Room temperature spin bolometer in sub-gigahertz frequency region

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Bolometer are highly sensitive rectification devices that convert electromagnetic waves into direct current (dc) voltage through a temperature change. A superconducting bolometer has a responsivity of approximately 10^6 — 10^7 V/W under cryogenic temperatures at infrared wavelengths. However, no devices have realized such a high responsivity in the sub-GHz frequency region. Magnetic tunnel junctions (MTJs) have been promising device for such the application. Spin-torque diode effect can convert the sub-GHz microwave into the dc voltage [1]. Recently, the responsivity of the spin-torque diode effect has increased up to 2×10^5 V/W using a spin-torque auto-oscillation [2]; however, it has not still achieved a bolometer level responsivity. In this study, we demonstrate the bolometer-level spin-torque diode effect using a MTJ with a MgO|FeB|MgO structure in which the heat-controlled magnetic anisotropy (HCMA) effect efficiently exerts a spin-torque on the free layer magnetization [3].

The samples, buffer layer | IrMn (7.0) | CoFe | Ru | CoFeB | MgO barrier (1.0) | FeB (2.0) | MgO cap (0.5) | metal cap, were deposited on silicon substrates by the magnetron sputtering. The MTJ with the diameter of 190 nm was fabricated by a photo lithography. The spin-torque diode voltage of dc-biased MTJ was measured by the conventional measurement system of spin-torque diode effect. Figure 1 shows the color mapping of diode voltages under various magnetic field conditions. We found that the highest diode voltage of 10.6 mV was observed at the magnetic field of 50 mT applied along the azimuthal angle θ of 11° and in-plane rotation angle φ from pinned layer magnetization of 135°. By considering the insertion loss of 1.16 dB, the responsivity is 4.40×10^6 V/W which is world's best responsivity in the sub-GHz frequency region [4]. This work was supported by JSPS KAKENHI Grant Number JP19K15435 and JP20H05666.

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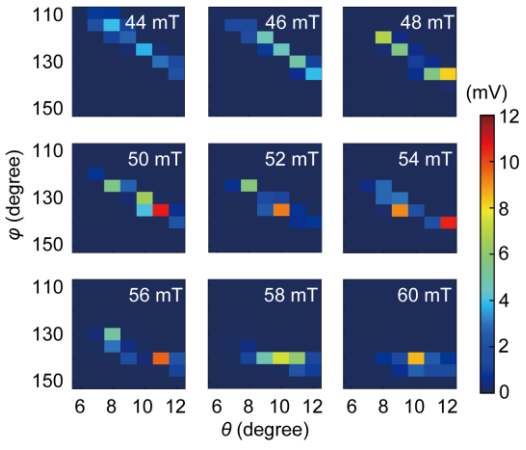

Figure 1 Color mapping of diode voltages under various magnetic field conditions. Color represents the magnitude of diode voltage.