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Tunable and responsive plasmonic properties of metal oxide nanocrystals

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Degenerately doped metal oxide semiconductors, like ITO, exhibit plasmonic resonance at near and mid-infrared wavelengths tunable by varying their composition. Nanocrystals of many such materials have now been synthesized and applications are emerging that leverage the responsiveness of their localized surface plasmon resonance (LSPR) to electronic charging and discharging. For example, electrochromic glass that can dynamically control heat loads in buildings is under development. In biological systems, plasmonic oxide nanocrystals can act as remote sensors, where changes in their optical absorption indicates biochemical redox has occurred. Nonetheless, significant fundamental questions remain open regarding the nature of the infrared optical response in these doped oxides. Dopant impurities influence the optoelectronic properties beyond simply donating free carriers. For example, the distribution of Sn in ITO was found to dramatically influence the line shape of the LSPR and the effective electron mobility. In addition, by post-synthetically modifying carrier concentrations (through photodoping or electrochemical doping), we have observed that aliovalent doping and electronic doping each modify LSPR spectra, providing access to a broad range of tunable optical properties. Heterogeneous broadening, uncovered by single nanocrystal spectroscopy, also contributes to ensemble line shapes, complicating direct interpretation of LSPR spectra. Finally, the possibility of electric field enhancement by metal oxide LSPRs is critically examined to suggest what future applications might be on the horizon.