The growth and magnetic properties of Mn on Si(100)

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Bulk Mn is a particularly interesting material having five different crystal structures that change with temperature: α-Mn is stable up to 727 °C, β-Mn between 727 and 1095 °C, γ-Mn between 1095 and 1133 °C, and δ-Mn between 1133 and 1244 °C (melting point).[1],[2] The α phase, which is stable at room temperature, has a body-centeredcubic (bcc) structure (bcc, a=8.911 Å, with 58 atoms per unit cell) and becomes a complex noncollinear AF below 95 K coupled to a tetragonal distortion in the crystal structure. The γ phase has a face-centered cubic (fcc) structure (fcc, a=2.73 Å) and becomes AF below about 500 K.[3],[4] The β-Mn (bcc, a=6.315 Å) and δ-Mn (bcc, a=3.0806 Å) phases are relatively unstable and show a spin glass of Tf=1.4 K and AF ordering, respectively.[1],[2],[5] It has been reported that as hydrostatic pressure increases, the T_N in the α phase shifts toward a lower temperature at a rate of 20 K/GPa up to 2 GPa (Ref. [6]) and above 165 GPa; bcc α-Mn becomes a hexagonal close-packed (hcp) structure (ε phase, tentatively described), which is AFM.[7],[8]

We reported the thermal strain due to the difference in the coefficient of thermal expansion between a Mn film and its semiconductor substrate is not negligible and is strong enough to overcome the thermal energy for a paramagnetic state and also to break AF magnetic symmetry to induce ferromagnetic ordering. We observed that a stable α-Mn film on GaAs (100) showed FM ordering up to 9000 Å with a TC of above 750 K rather than AF and PM orderings. It showed a net magnetic moment of 0.33 μB/Mn.[9]

In this work, we have investigated the temperature dependence of surface morphology, structural and magnetic properties of Mn films grown on Si (100) substrates using MBE. The crystal structure and surface morphologies of Mn films were determined by x-ray diffraction (XRD) and atomic force microscopy (AFM) measurements, respectively. In order to investigate the correlation between magnetization and charge carrier transport, we performed magnetoresistance (MR) and Hall resistance measurements by using a physical property measurement system.

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