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Nano magnets can now be made to order

Nanoparticles of ferrite (formula MFe_2O_4), described in paper #1, have magnetic and electronic properties that can be molecularly engineered by varying metal M. They are chemically and magnetically stable and are the most frequently chosen systems for studying nanomagnetism. Not only do they have possible applications in information storage and electromagnetic devices, but they are stable under physiological conditions and so are suitable for biomedical applications such as medical diagnostics and drug delivery.

However, they are not new, but what has hampered their use has been the lack of particles of standard size, ideally of less than 20 nanometres diameter. All that changed when Shouheng Sun, leading a group at IBM's T.J. Watson Research Centre, published his remarkable paper on how this problem could be overcome, and not surprisingly it now occupies position #1 in the Hot Ten. (The work also involved researchers at the IBM Almaden Research Center at San Jose and Stanford University, California. Sun is now based in the Chemistry Department of Brown University, Rhode Island.)

Paper #1 reports a one-pot method for making nanoparticles of Fe_3O_4 and one that is readily scaled up for mass production. The particles are formed by the reaction of iron(III) acetylacetonate and 1,2-hexadecanediol at temperatures up to 305^{o}C, and carried out in the presence of both oleic acid and oleylamine, neither of which must be omitted from the recipe. The nanoparticles of Fe_3O_4 are of uniform size, which can be 4, 6, or 8 nm, and depends on the final temperature of the reaction mixture, this being varied by the choice of solvent. For example, benzyl ether solvent produced 6 nm particles.

The smaller particles can be used to seed other reaction mixtures, thereby producing nanoparticles up to 20 nm diameter. Transmission electron microscopy proves the particles are uniform in size and shows them stacked-up in a crystal-like super lattice array. Sun also reports that the method can be extended to making nanoparticles of $CoFe_2O_4$ and $MnFe_2O_4$, and more recently his group have made dumbbell-like composite structures with gold or silver attached to the iron oxide.

Fe_3O_4 nanoparticles are hydrophobic, but paper #1 describes a method of making them hydrophilic by coating with a layer of tetramethylammonium 11-aminoundecanoate. After treatment they can be removed from solution by using a magnet and then they can be dispersed in water – and they still give a good magnetic signal, suitable for spin valve sensor detection.

Sun and his group have published a series of papers on iron oxide nanoparticles and their potential applications in materials such as nanocomposites and for bio-detection. Their most recent work in the latter area is reported in *Langmuir* 2005, 21: 3096, 5 and *J. Phys. Chem. B* 109:13030, 2005. Currently Sun has been testing nanoparticles as labels for highly sensitive DNA sequence detection.

Speaking to *Science Watch,* Sun says: “Our nanoparticles show far higher magnetic signals than any of the known bio-entities, so they really stand out in a non-magnetic background of biomolecules. By labelling a target molecule with such a particle, we are able, with magnetic sensors, to fish successfully for a needle in an ocean of other molecules and impurities.”

Sun’s nanoparticles are of the same dimension as a cell (10-100 nm), a virus (20-450 nm), a protein (5-50 nm) or a gene (2 nm wide and 10-100 nm long). In principle they can be attached to any of these entities and manipulated by an external magnetic field.

“These favorable attributes provide a controllable mean of magnetically tagging or addressing all biomolecules, leading to potentially highly efficient bio-separation, highly sensitive bio-detection and MRI contrast enhancement, as well as site-specific drug delivery,” he says. “They may even offer a ways to kill cancer cells without harming the healthy cells and tissues, by pulsing them with an alternating magnetic field, thereby allowing the transfer of magnetic energy to their surroundings in the form of enough heat to kill the cell.”

In support of this as a possible future use, Sun cites a recent publication from a Korean group that has used these nanoparticles in the magnetic resonance detection of cancer cells – see *J. Am. Chem. Soc.***,** 127: 5732, 2005.

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