Optical constants of silver nanowire networks : theory and experiments

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Silver nanowire (AgNW) networks have emerged as a promising class of Transparent Conducting Materials (TCMs), offering high optical transparency and excellent electrical conductivity, combined with advantages such as mechanical flexibility and cost-effective, scalable fabrication methods. The conductivity of AgNW networks arises from a percolation mechanism through nanowire junctions, while their transparency results from gaps between the nanowires, illustrating an intrinsic interplay between these properties. Understanding the optical properties of AgNW networks, often described by their refractive indices (*n, k*), is critical for advancing their integration into multilayer systems and devices. Furthermore, refractive indices provide fundamental insight into the material's optical behavior and enable accurate simulations of complex multilayer designs using the Transfer Matrix Method.

Mie's scattering theory and van de Hulst's mixing model, both parameter-free frameworks, are combined to theoretically predict the refractive indices of AgNW networks, facilitating accurate modeling of their far-field optical response and supporting their application in advanced technologies such as smart windows or solar cells. In this work, the refractive indices (*n, k*) of AgNW networks are for the first time computed across the visible and near-infrared spectral ranges and validated against experimental data. Transmittance spectra derived from numerical solutions of Fresnel's equations show excellent agreement with measurements, particularly for nanowires of larger diameters and at shorter wavelengths, thus validating the theoretical model. Notably, our results exhibit less than 10% relative error between theoretical prediction and experimental measurements at $\lambda = 550$ nm. Crucially, our results also highlight the dominant metallic nature of AgNW networks over their dielectric characteristics in determining their optical response.

By accurately modeling the optical properties of AgNW networks, this work facilitates their integration into multilayer optical systems, supporting the development of innovative devices such as displays, sensors, and energy-efficient smart windows. Additionally, this research paves the way for a more advanced theoretical understanding of the optical properties of silver nanowire networks at the fundamental level.