XX IMEKO World Congress
Metrology for Green Growth
September 9−14, 2012, Busan, Republic of Korea

CHARACTERIZATION OF MAGNETIC PROBES USING SCANNING ELECTRON MICROSCOPY WITH POLARIZATION ANALYSIS

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Abstract: We developed scanning electron microscopy with polarization analysis(SEMPA) system and utilized it to characterize the local magnetic probes used in the magnetic microscopy based on the scanning probe method. With a specially designed reference sample we could determine the Sherman function of spin detector and the uncertainty in measurement of spin polarization. Based on the measurement procedure established with the reference sample, we could characterize the local magnetic probes by measuring the magnetic domain images and the spin polarization of the magnetic probes.

Keywords: scanning electron microscopy with polarization analysis, spin polarization, magnetic probe.

1. INTRODUCTION

Scanning electron microscopy with polarization analysis(SEMPA) is a unique tool that makes possible imaging magnetic domains with a spatial resolution below 10 nm, as well as measuring quantitatively the spin polarization of the surface of a magnetic sample. The technique is based on analyzing the spin polarization of secondary electrons created at the surface of metallic ferromagnetic materials by electrons[1]. The fundamental idea is to use the narrow primary beam of a scanning electron microscope (SEM) to create secondary electrons and analyze their spin polarization. Thus, the microscope consists of a SEM and an attached spin-polarization analyzer[2].

In this research, we present the results of our efforts to characterize the magnetic probes used in the magnetic microscopy based on scanning probe method, employing the capability of SEMPA technique which enable the quantitative measurement of spin polarization of magnetic samples.

2. PRINCIPLE OF POLARIZATION MEASUREMENT

Among the various methods which have been reported for detecting electron spin polarization, the Mott detector is generally used for SEMPA system because of its stability and relatively high efficiency. The Mott detector is also employed in the SEMPA system used in the current research. The Mott detector is based on the Mott scattering, which refer to the spin-coupled inelastic scattering, that is, the phenomena that the electron scattering angle depends on the spin-state of incident electrons due to the strong spin-orbit coupling when the electrons are scattered by the Coulomb field of heavy element atoms[3]. The basic principle of the Mott detector is shown in Figure 1. Incident polarized high energy electrons are scattered by the heavy atom film. Due to the strong spin-orbit interaction, the number of electrons scattered in two symmetrical right-left directions are not equal. If these numbers are defined as N_r and N_l, the polarization vector component P_i, normal to the scattering plane, is determined by :

$$P_i = (1/S)(N_l - N_r)/(N_l+N_r) \qquad (1)$$

where S is the so-called Sherman function determined by the scattering condition only. It is very important to determine S precisely for quantitative measurement of the spin polarization of the ferromagnetic sample.

3. RESULTS

To determine the Sherman function, we used Fe thin films because the spin polarization of low energy secondary electrons from Fe surface is well known as 0.5. Figure 2 shows the SEMPA image of Fe films. The left-right spin asymmetry measured by the Mott detector for a single domain(indicated by a yellow circle) was 0.22±0.015 with 95 % uncertainty level. Assuming the spin polarization of Fe sample as 0.5, we could determine the value of Sherman function as 0.44±0.029.

With this value of the Sherman Function, we could successfully measure the magnetic domain and the spin polarization of the local magnetic probes. Figure 3 shows the magnetic domain image and the spin polarization of a single domain(indicated by a yellow box) of the commercial magnetic cantilever for the magnetic force microscopy(Nanosensor MFMR 5M). The determined spin polarization of the cantilever was 0.43±0.034.

We also tried to characterize the magnetic tip for spin-polarized scanning tunnelling microscopy. The results displayed in the figure 4. The magnetic tip was made by depositing 15 atomic layer of Fe on a etched W tip. We obtained very high spin-polarization value of 0.86±0.055. This unusually high spin polarization might be due to a novel phenomenon of nano-scale magnetism, but artificial effect due to the large curvature of the tip end cannot excluded.

4. FIGURES AND TABLES

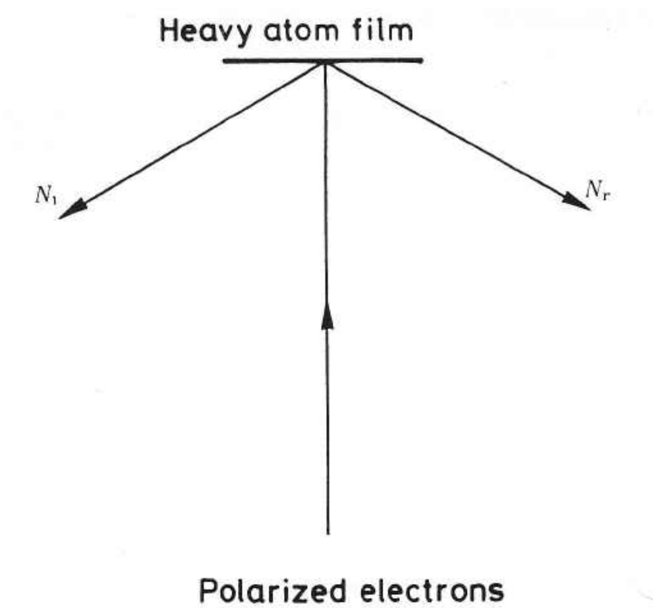

Figure 1: Principle of Mott detector

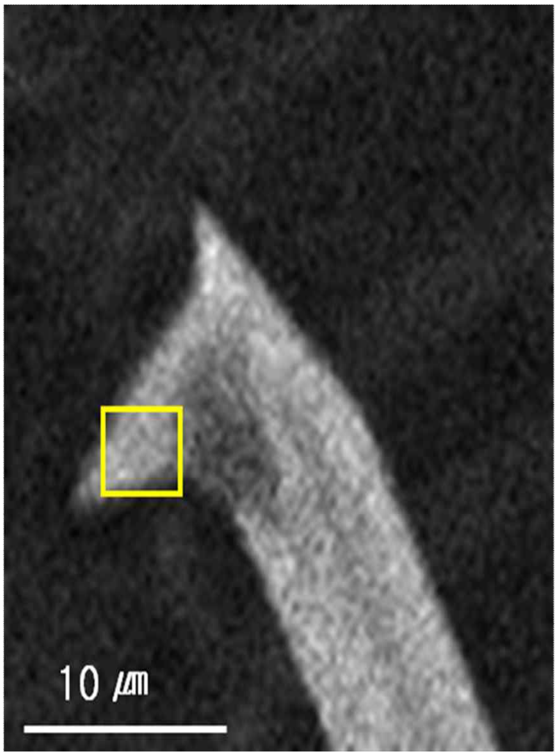

Figure 2: A SEMPA image of a commercial magnetic cantilever for magnetic force microscopy.

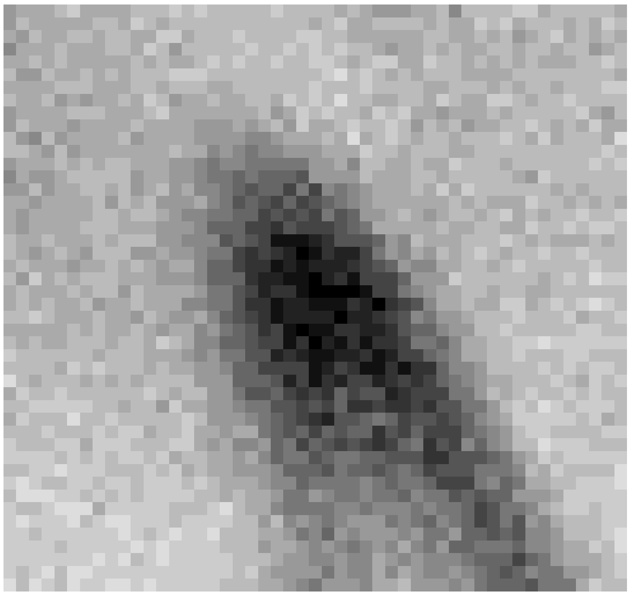

Figure 3: A SEMPA image of a Fe-covered W tip for spin polarized scanning tunnelling microscopy.

5. REFERENCES

[1] K. Koike, H. Matsuyama and K. Hakayama, " Spin-Polarized Scanning Electron Microscopy For Micro-Magnetic Structure Observation", Scanning Microscopy Supplement 1, pp. 231-253, 1987 .

[2] R. Frömter1,H.P. Oepen and J. Kirschner, "A miniaturized detector for high-resolution SEMPA", Appl. Phys. A, vol. 76, pp. 869–871,2003.

[3] T. J. Gay and F.B. Dunning, " Mott electron polarimetry", Rev. Sci. Instrum. vol. 63, no. 2, February 1992.