Phonons in PtFe Thin Films as High-density Magnetic Recording Media

Since an $L1_0$ (CuAu I) type PtFe alloy has a large uniaxial magnetocrystalline anisotropy energy of 7×10^7 erg/cm^3 [1], saturated magnetization and good chemical stability, this alloy is considered to be an excellent candidate for future ultrahigh density perpendicular magnetic recording media. Moreover, the alloy is expected as a thin film magnet which applies microscopic magnetic fields to an integrated circuit. PtFe alloy undergoes a chemical ordering transition from the disordered-fcc phase to the ordered-fct phase at about 1300 ºC. The ordered crystal has an uniaxial anisotropy along the [001] direction. Recently, one of the present authors found that the tetragonal lattice distortion (1-c/a) of PtFe alloy increases with increasing temperature up to 750K [2]. Since the magnetic anisotropy energy is strongly related to the tetragonality of the lattice, it is important to understand the origin of the increasing tetragonality at high temperature. To investigate the increasing tetragonality of the lattice, we tried to look into the phonon density of states (PDOS) in PtFe alloy. In particular, we take notice of information for thin film as an application material.

The PDOS of ^{57}Fe atoms in the PtFe alloy was investigated using the nuclear resonant inelastic scattering (NRIS) method. The NRIS experiments were performed at beamline **BL11XU** [3,4]. The incident beam energy of the synchrotron radiation was varied around the first nuclear resonant energy of ^{57}Fe (14.413 keV). The incident beam intensity was monitored with an ionization chamber and a beam flux monitor. A Si-avalanche photodiode (APD) detector was used to observe the delayed photons in the nuclear resonant scattering from ^{57}Fe in the PtFe alloy.

The PtFe thin film sample was deposited on a MgO single crystal substrate and piled up to 25 PtFe layers. This sample was prepared in Takanashi Laboratory at the Institute for Materials Research, Tohoku University. To investigate the special feature of thin film, bulk crystal and powder samples were also prepared and the results were compared. Fe atoms enriched by the ^{57}Fe isotope were used in these samples. The bulk crystal was prepared in a furnace with a carbon electrode in Ar gas atmosphere. The powder sample was prepared by filing down the bulk crystal with a diamond file. From X-ray diffraction, it is confirmed that the bulk sample is chemically ordered and the powder sample is disordered.

Figure 1 shows raw energy spectra obtained at room temperature for the bulk crystal, powder sample and thin film. Figure 2 shows the PDOS of bulk, powder and thin film samples derived from the observed energy spectra after correcting the multiphonon process. The greater part of PDOS is in the high energy side. In the NRIS method, phonons

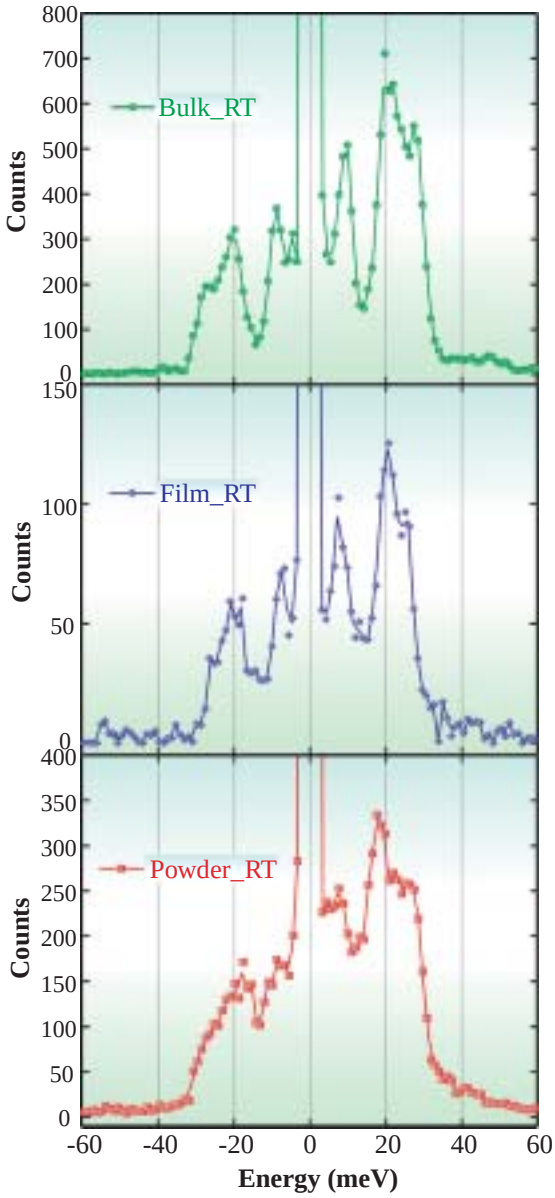

Fig. 1. Energy spectra at room temperature for bulk crystal, powder sample and thin film.

of resonant nuclei (^{57}Fe) are observable. Since an Fe atom is far lighter than a Pt atom, Fe's contribution to the acoustic phonon is small. On the other hand, the optical phonons are mainly determined by the vibrations of Fe atoms. There is a phonon band gap around 13 meV due to the large difference between the atomic masses of Fe and Pt. Comparing the PDOS in Fig. 2, the bulk crystal shows a well-defined band gap, while for the powder sample and thin film, the band gap is buried under the tails of the acoustic and optical phonons. This is already seen in the raw data at around 13 meV (Fig. 1). Considering that the powder sample is chemically disordered, the loss of the band gap in the thin film is caused by the chemical disorder, indicating that the atomic order parameter of the thin film sample is smaller than that of the bulk sample. The optical phonon band width of the thin film is narrower than those of the bulk crystal and powder sample. Although the bulk crystal and powder sample have a multidomain, the thin film surface is oriented to the [001] axis. Thus, the phonons on the (001) plane were predominantly observed for the thin film specimen. Figure 3 shows the temperature variation of the thin film PDOS. At any temperature, the phonon gap around 13 meV is ill defined. The PtFe thin film is a very important material as magnetic recording media. In order to improve its performance, raising the degree of atomic order would be important.

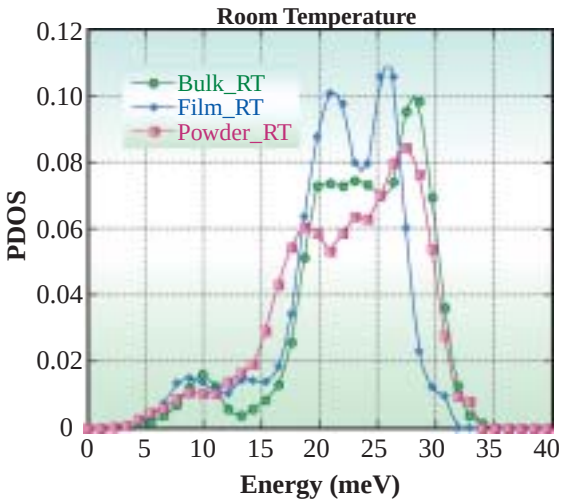

Fig. 2. PDOS at room temperature for bulk crystal, powder sample and thin film.

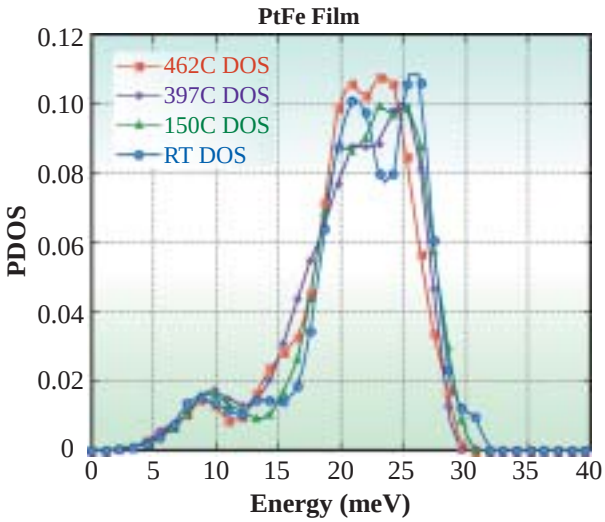

Fig. 3. PDOS for thin film at various temperatures.

Mabune Hideshima

Department of Applied Physics, Waseda University

E-mail: mabune-h@fuji.waseda.jp

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