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OPTICAL PARAMETERS OF 10 NM TO 100 NM THICK SILVER FILMS

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Abstract. In plasmonics there is a need for thin metal films with ultra-low scattering and ohmic losses. Refractive index and extinction of silver nanolayers depend on experimental parameters of deposition process, film thickness, wetting and anticorrosion capping layer. Here, we report on the results of spectral ellipsometry measurement in silver layers of thickness 10 to 100 nm deposited at 180 or 295 K on glass or sapphire substrates with and without the use of Ge wetting layer and one of three anticorrosion overlayers. To parametrize the complex permittivity of the Ag layers, the Drude-Lorentz, Tauc-Lorentz, and Gaussian oscillator models were used in the fitting procedure.

In plasmonic and metamaterial applications there is a need for thin silver films with ultra-low scattering and ohmic losses [1–6]. The quality of Ag films evaporated in physical vapour deposition process depends on such experimental parameters as deposition rate, substrate temperature as well as wetting layer and capping layer. Thin, continuous and smooth Ag layers are fabricated with the use of wetting layers such as Ti, Ni, Cr or Ge [1, 5]. The role of wetting layers consists in reduction of island growth due to large adhesion. Germanium wetting layer of single nanometer thickness allows for the smoothest surface of Ag which reduces scattering losses, however it also introduces increase of ohmic losses due to segregation [6]. Germanium segregation to both the Ag free surface and grain boundaries results in increase of the specific resistivity of Ag films which in turn results in decrease of surface plasmon-polariton wave range. Segregation process develops over time, and eventually saturates when all the germanium is transported to defects such as lattice non-uniformity, grain boundaries and film surface. Decrease of substrate temperature during deposition does not improve quality of the surface [2]. However, in Ag films cooled below 50 K the ohmic losses are considerably reduced [3]. Fabrication of ultrasmooth metal films deposited onto epi-polished substrates has to be performed at pressure and temperatures that are located on the gas side of the phase-boundary curve of water in a p-T diagram. This assures that silver is not deposited on water ice crystals that grow on cooled substrates [2]. At a wide deposition temperature range from 90 to 500 K, the mismatch of thermal expansion coefficients of Ag, wetting layers, and sapphire or silica substrates does not deteriorate the metal surface. Chemical instability of silver creates a need for capping the silver layer with various anticorrosive dielectric overlayers like SiO_2, Al_2O_3 or LiF, which prevent the silver layer from oxidation or sulfation. If the capping layer is made of a material which segregates in silver, like Al_2O_3, it can also damp the increase in losses due to the use of segregating wetting layers [6]. Recently, apart from low-loss silver, also aluminum films attract attention both as autonomous films as well as 4% concentration dopant of Ag films that considerably smooth silver surface [7, 8].

Since all of the effects described above contribute to the values of optical parameters of silver based multilayers, the values determined by Johnson and Christy [9] or Palik [10] should be complemented by complex measurements of properties of silver nanolayers. In this paper, we present the values of index of refraction, extinction coefficient as well as real and imaginary parts of permittivity for silver layers of thicknesses in range 10–100 nm, deposited on glass and sapphire substrates, with and without the use of Ge wetting layer deposited in either room temperature or 180K, as well as with the use of three different capping layers – SiO_2, Al_2O_3 and LiF, before and after annealing. Investigated parameters are evaluated from spectroscopic ellipsometry data in the range of 0.62–6.5 eV. The refractive indices and extinction coefficients of investigated systems have been measured and interpreted in terms of the Drude-Lorentz, Tauc-Lorentz, and Gaussian oscillator models. To model the intermix layers at interfaces of substrate/wetting layer, wetting layer/silver, silver/capping layer and capping layer/air, AFM scans of fabricated samples are performed and RMS of surface roughness are taken into account.

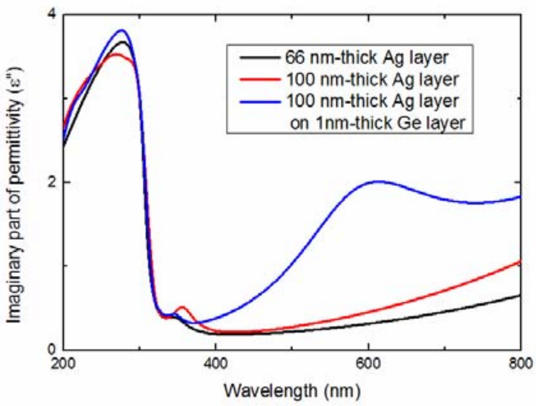

Fig. 1

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