CONSTRICTION OF FERROMAGNETIC PATTERNED THIN FILM BY SCRATCH PROCESS USING ATOMIC FORCE MICROSCOPE

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Introduction

Lithography techniques using scanning probe microscopes (SPM) have attracted much interest as novel tools for fabricating electron devices with well-defined nanostructures. It has been reported that surfaces of Si [1,2], GaAs [3], Ti [4], Al [5], Cr [6] and Nb [7] thin films are selectively oxidized by applying a bias on the SPM tip. As this anodic oxidation process does not require any pretreatments such as resist coating, it is a useful tool for fabricating nanostructure materials devices. We have demonstrated fabrications of magnetic nanostructures using this technique [8,9]. Nanoscale fabrication techniques for magnetic materials are important for developing magnetic devices such as a high-density recording system, memories and a new class of spin-related devices. In this paper, fabrication of magnetic nanostructures using atomic force microscopy (AFM) nano-oxidation technique is reported. Also a direct modification of scratching photoresist and magnetic metal thin film is also discussed.

AFM nano-oxidation of magnetic thin films

Figure 1(a) shows the principle of the AFM nano-oxidation process. Thin films with their thickness of a few - 20 nm are prepared on insulating substrates. Surface roughness of the film should be smooth enough to perform this surface-sensitive AFM-based oxidation process because the size uniformity of the modified structures may be highly dependent on the surface roughness of the material. When negative bias voltage is applied to the AFM conductive cantilever in air, the anodization through the water adsorbed on the sample surface could occur at just below the cantilever. In other words, water and/or oxygen-containing species on the sample surface could electrochemically react with the material as a result of applying the bias voltage, resulting in the formation of oxide. In order to obtain the modified-structure wires, the cantilever should be scanned at a constant speed, while applying the negative bias voltages.

Direct nano-lithography of scratching resist

Recently, it has been reported that a magnetoresistance (MR) ratio as large as approximately 140% was successfully achieved on a nano-constricted part [10]. In order to fabricate the nano-constricted part, we have developed an AFM nanolithography process for patterning a photo-resist. Figure 2 shows the schematics of fabricating the nano-constricted part on the NiFe. The photo-resist coated on the NiFe thin film was removed by scratching the resist by the scanned cantilever. After the sample was etched by dry etching process, nano-constricted part was fabricated on the patterned NiFe thin film.

Figure 3 shows the example of fabrication of constricted part on the patterned NiFe thin film. The

sample film was NiFe of 30 nm thickness. A thin Al-oxide was capped in order to avoid surface degradation by oxidation. At first, resist-scratching and dry etching was performed. Then patterned NiFe film itself was scratched directly by the AFM tip as to narrow the constricted area. Details of the experiment including current-voltage characteristics are also discussed.

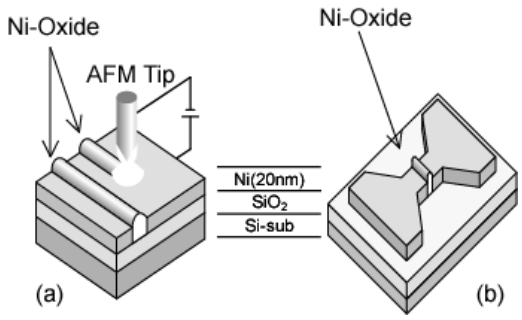

Fig. 1. Schematics of nano-oxidation process using AFM (a) and planar-type Ni/Ni-oxide-based MIM diode (b).

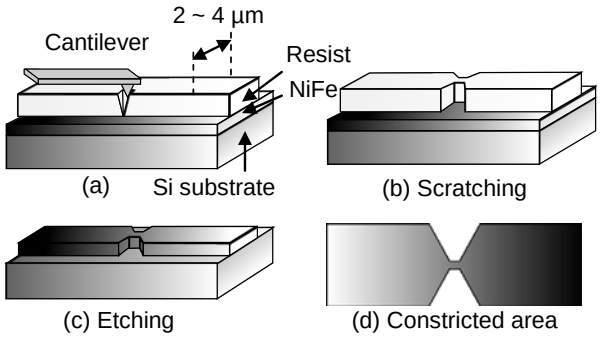

Fig. 2. Schematics of fabrication process of scratching photo resist using atomic force microscope.

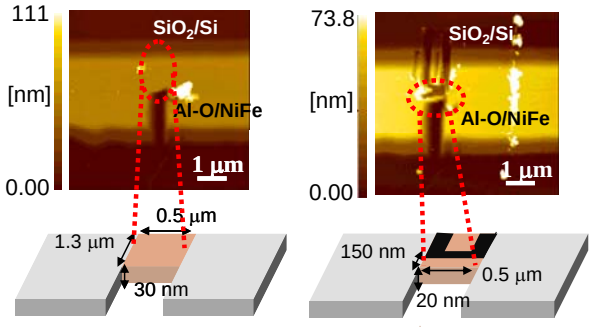

Fig. 3 AFM image of constricted part in pattered NiFe thin film by resist-scratching (a) and by combination of resist-scratching and direct film scratching (b).

References

[1] J. A. Dagata, J. Schneir, H. H. Harary, C. J. Evans, M. T. Postek, and J. Bennett, *Appl. Phys. Lett.* **56**, 2001 (1990).

[2] L.Tsau, D.Wang and K. L.Wang, *Appl. Phys. Lett.* **64**, 2133 (1994).

[3] J. A. Dagata, W. Tseng, J. Bennett, E. A. Dobisz, J. Schneir and H. H. Harary, *Vac. Sci. Technol.* **A10**, 2105 (1992).

[4] H. Sugimura, T. Uchida, N. Kitamura and H. Masuhara, *Jpn. J. Appl. Phys.* **32**, L553 (1993)

[5] E. S. Snow, D. Dark and P. M. Campbell, *Appl. Phys. Lett.* **69**, 269 (1996).

[6] D. Wang, L. Tsau, K. L. Wang and P. Chow, *Appl. Phys. Lett.* **67**,1295 (1995).

[7] J. Shirakashi, M. Ishii, K. Matsumoto, N Miura and M. Konagai, *Jpn. J. Appl. Phys.* **35**, L1524 (1996).

[8] Y. Takemura and J. Shirakashi, *Jpn. J. Appl. Phys.*, **39**, 1292 (2000).

[9] Y. Takemura, S. Kidaka, K. Watanabe, Y. Nasu, T. Yamada and J. Shirakashi, *J. Appl. Phys.* **93**, 7346 (2003).

[10] Y. Ohsawa, *IEEE Trans. Magn.* **43**, 3007 (2007).