Development of Mn-based novel magnetic materials through lattice engineering

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High performance rare earth based permanent magnets have been used widely as a magnetomotive force in applications such as motors, actuators and sensors for $Nd_2Fe_{14}B$ alloy's large magnetocrystalline anisotropy (K_{u1} = 4.5 x 10^6 J/m^3 at room temperature) and relatively high magnetization (M_s = 1.6T). Recently, the consumption of Nd-Fe-B sintered magnets has increased due to the utilization for hybrid, plug-in hybrid and electric vehicles (HV's, PHEV's and EV's). However, due to the scarce natural resource of key elements such as Dy and Tb, a lot of efforts have been done to find another permanent magnet materials instead of rare earth based alloys. One of the candidate materials is Mn-based alloys. The binary Heusler-like compounds Mn_xGa (x = 2~3) have attracted much attention due to its high Curie temperature and large magnetic anisotropy[1, 2]. However, as shown in Fig. 1, for Mn compositions of x =2~3, the tetragonal $D0_{22}$ structure possesses ferrimagnetic property, and consequently it demonstrates a low saturation magnetization. Recent studies revealed that Mn_xGa alloy with the $D0_{22}$ structure demonstrated large coercivities[3, 4] in exceeding 2 T at room temperature, this arise from a large magnetocrystalline anisotropy (K ~ 10 Merg/cm^3). Such high magnetocrystalline anisotropy makes Mn_xGa alloy possible alternative to rare earth and noble metal based magnets in future permanent magnet applications. In this talk, in addition to the theoretical prediction, our recent activities of the lattice engineering on the preparation and evaluation of the bulk and film samples[5, 6] for $D0_{22}$ and $L1_0$ structure of Mn_x(Ga, Ge) alloys with the addition of third elements will be introduced.

Mn-based bulk alloys have been prepared by arc melting in an argon gas atmosphere. All samples were re-melted at eight times to perform homogenization. The samples were powdered by diamond file or grinding in an agate. Then, the powders have been vacuum sealing in a quartz tube and annealed from 350℃ to 550℃ at Muffle furnace. For the preparation of film samples, MgO(100) single crystal substrates were selected and they were prepared using an ultra-high vacuum (UHV) electron beam evaporation system or UHV sputtering system. The substrate was heated to T_s = 300 ℃ during the deposition and they were annealed at 300 ~ 500 ℃. The crystal and surface structures were investigated by XRD and AFM. Composition of samples was analyzed by EDX. Magnetic properties were measured by using a SQUID or PPMS-VSM, and M_s and K_u for each thin film were evaluated from magnetization curves.

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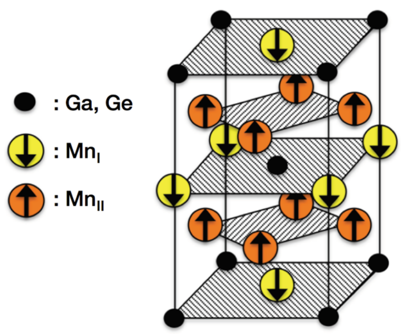

Fig. 1 Crystal structure of DO_{22}-type Mn_3(Ga, Ge) ordered alloy (magnetic structure).