Two Dimensional Active CNP Metafilms

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Recent work on resonant electrically small CNPs, formed as a set of concentric spherical shells has demonstrated that they have highly tunable polarizabilities. The sizes of these CNPs at optical frequencies are on the order of tens of nano-meters, making them attractive candidates for use as inclusions in potential realizations of optical metamaterials. Current nano-fabrication capabilities encompass the successful synthesis of CNPs, and many of their optical properties have verified experimentally. To achieve resonant tuning of these spherical CNPs at optical frequencies, one must incorporate plasmonic materials, such as metals, into the shells. Unfortunately, the polarizabilities of these plasmonic-based structures remain dominated by high absorption losses at optical frequencies. In an attempt to counter these intrinsic losses, active media in multi-layered spherical plasmonic nano-shelled particles has also been investigated. The optical properties of a highly resonant, nanometer-sized, *active* dielectric sphere that is coated with a plasmonic shell and its use as an inclusion to realize optical metamaterials(MTMs) will be reported here.

Many of the most notable successes to date in realizing optical MTMs include achieving negative index materials (NIMs). Several of the largest effective negative index values in MTMs near and at optical wavelengths have been experimentally demonstrated using two dimensional planar arrays of coupled plasmonic particles and strips such as gold nano-rod configurations, gold layered fishnet geometries, and metallic split ring resonator arrays. Although effective material parameters of these configurations have been reported, it must be emphasized that strictly speaking a planar mono-layer array of these inclusions form a ***film*** and not a bulk material. To address the losses inherent in the plasmonic materials that are used in these optical metafilms an example of an optical metafilm designed with these active CNP inclusions is investigated.

Simulation results for a two dimensional optical metamaterial film that is derived from these lossless active CNP inclusions will be presented. The optical properties of this metafilm operating in the visible range of the spectrum between 400nm and 700nm are explored. The CNP particle used in these simulations consists of a plasmonic shell made of silver with inner radius R_1=8nm, and outer radius R_2=10nm that surrounds and active dielectric core, where the core permittivity in the absence of gain takes on the value for silica, SiO_2, $\varepsilon_1 = 2.05\ \varepsilon_0$. With this material and geometrical configuration the resonance position of this CNP occurs at a free space wavelength of $\lambda_{res} = 491.2nm$. The optical properties of this CNP metafilm will be derived following the generalized sheet transition conditions (GSTCs) for a planar array of scatterers. Several novel properties of this metafilm will be presented such as gain tunable transmission and reflection.