Pulse-laser-induced terahertz emission from CoFeB films with various capping layers

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In recent years, it was demonstrated that the terahertz (THz) wave can be created using ferromagnet / nonmagnetic metal heterostructures [1-3]. Ultrafast spin current can generate from ultrafast demagnetization in ferromagnetic layers induced by the irradiation of femtosecond laser pulse. The generated spin current can be converted to the charge current and THz electric field by the inverse spin-Hall effect in nonmagnetic metal layer. Thus, the spin Hall-effect in various nonmagnetic materials can be studied by measuring THz wave emitted. In addition, the THz wave signal reflects how fast the spin travels across the magnetic/nonmagnetic structure [1], which is unique in this measurement and is different from the conventional dc or rf inverse spin-Hall effect measurement. In this study, the THz emission in CoFeB with various nonmagnetic capping layers were investigated to gain insights into the femtosecond spin transport properties. The stacking structure used in this study is Si / SiO_2 sub. / Ta (5) / MgO (2) / CoFeB (2) / X (5) (X = Ta, Ru, IrMn, Cr, Mg, and MgO) (thickness is in nm). The duration and center wavelength of the femtosecond laser pulse used were ~120 fs and ~800 nm, respectively. The THz wave was detected by an electro-optic sampling technique using 1-mm-thick ZnTe (110) crystal [3]. Figure 1 shows the THz waves measured for the samples with different nonmagnetic capping materials X. The THz wave signals are clearly observed even in non-heavy element such as Cr and Mg. Positive or negative maximum of the signals at the delay zero is related to the sign of the spin-Hall angle for the non-magnetic capping layer. Among the series of our samples, it was unveiled that the sign of the spin-Hall angle for Ta and Cr are opposite with that for Ru, IrMn, and Mg. The intensity for Ta was found to be highest among these samples, which may be due to the largest spin-Hall angle among them. The spin traveling dynamics with different nonmagnetic materials will be discussed with analyzing the waveforms for the THz signal. This work was partially supported by KAKENHI (16H03846, 26103004). Y.S. acknowledges the GP-Spin.

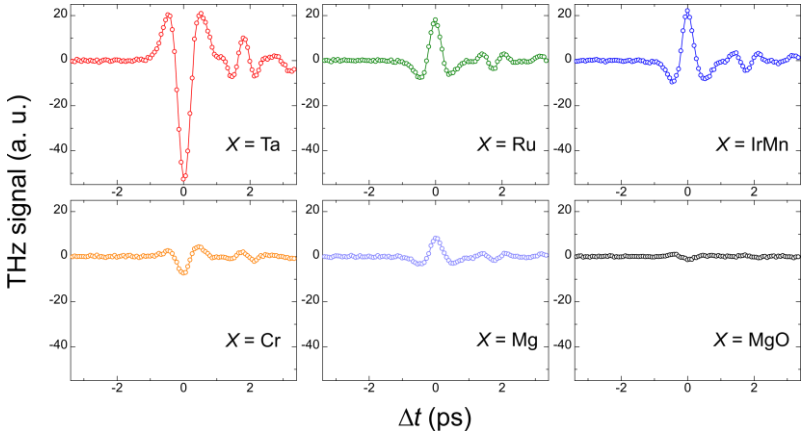

Figure 1 Emitted THz wave signals measured for CoFeB (2) / X (5) structure.

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[3] Y. Sasaki *et al*. Appl. Phys. Lett. **111**, 102401 (2017).