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Effect of anisotropy constant distribution on domain wall motion

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Recently many researches on domain wall motion driven by spin polarized current and magnetic field have been done.[1~4] The high density non-volatile memory application as well as the reconfigurable logic was suggested for the application of current driven domain wall motion. However, for the realization of those electronic devices, the reduction of operation current is required. Such a low current cannot be achieved with widely used NiFe nanostrips, in which critical current density has been reported to be ~1.e8 A/cm^2. Much attention has been paid to the high perpendicular magnetic anisotropy (PMA) materials in other to obtain low operational current based on the report of recent theoretical results such as CoCrPt and Co/Pt multilayer.[5] However, experimental finding is not consistent with theoretical one.[6] This might be related with the intrinsic defect or peculiar property like uniaxial anisotropy constant (Ku) in PMA materials. Specially, large Ku dipersion in PMA multilayer film was reported in the measurement of switching field, [7] which might provide some clue of this contradiction.

In this work, we examined the effect of Ku dispersion on domain wall motion driven by magnetic field or current. And hysteresis loops with varying Ku dispersions will be compared with experimental hysteresis loops.

Current induced magnetization dynamics are micromagnetically modeled by including spin transfer torque term in LLG eqations.[4] Material parameters were Ms=400emu/cc, Ku=2.0×106erg/cc, the exchange constant A=1.0×10^{-6} erg/cm, spin polarization=0.5, damping constant=0.1, and non-adiabaticity β=0.01. The width, length, and thickness of the strips were 800 nm, 60 nm, and 5 nm, respectively. The size of a unit cell is 4 nm × 4 nm × 5 nm. The orientation of the easy axes for anisotropy is perfect perpendicular direction of nanowire. Current pulse width is 50 ns. Time step for LLG eq. is set to be 0.02 ps. Average terminal domain wall velocity was calculated as function of current density and magnetic field.

Fig. 1 shows the hysteresis loops with two different Ku standard deviations. With mean Ku of 1.e6 erg/cc, standard deviation of Ku is 0 erg/cc or 1.e6 erg/cc. There was a slight difference between coercivity (Hc) out of plane and saturation field (Hs) in plane in the hysteresis without Ku dispersion. Hc is same of Hs of ~2900 Oe. When standard deviation of Ku was 1.e6 erg/cc, Hc was ~700 Oe and Hs was ~7000 Oe. As standard deviation of Ku increases, Hc decreases and Hs increases. From hysteresis loop, we can expect how large standard deviation of Ku is in the perpendicular magnetic materials.

Fig. 2 shows the domain wall velocity in field driven and current driven domain wall motion. As seen, critical magnetic field and critical current for domain wall motion were 470 Oe and ~1.7e7 A/cm^2 comp. It is well known that critical current with non-zero adiabaticity are zero in perfect nanowire track.[5]It is found that Ku distribution of nanowire plays a role of pinning potential to the domain wall motion.

Therefore reducing Ku dispersion in perpendicular magnetic material can be necessary for reducing critical current for the application of domain wall motion.

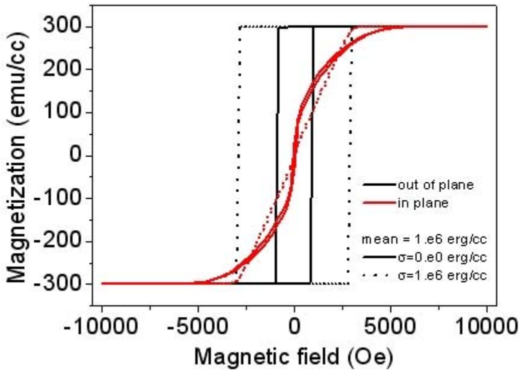

Fig. 1. Hysteresis loops of mean Ku of 1.e6 erg/cc, standard deviation of (a)Ku = 0, (b)Ku = 1.e6 erg/cc.

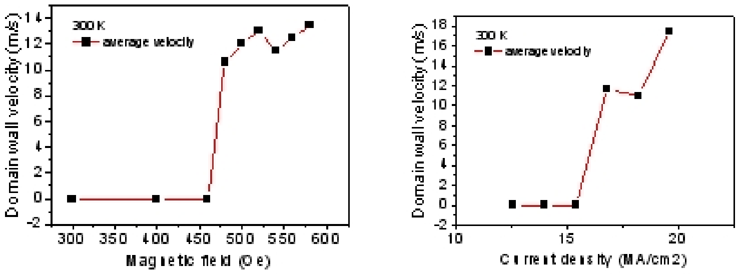

Fig. 2. domain wall velocity with magnetic field and current density of mean Ku of 1.e6 erg/cc and standard deviation of Ku = 1.e6 erg/cc.

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