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Thickness effects on Magnetic properties and Ferromagnetic Resonance of Co-Ni-Fe & Co-Ni-Fe-N Soft Magnetic Thin Films

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Co-Ni-Fe & Co-Ni-Fe-N 박막의 두께에 따른 자기적 성질과 강자성 공명에 대한 연구

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1. INTRODUCTION

As one of the great streams of IT revolution, recent improvements in electronic devices have led to a demand for further miniaturization and higher frequency operation of magnetic devices. The most important property of magnetic materials required for such applications is the frequency (f) response of permeability (μ), which is limited by eddy current loss and response. According to the modified Landau-Lifshitz equation, which predicts the μ-f response, large values of saturation magnetization (Bs), electrical resistivity (ρ) and anisotropy field (H_k) are required for magnetic materials to show an excellent μ-f response.

We have been reported as-deposited Co-Ni-Fe and Co-Ni-Fe-N soft magnetic thin films with high Bs and the excellent high frequency characteristics. In order to apply these films to high frequency magnetic devices, it is needed to investigate the high frequency behaviors of these films more systematically. In this study, it is therefore, the thickness effects on the magnetic properties and microstructures of Co-Ni-Fe-N and Co-Ni-Fe-N thin films have been studied.

2. EXPERIMENTAL

Co-Ni-Fe and Co-Ni-Fe-N soft magnetic thin films were fabricated over composition ranges of $Co_{22-25}Ni_{29-34}Fe_{42-48}$ and $Co_{21-24}Ni_{27-30}Fe_{43-49}N_{2-5}$, respectively, by rf reactive magnetron sputtering system. The

deposition of these films was carried out under an Ar or ($Ar+N_2$) atmosphere with the total gas pressure of 1 mTorr. The film compositions were analyzed by EPMA and AES.

The high frequency characteristics and magnetic properties of these films were investigated as a function of film thickness with the range of 0.01 -1.0 μm. The microstructures of the thin films were analyzed by XRD and TEM. B_s, coercivity (H_c), and magnetic anisotropy field (H_k) were measured by VSM. The permeability and the electrical resistivity were measured by a high permeability measurement system and a four-point probe method, respectively. The surface roughness of Co-Ni-Fe and Co-Ni-Fe-N thin films were measured using AFM. The FMR spectra are obtained at 9.45 GHz using the TE_{011} cylindrical cavity.

3. RESULTS AND CONSIDERATIONS

As for Co-Ni-Fe thin films, the coercivity (H_c) is increased from 1.5 Oe to 8.9 Oe with the decrease of the film thickness. The electrical resistivity (ρ) also is increased from 25 μΩcm to 88 μΩcm with the thickness. The initial permeability of these films is about 1100, which is maintained up to 200 MHz at 0.5 μm thickness, and above 700 MHz below 0.05 μm thickness. The changes in coercivity and electrical resistivity of Co-Ni-Fe-N thin films with the film thickness showed similar trend with those of Co-Ni-Fe thin films. In case of Co-Ni-Fe-N thin films, H_c and ρ are increased from 1.1 Oe and 53 μΩcm to 5.5 Oe and 188 μΩcm, respectively, with the decrease of the film thickness. The initial permeability of Co-Ni-Fe-N is about 850, which is maintained up to 400 MHz at o.5 μm thickness, above 700 MHz below 0.1 μm thickness. Therefore Co-Ni-Fe-N thin films show the excellent high frequency characteristics, which is interpreted to be due to the high electrical resistivity and anisotropy field.

We also investigated the microstructure of these films through X-ray diffraction patterns and TEM observation. For Co-Ni-Fe thin films, the α-FeCo (110) peaks are clearly observed in films above 0.1 μm thickness, and for Co-Ni-Fe-N thin films, the NiFe (200) peaks are clearly observed in films above 0.1 μm thickness. Whereas, both films below 0.1 μm thickness are constituted of amorphous phase, which gradually are changed to crystalline structure as the film thickness increases. It is considered that high electrical resistivity below 0.1 μm thickness is partly due to the amorphous phase.

From the FMR result, it is concluded that the magnetic phases change from amorphous to crystalline phase with the increase of the film thickness. From the result of the angular dependence in the main mode H_k of these films is increased from 25 to 50 Oe and 18 to 65 Oe, respectively, with the decrease of the film thickness. These values are similar to the VSM results. The g factor of Co-Ni-Fe and Co-Ni-Fe-N thin films decreases with the increase of the film thickness. This implies that soft magnetic properties are improved, due to the contribution of the spin-orbital interaction decrease.