Tufts

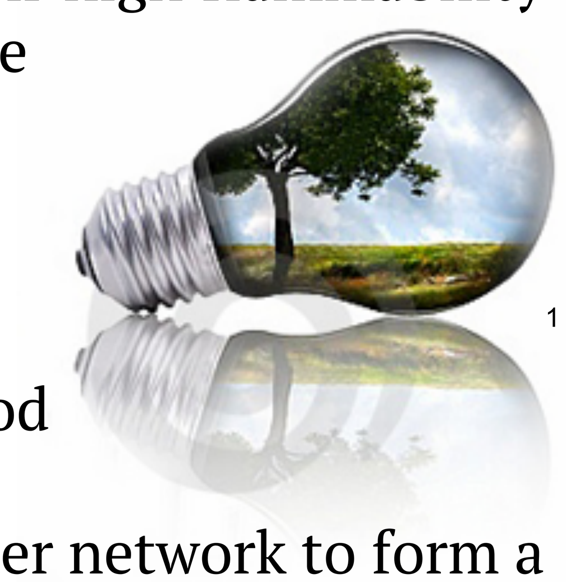
Zwitterion Effect in High-Conductivity Ionogels Of Varying Polymer Composition

Luis Rebollar
Chemical and Biological Engineering - Tufts University

GENE LAB

Introduction

The most efficient means of storing and transporting chemical energy is realized via fuel cells, batteries, and supercapacitors. Conventional electrolytes used in energy storage devices are organic-solvent-based salt solutions that present safety concerns due to their high flammability and liquid nature. Ionic liquids (Ils) have been attracting attention as potential replacements for organic electrolytes due to their outstanding safety properties (i.e. nonvolatility, nonflammability), while still having good stability and high ionic conductivity.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Immobilizing an ionic liquid in a polymer network to form a leak-proof ionic liquid gel (ionogel) is additionally recognized as a further gain in electrolyte safety. However, retaining the pure liquid's ionic conductivity in the gel network remains a challenge. A solid-state ionogel with high ionic conductivity would therefore be a remarkable advance in the field of energy storage devices and energy sustainability.

In this work, several zwitterion (ZI) containing ionogels were made with varying polymer composition with hopes to increase their ionic conductivities. Their nature and performance were further evaluated across three unique ionic liquids.

Objectives

- Investigate the potential for ZI copolymer-supported ionogel electrolytes to exhibit both high ionic conductivity and tunable elastic moduli
- Explore the "zwitterion effect" in diverse chemical environments by integrating the polymer scaffold into three unique ionic liquids
- Side objective: find an alternative experimental set-up to measure ionic conductivity with greater percision

Images

[1] http://goeeg.com/wp-content/uploads/2014/02/green-energy-lightbulb.png
[2-6] Taken personally.
[7] Lind, F.; Rebollar, L.; Bengani, P.; Panzer, M.J.; *Unpublished Manuscript.* **2016**

Experimental Methods

Several ZI-containing ionogels with different ionic liquids and varying polymer compositions were fabricated via UV-initiated polymerization. Precursor solutions were prepared and polymerized inside a nitrogen-filled glove box. The ionic conductivities were measured using a gelboard.


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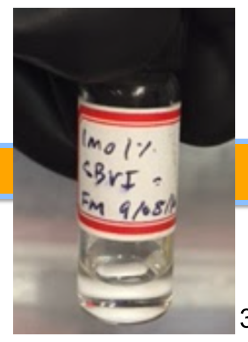
20 mol % Polymer, 1-7 mol % SBVI

80 mol % Ionic Liquid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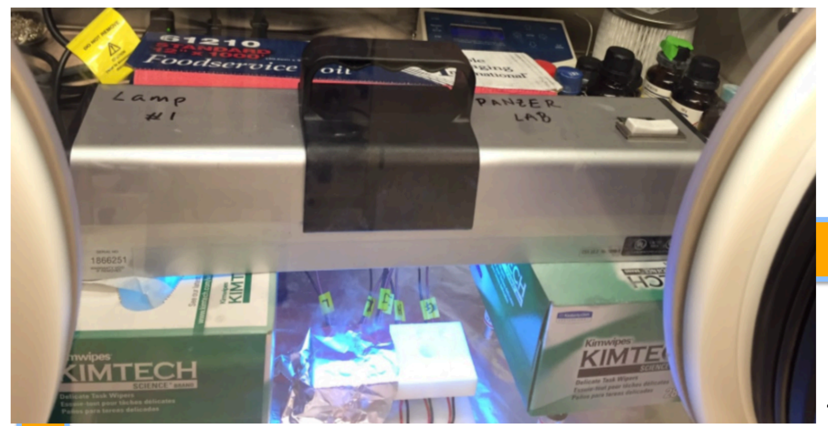
1 mol % SBVI precursor solution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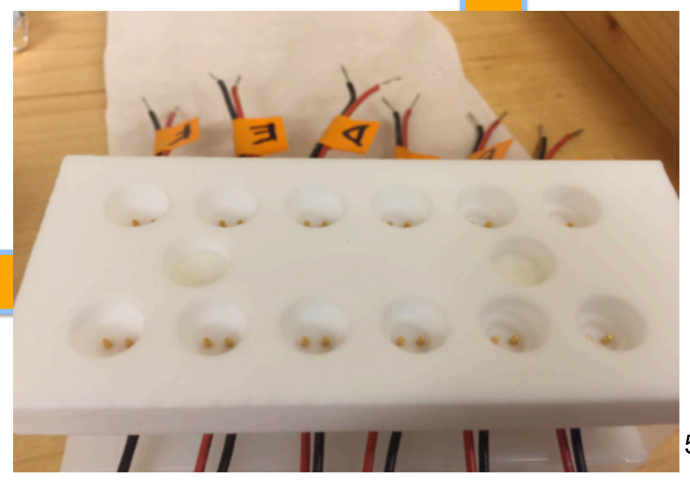
UV free radical polymerization stage. Precursors are exposed to UV radiation for 7 minutes.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Gelboard used to measure conductivity. Precursor solution is injected into each well containing gold-pin electrodes.


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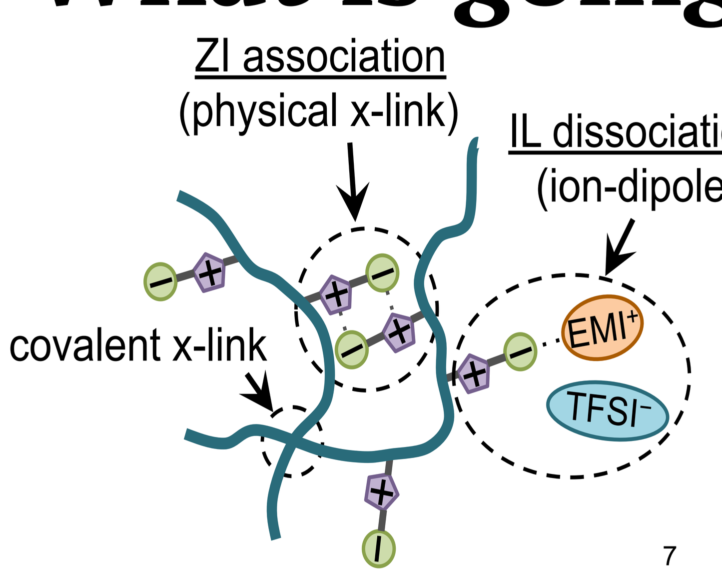
1 mol % | 4 mol % | 7 mol%

SBVI in EMI TFSI

The result: self-standing ionogels with varying zwitterion content and good ionic conductivity. A macroscopically observable increase in ionogel robustness can be appreciated as zwitterion content is increased.

What is going on inside?



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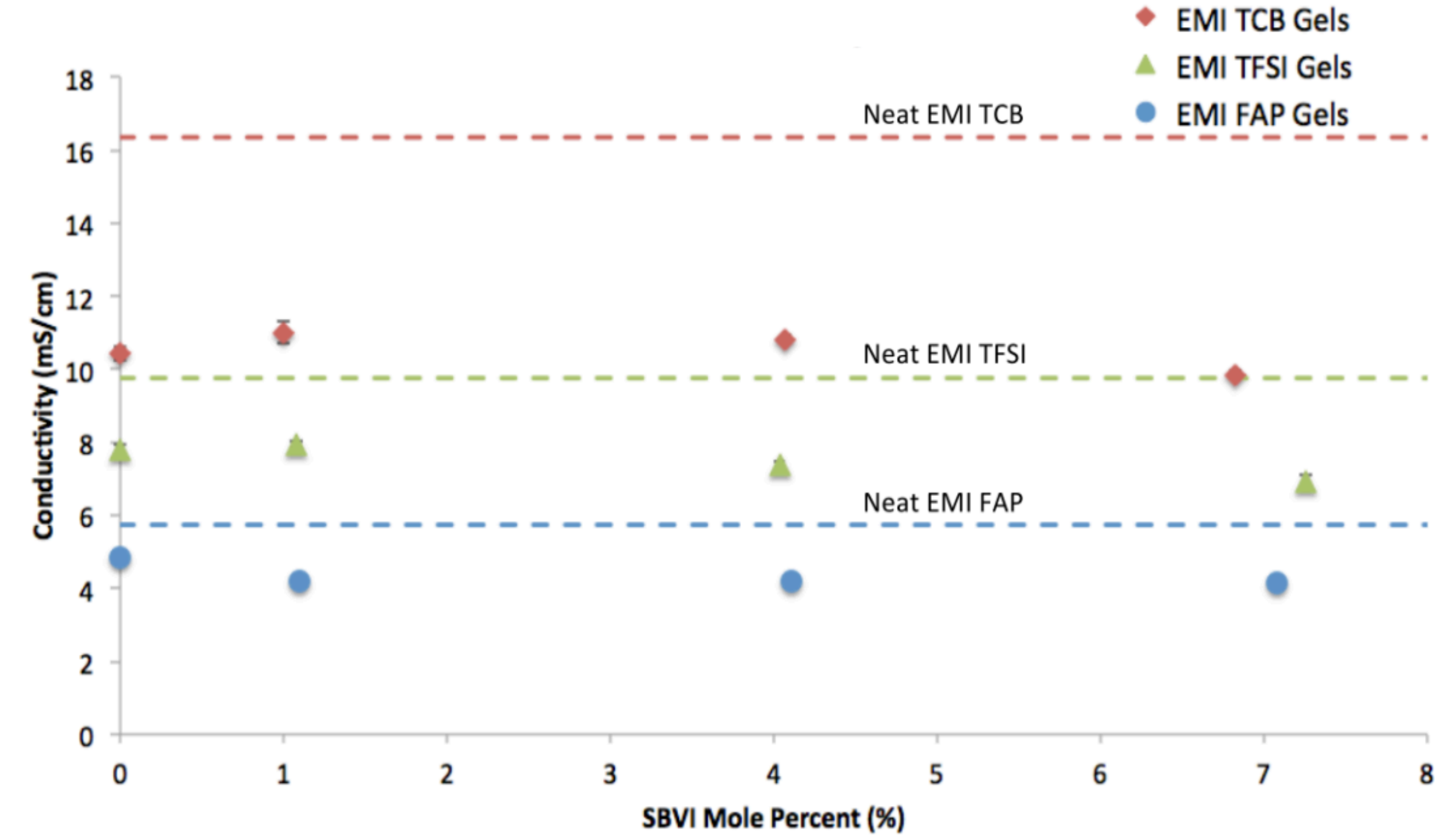
Schematic showing current understanding of the cross-links present in the ionogels, as well as the attractive ion-dipole interaction between the ZI and IL.

The dipole moments from the ZI serves two functions:

1) Acts as a physical cross-link (x-link) in the polymer backbone, leading to an increase in gel robustness
2) Creates a coulombic interactions, helping to dissociate ions and promote higher ionic conductivity.

Results

Ionic Conductivity of SBVI Ionogels of Varying Polymer Composition in Different Ionic Liquids



Conclusions

ZI-containing ionogels demonstrated high and nearly constant room-temperature ionic conductivity, *even though* ionogel robustness increased at a macroscopically observable level. The ability of the gels to increase their elastic moduli without experiencing a drop in their ionic conductivities is a *new* finding, and is strictly achieved by the unique dipole interactions introduced by the ZI. This outcome may introduce ways to successfully exploit the ionic liquid's remarkable properties for making safe, solid-state energy storage devices.

Ongoing and Future Work

- Quantify ionogel robustness by measuring elastic moduli
- Integrate alternative zwitterions into polymer scaffold to explore the effect of the zwitterions' dipole moment on observed results
- Verify that ionogel electrochemical and thermal stability remains unaffected

Acknowledgements

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