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TEMPERATURE DEPENDENCE OF SPIN WAVE RESONANCE IN AMORPHOUS FILMS

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Abstract-The temperature dependence of spin wave mode separation in amorphous $Co_{89.5}Zr_{10.5}$ thin film has been investigated at temperatures between 100 K and 300 K. The magnetization and the spectroscopic splitting factor were obtained for the main resonance mode in parallel and perpendicular magnetic field. $\triangle H_{2-3}$, the difference between resonance field of mode 2 and the resonance field of mode 3, increases with decreasing temperature. The linewidth increases for all the modes with decreasing temperature. Especially in mode 3 it increases rapidly below 200 K. This phenomenon could be caused by the increase of exchange stiffness constant or the decrease of surface magnetic anisotropy constant with decreasing temperature.

I .INTRODUCTION

In order to explain the temperature dependence of saturation magnetization of ferromagnetic materials, which could not be described by a simple mean field theory, the concept of spin wave was first introduced by Bloch, 1930. Bloch thought that the excitation of spin wave due to thermal energy results from the superposition of spins varying phase through the lattice under a dynamic state. Thus, the traveling of spin phase through the lattice is called a spin wave. The study on the spin wave has been performed by not only VSM[1] and SQUID experiments, which are an indirect method, but also neutron scattering, Brillouin Light Scattering[2] and FMR[3], through a direct behavior of spin wave excited due to the energy of electromagnetic wave or thermal energy.

FMR is a resonance phenomenon that occurs at the same frequency of microwave with the frequency of precessional motion of electron spins by an external static magnetic field. If the magnetic field of microwave is not homogeneous in the sample the spins take a precessional motion with different phase to each other. Then we can consider two cases according to the returning force as follows.

The first is that the returning force is caused by magnetic dipole interaction. This is called magnetostatic mode or walker mode[4]. The second is that the exchange force between spins plays a role of the returning force. This is called magnetoexchange mode. Inhomogeneous microwave magnetic field seems to be a necessary condition in exciting the spin wave. However the spin wave in the film can be created by a homogeneous microwave magnetic field if spins are pinned on the film surface as explained by Kittel[5].

On the other hand, the spin pinning occurs due to impurities absorbed into the film surface in addition to the intrinsic surface anisotropy proposed by Neel[6]. Hence the spin wave indicate different aspects owing to the spin pinning.

In this study, we analyzed the temperature dependence of spin wave occured in 1,080 Å thick amorphous $Co_{89.5}Zr_{10.5}$ alloy film which gives a clear splitting of resonance absorption curve.

II. EXPERIMENTAL PROCEDURE

1. Sample preparation

To fabricate $Co_{89.5}Zr_{10.5}$ alloy films, we used DC magnetron sputtering unit. The sputtering target consists of Zr flakes attached on Co target with 10 cm in diameter. The substrate was Si(100) wafer with 0.5 mm in thickness. In the sputtering chamber, the base pressure 5~6×10^{-7} torr was kept by a rotary pump and a turbo pump. To remove some impurities attached on the inner wall of sputtering chamber, the chamber was heated up to 100 ℃ for 1 hour and cooled down to room temperature. 1,080 Å thick thin films were fabricated under working gas pressure 3 mTorr.

2. FMR experiments

The prepared samples with 10 mm in diameter were cut to 3×3 mm size and attached on quartz tube connected to goniometer. These samples were placed in the center of resonator cavity where the microwave magnetic field and static magnetic field are perpendicular each other. Under this configuration the differential absorption curves were observed by varying the static magnetic field from 0 to 1.7 T. The film surface was fixed in parallel and in perpendicular with the static field. To observe the subsidiary signals the intensity of modulation signal was varied from 0.1 to 1 G. The temperature of sample was varied from room temperature to 103 K with 10 K step by controlling the liquid nitrogen flow rate. The temperature sensor was a copper constantan thermocouple. The microwave frequency and power were 9.057 GHz and 0.1 mW respectively. The modulation frequency was 100 kHz.

III. RESULTS AND DISCUSSION

When the magnetic field was applied in parallel to the film surface only one resonance absorption curve was observed and resonance field increased a little with increasing temperature as shown in Fig.1.

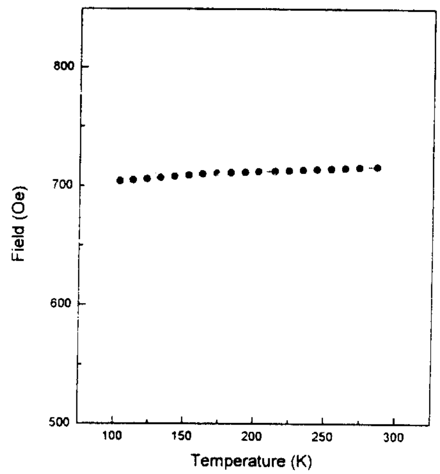

Fig.1 The temperature dependence of the resonance field for 1,080 Å $Co_{89.5}Zr_{10.5}$ thin film with the external field parallel to the film plane.

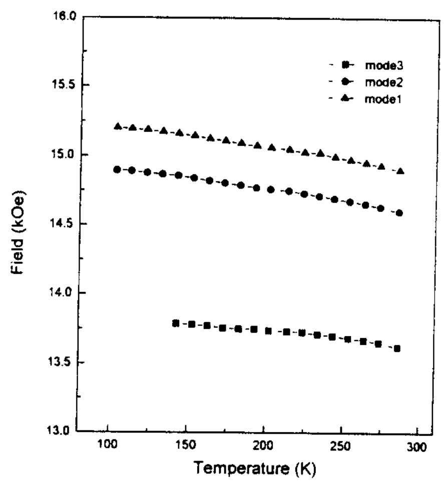

Fig.2 The temperature dependence of the resonance field for 1,080 Å $Co_{89.5}Zr_{10.5}$ thin film with the external field perpendicular to the film plane.

When the field was perpendicular to the film surface three absorption curves were observed and the resonance magnetic field decreased with increasing temperature(*see* Fig.2). The difference ΔH_{1-2} between the resonance fields of the first absorption curve and the second absorption curve and the difference $\triangle H_{2-3}$ between the resonance fields of the second absorption curve and the third absorption curve increased with decreasing temperature(*see* Fig.3).

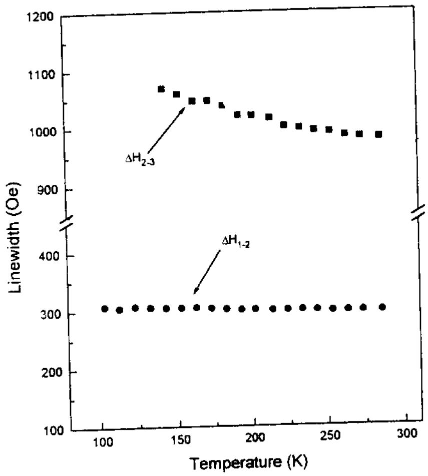

Fig.3 The temperature dependence of the spacings between the spin wave resonance fields for $Co_{89.5}Zr_{10.5}$ thin films.

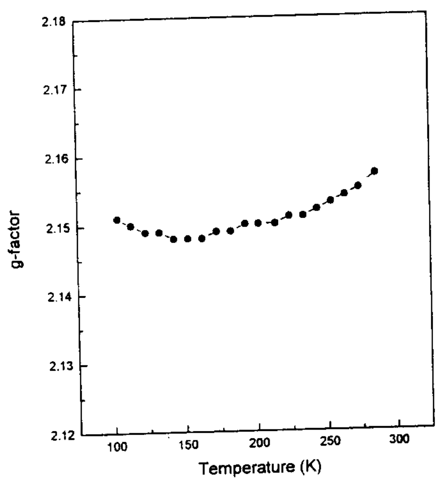

Fig.4 The temperature dependence of the spectroscopic splitting g-factor for 1,080 Å Co-Zr thin film.

These results are contradictory to the effect showing the increase of magnetization resulted from the decrease of temperature. On the other hand the spectroscopic splitting factor g due to the increase of temperature and the effective magnetization M_{eff}, considering the magnetic anisotropy of samples, are shown in Fig.4 and Fig.5.

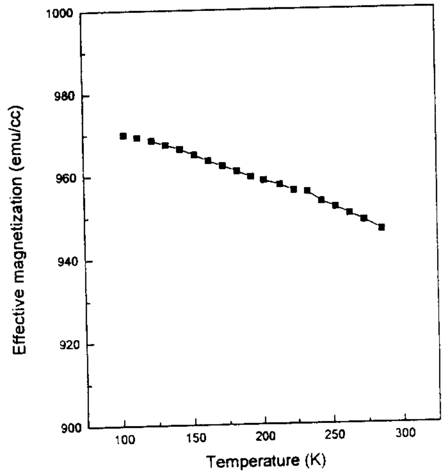

Fig.5 The temperature dependence of the effective magnetization for 1,080 Å Co-Zr thin films.

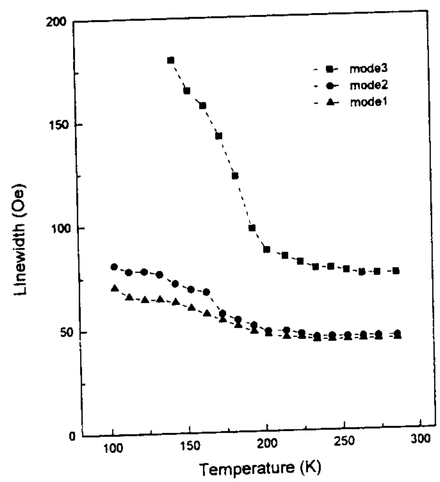

Fig.6 The temperature dependence of the linewidth for 1,080 Å Co-Zr thin films.

The effective magnetization increases gradually with increasing temperature. The g-factor decreases with decreasing temperature from room temperature to 150 K and increases with further decrease of temperature below 150 K. This phenomenon means that the relative contribution of orbital motion to the spin in magnetic moments yields minimum at 150 K. Fig. 6 shows the temperature dependence of linewidth. In all modes the line width increases with decreasing temperature. Especially the line width in mode 3 increases rapidly with decreasing temperature to below 200 K and the line shape vanishes below 140 K. This result, if we consider the increase of $\triangle H_{2-3}$ due to the increase of temperature, may be resulted from the increase of exchange stiffness constant or the decrease of surface magnetic anisotropy with decreasing temperature.

Ⅳ.CONCLUSION

The increase of $\triangle H_{2-3}$ and the rapid increase of the linewidth in mode 3 are caused by the decrease of surface magnetic anisotropy or the increase of exchange stiffness constant with decreasing temperature.

On the other hand the temperature dependence of g—factor means that the contribution of orbital motion of spins is determined by temperature and becomes minimum at 150 K.

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