Nano-stamped structures for bio-template and MRI applications

N. Farkas[1], R. Aryal[1], E. A. Evans[1], R. D. Ramsier[1], L. V. Ileva[2], S. T. Fricke[2], J. A. Dagata[3]
[1]The University of Akron, Akron, OH, [2]Georgetown University, Washington, DC,
[3]National Institute of Standards and Technology, Gaithersburg, MD

Statement of Purpose: Group IV metal systems are potential candidates for biomedical template fabrication and bio-implant production due to their excellent properties such as wear and corrosion resistance and biocompatibility. In these applications, surface modification is essential to achieve optimal performance. However, structuring of these metals at the sub-micron scale is fairly difficult. Here we present a quick and simple technique to generate large area patterns on ZrN thin films. In addition, we extend the process to FeN thin films as they are potential candidates for quantitative MRI measurements.

Methods: Zirconium and iron nitride thin films are reactively sputter deposited on silicon substrates with 5 sccm nitrogen flow rate. The 200 nm thick films are characterized by X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), Auger spectroscopy, scanning probe microscope (SPM) oxidation and magnetic force microscope (MFM) imaging. The silicon stamps used in the patterning process are fabricated by traditional photolithography and consist of arrays of 730 nm high features with different sizes and shapes as shown in the left side of Figure 1(A).

Results / Discussion: Our effort to develop large area patterning on different metal films is prompted by a novel method reported by [1]Cavallini *et al*. that extends SPM oxidation to parallel writing on silicon. We modify this technique to high-voltage parallel writing by applying 300 V dc voltages between a silicon stamp and the substrate in the presence of isopropyl alcohol. These process parameters are determined and optimized based on SPM oxidation and material characterization (resistivity, XRD, XPS) of the metal nitride films. We find that the presence of nitrogen in the films makes the oxidation and therefore the pattern transfer enhanced and well-controlled.

The resulting oxide patterns are 70 nm high on ZrN. Optical images of Figure 1(A) show part of the silicon stamp and the corresponding oxide patterns transferred to a ZrN film. Auger analysis of the modified ZrN area verifies that oxidation occurs during pattern transfer and shows complete nitrogen to oxygen replacement. In our previous work[2] we found reduced bacterial growth on zirconium oxide. Now the high-voltage parallel writing technique provides a means to investigate the effects on bacteria adhesion of topographical changes, in addition to chemical modification, of the zirconium material system.

Using the same stamp and conditions, the resulting patterns on FeN are different than on ZrN. The iron oxide dissolves during the process exposing the silicon substrate under the extrusions of the stamp. This is verified by chemical etching and SPM cross section analysis shown in Figure 1(B) as the height of the remaining features equals the original thickness of the sputtered FeN film. Figure 1 also emphasizes the well-controlled nature of the procedure on both ZrN and FeN. The main advantage of

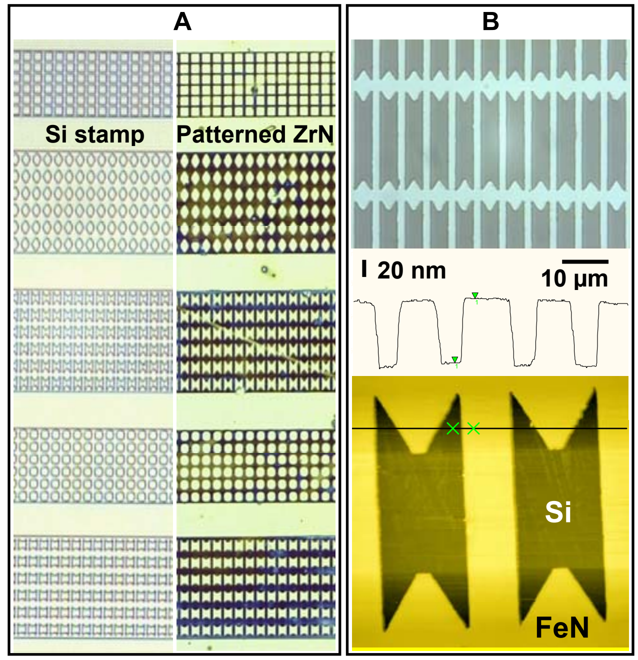

Figure 1

high-voltage parallel writing on FeN is that there is no need for any post-exposure etching to obtain isolated structures as one can see in Figure 1(B).

Several MRI studies report the successful use of iron oxide particles as contrast agents but very few attempts have been made to derive quantitative relationships between iron content and MRI signal attenuation. Such relationships are difficult to develop due to the fact that the particles exhibit broad size and iron content distributions.

We demonstrate that sparse arrays of FeN features cause signal decrease in MRI images due to the magnetic property of the pattern established by MFM characterization. Although the lateral dimensions and separation of the features are determined by the stamp, we precisely control the volume of the magnetic objects by changing the thickness of the FeN films. Consequently, high-voltage parallel writing on FeN is a promising way to relate iron content to MRI signal attenuation.

Conclusions: In this work, we described a novel method to structure metal nitride thin films. The most important characteristic of the process is that it is intrinsically simple, quick and needs no special instrumentation. Implication of the use of the high-voltage parallel writing for bio-template and MRI applications was discussed.

References: [1]M. Cavallini, P. Mei, F. Biscarini, R. Garcia, Appl. Phys. Lett. **83**, 5286 (2003)
[2]B. W. Buczynski, M. M. Kory, R. P. Steiner, T. A. Kittinger, R. D. Ramsier, Colloids Surf., B **30**, 167 (2003)

Acknowledgments: NIH Grant # EB003397-01, NIST - MEL