MICROMAGNETIC SIMULATION OF NON UNIFORM NANODOTS WITH PERPENDICULAR ANISOTROPY

N. Dao, N. Kikuchi, L. Abelnmann, and J. C. Lodder

Systems and Materials for Information Storage, MESA⁺ Research Institute, University of Twente, Enschede, the Netherlands

Introduction

For the realization of nanometer size magnetic dots, for use as patterned recording media for instance, we start with a continuous thin film with perpendicular anisotropy. In such a film, magnetization reversal takes place through propagation and nucleation of a magnetic domain wall [1]. When using for instance Co/Pt multilayers, to achieve perpendicular anisotropy, the film consists of grains with a diameter of 10-20 nm, separated by grain boundaries. The anisotropy in the grains is distributed, and nucleation will start in the grains with the lowest anisotropy. When the film is patterned into nanometer sized elements, one aims at changing the magnetization reversal to coherent rotation, resulting in a strong increase in coercivity. In a dot of 120 nm diameter, there will be on the average 50 grains. The distribution in anisotropy of the grains remains, however, and imperfections might be induced by the etching process.

Recent experiments have shown that the energy barrier for reversal in patterned dots is two orders of magnitude smaller than the ideal value for a single domain particle, and identical for two different dot sizes [2]. Analysis shows that the switching volume is comparable to the physical volume of one grain in the dot, and we propose that magnetization reversal in these dots is not through coherent rotation but rather through nucleation of a reversed area comparable to the grain size. To understand this phenomenon we have used anomalous Hall effect (AHE) measurements on an array of dots to measure the switching field, and we investigate by micromagnetic simulation the effects on the reversal of an area with reduced anisotropy in the dot.

Procedure

Multi-layered Pt/[Co (5 Å)/Pt (20 Å)]₅ films were fabricated into patterned circular dots with diameters of 120 and 200 nm by means of Laser Interference Lithography and measured by AHE [2]. Using OOMMF, the Landau-Lifshitz-Gilbert equation was solved quasi-statically as a function of time, where the effective field included the anisotropy, demagnetizing, exchange, and Zeeman fields. A single dot was simulated with an exchange constant A of 3 pJ/m [3], perpendicular anisotropy K_u of 190 kJ/m³, saturation magnetization M_s of 400 kA/m and a diameter ranging from 60 to 800 nm. The discretized cell size was 2.5 x 2.5 x 4 nm³ in x , y , z -direction (z is perpendicular to the dot). An area with reduced A and K_u and having a size of 10 to 20 nm was introduced in a dot of 120 nm diameter.

Results

For the 120 nm dot, the simulated switching field is five times higher than the experimental value (circles in Fig. 1). When an area with K_u reduced to 0.1 of its original value is introduced in the dot, the switching field reduces tremendously (triangles). Also shown in Fig. 1 are three domain configurations (a to c with increasing time) for the formation of a domain with reversed magnetisation. Such a reversed area domain is not observed in an uniform dot. The radius of this reversed domain expands through the dot to complete the reversal. If the area with reduced anisotropy is at the edge, then "strip-out" will occur since there is only one direction for domain wall movement. In this case the switching field is even lower.

To check whether the reduction in switching field is not caused by a change in the shape of the dot, we set the magnetisation in the area to zero. In that case the switching field returns to a value close the the switching field of the uniform dot. This shows that a reduction in switching field is caused by an area of reduced anisotropy. In this contribution, the effect of various combinations of a reduction in anisotropy and/or exchange constant, and the size and shape of the area, will be discussed.

Fig. 1 Hysteresis loops for the 120 nm dot: uniform (circles, solid line), with a soft area inside to dot (triangles, broken line), and the experiment (square symbols). a, b, and c are snapshots at three different times during the reversal.

References

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