Plasmonic Nanoparticles: Molecular Orbitals writ large

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In recent years we have shown that certain metallic nanoparticles possess plasmon resonances that depend very sensitively on the shape of the nanostructure. This interesting observation has led to a fundamentally new understanding of plasmon resonances of metallic nanostructures- “Plasmon Hybridization”- where the collective electronic resonances in a metallic nanostructure are understood to be a classical analog of the single electron quantum states of simple atoms and molecules. The Plasmon hybridization picture explains the tunability of nanoshells, a dielectric core, metallic shell nanoparticle which is the simplest nanostructure with tunable plasmon resonances. Moreover, this picture provides a nanoscale “design rule” for understanding the plasmon resonances of an entire new family of plasmonic nanostructures: reduced symmetry nanostructures (nanoeggs and nanorice), multilayer nanoshells (nanomatryushkas), nanoscale dimers, trimers, and N-mers, and a metallic nanosphere adjacent to a thin metallic film, a photonic analog of the spinless Anderson model. A variety of surface enhanced spectroscopies such as Surface Enhanced Raman Scattering, (SERS) Surface Enhanced Infrared Absorption (SEIRA), as well as fluorescence enhancement of nearby molecules and materials, can exploit these types of designed metallic nanostructures as tailored, high-performance substrates yielding large and highly reproducible enhancements. In addition, by tuning plasmon resonances into the near infrared region of the spectrum, the physiological “water window” can be accessed, where blood is essentially transparent and light penetrates maximally through human tissue. With bioengineers, we have developed a suite of applications for nanoshells in the human body, such as an all-optical nanoscale pH “meter” and a nanoshell-based approach to cancer therapy which will be described.

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