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Nuclear Magnetic Resonance Imaging with 90-Nm Resolution

Nuclear magnetic resonance imaging with 90-Nm resolution has been achieved by John Mamin and his colleagues at the IBM Almaden lab in San Jose, California. The approach used, magnetic resonance force microscopy (MRFM), maps the location of matter at small scales by observing the resonant vibration of a spindly sliver of silicon (bearing the sample in question) when it is both exposed to radio-frequency waves and scanned over a tiny magnetic tip (see figure at **http://www.aip.org/png/2007/278.htm (http://www.aip.org/png/2007/278.htm)**).

Previously this same group of physicists had used a similar setup to detect the magnetic resonance of a single unpaired electron in a sample (**http://www.aip.org/png/2007/278.htm (http://www.aip.org/png/2007/278.htm)**) But now they are detecting the magnetic resonance of nuclei in the sample, a much more difficult thing since nuclear magnetism is much weaker than electron magnetism (in the case of hydrogen some 660 times weaker). The advantage in focusing on nuclear magnetism is that the response of various atoms biologically and technologically important atoms such as H, P, C-13 or F can be differentiated.

Nuclear spin MRFM has been performed before but only with micron-scale resolution. The new imaging, in effect, explores volumes as small as 650 zeptoliters, which is some 60,000 times better than the best conventional MRI can do. Improvements in the imaging process were facilitated by the use of colder temperatures (reducing the thermally driven motion in the cantilever) and the use of very sharp magnetic tips, which enhances the magnetic force due to the spins.

The magnetic field gradient in the vicinity of this tip is greater than a million tesla/meter. The test objects being imaged consisted of tiny islands of calcium fluoride evaporated onto the cantilever tip. Closely spaced islands, roughly 300 nm x 180 nm x 80 nm in size, could be clearly resolved. One of the researchers, Dan Rugar (**rugar@almaden.ibm.com (mailto:rugar@almaden.ibm.com)**), says that the tiny sample volumes being interrogated hold about 10 million nuclear spins, and that the net nuclear polarization they are detecting adds up to about 3300 spins.

He believes, however, that their current apparatus can now detect nuclear magnetism at the level of 200 spins. This would take them much closer to their ultimate goal of imaging molecules at the single nuclear spin level. Mamin *et al.*, **Nature Nanotechnology (http://www.nature.com/nnano/index.html)** , May 2007)

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