Fabrication of NiCrMnSi equiatomic quaternary Heusler alloy thin film

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Heusler alloys were reported to be applied to the ferromagnetic layers of magnetic tunnel junctions (MTJ) and to exhibit high tunneling magnetoresistance ratio (TMR) at low temperature. However, those TMR ratios decrease significantly at room temperature [1]. Therefore, the Heusler alloys with high Curie temperature T_c and half-metallicity are necessary. Recently, Kanemura *et al.* predicted that a *Y*-ordered tetragonal NiCrMnSi Heusler alloy exhibits high T_c over about 1500°C [2]. Here we experimentally investigated thin film growth of this alloy. NiCrMnSi thin films were grown by magnetron sputtering with various substrates and buffer layers. Deposition temperatures and annealing temperatures were also varied. The films were characterized by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The magnetic properties were measured by polar magneto-optical Kerr effect (MOKE) with a maximum out-of-plane field of 2 T. All the measurements were carried out at room temperature. From the XRD results, The samples grown on MgO(001) substrates showed no visible diffraction peaks when the deposition temperatures and annealing temperatures were up to 500 and 600°C. There were diffraction peaks observed for the samples deposited and annealed above 700°C. TEM images for the sample deposited at 500°C and 700°C shows amorphous structure and polycrystalline structure, respectively, which are consistent with the XRD data. Elemental composition mapping of the films deposited at 700°C indicated the phase separation, in particular Ni-rich and Cr-rich regimes were visible. Detailed XRD analysis suggested that the films deposited at 700°C consisting of $Mn_6Ni_{17}Si_7$, Mn_3Si and Cr phases. Those coexisting phases are nonmagnetic at room temperature [3][4][5], being consistent with the MOKE data. The results indicated that NiCrMnSi was not thermally stable and another growth process should be considered. This work was partially supported by JST-CREST (No. JPMJCR17J5) and JSPS Core-to-Core program.

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