Realization of 2D and 3D All-Dielectric Optical Metamaterials

Yuanmu Yang, Parikshit Moitra, Jason Valentine
Mechanical Engineering Department, Vanderbilt University, Nashville, TN 37235
jason.g.valentine@vanderbilt.edu

Ivan I. Kravchenko, Dayrl P. Briggs
Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

Absorption loss continues to be one of the primary impediments to the application of metal based metamaterials at optical frequencies. Dielectric metamaterials offer one potential solution to this issue by eliminating Ohmic loss, allowing highly transparent metamaterials while also preserving the freedom to freely engineer the optical properties. In this talk, I will discuss our recent efforts to develop purely dielectric metamaterials which exhibit low absorption loss at optical frequencies. These metamaterials are formed from silicon-based unit cells that exhibit both electric and magnetic Mie resonances, allowing us to manipulate the optical properties of the composite.

I will outline the implementation of both 2D and 3D metamaterial designs. I will first discuss how 2D metamaterials, or metasurfaces, can be used to tailor the wavefront of light at a surface for applications such as lensing, complex beam formation, and polarization control (Figure 1a). I will also discuss how we have used self-assembly to realize large-area dielectric metamaterials (Figure 1b). Importantly, these metamaterials are relatively insensitive to disorder in the lattice, relaxing the required uniformity in the pattern.

Lastly, I will also discuss how we have used 3D dielectric metamaterials for achieving an impedance matched near-zero refractive index at optical frequencies (Figure 1c). The use of dielectrics greatly simplifies the unit cell geometry of the metamaterial and allows reactive ion etching to be used for thick multilayer fabrication. Such materials can be applied for a variety of applications including directional emitters, low threshold lasers, and boosting the efficiency of non-linear conversion processes.

All of the metamaterials that will be presented were fabricated at the Center for Nanophase Materials Science at Oak Ridge National Laboratory, a DOE Office of Science User Facility.

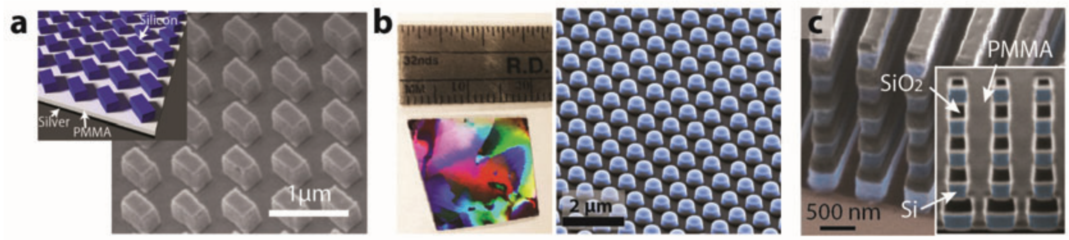

Figure 1: (a) Metasurface for controlling the wavefront. (b) Large-area metasurface possessing near-unity reflection. (c) 3D zero-index metamaterial formed from silicon rods.