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Effect of Dielectric Layers on Localized Surface Plasmon Resonance of Sputtered Silver Nanoparticles

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Silver nanoparticles have attracted much attention for the unique optical properties with potential applications in optical devices, chemical and biological sensors, and surface-enhanced spectroscopies (SES). Silver nanoparticles exhibit light-induced localized surface plasmon resonance (SPR), resulting in an anomalous absorption in the visible region. The SPR excitation can dramatically enhance the local electromagnetic field, which plays a key role in SES.

It is highly desirable that the SPR frequency be tunable. One motivation comes from SES, in which the excitation and emission frequencies must overlap the SPR frequency of the substrate. Conventional methods of tuning SPR include the development of new fabrication techniques to control the geometry and spacing of the silver nanoparticles, an optimization of fabrication conditions in thermal evaporation, and the altering of the component of the silver nanoparticles by alloying with other metals.

We noticed the fact that the SPR can be shifted by select different substrate material with different dielectric constants. In addition, we demonstrated theoretically and experimentally in this study a simple but very effective way to tune the SPR by introducing different dielectric matrix in the form of ultra-thin films around the Ag particles with varied sizes.

A variety of oxides such as Al_2O_3, MgO, ITO, ZrO_2, and TiO_2, which possess different refractive indices, was studied. It reveals that the introduced layer can dramatically enhance redshift of the peak wavelength of SPR, λ_{SPR}, and the larger the refractive index, the more significant of the redshift. In the case of Ag particles on various substrates, the sensitivity factor, $\Delta\lambda_{SPR}/\Delta\varepsilon_{av}$, where ε_{av} is the averaged interparticle dielectric constant, is found to be size dependent. It increases approximately linearly with silver mass thickness up to 4 nm, from 60 nm to about 160 nm per dielectric constant unit. A generalized Maxwell-Garnett theory was used to account for the result.

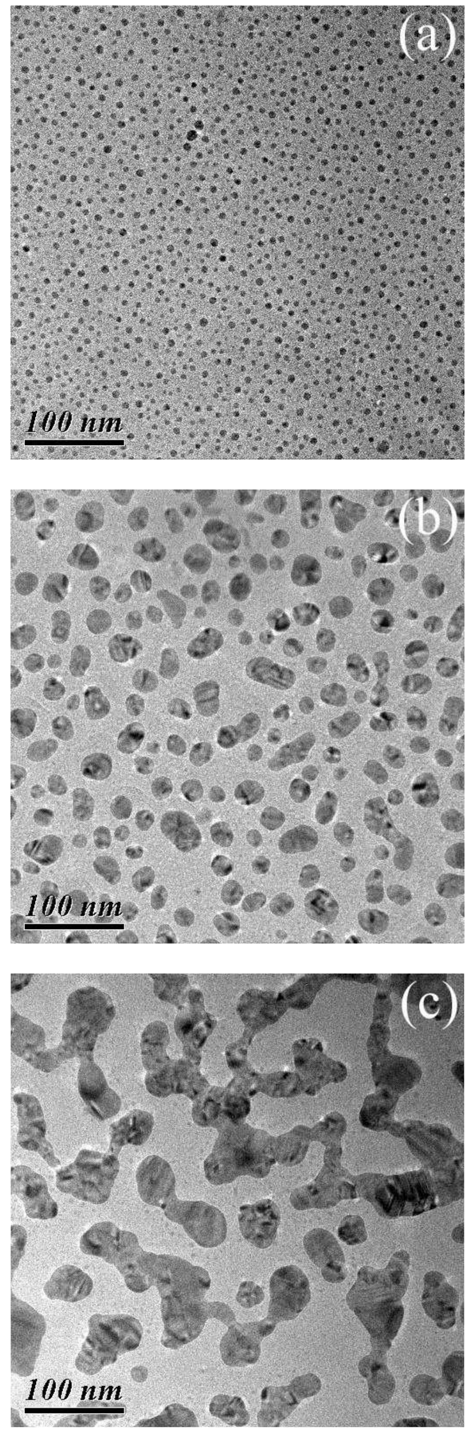

Fig.1. Transmission electron micrographs of silver nanoparticles deposited by sputtering with mass thickness of (a) 0.6nm, (b) 3.3nm and (c) 5nm.