The effects of magnetic field annealing on structural and magnetic properties of ion-beam deposited [Mn/Bi] multilayered thin films

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MnBi in the low temperature phase (LTP) exhibits a large magnetic anisotropy as well as a high coercivity that increase with warming [1]. In this study, the magnetism of [Mn/Bi] multilayered thin films deposited with in-situ Ar ion-beam bombardment and post-deposition annealed were examined. The $[Mn(\sim 1nm)/Bi(\sim 1nm)]_{10}$ thin films (~ 20 nm thick) were prepared on amorphous SiO_2 substrates using a dual ion-beam sputtering deposition technique [2] and then capped with an Ag layer (~ 7 nm) to avoid oxidation. Post deposition magnetic field annealing was carried out to enable MnBi formation. The as-deposited $Ag/[Mn/Bi]_{10}$ thin film consisted of Ag, Mn, and Bi structures, as characterized by XRD. To enhance the intermixing between the Mn and Bi interfaces, Ar ion-beam bombardment was used, and MnBi diffraction peaks (e.g., (102), (202)) were observed indicating the formation of MnBi phases. After a post deposition annealing processes different preferred orientations and phases (LTP and orthorhombic) of MnBi were found, depending on annealing temperatures and times. This in turn affected the films' magnetic properties. Results obtained by VSM and AGM have shown that no ferromagnetic signal was detected for the as-deposited or Ar-ion bombarded $[Mn/Bi]_{10}$ thin films. In contrast, magnetic field annealing ($H_{app.}$ ~ 5000 Oe, perpendicular to the film plane at 400 ºC for 1 hour under vacuum) resulted in an out-of-plane hysteresis loop. In addition, an annealed Ar-ion bombarded $[Mn/Bi]_{10}$ thin film (annealed at 550 ºC for 30 mins.) also exhibited a hysteresis loop (ferromagnetic properties) which is indicative of a part of the film having LTP-MnBi. Further increased annealing temperatures or times resulted in the loss of ferromagnetism, ascribed to a structural phase transformation from ferromagnetic LTP-MnBi to non-magnetic orthorhombic MnBi. Our results indicate that the magnetic properties of rare-earth-free ferromagnetic MnBi thin films can be tuned via ion-beam bombardment as well as with annealing processes.

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