Focused Ion Beam-based fabrication of sub-200 nm permalloy islands for Lorentz TEM

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ABSTRACT

The fundamental magnetic behavior of patterned nanostructures depends strongly on their dimensions. Lateral confinement of a ferromagnetic film will change its magnetic structure from multidomain to flux closure (e.g. a magnetic vortex) to single domain as the dimensions are reduced to the nanoscale, with the phase diagram depending on parameters such as material and film thickness [1]. In case of interacting nanostructures the overall pattern layout and in particular the spacing between individual ferromagnetic elements also influences the magnetic structure. We intend to study the magnetization behavior and the physical structure of closely spaced sub-200 nm size permalloy islands by Lorentz transmission electron microscopy (LTEM). This technique allows the examination of nanoscale correlations between structure and magnetic reversal behavior with high spatial resolution (5 nm) and a relatively large field of view [2]. For sample preparation we use focused gallium ion beam (FIB) direct-write lithography to produce patterns in a sputter-deposited 2 nm Cr / 20 nm Py / 2 nm Cr thin film on a 50 nm thick silicon nitride TEM membrane window.

In this presentation we explore the limitations of the FIB-based fabrication method when our ultimate goal is to produce and characterize the smallest possible permalloy islands that are still crystalline and magnetically active. As a preliminary result, we show the microstructure of approximately 150 nm diameter islands (Fig. 1) that were confirmed to host magnetic vortex structure. The full array is shown in Fig. 2. This sample was prepared by a common dual beam SEM/FIB instrument using 30 kV acceleration voltage, 40 pA ion beam current and 8 nm spacing between ion dwell points. It is not only the ion beam profile but also the dynamics of the milling process and the original physical structure of the permalloy film that need to be considered for improvement. We are currently investigating various patterning techniques in order to achieve better results.

References

1. J. I. Martín, et al., "Ordered magnetic nanostructures: fabrication and properties," J. Magn Magn. Mater. 256, 449 (2003).
2. M. Tanase and A. K. Petford-Long, "In Situ TEM observation of magnetic materials," Microsc. Res. Tech. 72, 187 (2009).

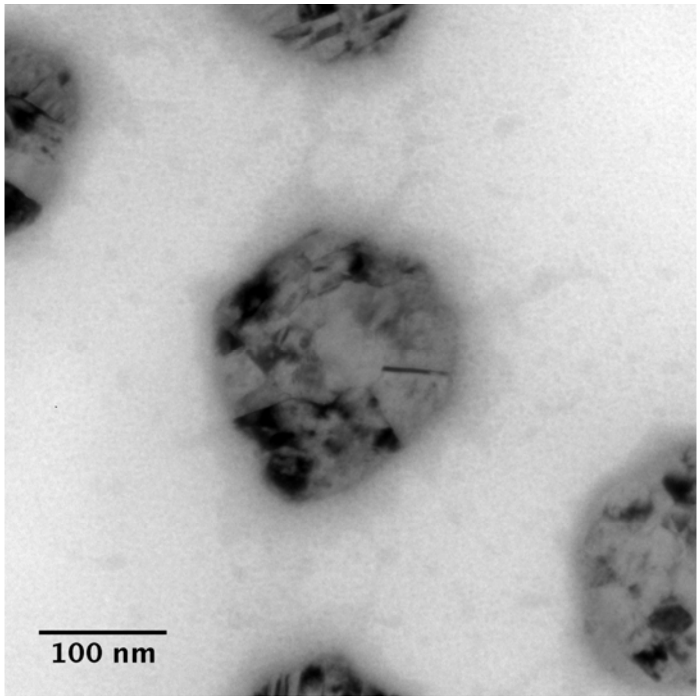

Figure 1. 200 kV bright field TEM image of a 20 nm thick permalloy island in magnetic field-free environment

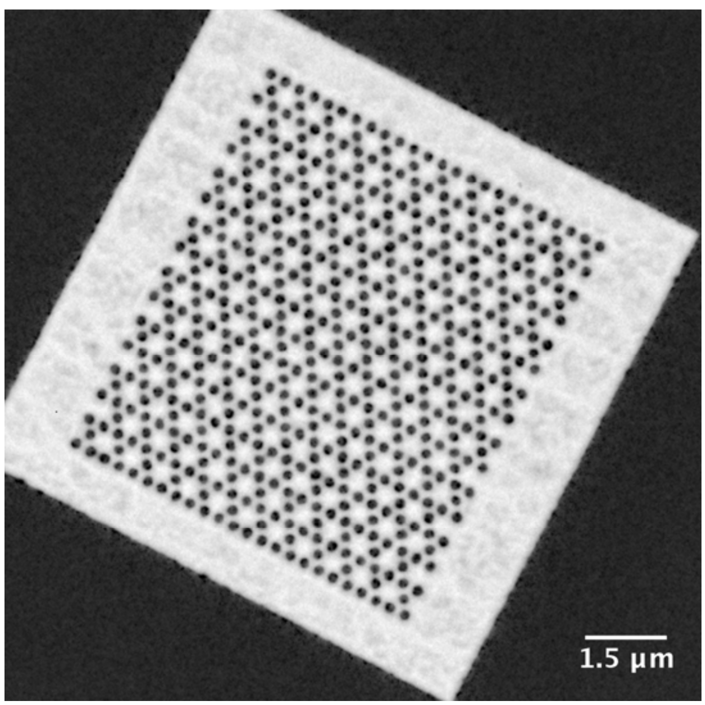

Figure 2. Array of permalloy islands milled out from a continuous thin film deposited on a TEM membrane window. The size of the patterned square is 10 µm by 10 µm.