MR Head Response from Arrays of Lithographically Patterned Perpendicular Nickel Columns

S. Y. Yamamoto, R. O'Barr, and S. Schultz
Center for Magnetic Recording Research and Department of Physics, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0319

A. Scherer
Department of Electrical Engineering, California Institute of Technology, Pasadena, CA 91125

Overview

In an effort to explore the feasibility of a patterned perpendicular magnetic storage medium, we have lithographically prepared arrays of nickel columns embedded in SiO_2. The arrays have been planarized using a chemical mechanical polish. By raster-scanning a magnetoresistive (MR) head in contact with the medium, we have obtained magnetic images of the arrays, demonstrating the ability to "read" the magnetization state of the Ni columns.

Preparation method

The principle steps in the preparation of the Ni columns are e-beam lithography, ion milling, reactive ion etching, Ni electroplating, and chemical mechanical polish [1]. Electron beam lithography is used to write a pattern of dots in a 370 nm thick layer of 4% polymethyl methacrylate (PMMA). The patterns are developed in a 3:7 cellulose:methanol mixture, and then transferred to an underlying 100 nm Au layer by ion beam milling. The Au layer is used as a mask to transfer the patterns into a 400 nm thick SiO_2 layer by reactive ion etching in C_2F_6. The result is a SiO_2 layer with a pattern of cylindrical holes which are then filled with Ni by electroplating at constant current. Typically, the nickel overplates and "mushrooms" onto the surface of the SiO_2. These Ni bumps are removed from the surface via a chemical mechanical polish using colloidal silica. Fig. 1 shows an SEM micrograph of an *unpolished* sample of Ni columns with a nominal diameter of 150 nm and a center-to-center spacing of 2 μm.

MR head response

"Scanning Magnetoresistance Microscopy" (SMRM) [2] has been used to image the Ni arrays. This technique is essentially a scanned probe microscopy which uses commercial MR heads as sense probes. The head is raster-scanned in contact with a medium, and a magnetic image is constructed by plotting the MR voltage as a function of scan position. Fig. 2 is a SMRM image of an array of Ni columns after chemical mechanical polish. Before polishing, attempts to image this array by SMRM were unsuccessful due to the large head/sample spacing. Because the columns have a spacing of 2 μm and the MR element has a stripe width of 4 μm, the MR head signal on average includes signal from two adjacent columns. Since the peak signal over two columns is ~ 50 μV, and since the head has a linear response, we would expect the signal from a single column to be ~25 μV, much larger than our instrument noise floor of ~ 1 μV.

Conclusions

We have imaged arrays of Ni columns with the SMRM. The MR head response demonstrates the feasibility of reading individual columns even with conventional MR heads. A high permeability "keeper", and further advances in head technology such as GMR and spin-valve heads would enable the investigation of higher density arrays with good signal-to-noise. Our demonstrated ability to "read" these columns with an MR head is an important stepping stone toward the goal of using MR read/inductive write heads to switch (i.e., "record") individual columns.

Acknowledgment

This work is supported by CMRR, NSF (MRSEC) DMR-94-00439, and CA Trade & Com. Def. Conv. Matching Grant C94-0178.

[1] R. O'Barr, S.Y. Yamamoto, S. Schultz, W. Xu, and A. Scherer, Submitted to MMM '96.
[2] S.Y. Yamamoto and S. Schultz, *Appl. Phys. Lett.* **69**(21), 18 November 1996.

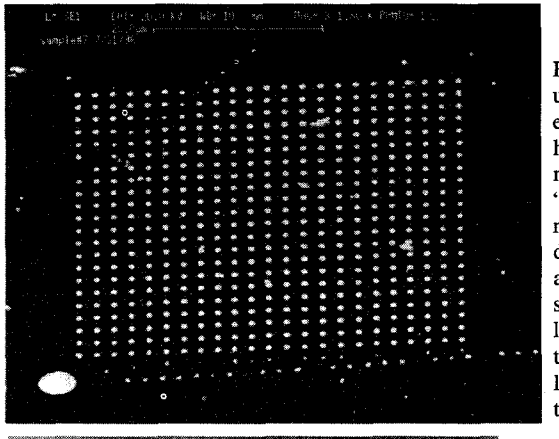

Fig. 1: SEM micrograph of an unpolished array of Ni columns embedded in SiO_2. The columns have a nominal diameter of 150 nm, but appear larger due to "mushrooming" of the overplated nickel. The image is taken at a 45 degree tilt angle, and thus the array appears rectangular rather than square. The large disk at the lower left, the horizontal line at the bottom, and the 45°. line at the upper left of the array are all artifacts of the e-beam writing.

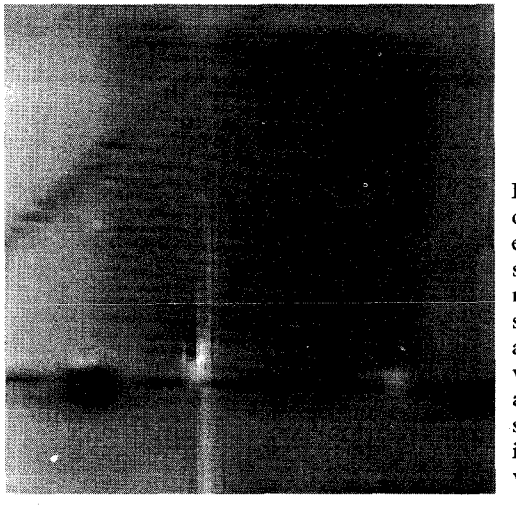

Fig. 2: A 70 x 70 μm magnetic image of a polished array of Ni columns embedded in SiO_2, similar to that shown in Fig. 1. This image was recorded using Scanning Magnetoresistance Microscopy (SMRM) in which a MR head is raster-scanned in contact with the sample. Individual columns are 400 nm tall, 150 nm diameter, and spaced 2 μm apart. The e-beam writing artifacts visible in Fig. 1 are clearly visible in this magnetic image.

Dr. Sheldon Schultz
UCSD, Physics, 0319
9500 Gilman Drive
La Jolla, California 92093-0319 U.S.A.
tel. (619) 534-4078
fax.(619) 534-6301
e-mail: sschultz@ucsd.edu

0-7803-3862-6 4/97/$10.00