

Metal Nanocluster Metamaterial

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Metamaterial, an artificial material that can exhibit a negative refractive index has been studied extensively for its potential applications such as sub-wavelength image and cloaking. Negative index materials made by various metallic resonators have been demonstrated from microwave to optical frequency region. We studied a new metamaterial architecture based on metal nanoparticles and clusters of nanoparticles which we referred them as nanoclusters. The nanoparticles can exhibit a resonance in the effective permittivity when they are placed close to each other. Furthermore, a negative effective permeability is found when the nanoparticles are assembled to finite size nanoclusters. The magnetic response of this medium comes from the magnetic Mie resonance of each nanocluster and it can occur at visible light region when silver or gold nanoparticles are used. With these nanocluster based magnetic metamaterials, we designed composite media composed of nanoclusters and other metal components such as metal film and nanoshells and demonstrated their negative refractive indices by numerical simulations.

To realize the nanocluster based metamaterials, we developed a bottom-up fabrication method which is based on colloidal self-assembly of gold nanoparticles on a patterned template. We first synthesized solution based gold nanoparticles and prepared a 2D square pattern on photoresist by interference lithography. Then the gold nanoparticles are self-assembled on the patterned template and formed nanocluster arrays according to the predefined patterns. Samples with different cluster size and density are fabricated and their optical properties are studied by spectroscopy. Magnetic responses were shown by comparing the measured spectrum with the numerical simulations.

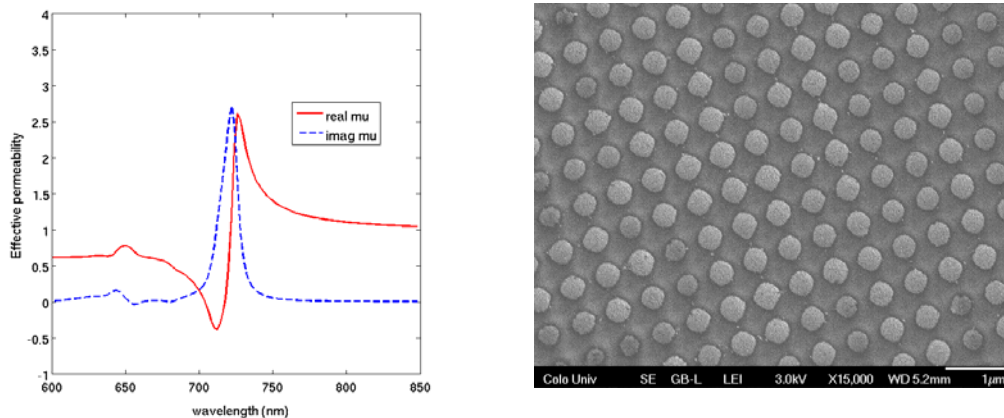


Figure: (left) calculated effective permeability of a square array of cylinder shape nanoclusters. (right) SEM picture of self-assembled gold nanoparticles into a square array of nanoclusters.

- [1] W. Park and Q. Wu, "Negative Effective Permeability in Metal Cluster Photonic Crystal," *Solid State Commun.*, 146, 221 (2008)
- [2] Y. Xia, Y. Yin, Y. Lu, and J. McLellan, "Template-Assisted Self-Assembly of Spherical Colloids into Complex and Controllable Structures," *Adv. Funct. Mater.*, 13, 907-918 (2003)