SD06

Angular Dependence of Walker Breakdown Field

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The magnetic domain wall (DW) has attracted a considerable interest because it can be used for logic devices [1] or information storage [2]. The correlation between intensity of magnetic field and velocity of DW differs significantly below and above the Walker breakdown [3]. When a DW is propagated by magnetic field in a nanowire, the velocity of DW decreases above a certain field, i.e. Walker limit. Walker wrote down an exact solution for the motion of the simplest planar DW in a material with uniaxial anisotropy. Despite well known novel phenomena, there still exist questions about the angular dependence of Walker breakdown field.

In this work, we performed micromagnetic studies on the angular dependence of Walker breakdown field in a Permalloy nanowire. The DW velocity as a function of the field intensity shows a dramatic change as the angle varies (Fig. 1 (a)). However, it falls into an almost universal curve when we normalized the curves by the component (//x) of the magnetic field along the length of nanowire (Fig. 1 (b)). We also derived a theoretical equation for the angular dependence of the Walker breakdown assuming a one-dimensional rigid DW. In the presentation, we will discuss how angular variation of the applied field leads to increase in the average velocity of DW above the Walker breakdown field.

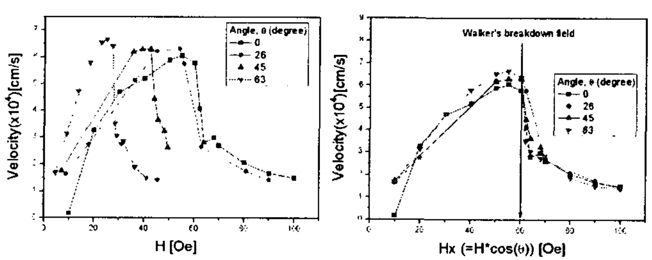

Fig. 1. Angular dependence of average DW velocity as a function of (a) the field intensity, and (b) the normalized field intensity.

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SD07

Numerical Study on Attempt Frequency in Single Domain Particle

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As a magnetic device gets smaller, the thermal stability of stored magnetic information in the device becomes an important issue. The Arrhenius-Néel law has been widely used to estimate the thermal stability. It describes the relaxation time, t by $1/t = f_0 \exp(-E_B/k_B T)$ where f_0 is the attempt frequency, E_B is the energy barrier, k_B is the Boltzmann constant, and T is the temperature in Kelvin. The attempt frequency has been considered as a constant and of the order of 109Hz. However, the dissipation-fluctuation theory showed that it varies from 10^9 to 10^{12} Hz as a function of the effective energy barrier and the temperature [1]. Boerner and Bertram performed micromagnetic studies on the relaxation time and obtained the attempt frequency by fitting to the Arrhenius-Néel law [2]. They found that the attempt frequency is strongly deviated from the theoretical estimation of ref. [1] when the ratio of the effective energy barrier to the $k_B T$ is smaller than 10. In order to estimate the thermal stability, it is essential to study the attempt frequency since it is still remained unclear.

Here, we performed micromagnetic studies on the attempt frequency by direct stochastic calculations. We calculated each component of magnetization for 100ns with applying thermal fluctuation field at every integration time step. The magnetization variation allows us to obtain the attempt frequency by the Fourier transformation (Fig. 1). The result is in a good agreement with ref. [2] indicating our approach is valid. In the presentation, we will show the calculated attempt frequency in various magnetic nano-structures and anisotropies.

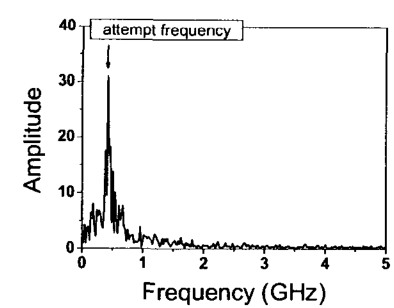

Fig. 1. Result of direct calculation of the attempt frequency

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