RESEARCH HIGHLIGHTS

IMAGING AND VISUALIZATION

Multiplexing MRI

By engineering magnetic microstructures, researchers demonstrate the potential for multiplexed MRI.

In optical imaging experiments, researchers can take advantage of different colored fluorophores to track different cells or even different molecules inside cells. However, things become a bit difficult when trying to image these things deep inside a living, solidly opaque animal or human. Magnetic resonance imaging (MRI) is an established technology for *in vivo* imaging, but multiplexing capabilities have not been available.

Gary Zabow of the US National Institutes of Health and the National Institute of Standards and Technology and his colleagues now provide a solution to bring ‘color’ to MRI. They developed a design for microfabricating magnetic particles that encode distinct spectral signatures, or ‘colors’.

Contrast agents used for MRI include iron oxide nanoparticles that, when subject to the MRI magnetic field, produce their own magnetic fields. This leads to a change in the relaxation rates of the surrounding water molecules through a process known as dephasing and results in a dark spot in the MRI image. Although they are extremely useful, all contrast agents are essentially monochromatic. “As you go further away from the iron oxide beads, the magnetic field gets smaller and smaller,” explains Zabow. “So if you were to look in spectral terms, you’d just get a big blur because you’d have all different frequencies.”

Zabow and his colleagues turned to microfabrication to create contrast agents with distinct spectral signatures. They designed micrometer-sized magnetic particles with an open double-disk shape, containing either a central post or three outer posts (**Fig. 1**). The gap between the disks is the key to spectral distinction and thus multiplexing. “We have a region inside the particle which has a very uniform magnetic field, which gives you a specific frequency that the MRI can pick up,” explains Zabow. By changing the geometry of the particles—the size of the gap, the thickness of the disks or the radius of the disks—the researchers can obtain discrete spectral signatures.

Though the researchers have not yet tested their magnetic microfabricated particles

Figure 1 | Magnetic microstructures for MRI. (a,b) Scanning electron microscope images of double disk microparticles containing one central post (a) or three outer posts (b). Reprinted from *Nature*.

in a living cell or organism, they have high hopes for their application in biology and medicine. One issue they must address first is toxicity; currently they make the particles out of toxic nickel. “We used nickel because it is a material that we know how to work with easily in terms of microfabrication. But we’re looking at moving to iron, which is relatively nontoxic,” says Zabow. They are also working on making the microfabrication more precise such that they can increase the number of different ‘colors’ they can observe simultaneously.

Another issue they must address is the size of the particles, which at the current micrometer scale may be rather large for cell-based applications. But Zabow believes that this will be relatively easy to address. “Because the signal relies on the water that moves through the gap in the middle of the particle, as you make the particle smaller it takes less time for water to move through the gap. So you actually have a lot more water moving through the gap, so you can get a lot more signal than you otherwise would have expected,” he explains.

The researchers have a busy future working out these issues and beginning testing of the magnetic microfabricated particles in cells. “An ultimate goal is to do this inside the body, but that is still a long way off,” says Zabow. It will certainly be very exciting to see whether multiplexed MRI can be realized in biological research and medical diagnostics.

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Zabow, G. *et al.* Micro-engineered local field control for high-sensitivity multispectral MRI. *Nature* **453**, 1058–1063 (2008).