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Magnetic Force Microscope Using Carbon Nanotube Probes

T. Manago[1], H. Kuramochi[1,2], T. Uzumaki[1,3], M. Yasutake[1,2], A. Tanaka[1,3], H. Akinaga[1] and H. Yokoyama[1]

[1]Research Consortium for Synthetic Nano-Function Materials Project (SYNAF), Nanotechnology Research Institute (NRI), National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan
Phone: +81-298-61-7156 E-mail: t-manago@aist.go.jp
[2]SII NanoTechnology, 36-1 Takenoshita, Oyama-cho, Sunto-gun, Shizuoka 410-1393, Japan
[3]Fujitsu Ltd., 10-1 Morinosato-Wakamiya, Atsugi, Kanagawa 243-0197, Japan

1. Introduction

Spintronic devices such as hard disk drive (HDD), magnetic random access memory (MRAM) have progressed owing to the various techniques of the thin-film growth, the nanofabrication and the observation methods. In order to develop the HDD with the high areal density, the observation of the magnetic domain structure with high resolution is indispensable as well as the development of the recording media. Lots of methods were applied and developed for observation of the magnetic domain structure with the high resolution, such as a magnetic force microscope (MFM), a spin polarized scanning electron microscopy (SP-SEM), a spin-polarized scanning tunnelling microscopy (SP-STM), a Lorentz electron microscopy, and a magnetic circular-dichroism X-ray microscopy. The MFM is the most popular observation method of magnetic domains, which is wildly used in the research and development of magnetic thin films and magnetic nanodevices, because of its convenience and the relatively high resolution. It is well known that the tip diameter strongly affects on the tip-sample interaction. Hence, decrease of the tip diameter is the most significant point to improve the lateral resolution for the magnetic domain observation. Some methods were experimented for decreasing the tip diameter, such as acumination, reduction in the magnetic coat thickness, and utilization the carbon nanotube probes [1, 2]. As results of these efforts, the lateral resolution reached to less than 20 nm [3]. Considering the future progress in nanodevices, much higher resolution is required to evaluate various nano devices, e.g., recording media with a density of Tbit/inch2 (< 15 nm in bit length).

2. Experimental procedure

MFM measurements were carried out using an environmental control SPM unit in magnetic force mode at room temperature. The MFM was operated in vacuum for a high Q factor. The cantilever with a carbon nanotube (CNT) (~ 11 nm in diameter) was coated with CoFe by sputtering deposition. Perpendicular magnetic storage media with various densities from 600 to 1100 k flux change per inch (kFCI) was observed by the MFM.

3. Results

Figures 1 shows SEM images of a CNT tip after CoFe deposition. The CNT and Si tip were continuously covered by films. The diameter of coated CNT tip is about 40 nm.

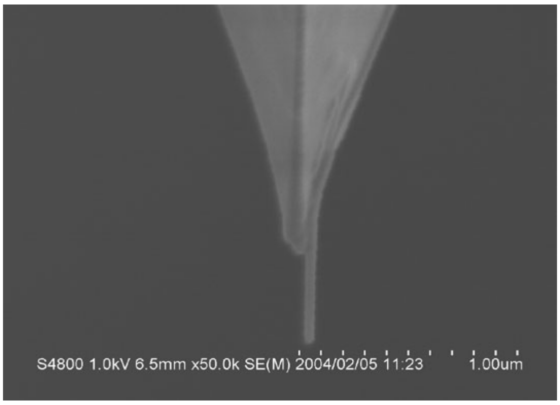

Fig. 1 A SEM image of a CoFe-coated CNT probe.

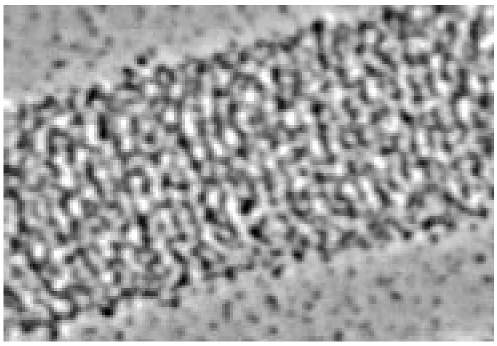

Fig. 2 A MFM image (1x1 μm) of an area of ultra-high-density recording media (1100 kFCI).

The magnetic recording patterns with the densities from 600 to 1100 kFCI were clearly observed. The lateral resolution is largely improved using a carbon nanotube (CNT) probe. Figure 2 is the MFM image of the ultra-high-density recording patterns of 1100 kFCI. The MFM image corresponds to an area of 1x1 μm^2 of the surface. We defined the lateral resolution as an averaging value of the half width of the slope between the bright region and the dark region of the line profile. It varies from 7 to 13 nm depending on the location, and the average value is 10 nm. It is less than the bit length of a recording media with a density of Tbit/inch^2.

3. Conclusions

Fine MFM images of the magnetic domain structures of a perpendicular magnetic storage media with various densities (up to 1100 kFCI) were obtained using CoFe-coated CNT probes. The ultimate lateral resolution in magnetic structure is down to 10 nm. It is sufficient for observation a recording media with a density of Tbit/inch^2. It is demonstrated that the effectiveness of the predicted CNT probes with magnetic coating in MFM measurements.

Acknowledgements

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