Micromagnetic simulations based on directly observed microstructures

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1. Introduction

In recent years, micromagnetics has been the most popular numerical method in the field of magnetic recording owing to its fast, reliable and economic way of study1. Introduction of the finite element method (FEM) to micromagnetics has enabled us to take into consideration of the real microstructures, such as granular structure with irregular grain shape and distributions, soft/hard phase dispersions and local defects in order to find the contribution to magnetic behaviors2-6. In order to implement the microstructure of a given specimen into finite element models, investigation of the microstructure using X-ray diffraction (XRD) analysis or transmission electron microscopy (TEM) study is the prerequisite, as well as the material parameters measured by proper experiments, i.e. vibrating sample magnetometry (VSM). Micromagnetic simulations based on the realistic microstructure are performed by assigning the magnetic parameters on the finite element models prepared based on the experimental findings. In this talk we are going to present a couple of examples of the micromagnetic simulations based on the directly observed microstructures, particularly on magnetic recording media: FePtCu L10 phase based bit patterned media7,8.

2. Experimental and Micromagnetic simulation details

FePtCu L10 thin film is prepared by deposition of FePt(4.7 nm) and Cu(0.3 nm) bilayer film using dc magnetron sputtering, then a sequential rapid thermal annealing (RTA) process for 30 seconds at 600oC under N2 atmosphere. The chemical composition of (Fe52Pt48)91Cu9 was determined by Rutherford Backscattering Spectroscopy (RBS), and the (001) texture perpendicular to the plane was revealed by XRD. 5 nm of Ta layer was deposited on top of the film as a hard mask for post-patterning process. Material parameters of Keff = 0.55 MJ/m3 and MS = 770 kA/m were determined from the hysteresis loop obtained by superconductive quantum interference device (SQUID). The FePtCu film is patterned to 30 nm diameter and 60 nm pitch using nanoimprint lithography. The geometry and microstructure of the bit paterned media, for example, bit size distribution and crystalline structures are studied using scanning electron microscopy (SEM) and TEM. In order to deeply understand the magnetization behaviors of the bit patterned media, finite element models are prepared following the findings from the electron microscopy, then micromagnetic simulations were performed on the models.

3. Experimental and Micromagnetic simulation results and discussion

Comparing the hysteresis loops obtained from the film and the patterned media, much larger coercivities and broader switching field distribution (SFD) are found in the pattenred media. Moreover, the angular dependency of the switching field was also deviated from the Kondorsky mode after patterning, but cannot be described by the Stoner-Wohlfarth model either. The microstructural investigations give us some clues on the origin of the changes in magnetic behaviors. From analysis of the SEM plan view image, the standard deviation of the bit diameters is 7 % of the mean value, this might be one of the origin of the SFD. From the TEM cross sectional studies, the shape of the bit is found to be a truncated cone, with a damage on the crystalline structure at the shoulder of the bits,with distributions in the easy axis alignment. We have assumed the deviation of the intrinsic parameters - easy axis alignement and anisotropy constant as well as the size distribution and damages on the lattice structures in micromagnetic simulations. The contributions of each sources on SFD have been studied quantitatively, finally summarized. The angular dependency was explained by inhomogeneous magnetization reversals owing to the damages on the specimen.

4. Summary

We have prepared FePtCu L10 bit patterned media, of which magnetic properties and microstructural details are obtained by direct measurement and observations. The patterning process on the continuous film induced a drastic changes in the coercivity, SFD, and angular dependencies. The origin of the changes are explained by micromagnetic simulations with the finite element models including the details of the microstructures.

5. References

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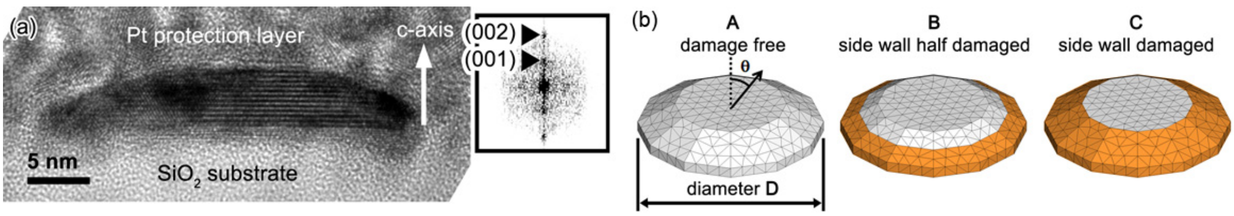

Fig. 1. (a) Cross-sectional TEM image and the Fast Fourier Transformation of the FePtCu single bit. (b) Finite element models for micromagnetic simulation of the bit patterned media.