Piezoelectric effect on anisotropic magnetoresistance in epitaxial CoFe films

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A recent study reported that the anisotropic magnetoresistance (AMR) effect of single-crystalline CoFe shows a current-orientation dependence due to the electronic band crossing near the Fermi level, meaning an intrinsic mechanism [1]. However, the influence of the electronic band structure was indirectly proved by a comparison of theoretical calculations and experimental data. To verify the intrinsic mechanism, we utilize the piezostrain as a well-established means to tune the electronic band structures [2].

30-nm-thick epitaxial CoFe films were grown on ferroelectric $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) (001) substrates by molecular beam epitaxy. Using the photolithography and Ar ion milling techniques, two different Hall-bar devices for AMR measurements were fabricated along the PMN-PT[100] (CoFe[1-10]) or [110] (CoFe[100]) directions, respectively (see insets of Fig. 1). To modulate the electronic band structure of CoFe via piezoelectric strain, we applied electric fields (E) to the PMN-PT[001] direction. At each E, angle φ dependence of the resistance was measured under a sufficient magnetic field of ~2 kOe at room temperature. Here φ is the relative angle between the current $\boldsymbol{J}$ and the magnetization directions.

Figure 1 shows AMR ratios for the CoFe[1-10] and [100] Hall-bar devices at various E. The φ-dependent AMR shows a four-fold symmetry for the [1-10] Hall-bar while a two-fold symmetry is found for the [100] one, being consistent with the previous report in epitaxial CoFe film on MgO(001) [1]. The results are fitted with a phenomenological equation [$\mathrm{AMR}(\varphi) = C_0 + C_2\cos(2(\varphi+\varphi_2)) + C_4\cos(4(\varphi+\varphi_4))$]. From these analyses, we find that the values of C_i are modulated with hysteric behavior by varying E. On the basis of the first-principles calculation, the correlation between the AMR changes and electronic band modulation by varying E will be discussed.

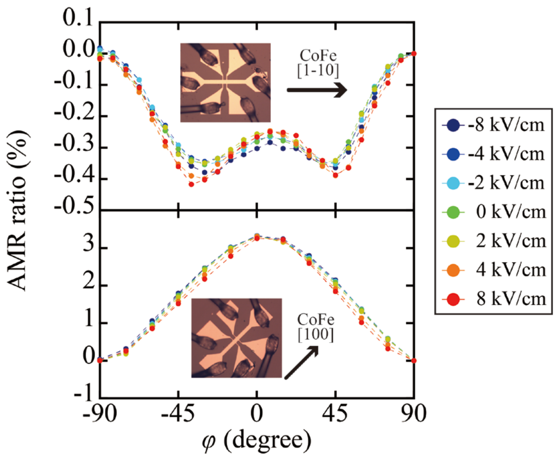

Fig. 1. φ dependence of AMR ratios for the CoFe[1-10] and [100] Hall-bar devices at various E at room temperature. The insets show optical micrographs of the fabricated Hall-bar devices.

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