Plasma Synthesis of Superparamagnetic Iron Oxide Nanoparticles

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There is currently intense interest in the use of superparamagnetic iron oxide nanoparticles for biomedical applications, including as contrast agents for magnetic resonance imaging and as targeted agents that can be heated by applying an alternating magnetic field, killing cancer cells by hyperthermia. Conventionally these nanoparticles are synthesized by wet chemical methods. However plasmas and other gas-phase synthesis methods have a number of potential advantages over wet chemistry, including higher production rates, the avoidance of impurity residues, the avoidance of the need to manage and dispose of hazardous solvents, and the avoidance of the need to remove surfactants before adding layers that impart additional functionality to the nanoparticle.

A number of researchers, dating to the early 1980s, have reported plasma synthesis of iron oxide nanoparticles. However in none of these studies were the measured magnetic properties of the produced powder satisfactory from the viewpoint of biomedical applications. Here we report synthesis of iron oxide nanoparticles using a DC argon-helium thermal plasma with injected ferrocene vapor and oxygen. The powders produced have a mean particle size below 10 nm, and are superparamagnetic, with measured magnetic properties (saturation magnetization ~40 emu/g, coercivity ~25 Oe) that are far superior to results previously reported for any plasma process.

After exiting the plasma reactor the iron oxide nanoparticles are coated with very thin layers of silica, using photoinduced chemical vapor deposition, driven by a xenon excimer lamp that emits at 172 nm. Tetraethylorthosilicate (TEOS) vapor is used as the coating precursor. SiO_2 coatings improve the nanoparticles' stability, suppress agglomeration, and can serve as an excellent substrate for additional surface layers or biofunctionalization. Preliminary results are presented for the effect of operating parameters on coating thickness, surface chemical composition, magnetic properties, and stability of the nanoparticles in aqueous dispersion.

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