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Revisiting the experimental dielectric function datasets of gold in accordance with the Brendel-Bormann model

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ABSTRACT

As a result of adopting various sample preparation techniques and optical measurement strategies, there are different experimental datasets available for presenting the complex dielectric function of gold. Therefore, evaluating them and selecting the most reliable ones seem essential for the corresponding optical-based designs and applications. The Brendel-Bormann model, one of the most accurate theoretical models for rendering the complex dielectric function of materials, is considered an appropriate criterion for this purpose. Despite the model's computational complexity, MS Excel has been employed as a fast and accessible tool for calculating the model. According to the results, 'Palik' and 'Babar' exhibit the most accurate datasets representing the real part of the dielectric function of gold in the short- (< 500 nm) and long-wavelength (> 500 nm) ranges, respectively. While the proposition reverses for the imaginary part of the dielectric function. This validity owes to using gold samples with the lowest structural and surface imperfections.

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1. Introduction

In optics, the complex dielectric function of a material is classically defined as its susceptibility to polarization in an applying electromagnetic field. This wavelength-dependent parameter $\varepsilon(\lambda)$ consists of two real $\varepsilon_{re}(\lambda)$ and imaginary $\varepsilon_{im}(\lambda)$ parts, expressing the light's deflection and absorption, respectively [1,2]. The complex dielectric function is usually deemed the key parameter for materials defined in optical modelings, simulations, and designs, directly governing the final outputs. Therefore, it is not surprising to know that a significant share of research in the context of optics has always belonged to determining the complex dielectric function of materials. Gold is not an exception in this context, having a wide variety of optical-based applications such as in sensing [3–5], imaging [6–8], diagnosis [9–11], and therapies [11–13]. Various researchers have attempted over decades to determine the most reliable complex dielectric function data for gold to improve its optical cognition and applications.

It is worth spending a few sentences on optical measurement methodologies adopted for extracting the complex dielectric function of gold. Spectroscopic ellipsometry is generally known to be the most frequently-used technique. It is based on measuring the change in the polarization states of the light reflected off material's surface. After that, an appropriate model is employed to parameterize the complex dielectric function, followed by its fitting to the measured data. There are various ellipsometry models, including Sellmeier, Cauchy, and Forouhi-Bloomer dispersion models, which their adoption depends on the sample properties and considering different models' limitations [14–16]. The complex dielectric function can also be derived by applying Kramers–Kronig analysis on reflectance, transmittance, or absorbance spectra obtained utilizing the spectrophotometry technique [17,18]. Furthermore, there are other spectroscopic approaches in this context, such as electron energy-loss spectroscopy, which applies an electron beam rather than photons for optical measurements [19,20].

Various experimental techniques available for sample preparation affect its structural features, such as surface roughness and morphology, film thickness, grain size, voids density, and purity. The difference in these parameters, and the adoption of diverse optical measurement strategies and instrumentations, have resulted in slightly different complex dielectric function data for

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