Structure and magnetic properties of Sm(FeCo)\textsubscript{12} thin films


RFe\textsubscript{12} (R: rare earth element) phase with ThMn\textsubscript{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\textsubscript{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\textsubscript{12} structure. Recently, Suzuki et al. reported that (Sm\textsubscript{0.8}Zr\textsubscript{0.2})(Fe\textsubscript{0.75}Co\textsubscript{0.25})\textsubscript{11.5}Ti\textsubscript{0.5} showed high magnetization of 1.63 T, high anisotropy field of 7.4 T and high Curie temperature of 880 K\textsuperscript{[1]}. Thus, Sm(Fe\textsubscript{1-x}Co\textsubscript{x})\textsubscript{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\textsubscript{1-x}Co\textsubscript{x})\textsubscript{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\textsubscript{1-x}Co\textsubscript{x})\textsubscript{12}(500nm)/V(2nm). For the polycrystalline films, NiTa(100nm)/Mg(10nm) was used for the underlayer. The deposition temperature for the Sm(Fe\textsubscript{1-x}Co\textsubscript{x})\textsubscript{12} layer was 400°C. Structure, microstructure and magnetic properties were characterized by XRD, TEM and VSM, respectively.

The Sm(Fe\textsubscript{0.81}Co\textsubscript{0.19})\textsubscript{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\textsubscript{2}Fe\textsubscript{14}B. Judging from these intrinsic properties, Sm(Fe\textsubscript{0.81}Co\textsubscript{0.19})\textsubscript{12} has a potential beyond the Nd\textsubscript{2}Fe\textsubscript{14}B magnet\textsuperscript{[2]}. Fig. 1(a) shows the XRD pattern of the Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12} polycrystalline film. It shows strong (002) and (004) diffraction peaks from Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12}. By tiling the sample, we clearly observe the superlattice peaks of (132) and (332), which indicates that this film has ThMn\textsubscript{12} structure. In addition to the diffraction peaks from Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12} phase, the peaks of α-Fe(200) is observed. Fig. 1(b) shows the magnetization curves of the Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{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 α-Fe and the FeCo layer in the interface between V and Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12} layers. Fig. 1(c) shows the cross-sectional TEM image of this sample. Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12} grains have columnar shape and grows epitaxially on the V underlayer. From these result, Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12} has the potential for new permanent magnet, if we can enhance the coercivity.


Fig. 1(a) XRD pattern of Sm(Fe\textsubscript{0.79}Co\textsubscript{0.19})\textsubscript{12} polycrystalline film (b) magnetization curves, (c) cross-sectional TEM image.