

Fabrication of L1₀-FeNi films by nitrogen topotactic extraction from FeNiN films

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Ferromagnetic materials possessing large uniaxial magnetic anisotropy energy (K_u) and composed of earth abundant elements are required in order to realize the next-generation permanent magnets. We have focused on the L1₀-ordered FeNi alloy as a rare-earth free high K_u ferromagnetic material [1]. Recently, the synthesis of L1₀-FeNi powder by nitrogen topotactic extraction from FeNiN powder was reported, and a high degree of order (S) was achieved [2]. However, the mechanism of nitrogen extraction and the exact K_u value of L1₀-FeNi formed by nitrogen extraction are still unclear. Thereby, the experiment using the single-crystal FeNiN and L1₀-FeNi film is required. In this study, we grew epitaxial FeNiN films by molecular beam epitaxy (MBE), and fabricated L1₀-FeNi films by the nitrogen topotactic extraction [3].

20 nm-thick FeNiN films were grown on SrTiO₃(STO)(001) substrates by MBE supplying Fe, Ni, and radio-frequency (RF) N₂ plasma, simultaneously [4]. Supply rates of Fe and Ni were controlled so that Fe/Ni composition was 1. The growth temperature, N₂ gas flow rate, and RF input power were fixed to be 300 °C, 1.0 sccm, and 250 W, respectively. Denitriding was performed by *ex-situ* furnace annealing at 300 °C for 4 h under H₂ gas flow rate of 1 L/min at ambient pressure. Structure of the samples was characterized by out-of-plane and in-plane x-ray diffraction using Cu-K α radiation. Magnetization curves were measured by vibrating sample magnetometer at room temperature, and the K_u value was estimated by magnetic torque measurements.

From the XRD measurements, we confirm the multi-domain epitaxial growth of FeNiN films on STO(001) with epitaxial relationships of FeNiN[001](100)//STO[100](001) and FeNiN[010](100)//STO[100](001). These epitaxial relationships are maintained after the denitriding, which means that L1₀-FeNi films textured with the a -axis perpendicular to the film plane with two variants have been fabricated. The uniaxial magnetic anisotropy along two in-plane c -axis directions of the a -axis textured L1₀-FeNi films is confirmed by the magnetization curve measurements. The K_u value is calculated to be 4.4×10^6 erg/cm³ by magnetic torque measurements. From the relationship between K_u and S reported for L1₀-FeNi films prepared by MBE [5], K_u of 4.4×10^6 erg/cm³ corresponds to S of 0.4. As a next step, we try to grow c -axis textured single-crystal FeNiN films, and form c -axis textured single-crystal L1₀-FeNi films with the high K_u and S values by the *in-situ* nitrogen topotactic extraction method.

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