Silver-decorated silica nanoparticles in a multilayered plasmonic structure

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Introduction

Optical properties of noble metal nanoparticles, such as gold and silver, are dominated by coherent oscillations of conduction electrons, which give rise to localized surface plasmon resonances. The wavelength of the resonances depends on the particle size, shape and dielectric environment.

In our previous study (Harra *et al*, 2012), the plasmon resonance wavelength of spherical single-component silver particles was tuned by controlling their size (50–130 nm). Even though the coverage of the silver particles on the substrate was relatively low ($<$ 10 %), the overlapping of the particles caused the extinction spectra of the prepared surface samples to broaden to longer wavelengths ($>$ 500 nm).

In plasmonic applications, such as colored coatings and nonlinear optical materials, it is preferable to be able to tune the extinction while maintaining a narrow and well-defined resonance band. In this study, we demonstrate such control by using a multilayered structure consisting of silver-decorated silica nanoparticles.

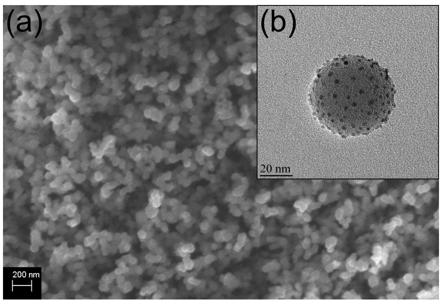

Figure 1: (a) An SEM image of the decorated particles on a glass substrate after a collection time of 30 min and (b) a TEM image of a single particle.

Experimental

Aerosol techniques were used to synthesize the silver-decorated silica nanoparticles. The synthesis process composed of chemical vapor synthesis of larger silica particles and their subsequent decoration with smaller silver particles by an evaporation–condensation method. A layer of decorated particles was deposited on a glass substrate and coated with a thin layer of glass by electron beam evaporation. This process was repeated several times in order to obtain a multilayered structure.

The synthesized particles were characterized with a scanning mobility particle sizer and a transmission electron microscope (TEM), whereas, the plasmonic glass samples were studied with a UV-VIS spectrophotometer and a scanning electron microscope (SEM).

Results and discussion

Figure 1a shows an SEM image of a glass substrate covered with a porous layer of nanoparticles after a collection time of 30 minutes. The individual particles consisted of approximately 50 nm silica spheres decorated with a few nanometer silver particles, as shown in a TEM image (Fig. 1b).

Figure 2 shows extinction spectra of the multilayered nanoparticle structures containing 1–4 layers. The plasmon resonance band, typical of silver at around a wavelength of 400 nm, remains well-defined and relatively narrow, while the extinction grows linearly as the number of layers increases. The inserts show how the yellow color of the multilayered samples intensifies as well.

This study shows that the dielectric silica in the decorated particles reduces unwanted contacts between metal particles, thus, a well-defined extinction spectrum can be maintained. In addition, multilayered structures can be used to improve the mechanical and chemical stability of the nanoparticles in plasmonic materials.

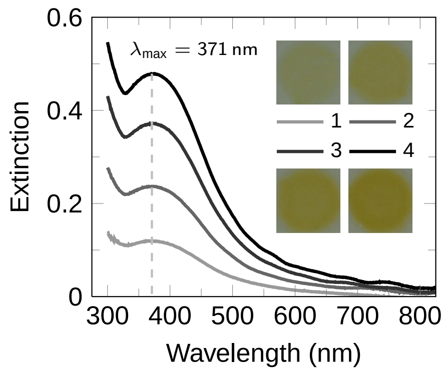

Figure 2: Extinction spectra of the multilayered nanoparticle structures with 1–4 layers. The inserts show photographs of the samples.

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