Microscopic Study of Thin Films of Ni-filled Carbon Nanocapsules

V.D. Frolov*, E.V. Zavedeev, S.M. Pimenov, V.I. Konov
General Physics Institute, Moscow, Russia

S. Tomita, M. Fujii, and S. Hayashi
Department of Electrical and Electronics Engineering, Kobe University, Kobe, Japan

***e-mail: frolov@ran.gpi.ru**

Results are reported on examination of electrical and magnetic properties of thin (~ 30 nm) films containing Ni-filled carbon nanocapsules by means of SPM. A method for fabricating the films consists of cosputtering Ni and graphite, and subsequent thermal annealing in vacuum at 400°C [1]. For the films, TEM measurements evidence the nanocapsule size of 5 nm. The magnetization-magnetic field curve exhibits a hysteresis loop with the coercivity of 50 Oe and saturation magnetization about 500 emu/cm^3 at the magnetic field 10000 Oe, suggesting that the sample has ferromagnetic behavior due to metallic Ni nanoparticles.

Microscopic measurements were carried out in the combined STM/AFM device Solver P47. Spreading resistance imaging (SRI) with STM revealed a periodical structure which cell was represented as a ring-like cluster of high-conducting inclusions (Fig.1).

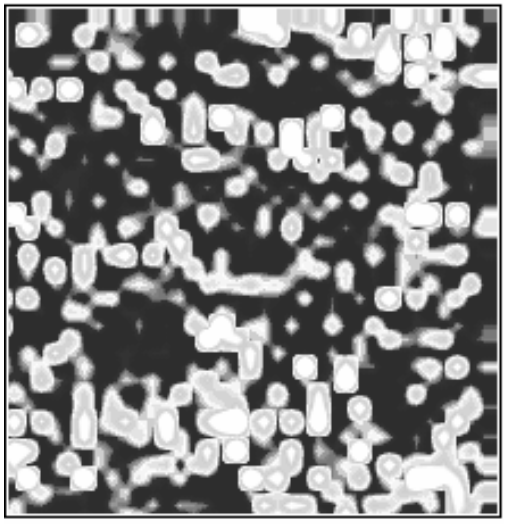

Fig. 1. STM-SRI of the film surface. The scanned area is 20×22 nm^2

As is seen from Fig. 1, the cell is about 5 nm in diameter that allows us to associate this object with the carbon nanocapsule. For magnetic measurements, two-pass scanning in a resonant mode regime with a Co-coated cantilever was used. During passes the relief and phase shift signals were registered. As a preliminary step, the sample was magnetized: (a) normal or (b) parallel to the surface. Generally it was found that for both cases the micrometer scaled phase imaging revealed a spot-like structure with the spot size of 0.2-0.5 μm (Fig. 2). Inside the spot, the MFM showed irregular structure (Fig. 3). As far as nano-scaled mapping, no fine structure was observed.

The main question is whether the obtained experimental data can be correspondent to real magnetic properties of the films tested or not? Indeed, many factors influence the accuracy of MFM measurements, and electro-dynamic forces in the first place. In order to clear up the situation, we have developed the method of three-pass scanning with both Co-coated and Pt-coated cantilevers. The first and second passes were similar to those used in the previous case. During the third pass the Kelvin Probe Microscopy method was realized to register the contact potential distribution. For comparison, we have explored magnetic properties of hard disk.

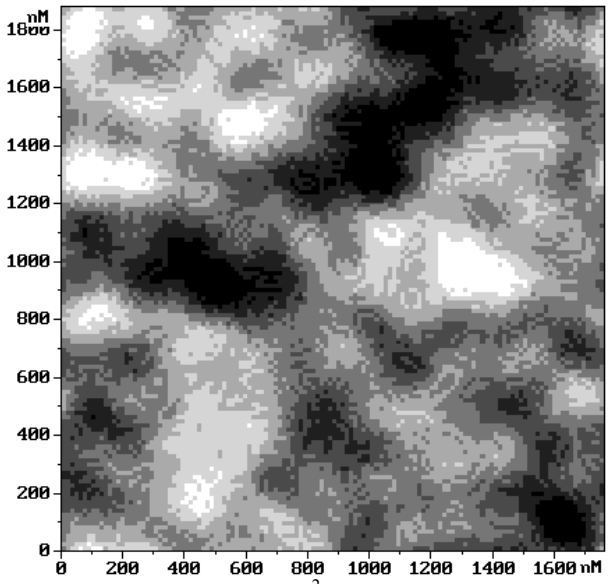

Fig. 2. The 1700×1800 nm^2 MFM image of the film.

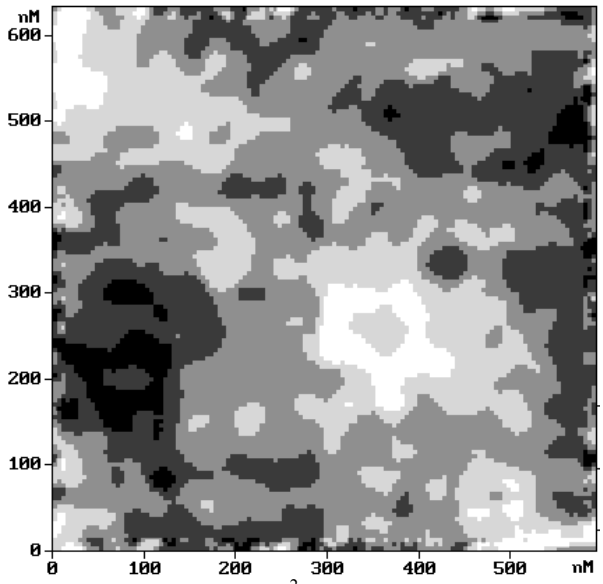

Fig. 3. The 590×620 nm^2 MFM image of the film.

The results can be summarized as follows. For both the samples, the phase signal magnitude was practically independent on the type of cantilevers used. At the same time, variations of contact potential registered with the Pt-coated cantilever are about 3 times higher. The results evidence in favor of substantial influence the electro-dynamic forces on the MFM measurements. So, the electro-dynamic forces need to be compensated during the second pass. However, no essential improvement of the phase image was observed if the second pass was made under the applied voltage equal to the average value of contact potential. It thus can be concluded that a new MFM measuring procedure including an automatic compensation of contact potential in each point of the scanned area needs to be elaborated.

The work was supported by ISTC project #1400.

[1] O. Mamezaki, H. Adachi, S. Tomita, M. Fujii, S. Hayashi, Jpn. J. Appl. Phys. 39 (2000) 6680-6683.