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Detection of millimeter-wave without external magnetic field using spin-torque -diode having an $L1_0$-ordered FePd free layer

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Spin-Torque -Diode (STD) has attracted much attention as a microwave detector having a high sensitivity. [1] Because the microwave frequency is determined by the ferromagnetic resonance, it is difficult to detect millimeter-wave band using an STD having an ordinary ferromagnet (*e.g.* CoFeB, CoFe) under a small magnetic field. In order to detect the millimeter-wave, it is necessary to use a free layer which has a large magnetic anisotropy constant (K_u) in magnetic tunnel junctions (MTJs). An $L1_0$-ordered alloy is one of the promising candidates because of its high K_u. Previously we detected frequency as high as 28 GHz using an $L1_0$-FePd free layer [2], however, the detection beyond millimeter wave has not been realized. In this study, we report the detection of the millimeter-wave using the perpendicularly magnetized $L1_0$-FePd free layer under zero fields.

The films consisting of Cr(40)|Pd(10)|FePd(2.0)|$Co_{40}Fe_{40}B_{20}$(0.5)|MgO(0.85)|$Co_{40}Fe_{40}B_{20}$(2)|Ru(0.85)|$Co_{75}Fe_{25}$(2)|IrMn(10)|Ta(5)|Ru(8) (in nm) were deposited on MgO(001) substrates by UHV magnetron sputtering. They were micro-fabricated into the small MTJs with a diameter of 100 nm by means of electron beam lithography and Ar ion milling. The TMR ratio and the resistance-area product were about 18% and 4 $\Omega\mu m^2$, respectively. The STD spectra were measured at room temperature by a modulation method with a signal generator and a lock-in amplifier under an external out-of-plane magnetic field (H_{OP}).

Fig. 1 shows the spectra under the various H_{OP} (background noise of 25 – 40 GHz were not subtracted). The highest frequency of the STD signals was observed at 40 GHz under zero fields, which is much higher than the previous study [2]. The observed peaks were shifted to the higher frequency by decreasing the H_{OP}. The H_{OP} dependence of the frequency was well fitted by the Kittel's formula, where the perpendicular magnetic anisotropy field of the FePd was partly canceled by the opposite applied H_{OP}. Therefore, we concluded that the observed peaks originated in the STD effect.

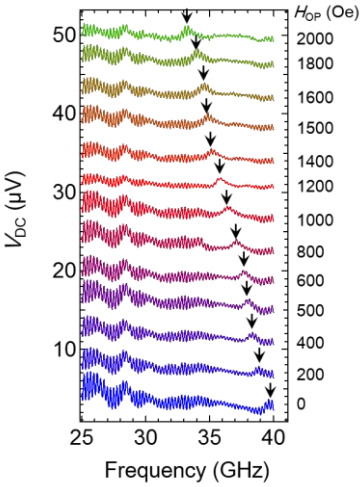

Fig.1 STD spectra measured under the various H_{OP}

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[1] S. Miwa *et al.*, Nat. Mater. **13** (2013) 50., [2] H. Naganuma *et al.*, Nano Letters, **15** (2015) 623.