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Temperature Dependent Magneto-Transport Properties of MnAl Binary Alloy Thin Films

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Abstract : High perpendicular magnetic anisotropy (PMA) and low damping constant (α) in ferromagnets are one of the few necessary requirements for their potential applications in the field of spintronics. In this regards, ferromagnetic τ-phase of MnAl possesses the highest PMA (Ku > 107 erg/cc) at room temperature, high saturation magnetization (Ms~800 emu/cc) and a Curie temperature of ~395K. In this work, we have investigated the magnetotransport behaviour of this potentially useful binary system Mn_xAl_{1-x} films were synthesized by co-sputtering (pulsed DC magnetron sputtering) on Si/SiO_2 (where SiO_2 is native oxide layer) substrate using 99.99% pure Mn and Al sputtering targets. Films of constant thickness (~25 nm) were deposited at the different growth temperature (T_s) viz. 30, 300, 400, 500, and 600 ºC with a deposition rate of ~5 nm/min. Prior to deposition, the chamber was pumped down to a base pressure of 2×10^{-7} Torr. During sputtering, the chamber was maintained at a pressure of 3.5×10^{-3} Torr with the 55 sccm Ar flow rate. Films were not capped for the purpose of electronic transport measurement, which leaves a possibility of metal oxide formation on the surface of MnAl (both Mn and Al have an affinity towards oxide formation). In-plane and out-of-plane transverse magnetoresistance (MR) measurements on films sputtered under optimized growth conditions revealed non-saturating behavior with MR values ~6% and 40% at 9T, respectively at 275 K. Resistivity shows a parabolic dependence on the field H, when the H is weak. At higher H, non-saturating positive MR that increases exponentially with the strength of magnetic field is observed, a typical character of hopping type conduction mechanism. An anomalous decrease in MR is observed on lowering the temperature. From the temperature dependence of reistivity, it is inferred that the two competing states are metallic and semiconducting, respectively and the energy scale of the phenomenon produces the most interesting effects, i.e., the metal-insulator transition and hence the maximum sensitivity to external fields, at room temperature. Theory of disordered 3D systems effectively explains the crossover temperature coefficient of resistivity from positive to negative with lowering of temperature. These preliminary findings on the MR behavior of MnAl thin films will be presented in detail. The anomalous large MR in mixed phase MnAl system is evidently useful for future spintronic applications.

Keywords : magnetoresistance, perpendicular magnetic anisotropy, spintronics, thin films
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