Magnetotransport of Co_2MnAl Heuslar alloy

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High spin polarization materials are essential to advanced spinelectronics devices such as high density magnetic random access memory (MRAM). Fe_2O_3 [1] or CrO_2 [2] thin films, those are considered to be half metal, showed isotropic negative magnetoresistance effect. The negative magnetoresistance would be due to large asymmetry of scatterings for spin-up electrons and spin-down electrons. Another candidate for half metal is Heuslar alloy. Ishida et al. predicted theoretically that Fermi energy of down-spin electrons is in band gap in Co_2Mn(Si-Al) Heuslar alloy [3]. In this report, structure, magnetic and transport properties of Co_2MnAl bulk ribbons, thin films and magnetic tunnel junctions were investigated experimentally. Electronic band structures of Co_2MnAl were also investigated theoretically.

Bulk ribbons were prepared using rapid quenching. Some samples were annealed at temperatures up to 600 °C. Thin films and tunnel junctions were prepared on Si or glass substrates using magnetron sputtering at an Ar pressure less than 1 Pa. The magnetic tunnel junction (MTJ) had a stacking structure of Cr(0-5 nm)/Co_2MnAl(50-130 nm)/Al(1-3 nm)-O/Co-Fe(4 nm)/Ir-Mn(10 nm)/Ta(5 nm). The junctions were patterned using metal shadow masks. Substrate temperature was raised up to 600 °C. Crystal structure was analyzed using x-ray diffraction. Magnetization and magnetoresistance curves were measured between 4.2 K and RT with maximum fields of up to 2 T. Band calculations were performed using *ab initio* calculation combined with coherent potential approximation method.

All the sample showed polycrystalline B2 structure regardless of preparation method or heat treatment, in which Mn atoms or Al atoms occupy randomly the body centre of Co sublattices. This disorder resulted in high resistivity of more than 200 $\mu\Omega\cdot$cm both in the ribbons and the thin films. Magnetization of the ribbons and the thin films prepared at substrate temperature more than 300 °C were almost the same as the bulk value reported. Magnetoresistance curves of the ribbons and the thin films showed isotropic resistance decrease with applying magnetic fields. The resistance changes were in the order of 0.1%. The small value was mainly due to large resistivity of the alloy. The correspondence of magnetoresistance curve with magnetization curve $(1-(M(H)/M_s)^2)$ suggested that the alloy would have high spin polarization resulted in the isotropic magnetoresistance effect with GMR like mechanism. The maximum tunnel magnetoresistance ratio (TMR) observed in the junctions were 17% and 26% at RT and 25 K, respectively. The barrier heights were about 0.7 eV, which is smaller than the value reported in Co-Fe base MTJs. The optimization of insulating properties of thin Al-O layers on Co_2MnAl films is required. Electronic band structure of Co_2MnAl with partial disorder (B2) showed that every peak of density of state (DOS) became broader but asymmetry of DOS at Fermi energy (E_F) increased compared to that with ordered structure ($L2_1$). The highly asymmetric DOS between spin-up and –down electrons at E_F of B2 structure, corresponding well with the speculation about the experimental results, is quite promising for industrial application.

References

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