Enhanced electrical conductivity of carbon-based nanoparticles in ionic liquid electrolytes

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Ionic liquids (ILs) are attractive electrolytes because of their good chemical and thermal stability, non-volatility, and ability to act as a solvent and source of redox couple (solvent-free electrolyte).(1-3) The addition of nanoparticles to IL electrolytes could further improve the efficiency of electrochemical devices. For example, the addition of carbon-based nanoparticles (CNPs) to a solvent-free IL showed an efficiency improvement of 300% in dye-sensitive solar cells. (2, 4) In this report, we show that CNPs increase significantly the electrical conductivity of neat ILs. As shown in Figure 1, we tested 3 different imidazolium-based ILs and carbon nanotubes (CNTs). The conductivity increase can be as high as 3 fold in 1-propyl-3-methylimidazolium and 1-butyl-3-methylimidazolium.

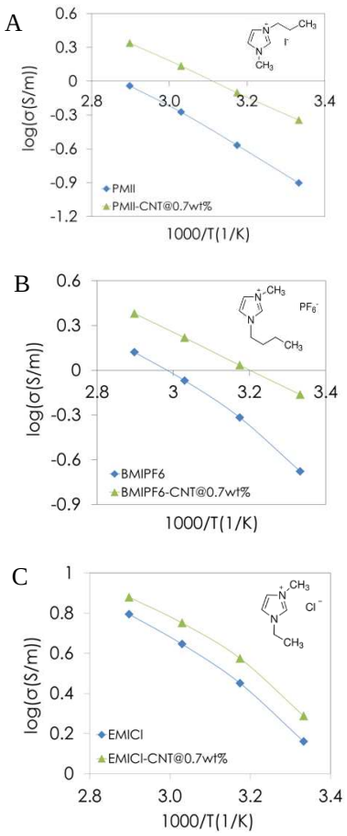
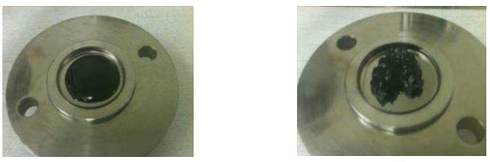


Figure 1. Temperature dependence of the electrical conductivity of solvent-free ILs before (blue curves) and after addition of CNTs (green curves). CNTs were multi-wall with an estimated diameter of 50 nm, length of 10-20 μm and intrinsic conductivity of 100 S/cm. The amount of CNTs added was 0.7wt%. A: 1-propyl-3-methylimidazolium iodide (PMII). B: 1-butyl-3-methylimidazolium hexafluorophosphate ($BMIPF_6$). C: 1-ethyl-3-methylimidazolium chloride (EMICl). Conductivity measurements were estimated from electrochemical impedance spectroscopy. The measurements were calibrated from conductivity values of 0.1 M of NaCl.

The main objective of this work is to understand the physicochemical properties in CNP/IL mixtures that enhance their electrical conductivity. The possibilities of breaking of ion pairs, percolation and the effect of surface charge of the nanoparticles are analyzed through a spectroscopy and electrochemical characterization. We also evaluate the dependence of electrical conductivity on other properties or material characteristics; such as, temperature, supporting electrolyte, redox couples and; shape, length and concentration of the CNPs.

The addition of CNPs above 1wt% in these imidazolium-based ILs leads to the formation of a gel and drop in conductivity, as shown in Figure 2. Herein, we study the structural changes, possible cation-π interactions or chemical bond formation through NMR and XPS spectroscopy.



A B

Figure 2. Phase change after addition of CNTs (>1wt%) on neat ILs. A: PMII/CNT 0.2 wt%. B: PMII/MWCNT 1.5 wt%

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