Thickness Dependent Structural Morphology and Optical Properties of Thin Gold Films

D. Yakubovsky\textsuperscript{1,}\textsuperscript{*}, A. Arsenin\textsuperscript{1,2}, Y. Stebunov\textsuperscript{1,2}, D. Fedyanin\textsuperscript{1}, V. Volkov\textsuperscript{1,3}

(1) Moscow Institute of Physics and Technology, Dolgoprudny, Russia
(2) GrapheneTek, Skolkovo Innovation Center, Moscow, Russia
(3) SDU Nano Optics, Mads Clausen Institute, University of Southern Denmark, Odense, Denmark

Thin gold films are an essential element in nanophotonic and plasmonic applications\textsuperscript{1}, enabling to localize light-matter interaction at nanoscale and having the resonant optical behavior, they are commonly used in optical sensing, plasmonic circuits, nanolasers, waveguides and many others. Performance of such plasmonic devices is strongly determined by intrinsic characteristics of metal films: optical absorption in metal through the interband and intraband electron transition, including electron-phonon and grain-boundary electron scattering\textsuperscript{2}. Nowadays, gold still remains the most used plasmonic material due to its high electrical conductivity, low optical losses and chemical stability. However, optical and electrical properties of polycrystalline gold are highly dependent on its structural features and thickness, which may vary from a few tens to hundreds of nanometers depending on a particular plasmonic application. Moreover, extremely thin gold films (< 10 nm) can demonstrate optical response fundamentally different from that of thick continuous films. In this context, questions remain unanswered regarding the optical constants of thin gold films of different thickness and morphology.

Here, we report on a comprehensive study of the correlation between the optical properties of gold films and their thicknesses (in a wide interval of 2 - 200 nm), deposited under the similar conditions. In our work gold films were accurately characterized via different methods, including X-ray diffractometry, atomic force and scanning electron microscopy to study the structural features, four-point probe measurements to determine the electrical conductivity and spectroscopic ellipsometry to extract optical constants in visible and NIR regions. By this approach we were able to demonstrate reliable dependence between dielectric function of thin gold films and thickness-dependent structural morphology, which is found to be in good agreement with the theoretical model describing the contribution of scattering at crystallite boundaries to overall optical losses\textsuperscript{3}. In addition, the effect of transition from island-like clusters to a continuous gold film with metal growth on optical properties was studied (see Figure 1).

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\textbf{Figure 1.} (a) Measured effective imaginary dielectric function of gold films of different thickness (data of Johnson and Christy are plotted for comparison); (b) Transmission spectra of discontinuous thin gold films

\textbf{References}


Corresponding author email: dmitrii-y@mail.ru