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Spin Wave Propagation in Ferrimagnetic GdCo

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Abstract

Rare earth-transition metal ferrimagnets are known as promising materials for antiferromagnetic spintronics. In this study, we measured propagating spin waves in ferrimagnetic amorphous GdCo with various compositions, and evaluated the group velocity v_g and attenuation length L_{att}. The obtained values of v_g and L_{att} are explained by ferromagnet-based spin-wave theory when the composition of Gd_xCo_{1-x} is far from the compensation point.

1. Introduction

Rare earth (RE)-transition metal (TM) ferrimagnets exhibit compensation temperatures of magnetization (T_M) and angular momentum (T_A), because magnetic moments of the RE and TM elements are coupled antiferromagnetically and depend differently on temperature [1]. At the vicinity of T_A, the significant increase of resonant frequency [2] and fast field-driven domain wall motion [3] have been reported. Those phenomena result from the antiferromagnetic spin dynamics in the RE-TM ferrimagnets, and motivated us to investigate the magnetization dynamics, such as spin waves. In this study, we measured propagating spin waves in ferrimagnetic amorphous GdCo, and evaluated the group velocity and attenuation length in GdCo with various composition.

2. Experimental Results

The films consisting of Gd_xCo_{1-x} (20 nm)/Pt (2 nm)/Ta (5 nm) were prepared on thermally oxidized Si substrates by dc magnetron sputtering. The Gd_xCo_{1-x} alloys were deposited by cosputtering of Co and Gd targets with different sputtering power. Figure 1 shows the temperature dependence of magnetization for the sample with x =0.22, 0.30, 0.40, 0.59. In the temperature range of 20-300 K, Co magnetic moment dominates for the sample with x = 0.22 and 0.30, whereas Gd magnetic moment does at the sample with x = 0.59. We found the magnetization compensation temperature T_M to be approximately 170 K for the sample with x = 0.40.

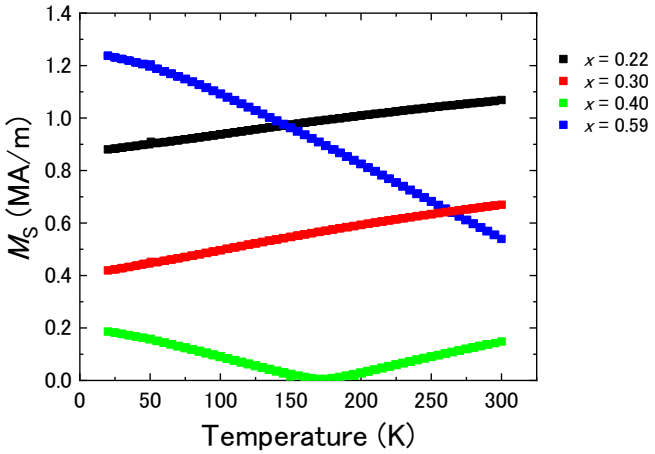

Fig 1. Temperature dependance of magnetization for Gd_xCo_{1-x}.

The films were patterned into rectangular shape and two shorted coplanar waveguides for exciting and detecting the spin waves were fabricated. Propagating spin wave spectroscopy was performed by using a vector network analyzer under the in-plane magnetic field transverse to the direction of the spin wave propagation. We measured transmission signal (S_{21}, S_{12}) and reflection signal (S_{11}, S_{22}) at room temperature. Figure 2 shows transmission signal S_{21} for the sample with x = 0.22. The group velocity v_g and attenuation length L_{att} were estimated for the sample with x = 0.22, 0.30, 0.59.

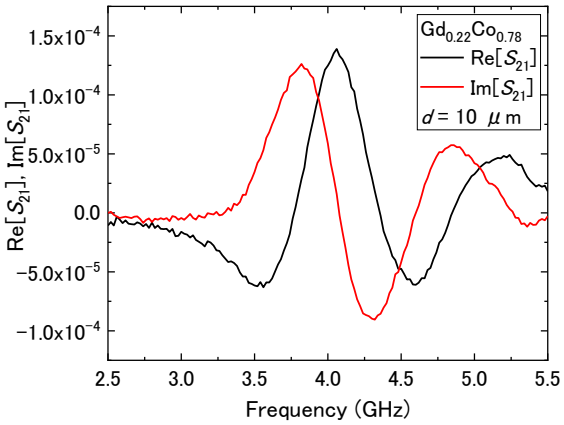

Fig 2. Transmission signal for $Gd_{0.22}Co_{0.78}$.

We also calculated v_g and L_{att} from ferromagnet-based spin wave theory as follows.

$$v_g = \frac{(\mu_0\gamma)^2 M_{s,eff} \cdot M_s d}{8\pi f} \quad (1)$$

$$L_{att} = \frac{v_g}{\mu_0\gamma(2H + M_{s,eff})\alpha} \quad (2)$$

where d is the film thickness (20 nm), γ is the gyromagnetic ratio, μ_0 is the permeability, α is the damping constant, M_S is magnetization of the film, and $M_{S,eff}$ is the effective saturation magnetization. γ, α and $M_{S,eff}$ are estimated from the reflection signal measurement under the in-plane magnetic field longitudinal to the direction of the spin wave propagation.

Table I lists the experimentally and theoretically obtained v_g and L_{att} values. It shows that the theoretically calculated v_g and L_{att} qualitatively reproduce the experimental results when the composition of Gd_xCo_{1-x} is far from the compensation point. The overestimation of v_g in the experiments may have resulted from the finite widths of the CPWs [4].

Table I. The values of group velocity and attenuation length for the sample with x = 0.22, 0.30, 0.59. The values in parentheses are theoretically calculated values using Eqs. (1) and (2), respectively.

x	v_g [km/s]	L_{att} [μm]
0.22	10.4 (7.5)	2.13(2.60)
0.30	7.5 (3.2)	(0.98)
0.59	3.2 (2.8)	1.65(1.85)

3. Conclusions

We investigated the spin wave properties in RE-TM ferrimagnetic Gd_xCo_{1-x} films with various composition x. The experimentally obtained v_g and L_{att} were almost consistent with the ferromagnet-based spin wave theory when the composition of Gd_xCo_{1-x} was far from the compensation point.

Acknowledgements

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