Widely Tunable Semiconductor Meta-atoms for Science and Tech ology: Towards Programmable Optics and Metasurfaces.

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Antenna resonators are at the heart of modern radio and microwave frequency communications technologies. Antenna concepts have been recently extended to the infrared and optical frequency domains, greatly enhancing light-matter interactions in a variety of nanophotonic systems (e.g. solar cells, detectors, molecular sensors, light emitters, optical tweezers) and launching the field of optical metamaterials and their 2D equivalent – metasurfaces. Thus far, metals have played a pivotal role for constructing single 'meta-atoms' – the individual constituents of metamaterials, due to their ability to support surface plasmon oscillations. However, metals suffer from high ohmic losses in the visible to infrared spectral ranges and are incompatible with CMOS fabrication. Growing interest has recently shifted to high-index dielectrics as means to overcome metallic losses while facilitating light manipulation at subwavelength scales. In this talk, I discuss the rich optical response of semiconductor and dielectric subwavelength particles arising from multipolar Mie resonances. I demonstrate bottom-up techniques for fabricating nanoparticles with controlled size and shape and the ability to engineer their multipolar resonances across the visible to mid-infrared spectral ranges. I show how the wealth of electric and magnetic resonances in these nanoparticles can be exploited to manipulate light and observe novel optical phenomena. Next, I experimentally and theoretically discuss tunability in metamaterials. I demonstrate two tuning mechanisms for reconfigurable meta-atoms in the infrared. First, by modulating free carrier densities in semiconductor meta-atoms; and secondly by exploiting materials with extremely large thermo-optic effect such as the lead chalcogenide family. I conclude by demonstrating that when combined into metasurface arrays, these effects are further enhanced leading to ultra-wide tunability with relaxed external excitation.