Possible stabilization of room-temperature skyrmions in Heusler alloy based magnetic multilayers

Magnetic skyrmions are chiral spin textures that exhibit a great potential for the future spintronic data storage by providing nonvolatile, nanoscale and low-power energy consumption information carriers. Searching of novel skyrmion materials with desired properties thus constitutes as one of the major trends in spintronics which motivates the present study. In this collaboration work, we explore the realization of skyrmion in Heusler alloy based multilayers with ultra-low damping that could result in efficient electric manipulation.

Strong spin-orbit interaction together with broken inversion symmetry gives rise to many exciting physics [1]. Magnetic skyrmions and current induced spin-orbit torques are representative examples[1-3]. The material system along these directions is typically heavy metal/ultrathin ferromagnet/insulator trilayer in which the strong spin-orbit interaction of heavy metal provides (a) a source of interfacial noncollinear Dzyaloshinskii-Moriya interaction (DMI) that stabilizes chiral domain wall/skyrmion and (b) a source of spin currents/spin-orbit torques that enables efficient electrical manipulation. Typical magnetic multilayers are made of ultrathin Co and CoFeB in adjacent to Pt, W, Ir and Ta which exhibit relatively high intrinsic damping, in addition to the extra interfacial contribution to damping. Owing to the low intrinsic damping, Heusler alloy and MnGa based single-crystalline multilayers are currently attracting attention from the community which motivates the present study. Specifically, Heusler alloy and MnGa based materials were explored for simultaneously realizing nanoscale densely packed skyrmion lattices with the size approaching 50 nm, and efficient electrical manipulation produced by the current induced spin-orbit torques as a result of low magnetic damping. These aspects are the heart of the current skyrmion based spintronics research. Realizing of which could pave the pathway towards future functional skyrmion racetrack memory devices. It could also enable room temperature emergent topological spin transport to be investigated, such as topological Hall effect, skyrmion Hall effect and their reciprocity.

Using ultra-high vacuum magnetron sputtering technique, Pt/MnGa/MgO, Pt/FePt, Pt/Co2(Fe0.4Mn0.6)Si/MgO, multilayers with various thicknesses of each layer were synthesized which were done in collaboration with Prof. Koki Takanashi. Selected results on MnGa based magnetic multilayer are shown in Fig 1.

Fig.1 shows magnetic hysteresis loops measured in-plane and perpendicular to the plane in a MgO / Cr (2) /Pt (3) / MnGa (3) / MgO (2) / Ta (2) multilayer (unit in nm) that was annealed at 300 °C for 1 hour. The presence of perpendicular magnetic anisotropy is clearly presented which is more promising for realizing room-temperature skyrmions. The strength of DMI and damping parameters are currently being examined using Brillouin light scattering (BLS) and FMR techniques, respectively. Associated films were also deposited onto TEM membrane for identifying skyrmion phase in real space by using Lorentz TEM in collaboration with Dr. Ying Zhang (IOP, CAS).

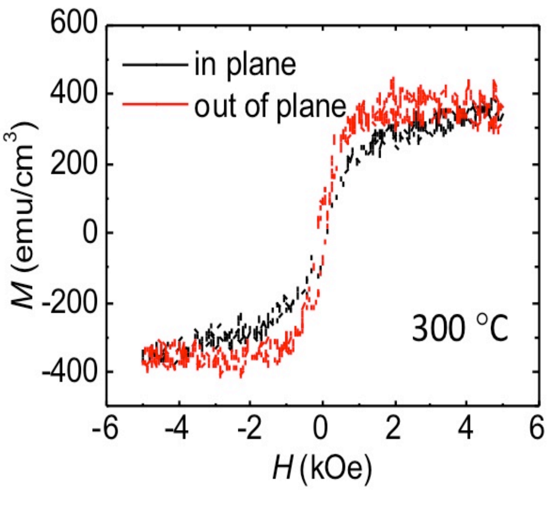

Fig. 1 Magnetic hysteresis loops measured in in Pt 3 nm / MnGa 3 nm / MgO 2 nm / Ta 2 nm.

References

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