Effect of thermal magnetization fluctuation on geometrically constrained magnetic domain wall at the ferromagnetic nanowire

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We experimentally investigated the thermal magnetization fluctuation of a geometrically constrained magnetic domain wall (CDW) in the ferromagnetic nanowire at room temperature (RT). By considering the thermal fluctuation of the 2-dimensional magnetization, $\vec{M}(r,\ t) = m_x(r,\ t)\,\vec{x} + m_y(r,\ t)\,\vec{y}$ at RT, the oscillatory depinning behaviour of the CDW is elucidated. We find that thermal fluctuation of the CDW exists at 4 kinds of specific frequencies—1.52 (mode 1), 2.28 (mode 2), 3.58 (mode 3) and 4.52 GHz (mode 4) — and the frequencies of CDW are distinguishable from those of domains of nanowire. Especially, the m_x and m_y show stepwise reductions at mode 1 and mode 3 with increasing H_t in the transverse direction (-y direction). It is caused by the thermal fluctuation in transverse $\vec{M}$ of vortex-type CDWs at notches. Thus, it is clearly seen that as the specific modes of thermal M fluctuations in the CDWs exist, the strength of the thermal M fluctuations in the CDWs depends on each mode. It is clearly seen that the behaviour of thermal $\vec{M}$ fluctuation at mode 1 and mode 3 corresponds to that of oscillatory depinning field from notches. Thus, this depinning behaviour is related to the thermal $\vec{M}$ fluctuation in the CDWs at the notches, as confirmed by a micromagnetic simulation at 300 K.

Keywords: Thermal magnetization fluctuation, constrained magnetic domain wall, transverse magnetic field

1. Introduction

The thermal fluctuation in a geometrically constrained magnetic domain wall (CDW) is critical to understand the depinning of the CDWs as inputs for a random variable generator for probabilistic computing [1]. As those are based on operations at room temperature (300 K), extensive studies on how the thermal effect on MDW depinning can be controlled by various geometrical and methodological considerations should be considered. In this study, we elucidate the effect of thermal magnetization fluctuation on its oscillatory depinning behavior [2]-[3].

2. Results and discussion

Fig. 1(a) shows noise spectra in magnetization components (m_x and m_y) at specific frequencies of 4 kinds of modes—the red region indicates the highest magnetization fluctuation at each mode as shown in the inset of Fig. 1(b). Fig. 1(b) shows noise spectra at specific frequencies under H_T=-150 Oe corresponding to maximum downward field. Compared to Fig. 1(a), peaks at 1.52 (Mode 1) are strengthened, whereas peaks at 2.28 (Mode 2), 3.58 (Mode 3), and 4.52 GHz (Mode 4) are weakened.

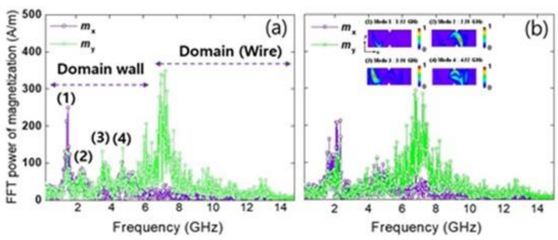

Figure 1: Noise spectra in magnetization components (m_x and m_y)

Especially, the mx and my show stepwise reductions at Mode 1 and Mode 3 with increasing HT in the negative direction as shown in Fig. 2(b). It is clearly seen that the behavior of thermal magnetizations fluctuation at mode 1 and mode 3 of Fig. 2(b) is similar to that of depinning field from notches as shown in Fig. 2(a). Thus, this depinning behavior is related to the thermal m fluctuation in the geometrically constrained DWs at the notches, as confirmed by a micromagnetic simulation at 300 K.

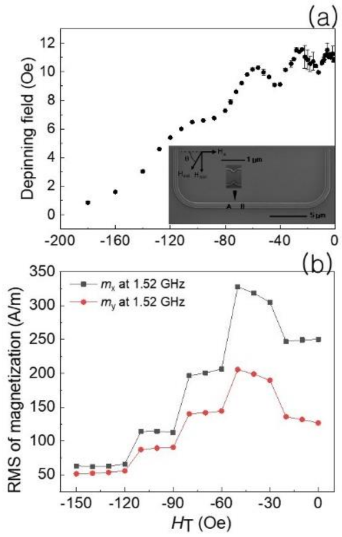

Figure 2: (a) Depinning field and (b) RMS values of m_x and m_y

References

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