Characteristic Investigation of Spin Gapless Semiconductor CoFeMnSi Thin Films for Spin Injection

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The spin-MOSFET is expected to show a high performance in integrated circuits[1]. Efficiency spin injection into semiconductors from ferromagnet is important for the realization of spin-MOSFET. However, it is difficult to realize efficient spin injection due to the conduction mismatch problem[2]. To enhance the efficiency of spin injection, ferromagnet with high spin polarization and semiconductor like resistivity were proposed. We focused on a new class material with both these properties: Spin gapless semiconductor CoFeMnSi (CFMS). CFMS have a spin gapless structure and semiconductor behavior which have been proofed in theory and experiment[3][4]. In this study, we aim to investigate the crystal structure, magnetic and electrical properties of CMFS thin films on MgO substrates.

A structure of CFMS (50nm)/Ta (5nm) was deposited by magnetron sputtering on MgO (100) substrates. The annealing temperature (T_a) of CFMS layer was between 200 and 600ºC. X-ray diffraction (XRD) and vibrating samples magnetometer (VSM) were performed for characterization of crystal structure and magnetism, respectively. Fig. 1 shows the annealing temperature dependence of (111) peaks of CFMS thin films. The (111) peaks were obtained above T_a = 300ºC, indicating that the epitaxial growth of highly ordered ($L2_1$ or Y-type) CMFS thin films was successful. Fig. 2 shows the magnetic curves along [110] axis of CMFS thin films at each annealing temperature. The saturation magnetization increased with increasing annealing temperature, and the maximum M_S ~ 830 emu/cc was obtained at T_a = 500ºC. The electrical conductivity σ_{xx} value of our sample is around 6.15×10^3 S/cm, about two orders of magnitude lower than the half metallic ferromagnetic alloy Co_2MnSi (~10^5 S/cm). In conclusion, we fabracated highly ordered epixial CoFeMnSi thin films on MgO substrate at T_a = 500ºC.

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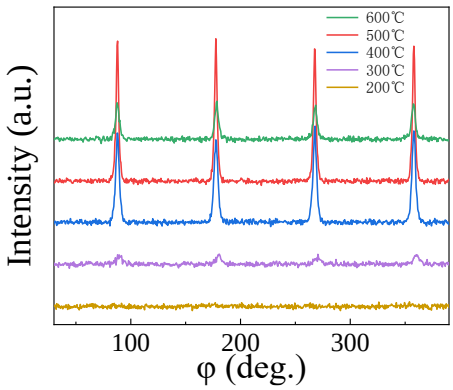

Fig. 1 Temperature dependence of XRD ϕ-scan for $L2_1$ (111) peaks

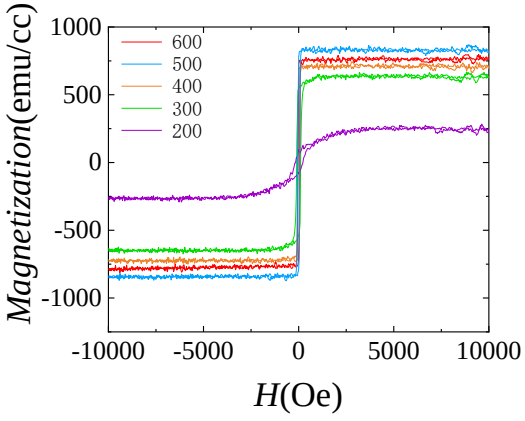

Fig. 2 Temperature dependence of magnetic curves