MICROMAGNETIC SIMULATION OF NON UNIFORM NANODOTS WITH
PERPENDICULAR ANISOTROPY

N. Dao, N. Kikuchi, L. Abelmann, 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
comparative 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 A)/Pt (20 A)]x 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 Kx 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 Kx and having a size of 10 to 20 nm was introduced in a dot of 120 nm diameter.

Result

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 Kx 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 magnetization in the area to zero. In that case the switching field
returns to a value close to 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 dot (triangles, broken line), and the experiment (square symbols). a, b, and c are snapshots in three different times during the reversal.

References