Laser Manipulation of Gold Nanoparticles

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Nanostructured materials have electronic, optical and chemical properties that differ from those of the bulk. In particular, materials containing noble metal nanoparticles (NPs) are promising for optical filters, broadband waveguide polarizers and ultrafast all-optical switches.[1] Their main optical feature is the presence of an enhanced absorption at the surface plasmon resonance (SPR) wavelength related to confinement effects for NPs dimensions smaller than the excitation wavelength.[2] To fully exploit the special properties of NPs, it is essential to develop means to control the particle size, shape and separation. The aim of this work is to explore the possibility to control the size- and shape- distributions of gold NPs by means of laser irradiation.

The samples used in this work are produced by pulsed laser deposition (PLD) on carbon-coated mica and glass substrates by means of an ArF laser. A 10 nm thick Al\textsubscript{2}O\textsubscript{3} layer has always been deposited first to define a standard and homogeneous surface on which the NPs nucleate. The laser energy density and deposition time are respectively selected to be slightly above the ablation threshold of the gold and to produce NPs of average dimensions >5 nm. After deposition, the specimens are irradiated with single laser pulses of \textasciitilde{}6 ns from a tuneable optical parametric amplifier. Three different wavelengths have been selected for this study, namely 530 nm, 610 nm and 690 nm. These values are respectively shorter, approximately equal and longer than the SPR wavelength. Areas of 2.5x2.5 mm\textsuperscript{2} are irradiated at increasing energy densities and the absorption spectra are measured in-situ using white light at normal incidence in the wavelength range 400-800 nm. The structure of the specimens is studied by transmission electron microscopy in a Jeol 4000EX HREM microscope operating at an acceleration voltage of 400kV with a point-to-point resolution of 0.17 nm, both before and after irradiation.

The as grown specimens contain well defined gold NPs. Although most of the NPs exhibit a round shape and have diameters in the range of 5-8 nm, there are some smaller NPs and larger elongated ones, the latter most likely been produced by coalescence of smaller NPs. Upon irradiation, the average dimensions of the particles change and the optical measurements show a blue-shift of the SPR as well as a reduction of the absorption, both effects being stronger the higher the energy density. These changes depend however very little on the irradiation wavelength. The observed variations in the optical properties are finally discussed in terms of the changes in the dimensions and distribution of the NPs produced by laser irradiation.


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