# Structure and magnetic properties of $Sm(FeCo)_{12}$ thin films

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$RFe_{12}$ (R:rare earth element) phase with $ThMn_{12}$ structure has been received much attention as a new permanent magnet because it has a large magnetization due to its high Fe composition. However, the $RFe_{12}$ bulk alloy has not been considered as the new magnet because the nonmagnetic element such as Ti and Zr is necessary to stabilize the $ThMn_{12}$ structure. Recently, Suzuki *et al*. reported that $(Sm_{0.8}Zr_{0.2})(Fe_{0.75}Co_{0.25})_{11.5}Ti_{0.5}$ showed high magnetization of 1.63 T, high anisotropy field of 7.4 T and high Curie temperature of 880 K[1]. Thus, $Sm(Fe_{1-x}Co_x)_{12}$ without Ti has a potential to show higher magnetization since Ti causes significant reduction of magnetization. Here, we present the structure and magnetic properties of $Sm(Fe_{1-x}Co_x)_{12}$ anisotropic thin films in order to demonstrate the potential as the new permanent magnet.

Thin films were fabricated by a co-sputtering method using Sm, Fe and Co targets. The substrates were MgO(100) single crystal for the epitaxial films and a thermally oxidized Si for highly textured polycrystalline films. The film stack for the epitaxial film was MgO(100)/V(20nm)/$Sm(Fe_{1-x}Co_x)_{12}$(500nm)/V(2nm). For the polycrystalline films, NiTa(100nm)/Mg(10nm) was used for the underlayer. The deposition temperature for the $Sm(Fe_{1-x}Co_x)_{12}$ layer was 400C. Structure, microstructure and magnetic properties were characterized by XRD, TEM and VSM, respectively.

The $Sm(Fe_{0.81}Co_{0.19})_{12}$ film deposited on MgO substrate shows the epitaxial growth on the V(001) underlayer. It shows the high magnetization of 1.78 T and anisotropy field of 12 T. The Curie temperature is 859 K, which is much higher than that of $Nd_2Fe_{14}B$. Judging from these intrinsic properties, $Sm(Fe_{0.81}Co_{0.19})_{12}$ has a potential beyond the $Nd_2Fe_{14}B$ magnet[2].

Fig.1(a) shows the XRD patterns of the $Sm(Fe_{0.79}Co_{0.19})_{12}$ polycrystalline film. It shows strong (002) and (004) diffraction peaks from $Sm(Fe_{0.79}Co_{0.19})_{12}$. By tiling the sample, we clearly observe the superlattice peaks of (132) and (332), which indicates that this film has $ThMn_{12}$ structure. In addition to the diffraction peaks from $Sm(Fe_{0.79}Co_{0.19})_{12}$ phase, the peaks of $\alpha$-Fe(200) is observed. Fig. 1(b) shows the magnetization curves of the $Sm(Fe_{0.79}Co_{0.19})_{12}$ film. It shows high saturation magnetization of 1.78 T and anisotropy field. We can find the small increase in the magnetization around zero field in the in-plane magnetization curve. It is due to the $\alpha$-Fe and the FeCo layer in the interface between V and $Sm(Fe_{0.79}Co_{0.19})_{12}$ layers. Fig. 1(c) shows the cross-sectional TEM image of this sample. $Sm(Fe_{0.79}Co_{0.19})_{12}$ grains have columnar shape and grows epitaxially on the V underlayer. From these result, $Sm(Fe_{0.79}Co_{0.19})_{12}$ has the potential for new permanent magnet, if we can enhance the coercivity.

Reference:[1] S. Suzuki *et al*. *JMMM* **401**, 259 (2016).

[2] Y. Hirayama *et al*., *Scripta Mater* **138**,62 (2017).

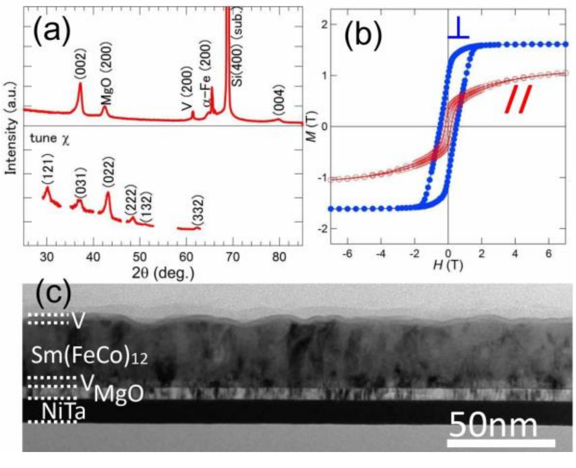


Fig. 1(a) XRD pattern of $Sm(Fe_{0.79}Co_{0.19})_{12}$ polycrystalline film (b)magnetization curves,(c)cross-sectional TEM image