Supporting informations:

Generalized Effective Medium Theory to Extract the Optical Properties of Two-Dimensional Non-Spherical Metallic Nanoparticle Layers

Yann Battie,[†,*] *Aotmane En Naciri,*[†] *William Chamorro,*[‡,§] *David Horwat*[‡]

LCP-A2MC, Institut Jean Barriol, Université de Lorraine, 1 Bd Arago, 57070 Metz, France.

Université de Lorraine, CNRS, Institut Jean Lamour, UMR7198, Nancy, F-54011, France.

Department Materials Science and Engineering, Saarland University, D-66123 Saarbrücken, Germany.

I. Effective dielectric tensor of isotropic, uniaxial or biaxial medium

The effective medium theory introduced in this paper can be used to describe isotropic, uniaxial or biaxial medium. A medium composed of randomly oriented nanoparticles embedded in a matrix can be considered as isotropic. The dielectric function of the matrix is ε_m. Although the nanoparticles are distributed in shape, we assume that all nanoparticles have the same dielectric function ε_i assimilated to the bulk value. By considering the formalism presented in this paper, the effective dielectric tensor isotropic material is given by:

$$[\boldsymbol{\varepsilon}_{\mathbf{eff}}] = \frac{\varepsilon_m(1-f) + f\varepsilon_i \int\int P(L_x, L_y) \frac{\lambda(L_x) + \lambda(L_y) + \lambda(L_z)}{3} dL_x dL_y}{(1-f) + f \int\int P(L_x, L_y) \frac{\lambda(L_x) + \lambda(L_y) + \lambda(L_z)}{3} dL_x dL_y} \mathbf{1}, \text{ (S1)}$$

Where $L_z = 1 - L_x - L_y$ (S2)

If all nanoparticles are oriented along the z direction, the medium has an uniaxial anisotropy. The effective dielectric tensor of uniaxial medium is described by:

$$[\boldsymbol{\varepsilon}_{\mathbf{eff}}] = \begin{pmatrix} \frac{\varepsilon_m(1-f) + f\varepsilon_i \int\int P(L_x, L_y) \frac{\lambda(L_x) + \lambda(L_y)}{2} dL_x dL_y}{(1-f) + f \int\int P(L_x, L_y) \frac{\lambda(L_x) + \lambda(L_y)}{2} dL_x dL_y} & 0 & 0 \\ 0 & \frac{\varepsilon_m(1-f) + f\varepsilon_i \int\int P(L_x, L_y) \frac{\lambda(L_x) + \lambda(L_y)}{2} dL_x dL_y}{(1-f) + f \int\int P(L_x, L_y) \frac{\lambda(L_x) + \lambda(L_y)}{2} dL_x dL_y} & 0 \\ 0 & 0 & \frac{\varepsilon_m(1-f) + f\varepsilon_i \int \mathrm{P}(L_z) \lambda(L_z) dL_z}{(1-f) + f \int \mathrm{P}(L_z) \lambda(L_z) dL_z} \end{pmatrix} . \text{(S3)}$$

The nanoparticles can also be aligned in three dimensions. If principal dimensions of the nanoparticles are not degenerated, the composite medium is biaxial and its effective dielectric tensor is given by:

$$[\boldsymbol{\varepsilon}_{\mathbf{eff}}] = \begin{pmatrix} \frac{\varepsilon_m(1-f) + f\varepsilon_i \int \mathrm{P}(L_x) \lambda(L_x) dL_x}{(1-f) + f \int \mathrm{P}(L_x) \lambda(L_x) dL_x} & 0 & 0 \\ 0 & \frac{\varepsilon_m(1-f) + f\varepsilon_i \int \mathrm{P}(L_y) \lambda(L_y) dL_y}{(1-f) + f \int \mathrm{P}(L_y) \lambda(L_y) dL_y} & 0 \\ 0 & 0 & \frac{\varepsilon_m(1-f) + f\varepsilon_i \int \mathrm{P}(L_z) \lambda(L_z) dL_z}{(1-f) + f \int \mathrm{P}(L_z) \lambda(L_z) dL_z} \end{pmatrix} . \text{(S4)}$$

The lower integration limit in equation (S1), (S3) and (S4) is zero while the upper one is determined from equation (S2) by considering the symmetry of nanoparticles.