Deep etching microfabrication of perpendicularly magnetized MTJ

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Low damage microfabrication is one of the most importance issue to fabricate higher density magnetic memory devices. Etching process of the pillar part of magnetic tunnel junction (MTJ) is thought to be the main origin of the processing damage. Argon ion beam etching has been used widely to fabricate the pillar part of MTJs because its etching rate is not much sensitive to film materials. Reduction of the beam voltage of Ar ion beam etching is a straight way to decrease the processing damage. Here, we report the deep etching microfabrication using low voltage Ar ion beam etching, and some of the deep etched MTJs show enhancement of coercive field (H_c) and keep thermal activated energy (Δ).

We introduced new fabrication machine which is combining one etching chamber and two deposition chambers. This machine makes possible to etch the pillar of MTJs and then to transfer the deposition chamber without breaking the vacuum. The beam voltage and current of Ar ion beam is set to 150V and 45 mA, respectively. Low resistance perpendicularly-magnetized MTJs [1] were used to estimate the process damage. We prepared a film of perpendicularly-magnetized MTJ, which is consisting of buffer layer / [Co (0.24 nm)/Pt (0.16 nm)]^9 / Co (0.24 nm) / Ru (0.52 nm) / [Co (0.24 nm)/Pt (0.16 nm)]^4 / W (0.1 nm) / CoB (0.4 nm) / W (0.1 nm) / FeB (1.1 nm) / MgO barrier / FeB (~2 nm) / MgO cap / cap layer by ultra-high vacuum sputtering machine (Canon-Anelva C-7100). The top of the buffer layer is about 50 nm-thick Ta layer. The film was annealed at 330°C for 1 hour, and then microfabricated into circular MTJs with etching masks of 85, 75, 65 nm diameters. The resistance-area (RA) product of the film was 2.0 $\Omega\cdot\mu m^2$.

Two etching processes are tested; the first is standard etching where the MTJ film was etched down to just top of the buffer layer; and the second is deep etching where the film was over etched into the middle of the buffer layer. The etching depth was monitored by secondary ion mass spectrometer, but we need to care that the etching depth near the pillar tends to be smaller than that of the plane part. The typical etching time for the standard etching is 30 min. and that for the deep etching is about 50 min. After that, the pillar was covered by SiO_2 layer without breaking the vacuum, and then lift-offed the etching mask and made the top electrode.

For both cases, the magnetoresistance (MR) ratios of the MTJs were 110~120% and well coincident. Diameters of the MTJs were estimated from the resistance of parallel state and the RA value. Reduction of the diameter was about 15nm for standard etching and that was about 25 nm for deep etching. We found the deep etched MTJs tend to have larger coercive field (H_c) that standard etched one and those MTJs have relative large thermal activation energy (Δ) where Δ was evaluated from the current dependence to the switching probability [2].

This work was supported by ImPACT Program of Council for Science, Technology and Innovation.

Reference

[1] K. Yakushiji *et al.*, Appl. Phys. Express 6 (2013) 113006, [2] Edited by T. Shinjo, "Nanomagnetims and Spintronics" (1st edition, Elsevier), Authors: Y. Suzuki, A. A. Tulapurkar, and C. Chappert, Chap. 3 (2009).

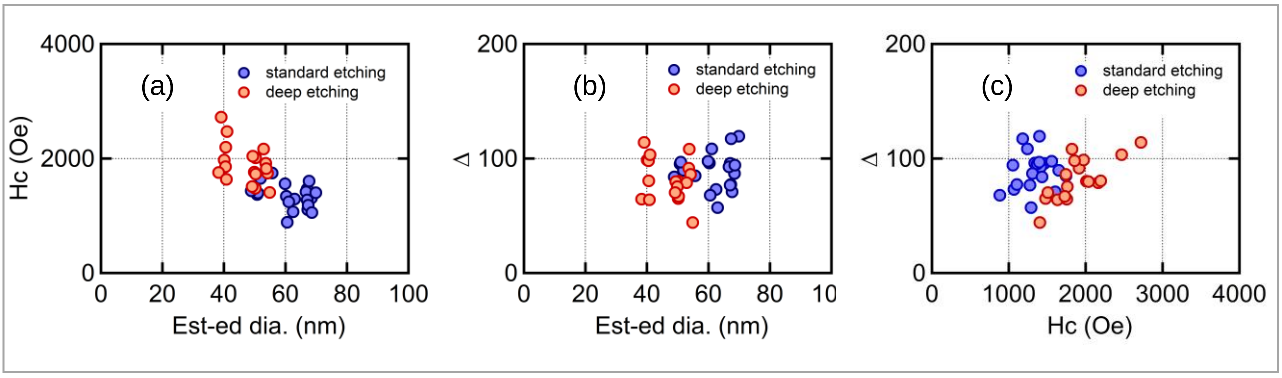

Figure 1　Relationships between (a) estimated diameter of MTJ and H_c, (b) estimated diameter and Δ, (c) H_c and Δ.