High frequency soft-magnetic properties and thermal stability of CoPd-$SrTiO_3$ nano-composite films

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Soft magnetic films with high permeability and ferromagnetic resonance frequency have been studied intensively for the application in micro-electronic device components. Recent work has been done on soft-magnetic Co-based nano-composite films to keep their permeability as high as possible to GHz frequency.[1)] However, the resonance frequency (*fr*) of the films is still low which may limit the application in higher-frequency magnetic devices. According to the modified Landau-Lifshitz equation, it is required of large values of magnetic anisotropy field (H_k) and saturation magnetization (M_s) to obtain high *fr*. Soft-magnetic films studied to date have large M_s, but show rarely high H_k. Recently, a few films demonstrate high H_k. whereas, they show low thermal stability, which is a big disadvantage for the high temperature processing in practical applications (such as Surface mounted technology at 250℃ for Printed circuit board). In this report, $SrTiO_3$ (STO) is employed as nonmagnetic ceramic phase due to its thermal stability and high resistivity (ρ). Pd is induced to form CoPd alloy nanoparticles to enlarge anisotropy (H_k). To prevent oxidation of Co metal, a kind of tandem sputtering method is used. The composition, structure, magnetic properties and thermal stability of the CoPd-STO films have been investigated.

The CoPd-STO nano-composite films were deposited onto Si and quartz substrates by sputtering methods, using a STO target and a composite target composed of a Co disk, Pd chips. The chemical composition of the films was analyzed by X-ray photoelectron spectroscopy (XPS). Film structures were investigated by XRD. The microstructure of films was characterized by TEM. The magnetization was measured with VSM. The permeability (μ) was determined by a shielded loop coil method.

The CoPd-STO films consist of amorphous STO matrix and CoPd nano-particles. The CoPd phase shows fcc structure. The CoPd-STO films have a typical in-plane uniaxial soft magnetic properties, with the easy axis (parallel) and hard axis (perpendicular to easy magnetic direction) (Fig. 1). The magnetization hysteresis loops of the films show magnetization (B_s) of about 10 kG, H_k of around 950 Oe, and ρ of 300 μΩ･cm. It is noteworthy that the magnetic properties of the sample after annealing treatment at 250 ℃ shows no obvious change compared with that of the as-deposited film. Form XRD analysis (Fig. 2), it is clearly proved that the CoPd particles have no change after annealing treatment for both size and crystalline structure. The measured μ' is approximately 10, which keeps constant up to 3 GHz. The calculated μ' by L.L.G. formula is consistent with the measured results and shows the resonance frequency at about 9 GHz.

Reference

1) Y. W. Zhang et al., IEEE Trans. Magn., vol. 47 (2011), 3795-3798.

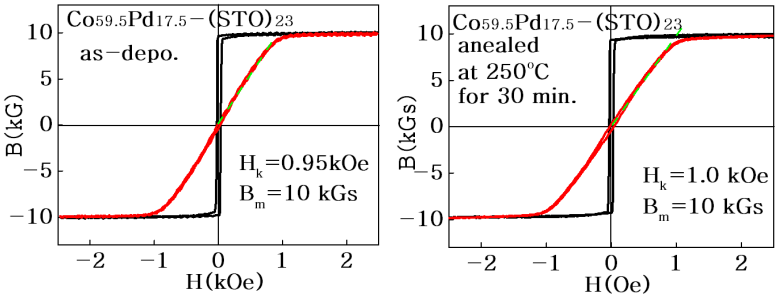

Fig.1 Hysteresis loops of CoPd-(STO) nano-composite film: a) as deposited, b) annealed at 250 ℃ for 30 min.

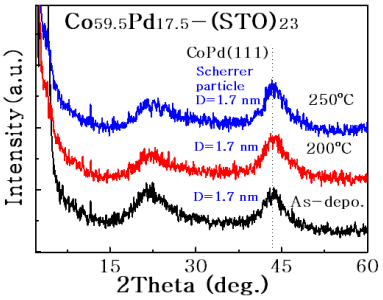

Fig.2 XRD spectra of the as-deposited and annealed CoPd-STO samples.