The Effect of Substrate Orientation on the Magnetic Properties of Electrodeposited Thin Films Grown on N-GaAs

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The idea of magneto-electronic devices such as spin transistors [1], has been attracting a lot of recent attention. Fabrication of such devices requires a thorough understanding and control of the growth of ferromagnetic (FM) films on semiconductors. Electrodeposition presents many advantages in this respect; for example, it is a low temperature process which could limit the amount of interdiffusion between the film and substrate. It has also been shown to be capable of producing very high quality films [2]

We studied the electrochemical nucleation and growth of FM metals and alloys on (001)- and (011)-oriented n-GaAs. The magnetic and structural properties of the films were investigated using VSM and XRD respectively.

Nickel films grown from simple sulfate solutions on (001) n–GaAs were found to exhibit two different epitaxial relationships with the substrate. Specifically (1) perpendicular to plane $(001)_{Ni}$ // $(001)_{GaAs}$ and in plane $[100]_{Ni}$ // $[110]_{GaAs}$ and (2) perpendicular to plane $(011)_{Ni}$ // $(001)_{GaAs}$ and in plane $[111]_{Ni}$ // $[110]_{GaAs}$. The films showed a small but definite four-fold magnetic anisotropy in plane (Figure 1) with the highest remanence being found along the GaAs [100] direction. It is interesting to note the difference between the [110] and $[1\bar{1}0]$ directions since these should be equivalent for a FCC type structure such as GaAs. Such difference has also been previously observed for vacuum grown Fe films on (001) GaAs [3]. In addition to the main bi-axial anisotropy parallel to the [001] direction of the (001) GaAs surface a smaller variation in anisotropy is observed about the $[110]_{GaAs}$ direction which may be due to the second epitaxial relationship described above. The anisotropy is also seen to be thickness dependent.

Nickel films grown on (011) n-GaAs show only a single epitaxial relationship: perpendicular to plane $(111)_{Ni}$ // $(011)_{GaAs}$ and in-plane $[110]_{Ni}$ // $[100]_{GaAs}$. However the in-plane orientation appears to be only approximate. Magnetically the films show a very pronounced uniaxial anisotropy (figure 2). Angular remanence measurements show the hard direction, with a coercivity of essentially 0 Oe, is along 83° from the $[100]_{GaAs}$ not along the $[110]_{GaAs}$. This corresponds to an anisotropy field of approximately 500 Oe.

Cobalt films were grown from acidic sulphamate baths. Figure 3 shows hysteresis loops of Co grown on (001) and (011) n-GaAs and an obvious difference can be seen. Angular remanence measurements show a local hard direction for the films at 19° from the $[110]_{GaAs}$ for Co films grown on (001) GaAs and a local hard direction at 27° from the $[110]_{GaAs}$ for Co films grown on the (011) GaAs surface. Work on Fe as well as AFM and XPS data will also be presented.

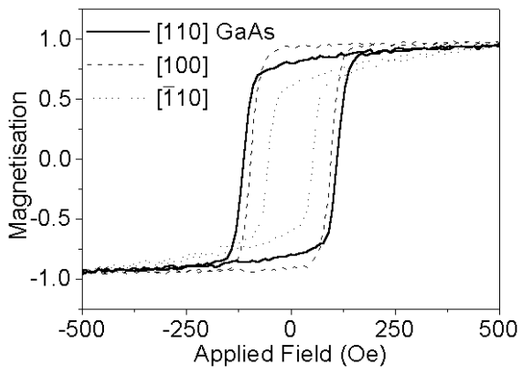


Figure 1: Hysteresis loops of nominal 72nm Ni film grown on (001) n-GaAs along the three major directions of the (001) surface

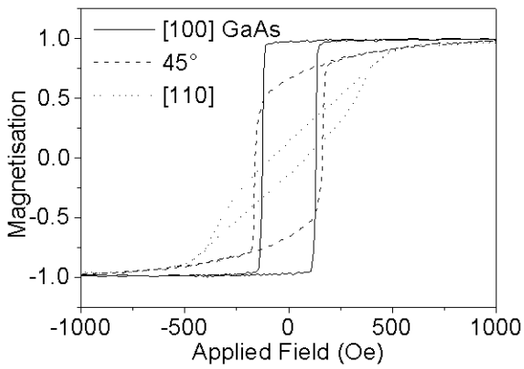
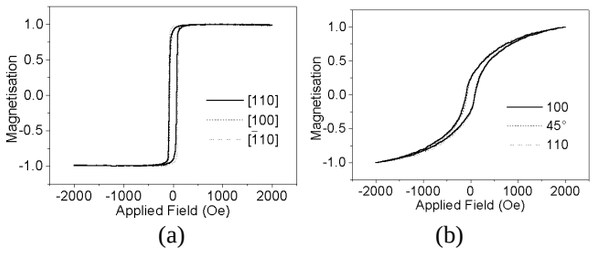


Figure 2: Hysteresis loops of nominal 60nm Ni film grown on (011) n-GaAs along the [100], [110] directions and along a direction 45° to both.



(a) (b)

Figure 3: Hysteresis loops of nominal 72nm Co film grown on (a) (001) n-GaAs and (b) (011) n-GaAs

References

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