Photochemical Tuning of Surface Plasmon Resonances in Metal Nanoparticles

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Abstract

Illuminated metal nanoparticles (MNPs) feature collective electron oscillations (so-called localized surface plasmons or LSPs) which facilitate concentrating light-matter interactions to length scales below the diffraction limit. Part I of this book describes two applications of this confinement effect. Firstly, the use of single particles as optically active probes for scanning near-field optical microscopy is demonstrated. Secondly, fluorescence enhancement in the vicinity of a single MNP is described theoretically. This description focuses on how the particle diameter and the surrounding medium influence the enhancement. It turned out that in these two examples the optical signal levels can be improved by manipulating the spectral LSP resonance position of the particles. This finding triggered the search for a method allowing optical particle tuning.

Part II of this thesis describes an approach which allows such a spectral LSP manipulation on the single-particle level. The method makes use of the optically induced reduction of metal salt complexes in solution, which leads to the deposition of thin layers of elemental metal onto single, intentionally addressed particles. The deposition process is monitored by optical LSP analysis, and thus the tuning of the optical particle properties is controlled in situ.

With this technique, a manipulation of both the size and the shape of single nanoparticles was achieved. Initial experiences were gained by manipulating spherical and ellipsoidal gold particles, for which a red- and a blueshift of the LSP resonance was observed, respectively. The insights obtained from these experiments were then applied to tune the interparticle separation in nanoparticle pairs, i.e., to tune the resonance wavelength of these plasmonic nanoresonators. Subsequently, single resonators were used to reshape the fluorescence emission spectrum of organic molecules.

Besides size and shape, also material parameters such as the surface roughness and the surface material composition influence the optical properties of MNPs. Both aspects are addressed using the example of rough platinum spheres and demonstrating the fabrication of bimetallic core-shell particles. As the material compositon of particles not only influences their optical, but for example also their catalytic or magnetic properties, photochemical metal deposition with in-situ optical LSP read-out builds a bridge to other fields of nanoscience. The presented method is a versatile tool for the fabrication and manipulation of nanostructures, and it is not limited to the field of plasmonics.