Micro- and Nanofabrication for Enhanced Magnetic Resonance Imaging and Sensing

G. Zabow [1,2,*], S. Dodd [1], J. Moreland [2], A. Koretsky [1]

1) Laboratory of Functional and Molecular Imaging, NINDS, NIH, Bethesda, MD 20892, USA

2) Physical Measurements Laboratory, NIST, Boulder, CO 80305, USA

**) Email: zabow@boulder.nist.gov*

Magnetic resonance imaging (MRI) has rapidly become one of the most widely used medical imaging and diagnostic tools. Not requiring ionizing radiation, it is a tool that can benignly probe deep within the body, offering excellent soft tissue contrast and, compared with other in vivo methods, high resolution imaging. It is also, notably, a tool not naturally associated with micro- or nanofabrication, but is one that we believe stands to benefit substantially from such technologies.

One of the keys to the current success of MRI has been the development of various chemically synthesized image contrast agents. Such agents are routinely used to help image blood flow, to distinguish between healthy and abnormal tissue, to delineate regions or organs of interest, and to identify various biomarkers of interest. While several different contrast mechanisms exist, at their core all ^{1}H MRI contrast agents rely on modifying the local magnetic fields experienced by surrounding water molecules. Yet, somewhat counterintuitively, existing chemically synthesized agents offer surprisingly crude control over these fields. Micro- and nanofabrication technologies, on the other hand, can offer new ways to create MRI contrast agents with better defined compositions and geometries that lead to better controlled field profiles and, in turn, enhanced MRI sensitivity and functionality. As examples, this talk introduces several new MRI agents based on specially designed, microfabricated magnetic nano- and microstructures (see Fig. 1) and discusses how (i) controlling the agent material composition can boost MRI contrast signal-to-noise levels by one to two orders of magnitude over existing agents, (ii) controlling the agent geometry can enable multiplex imaging capabilities that add a new dimension of “color” to traditional black-and-white MR images, and (iii) creating dynamically variable magnetic structures can add new environmental and physiological sensing capabilities to further extend the reach of MRI. Among others, such properties enable new MRI nanoprobes that may afford multiplexed imaging and sensing opportunities in many ways analogous to in vitro fluorescence-based probes (including fluorescent proteins, quantum dots, nanodiamonds, etc) but that can operate in the radiofrequency spectrum for true in vivo application.

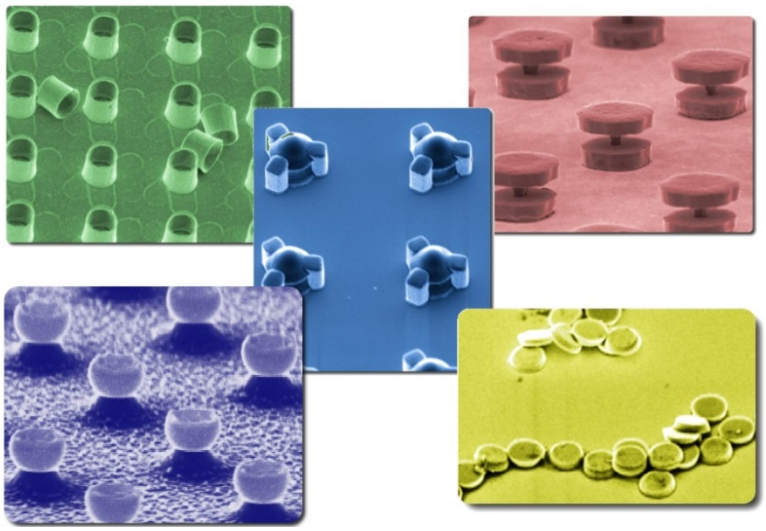

Fig 1. Angled scanning electron micrographs (SEM) of microfabricated magnetic microstructures designed for use as novel MRI contrast agents.