Tunnel Magnetocapacitance in Single-layered Fe/MgF_2 Granular Films

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Magnetocapacitance (MC) effects lead to some appealing spin-based phenomena such as frequency-dependent spin transport and spin capacitance, which are crucial for spintronic devices [1,2]. MC offers attractive prospects for materials research and device applications such as high-frequency devices and energy storage [3,4]. In magnetic nanogranular film devices, a type of MC referred to as tunnel magnetocapacitance (TMC) is observed. The advantage of using granular films is that they are relatively easy to fabricate and they have good thermal stability [5]. However, the TMC ratio is smaller than 1.0% in the low-field range (~1 kOe) even for two-dimensional (2D) granular films [6], in which a large TMC can be expected. Here, we present a better enhancement of TMC ratios in *single-layered* Fe/MgF_2 granular films.

Single-layered Fe/MgF_2 granular films were prepared on SiO_2/Si substrates by using an electron beam (EB) evaporation system with a base pressure of 10^{-7} Pa. The films consist of MgF_2(50 nm)/Fe(t = 2.4–5.7 nm)/MgF_2 (1 nm), which were formed on Au/Cr electrodes with a 10 µm gap. Fig. 1 shows TMC in MgF_2(50 nm)/Fe(4 nm)/MgF_2(1 nm) granular films. The largest TMC ratios were encountered at low frequency and then gradually diminished with increasing frequency. At 40 Hz, the TMC ratio with 1 kOe reaches 1.45%, which is larger than the value (0.8%) previously reported in 2D Co/Al fluoride (AlF) granular films [6]. This means that the enhancement of low-field TMC is observed in single-layered systems. Fig. 2 shows the frequency dependence of TMC. The TMC ratio reached a peak value of 2.89% at 30 Hz at room temperature. A combination of the Debye-Fröhlich (DF) model and the Julliere formula was used to fit the experimental data to theory, and an excellent agreement between the calculated values and the experimental data was obtained. To perfectly fit the data, the conventional DF model was extended to a three-phase model in which three capacitors (seen in the inset of Fig. 2) were introduced. Our findings will give further insight into the exact mechanism of TMC effect in nanogranular films, and will open broader opportunities for device applications, such as magnetic sensors and impedance tunable devices. This research was supported by JSPS KAKENHI (Nos. 15H01706, 16H04339, 16K18073, 17K19019 and 18H01485), MEXT Dynamic Alliance, and CSRN at Tohoku University.

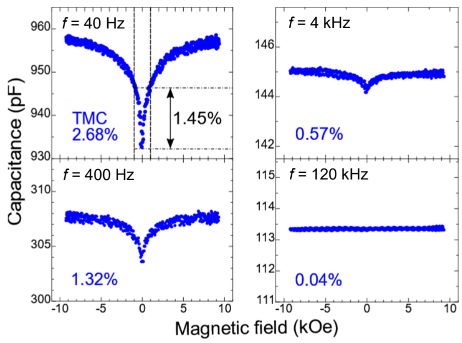

Fig. 1. TMC effect in Fe/MgF_2 granular films.

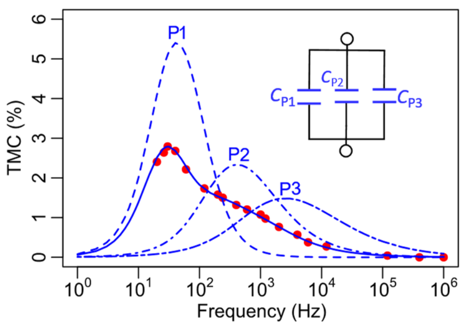

Fig. 2. Frequency dependence of TMC ratio.

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