Effects of Inhomogeneous Background to the Surface Plasmon Resonance Modes of Metal Nanoparticle Chains

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A fully-retarded point-dipole method is developed to obtain the dispersion relations and propagation loss for dipolar modes propagating along a chain of metal nanoparticles embedded in a multi-layered structure using layered media Green's functions (LMGF).

Previous experimental and theoretical studies clearly demonstrate the importance of radiation damping and retardation effects on the dispersion relation and propagation loss of metal nanoparticle chains [1, 2, 3, 4]. The theoretical models developed in [1] and [2] assume homogeneous backgrounds. [3] experimentally studies nanoparticles in an inhomogeneous background without using an appropriate theoretical model that incorporates the inhomogeneous background. This work addresses the need for such a theoretical model by extending the work done by Weber and Ford [1] to metal nanoparticles embedded in a multi-layered structure. This extended theoretical model is fully-retarded, includes the effects of multi-layered background, radiation damping, and shape dependence and finite size of the nanoparticles.

In the theoretical model, the point dipoles are assumed to be located at the center of the disks and the effect of inhomogeneous background is included using LMGF, which are computed by solving reflection coefficients of Sommerfeld integrals recursively [5]. The experimental values for the optical constants of gold are used [6], rather than the Drude model to avoid the concerns about the selection of the appropriate values for plasmon and relaxation frequencies. Modified Long Wavelength Approximation [4] is also employed to account for the shift in plasmon frequency and polarizability due to the finite size of nanoparticles.

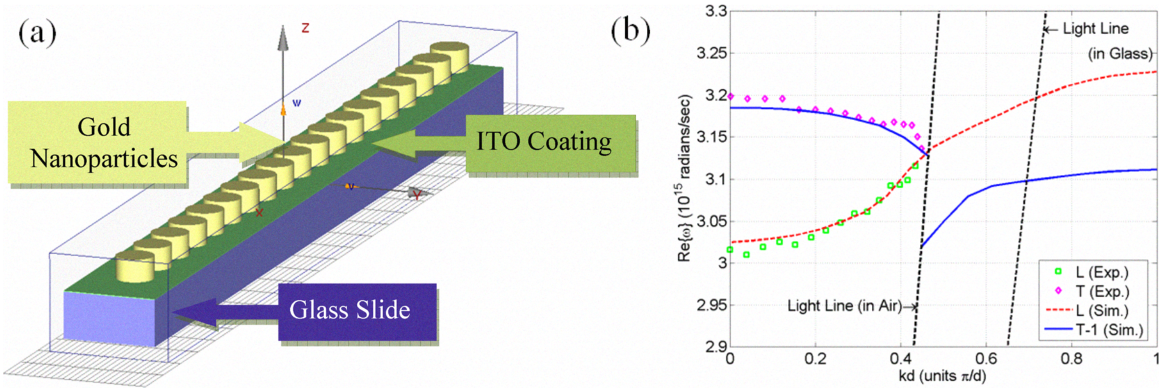

Fig. 1 (a) Gold nanoparticle chain on an ITO-coated glass slide. (b) A comparison of dispersion curves for transverse and longitudinal excitations obtained experimentally (green and magenta dots) via transmission spectroscopy [3] and with the developed method (red and blue lines). Dashed black lines depict the light line in air and glass.

In [3], gold nanoparticle arrays are fabricated by e-beam lithography on an indium tin oxide ITO-coated glass slide, shown as Fig. 1(a). The gold disks are 92 nm in diameter and 55 nm thick, and center-to-center distances of 140 nm along the length of the chain. The refractive indices of glass, ITO, and air are assumed to be 1.517, 1.45, and 1, respectively. The thickness of ITO layer is 30 nm. Fig.1 (b) shows a perfect agreement between the experimental [3] and theoretical results for the first transverse (T-1) and longitudinal (L) dispersion curves. Note that the theoretical results provided in [3] significantly differ from the theoretical results obtained with the developed method, since the former assumes a homogeneous background. The use of LMGF also clearly reveals the existence of the second transverse mode and gives the full picture for the propagation loss, both of which are not shown here for the sake of brevity.

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