Energetical Model Interpretation of Thermal Stability by Changing Direction of the Magnetization of Nano Magnetic Structure

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Abstract—The nonlinear dependence of magnetization on the direction of the applied magnetic field and history is described by statistical domain behavior using phenomenological adaptive parameters (like: $g[1]$, $h[A/m]$, $k[J/m^3]$, and q that are related to anisotropy, saturation field, static hysteresis loss, and pinning site density). The loop simulation data could be used also as parameters for thermal stability equation to calculate the relaxation time of the stored information on any magnetic nano particles (dots) of patterned magnetic media.

1. Introduction

Magnetic nano particle thermal stability calculation is essential for development of patterned ultra high magnetic storage media. The use of reliable model (like: Energetic Model (EM) in the predication of non linear ferromagnetic materials properties [1], wich may depend also on direction and history of magnetization) is very important. EM simulation of hysteresis opens a very big opportunities to calculate values of parameters which we then use directly for interpretation of the stability condition of stored information on a nano magnetic structure. The main idea behind that is to change the direction of the applied field H and then see the stability conditions on a given nano bit volume. The value of the f_{BS} depends strongly on K_u and the volume of the nano structure which holds the stored magnetic information (a what so-called nano bit or nano dot). Research and development teams in companies implementing nano-technology are gaining more and more importance in the field of sensor systems and material science.

2. Interpretation of Magntization Processes and Result

The EM calculates the magnetic state of ferromagnetic materials by minimizing the total energy density w_T [1] (see Table 1) as the sum of the energy density:

Table 1: Relation between k_u, and relaxation time τ at dot-width $D_w = 22\,\text{nm}$ and $T = 10\,\text{K}$, as a result of dependence of magnetization on direction of the applied magnetic field at different Φ with values(0°, 45°, 90°), where f_{BS} condition is satisfied.

magnetization direction Φ	k_u [J/m^3]	τ [Years]
90°	602.51	22.3×10^3
45°	1110.67	22.5×10^{15}
0°	1895.46	12.4×10^{35}

$$w_T = w_H + w_M \tag{1}$$

Where:

$$w_H = -\mu_0 \vec{M} \cdot \vec{H} \tag{2}$$

of the applied field $\vec{H}$ and the magnetization $\vec{M}$ and the material energy density

$$w_M = w_d + w_R + w_I \tag{3}$$

The latter term is divided into the energy density of demagnetizing fields w_d and into contributions described by statistical domain behaviour: The reversible energy density w_R and the irreversible energy density w_I. It's very important to verify the components of the demagnetization factor that appears with in the magnetization process of a nano magnetic particles. Magnetization hysteresis loops, which display the magnetic response of a magnetic sample to an external field, have been widely used to characterize the behavior of nanostructured magnetic materials [2]. The effective demagnetization factor (or total-demagnetziation factor) is compound of two types (where Nd is a geometric and Ni is the inner demagnetizing factor, e. g., due to the magnetostatic stray Fields within the microstructure of grains or particles) as the following:

$$N_e = N_d + N_i \tag{4}$$

The characteristic features of the hysteresis loop are dependent on the material, the size and shape of the entity, the microstructure, the orientation of the applied magnetic field with respect to the sample, the magnetization history of the sample, and the demagnetization factor.

3. Equations

If N_d of the experimental arrangement is unknown then it can be estimated roughly by the differential susceptibility χ_c at coercivity of a measured hysteresis loop [3]:

$$N_d \approx \frac{1}{\chi_c}\Big|_{H=H_c} \tag{5}$$

The relation between N_d, $N_{e,0}$, $N_{e,\pi/2}$, and K_u is given as

$$N_d = N_{e,0} - \frac{K_0}{K_u}(N_{e,\pi/2-N_{e,0}}) \tag{6}$$

$$K_u = \frac{K_0}{N_{e,0} - N_d}(N_{e,\pi/2-N_{e,0}}) \tag{7}$$

K_u which is important for calculation of the bit stability factor (see Table 1) is also related to the N_d that depends on the magnetization. Further the identification of K_0 is given by

$$K_0 = \mu_0 M_s^2 \tag{8}$$

4. Conclusion

Nano-technology is providing a critical bridge between the physical sciences and engineering, on the one hand, and modern molecular biology on the other. Materials scientists, for example, are learning the principles of the nanoscale world by studying the behavior of biomolecules and biomolecular assemblies. Nano-technology will increase its influence in electrical engineering and electrical materials strongly. The need for further development in nano-technology is required. Companies with market-oriented innovation, research and advanced development strategies like EVGroup have had important positions and an excellent reputation in the practical implementation of nano-technology. New and light magnetic devices will be invented to make life in the 21st century more functional and the researchers have to gain more knowledge of quantum effects within nano-meter body size. The energetic model is used to identify hysteresis by changing the the direction of the applied field to nano magnetic particles of irradiated samples. Effects of changing the direction of the magnetization field on thermal stability and relaxation time could be then calculated. Choosing a reliable model (EM) for hysteresis simulation of nano magnetic particles is essential. Demands for the continuous increase in the data storage density bring the challenge to overcome physical limits for currently used magnetic recording media [5–14].

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