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Microstructure and ellipsometric modelling of the optical properties of very thin silver films for application in plasmonics

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Abstract

Excitation of surface plasmons in silver nanoparticles is a promising method for enhancing light trapping. The present paper reports results for the optical properties of the nanocrystalline silver thin films in attempt to understand the effects of the particle size. The microstructure of the films was probed by scanning electron-microscopy, Atomic Force microscopy (AFM) and X-ray diffraction (XRD). The size of the crystallites/grains calculated from the XRD measurements by the Debye-Scherrer formula is in a good agreement with the AFM results. The optical properties were determined from spectral ellipsometric measurements. It was shown that the Drude-Lorentz model is suitable for characterization of porous films, while an island structure required the extended Drude model with frequency dependent damping parameter, Γ . It was demonstrated that the maximum of the imaginary part of the complex permittivity, $\hat{\epsilon}(\omega) = \epsilon'(\omega) + i\epsilon''(\omega)$, that is due to the transverse oscillations of the polarization of the silver grains, can be positioned in the energy range of 1.5 - 2.8 eV in dependence of the deposition rate; it's been shifted to higher energies when reducing the grains size. Contemporarily, the resulting changes in the surface/volume ratio lead to shifts the maximum in the loss function $Im\left(-1/\hat{\epsilon}(\omega)\right)$ from 3.8 to 3.5 eV.

Keywords: very thin films, silver, spectral ellipsometry, plasmons.

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