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Presentation Title

Tetragonal Heusler-like alloy for nano spin memory application

Abstract

To realize nano-scaled magnetoresistive random access memory utilizing spin-transfer-torque effect (STT-MRAM), we need to develop nano scale magnetic tunnel junctions (MTJs) that should show high read-out voltage, low writing current, and 10 years data retention [1]. Such performances in MTJs are related significantly to properties of magnetic material electrodes [2]. Read-out voltage is proportional to tunnel magnetoresistance ratio (TMR) determined by *spin polarization* of the electrode. Data retention is also governed by *uniaxial magnetic anisotropy* energy of the electrode. Writing current is determined by a balance between STT and magnetic friction torque characterized by *Gilbert damping constant* of the electrode. These three fundamental properties of material are linked closely to each other from physical points of view. For instance, fully spin polarized band structure seems to lead not only high spin polarization but also low Gilbert damping constant because a spin-flip scattering is forbidden in such a band structure [3]. On the other hand, uniaxial magnetic anisotropy originates from axial symmetry in spin-polarized band structure perturbed by spin-orbit interaction, where the coupling between spin and lattice system may become significant and seems to lead large Gilbert damping constant [4]. Thus, it is challenging but interesting to explore such a unique magnet that exhibits a high spin polarization, large magnetic anisotropy, and low Gilbert damping constant simultaneously.

A Mn_3Ga has a chemical formula of Mn_2MnGa, similar to a X_2YZ Heusler alloy, and a ferrimagnetic structure consisting of magnetic moment of Mn at X cite coupled anti-parallel to that at Y cite. Tetragonal structure ($D0_{22}$) is more favor than cubic ($D0_3$) in Mn_3Ga, probably induced by the Jahn-Teller effect. Spin polarization is decreased by this tetragonal distortion but is still relatively high 88% in $D0_{22}$-Mn_3Ga, predicted by a German group [5]. On the other hand, this tetragonal distortion induces the large uniaxial perpendicular magnetic anisotropy exceeding 10 Merg/cm^3, as reported by our group in the thin epitaxial film of $Mn_{3-x}Ga$ (x = 0.5) alloys [6].

Recently, we observed ultrafast spin precession using all-optical pump-probe method in thin epitaxial films of $Mn_{3-x}Ga$ alloys (x = 0.88 and 1.46) [7] [Fig. 1(a)] and extracted Gilbert damping constants are relatively smaller than those reported in the other films with a large perpendicular magnetic anisotropy, as summarized in Fig. 1(b). Compatibility of large magnetic anisotropy and low damping constant in Mn_3Ga is also demonstrated by the calculations taking account of realistic band structure [7]. Therefore, $Mn_{3-x}Ga$ may be one of the unique materials suitable to a nano spin memory application. Current status of research on TMR in MTJs with $Mn_{3-x}Ga$ electrode, strategy of future research, and related physics will be discussed in our talk.

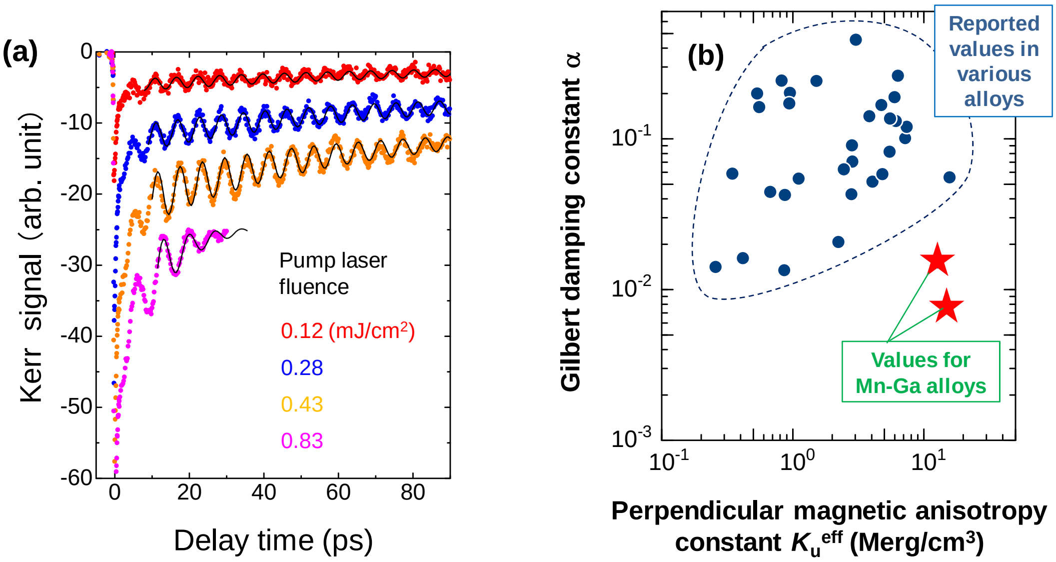

Figure 1 (a) Example of real time observation of ultrafast spin precession in the $Mn_{3-x}Ga$ alloy films (x = 1.46) with different pump laser fluences. (b) the effective Gilbert damping constant vs effective perpendicular (uniaxial) magnetic anisotropy constant reported in various alloys and in the $Mn_{3-x}Ga$ alloy films (x = 0.88 and 1.46).

References

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