Templated Growth of Lithographically Patterned Nanoparticle Arrays for Surface Enhanced Raman Scattering (SERS)

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In dense metal nanostructure arrays with small interparticle distance, efficient nanofocusing of light can be achieved. This results in high local electric fields and gives significant enhancement of Raman signals of analyte molecules (10^6-10^8 in bulk experiments) when they are in close proximity to the nanoparticle surface (Surface enhanced Raman scattering, SERS). SERS combines the high specificity and the possibility of gathering information about the molecular structure of the analyte in Raman Spectroscopy with a high sensitivity. A condition for the use of SERS in analytical applications is the use of stable and reproducible nanostructures. Furthermore the plasmon resonances and local electric fields in nanostructure arrays strongly depend on the size and shape of the structures. In principle, lithography e.g. electron beam lithography can be used to fabricate regular nanostructured arrays with defined size, shape and period, but the minimum achievable distance between the particles is often limited. Previous attempts to overcome this limitation require specialized fabrication approaches or particular structure designs [1, 2].

Here, we present a processing approach based on templated growth, i.e. lithographic prepatterning of gold nanostructures, followed by repeated deposition and thermal annealing of ultra-thin gold layers [3]. Using this approach, we have fabricated dense nanoparticle arrays with small interparticle gap sizes and distinct plasmonic properties. Ripening of nanoparticles was monitored using scanning electron microscopy and the optical properties, as well as the surface-enhanced Raman scattering (SERS) enhancement factor of the resulting structures, were characterized.

The influence of different parameters like the lattice period, the height and diameter of the initial nanostructures as well as the total thickness of the additionally deposited gold layers on the SERS enhancement was studied. In order to obtain information about the electromagnetic field distribution, we carried out 3D finite-difference time domain (FDTD) simulations of realistic nanoparticle structures in geometrical configurations corresponding to our fabricated samples. The generated structures can be used in different applications, ranging from biochemical detection to photocatalysis, ideally with large-area patterning techniques such as nanosphere lithography or interference lithography.

References:
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