72.

Co films grown on GaAs (001) show only a small anisotropy in the pH range 2 to 3. Co films grown on GaAs (011) can show a well-defined uniaxial anisotropy, although it is rotated by 90° with respect to that shown for Ni on (011) GaAs. Magnetic properties of the films are strongly dependent on the pH of the solution as well as on the growth conditions.

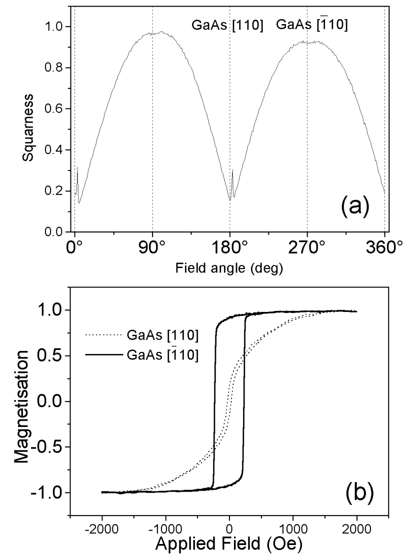

Figure 1: (a) Angular remanence and **(b)** hysteresis loops along hard and easy directions for a 55nm thick Ni film on (001) n-GaAs. Solution pH=2.72

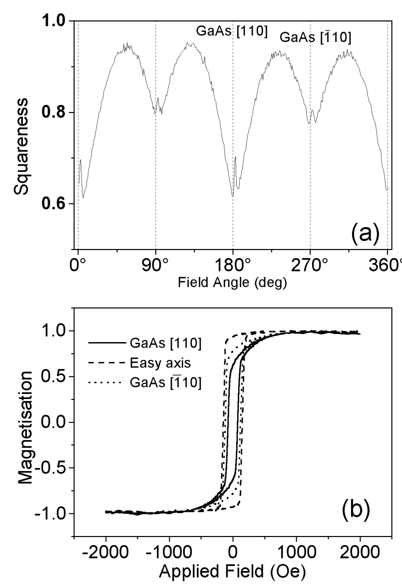

Figure 2: (a) Angular remanence and **(b)** hysteresis loops along hard and easy directions for a 44nm thick Ni film on (001) n-GaAs. Solution pH=2.48

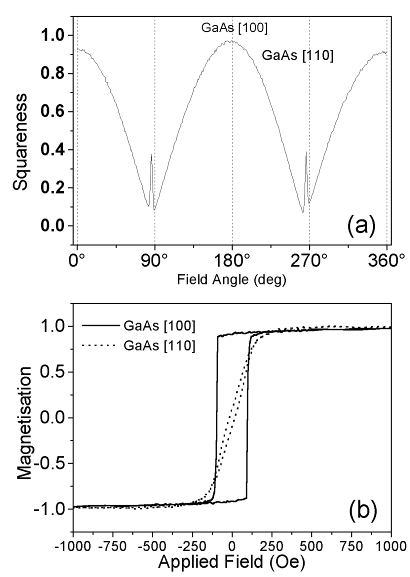

Figure 3: (a) Angular remanence and **(b)** hysteresis loops along hard and easy directions for 54nm thick Ni film on (011) n-GaAs. Solution pH=2.72