Inside Out: Visualizing chemical transformations and light-matter interactions with nanometer-scale resolution

In Pixar's *Inside Out*, Joy proclaims, "Do you ever look at someone and wonder, what's going on inside?" My group asks the same question about nanomaterials whose function plays a critical role in energy and biologically-relevant processes. This presentation will describe new techniques that enable *in situ* visualization of chemical transformations and light-matter interactions with nanometer-scale resolution. We focus in particular on i) ion-induced phase transitions; ii) optical forces on enantiomers; and iii) nanomechanical forces using unique electron, atomic, and optical microscopies. First, we explore nanomaterial phase transitions induced by solute intercalation, to understand and improve materials for energy storage applications. As a model system, we investigate hydrogen intercalation in palladium nanocrystals. Using environmental electron microscopy and spectroscopy, we monitor this reaction with sub-2-nm spatial resolution and millisecond time resolution. Particles of different sizes, shapes, and crystallinities exhibit distinct thermodynamic and kinetic properties, highlighting several important design principles for next-generation energy storage devices. Then, we investigate optical tweezers that enable selective optical trapping of nanoscale enantiomers, with the ultimate goal of improving pharmaceutical and agrochemical efficacy. These tweezers are based on plasmonic apertures that, when illuminated with circularly polarized light, result in distinct forces on enantiomers. In particular, one enantiomer is repelled from the tweezer while the other is attracted. Using atomic force microcopy, we map such chiral optical forces with pico-Newton force sensitivity and 2 nm lateral spatial resolution, showing distinct force distributions in all three dimensions for each enantiomer. Finally, we present new nanomaterials for efficient and force-sensitive upconversion. These optical force probes exhibit reversible changes in their emitted color with applied nano- to micro-Newton forces. We show how these nanoparticles provide a platform for understanding intra-cellular mechanical signaling *in vivo*, using *C. elegans* as a model organism.

Bio:
Jennifer Dionne is an associate professor of Materials Science and Engineering at Stanford. Jen received her Ph. D. in Applied Physics at the California Institute of Technology, advised by Harry Atwater, and B.S. degrees in Physics and Systems & Electrical Engineering from Washington University in St. Louis. Prior to joining Stanford, she served as a postdoctoral researcher in Chemistry at Berkeley, advised by Paul Alivisatos. Jen's research develops new nano and optical materials for applications ranging from high-efficiency energy conversion and storage to bioimaging and manipulation. This research has led to demonstration of negative refraction at visible wavelengths, design of optical tweezers for nano-specimen trapping, demonstration of a metamaterial fluid, and synthesis of high-efficiency and active upconverting materials. Most recently, Jen has developed *in situ* techniques to visualize chemical transformations and light-matter interactions with nanometer-scale spatial resolution. She is the recipient of the Adolph Lomb Medal, Sloan Foundation Fellowship, the Presidential Early Career Award for Scientists and Engineers, and the inaugural Kavli Early Career Lectureship in Nanoscience, and was recently featured on Oprah's list of "50 Things that will make you say 'Wow'!". She is also a recipient of the NSF CAREER award, AFOSR Young Investigator Award, and TR-35. When not in the lab, Jen enjoys teaching three classes ("Materials Chemistry", "Optoelectronics", and "Science of the Impossible"), exploring the intersection of art and science, and cycling the latest century.