Plasmonic Nanostructures for Sensing

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Noble metal nanoparticles have loosely bound conduction electrons that collectively oscillate when excited by an electromagnetic field. These plasmon resonances reside in the visible and infrared portions of the electromagnetic spectrum for silver and gold. At the resonance frequencies, the nanoparticle is highly polarizable, and the oscillating charge density results in a strongly enhanced field near the surface. The large field enhancements and the ability to selectively tune the resonance wavelength via particle morphology makes plasmonic nanostructures ideal for many sensing applications in chemistry and biology.

In this paper, we examine some of the more subtle (and fundamental) aspects of how nanoparticles couple to each other as well as to molecules, and how the nature of this coupling can affect the sensing properties of the system as a whole. As a first example, we examine periodic disk-on-pillar nanoarrays as a platform for surface-enhanced Raman spectroscopy (SERS) measurements. The nanostructure is a two-dimensional grating of silicon pillars covered by thin layers of silica and silver. The system supports both localized surface plasmons and surface plasmon polaritons, whose interaction can be tuned to synergistically enhance the electric field resulting in larger SERS signals. Next we show how coupling a molecule to a nanostructure can drastically alter the fluorescence. Specifically, we investigate the emission characteristics of a molecule placed in the gap of a nanoparticle dimer. In contrast to the single nanosphere-molecule system, we find that the emission intensity undergoes a quenching effect only when the inter-nanoparticle gap distance of the dimer is very small, meaning that strong coupling prevails over energy engaged in the heating process unless the molecule is extremely close to the metal surface. Both of these examples highlight the importance of understanding the interplay between system components in plasmonic sensing applications.