Nanoparticle Plasmonics for Field-Enhanced Microscopy and Spectroscopy

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The potential of metallic nanostructures to act as effective optical and infrared (IR) field transmitters, receivers, or enhancers has stimulated considerable research effort Collective oscillations of valence electrons in metallic materials, also known as plasmons, determine the optical response of these materials. The energy and strength of these surface oscillations are a function of the shape, size and coupling of the nanoparticles. With the use of the boundary element method (BEM), we solve Maxwell's equations to calculate light scattering and surface modes in nanostructures that are commonly used as hosts and/or samples in different field-enhanced scanning probe microscopies and spectroscopies. Light scattering and near field distribution of particles such as nanorings [1], nanorods [2], nanodisks [3], or nanowires [4] are calculated and interpreted in terms of their surface plasmon modes. The results are related to different spectroscopic experiments and connected with the capabilities of these structures to host biomolecules and perform the corresponding spectroscopy.

Special emphasis is placed on the near-touching limit for pairs of spherical particles to understand recent experiments in the literature [5]. We also study the electromagnetic response of gold particles when they are coupled to a metallic tip in scattering-type near field optical microscopy (s-SNOM) [3]. We obtain different optical and infrared contrast in the s-SNOM cavity, depending on the particle size and substrate material, and associate these differences in contrast to the properties of the tip-particle-substrate coupling [6]. Last, but not least, we address the spectral features of nanowire-like antenna resonances [2]. We focus on the departure of the plasmon resonances from standard $\lambda/2$ antenna theory, both in the optical and infrared regimen. Depending on rod thickness, the antenna resonance follows different linear behavior, from $L=0.1\lambda$ up to $L=0.4\lambda$ for thick rods. A map of resonances for different sizes and aspect ratios is discussed where no scaling with aspect ratio is found. We extend our simulations to micron-sized antennas in the infrared [7], and compare calculated properties of the plasmon resonances with experimental results from absorption spectroscopy. Results show that these nanorods can be excellent infrared antennas for Surface Enhanced Infrared Absorption.

The understanding of the coupling of surface modes in such a variety of systems, and the consequences for the local field enhancement are crucial to engineer and design plasmonic devices for detection and effective optical response.

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