SHAPE-CHANGING NANOMAGNETS: A NEW APPROACH TO IN-VIVO BIOSENSING

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The idea that optical color can be determined by size and shape is well known at the nanoscale. Colors of quantum dots and plasmonic nanostructures, for example, can be tuned through particle size and shape. Among others, this has directly enabled many different multi-colored nanoparticle labels that underpin a host of optically-based *in vitro* bioimaging applications, including multiplexed high-throughput bioassays and colorimetric sensing and visualization of biomolecular processes and function. Imaging and sensing in more realistic *in vivo* environments is more challenging, however. Optical probes can be sized or shaped to yield resonances closer to the more optically favorable near-infrared window, but optical penetration, signal intensity, and spatial resolution, still deteriorate rapidly with increasing depth beneath the surface. But what about in the radio-frequency (RF) portion of the spectrum? Are there any analogous nanoparticle structures that can shift the frequency, or equivalently color, of RF signals for which penetration and/or distortion through biological tissue would no longer be a limitation and where imaging and sensing would be naturally immune to any photostability, phototoxicity, and autofluoresence background issues?

This talk will discuss recent progress towards this aim, focusing on new, specially shaped, magnetic nanoparticle structures that are designed to shift the magnetic resonance frequency of surrounding nuclei, effectively using shape to determine the RF frequency, or color, of a resulting nuclear magnetic resonance (NMR) signal. In analogy to optically based nanoparticle probes, different magnetic nanoparticle shapes can yield different resonant frequency shifts, or effectively RF "colors", enabling multispectral labeling and multiplexed magnetic resonance imaging (MRI). With frequency determined by geometry, magnetic structures that can rapidly, dynamically vary their shape in response to a specific chosen biomarker or physiological condition therefore also function as RF analogues to fluorescent colorimetric sensors, with a potentially similarly broad range of applications[1].

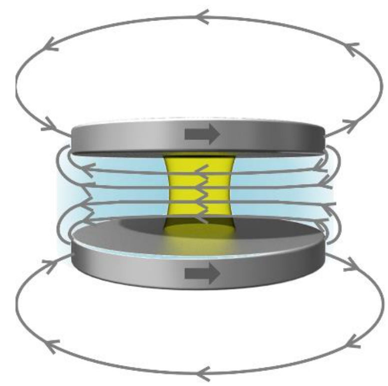

Fig 1. Schematic of shape-shifting magnetic sensor. Expansion of the inner hydrogel post shifts a pair of magnetic disks, changing the magnetic fields that in turn shift the NMR frequency of surrounding water protons.

The new NMR-readable RF sensors respond to their environment through the incorporation of nanoscale, smart (and biocompatible) hydrogel elements, which can be sensitized to a variety of different biomarkers of interest. As the hydrogel changes shape in response to local conditions, changes in the spacing between a pair of attached magnetic elements (see figure), leads to a change in the local magnetic field, which in turn shifts the local NMR water line. In this way, measurements of local physiological conditions are transduced into remotely detectable, quantitative NMR frequency shifts in the surrounding water signal. This talk will discuss in more detail how such structures work, how they can be made, and where they might be applied. As an example, RF-based pH sensing is demonstrated using acid sensitized hydrogel spacer elements, but given the inherent adaptability of the incorporated hydrogel sensing elements it is anticipated that the same measurement platform may be readily converted to measure many other biomarkers.

Reference:
[1] G Zabow, SJ Dodd, AP Koretsky. Nature 520, 73, (2015)