

Mixed Electron and Lithium Ion Conduction in Nanocrystal-Polymer Composites for Electrochromic Applications

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Composites of polymers and colloidal nanocrystals provide an attractive approach for fabricating electrochemical devices. Nanocrystals and polymers are amenable to solution processing, which allows for intimate mixing and interfacial interactions, as well as easily adaptable and potentially inexpensive device fabrication. Nanocomposite properties can easily be manipulated by changing the properties of its constituents and, for a given composition, can also be significantly altered by controlling the morphology and self-assembly of the nanocrystals within the polymer matrix.

We are studying a particularly interesting embodiment of this idea by dispersing colloidal tin-doped indium oxide (ITO) nanocrystals in a polyethylene oxide (PEO) solid polymer electrolyte matrix. ITO-PEO nanocomposites exhibit mixed electronic and ionic conductivity; electrons are transported through the ITO filler phase, while lithium ions are transported through the PEO matrix phase. The ionic and electronic conductivities are coupled and can be controlled by changing the nanocrystal loading fraction and the morphology and inter-particle distances of the nanocrystal domain within the polymer matrix.

Furthermore, the ITO phase is optically active, and exhibits electrochromic properties based on electrochemical modulation of the nanocrystals' localized surface plasmon resonance frequency. The electrochromic properties of the nanocomposite are highly dependent on the electronic and ionic conductivity, as well as morphology and polymer-nanocrystal and nanocrystal-nanocrystal interfaces.

ITO nanocrystals were prepared by colloidal synthetic methods and the nanocrystal surface chemistry was modified to achieve favorable nanocrystal-polymer interactions. Homogeneous solutions containing PEO, ITO nanocrystals, and lithium salt were then prepared and cast into nanocomposite films. The ITO nanocrystals form a complete, electronically connected electrode within the polymer electrolyte matrix, and controlled partial phase separation can be used to manipulate the morphology of the ITO phase. The result is a fully room-temperature-solution-processed, functional polymer-nanocrystal composite thin film with coupled electronic, ionic, and optical properties.

Electrochemical impedance spectroscopy, DC measurements, and spectroelectrochemical techniques were used to characterize the mixed conductivity, electronic conductivity, and the electrochromic properties of the nanocomposites, respectively. We will discuss the relationship of nanocomposite morphology and ITO volume fraction to conductivity and electrochromic properties.

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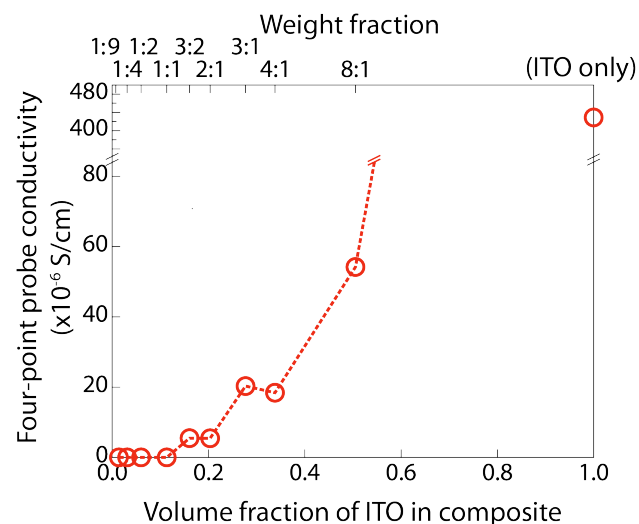


Figure 1: Relationship between ITO nanocrystal volume fraction and DC conductivity of ITO-PEO nanocomposites.

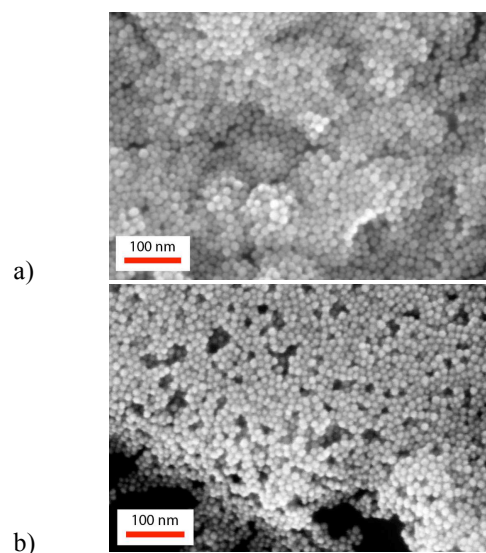


Figure 2: Controlled phase separation can be used to manipulate nanocomposite morphology. a) SEM micrograph of homogeneous nanocomposite with no phase separation b) SEM micrograph of nanocomposite with a small amount of induced controlled phase separation