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The Structure and Magnetic Properties of Nanoparticles and Their Arrays

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The physics of magnetic nanoparticles and arrays is a very important topic of current research. Many questions remain. How does the structure of a single nanoparticle influence its magnetic properties? For instance, core/shell interactions can increase the coercivity and lead to exchange biasing, causing ferromagnetic rather than superparamagnetic behavior. At what thickness does the oxide shell begin to behave like an antiferromagnet? How do uncompensated surface spins affect the magnetic behavior? In addition, novel nanoparticle structures can lead to interesting physical behavior. In a bio-inspired approach, we are synthesizing *highly* monodisperse oxide nanoparticles inside of protein cages. For these systems, magnetocrystalline anisotropy plays an important role; the surface anisotropy term becomes large, reducing the total particle moment. However, we find that the encapsulating protein shell reduces the surface anisotropy and increases the particle moment. Furthermore, we have synthesized mixed phase gamma-Fe_2O_3/CoO nanoparticles with large exchange biasing. Further questions arise for nanoparticle arrays. Dipole interactions modify the collective magnetic behavior. What are the strength and orientation of these interactions, and how do they depend on particle size, spacing, *and* array ordering. Recent experiments have shown the importance of array order in determining the collective magnetic properties. The physics of magnetic nanoparticles is rich and complex, and depends upon both the structure of the individual particles and their assemblies. By using synchrotron based magnetic circular dichroism, small angle X-ray scattering and neutron scattering, we have been able to quantify many aspects of both nanoparticle and array structures. A quantitative understanding of these structural relationships has led to a better understanding of their magnetic behavior.