CNFET devices on *p*-doped Si substrates covered with 10 nm of SiO_2, with a channel length of 300 nm, using three different source/drain metals (palladium, titanium, and aluminum) in direct contact with nanotubes, which had diameters of 0.6–1.5 nm. The Si substrate was used as the back gate while the SiO_2 was the gate dielectric. Single-walled CNTs grown by laser ablation were used for this study. The researchers correlated the device on-currents with the nanotube diameters and observed that *p*-type Pd-CNFETs (dia. >1.4 nm) have the highest I_{on} and Al-CNFETs have the lowest I_{on}, which follows a trend that would be expected from the clean-metal work function, but the researchers indicate that their results are not "directly correlated with the macroscopic clean surface work function values." Furthermore, the researchers observed larger variations in

Effects of Size and Surface Coating on Cytotoxicity of Nickel Ferrite Explored

Nanoparticles have attracted great interest recently for nanotechnology applications and, in particular, for biomedical applications, such as drug delivery and as biosensors. However, one area of concern for nanoparticles is toxicity and the consequent health effects of the particles, especially for *in vivo* applications. While it is clear that particle size and surface coatings affect chemical and physical properties of nanoparticles, corresponding effects on toxicological properties are as yet unknown. G.M. Chow, H. Yin, and H.P. Too of the National University of Singapore have unraveled some of the toxicological effects of nickel ferrite nanoparticles, both in terms of particle size as well as the presence of oleic acid as a surface coating. Their results will be reported in the October issue of *Biomaterials*; the article is currently available online (DOI: 10.1016/j.biomaterials.2005.02.036).

The researchers used ball milling to prepare uncoated nickel ferrite nanoparticles in two diameters, 150 nm ± 50 nm and 10 nm ± 3 nm. Using a polyol method, the research team also prepared samples with one or two layers of oleic acid coating, making the particles hydrophobic (see Figure 1). Cytotoxicity of the nanoparticles was measured using mouse neuroblastoma (Neuro-2A) cells and through use of a specific test that measures succinate dehydrogenase mitochondrial activity. In cytotoxic conditions, cell membranes were compromised and distinct cell shapes were no longer visible.

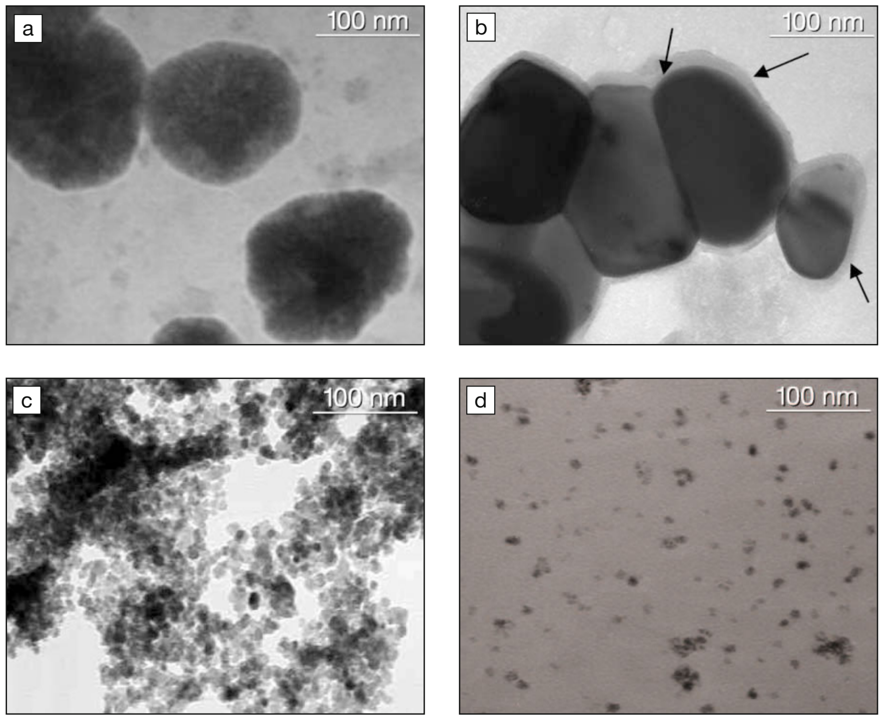

Figure 1. Transmission electron micrographs of nickel ferrite particles: (a) large particles (150 nm ± 5 nm diameter) prepared by ball milling; (b) large particles prepared by the polyol method; (c) small particles (10 nm ± 3 nm diameter) prepared by ball milling; and (d) small particles prepared by the polyol method. Arrows in (b) indicate the surfactant layer. Reprinted with permission from Biomaterials ***26*** *(2005), p. 5818; DOI: 10.1016/j.biomaterials.2005.02.036. © 2005 Elsevier.*

The size of uncoated nickel ferrite nanoparticles was found not to be a significant factor for cytotoxicity, since there were no toxic functional groups on the particle surface, although smaller particles were slightly less toxic than larger ones. The uncoated particles have a hydrophilic surface. When oleic acid molecules were present as a monomer, they were also not cytotoxic. However, when they were present as micelles or when they were coated on the nanoparticles, cytotoxicity was clearly observed. Particles with one layer of oleic acid (hydrophobic $-CH_3$ functional group) were more cytotoxic than particles with two layers of oleic acid (hydrophobic –COOH functional group). The researchers said, therefore, that a hydrophobic surface was more cytotoxic than a hydrophilic surface. The coated nanoparticles also had aligned oleic acid molecules, which resulted in greater cytotoxicity.

The smaller particles were found to be less toxic than the larger ones in medium concentrations (20–100 µg/ml) of the oleic acid for both one- and two-layer surface coverage. For higher concentrations, small and large particles were equally cytotoxic. This size effect could be related to the surface energies and surface interaction areas that were size-dependent, said the research team. The surface energy of small particles is higher than that of large particles. This may have resulted in different effects on surfactant absorption and conformation altering the chemical reactivity of the surfactant. Also, the effective interaction area of a large particle with a cell is greater than that for a small particle, thus resulting in a stronger stimulus on the cells, said the researchers.

The broad conclusion of the study, said the research team, is that the effects of intrinsic size and surface properties, both dependent on the synthetic and processing conditions, need to be cautiously considered in evaluating the biosafety of nanoparticles. In terms of future studies, the group is planning to investigate the interfacial interactions of nanoparticles and cells, particularly the mechanisms of cell degradation and death.

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