Polymer-Ionic Fluid Composites: Membranes of the Future

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INTRODUCTION

West Virginia native, Valerie Ives, is a Senior at the University of Southern California. She is studying Chemical Engineering with an emphasis in nanotechnology. Valerie's daily schedule is far from monotonous. She balances working at the USC Credit Union, being captain of the club softball team, leader in InterVarsity and gospel choir practice with being a full time student. As if she is not busy enough, she also is an undergraduate researcher in Dr. Malancha Gupta's composites lab. Her long time interest in math and chemistry sparked her interest in the new and upcoming chemical nanotechnology field. As a relatively new area of study, chemical nanotechnology focuses on the ability to control and alter any sort of chemical process at the molecular level. Essentially, the nanotechnology field deals with characterizing and designing on the nano scale. Thus, this new research has led to the development of cutting-edge new materials with unique structure, properties, and functions used in many industries ranging from semi conductors to pharmaceuticals.

As Valerie progressed in the chemical engineering curriculum, she found that she desired hands on experience in the field; therefore, she began researching the stability of polymer-ionic fluid

composites. She has been actively researching this subject with graduate student Robert Frank-Finney since August 2012. Being relatively new to the research world, Valerie admits that it is hard to familiarize herself with the complex background that is necessary to understand in order to grasp the concepts of the polymer units, however has learned a tremendous amount and gained invaluable experience.

BACKGROUND

The first step to understanding the complex topic of polymer-ionic fluid composites starts with extensive knowledge about ionic liquids. Ionic liquids are salts that are liquids at ambient temperatures and are largely made of ions and short-lived ion pairs. Ionic liquids are electrolytes, as they are electrically conducting fluids while ordinary liquids are predominantly made of electrically neutral molecules. They have many unique properties such as negligible volatility, non- flammability, thermal stability and high conductivity. Polymer-ionic liquid composites are solid materials that display many of the properties of the ionic liquids mentioned above. Thus, these polymer liquid composites are ideal substances for many applications as electrochemical devices. For example, they can be used as electrolytes in batteries because they evaporate at much lower rates than water, increasing battery life by drying slower.

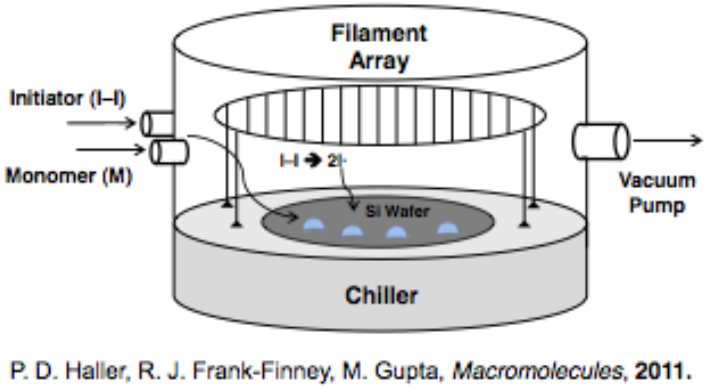

Figure 1: The iCVD process.

The Gupta lab focuses on functional polymer films and coatings, low cost microfluidic devices, and chemical vapor deposition. Their research is very unique because they utilize Initiated Chemical Vapor Deposition (iCVD). It is a very special process in which there is a vapor phase delivery of initiator species monomers into a vacuum chamber where they contact heated filaments. Thus, the initiator species breaks down into radicals, beginning the free-radical polymerization of the monomer on the surface. This iCVD process creates polymer-ionic liquid composites in one step. A simple schematic of the iCVD process is shown in Figure 1.

RESEARCH

Valerie specifically worked on testing the stability of these iCVD made polymer-ionic liquid composites. She concentrated on one type of composite consisting of poly(2-hydroxyethyl methacrylate) (PHEMA) and 1-ethyl-3-methyl imidazolium tetrafluoroborate (EMIM-BF4). Different samples of these PHEMA-EMIM-BF4 composites were fabricated at various reactor pressures and different stage temperatures. These samples were then observed under ambient conditions by Fourier transform infrared spectroscopy (FTIR) and stereoscope imaging.

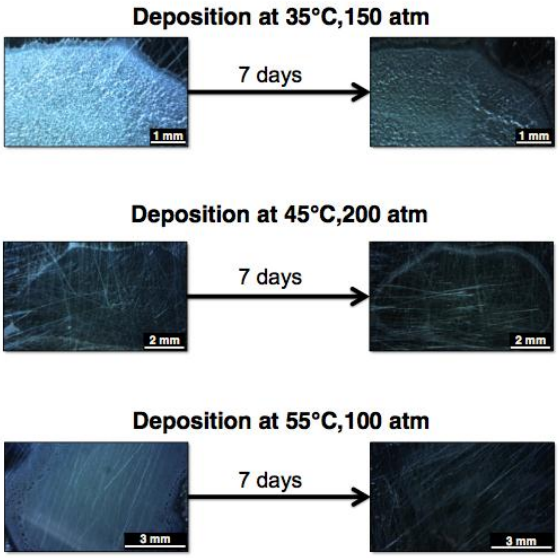

Figure 2: Stereoscope imaging photographs of the samples.

Stereoscope imaging is a very simple procedure where a small high powered camera photographs the surface of an object in great detail. By implementing the use of this technique, Valerie successfully studied the optical transparency. The results showed that the opacity of her samples steadily decreased over time. She hypothesized that this was due to the ionic liquid reaching equilibrium; therefore, the sample appearance was becoming more uniform throughout time as seen in Figure 2.

Stereoscope imaging can only be used to observe the physical appearances of the samples. Therefore, Valerie implemented Fourier transform infrared spectroscopy (FTIR) to further investigate. Early hypotheses included the change of an OH group in the composite and FTIR would indicate if the chemical composition of the composite changed over time. FTIR works by shining a beam of light containing multiple frequencies and measuring the amount of light absorbed by the sample. Then the beam of light is switched to a new composition of frequencies and the process is repeated numerous times. The absorption data is then mathematically analyzed by Fourier transformations into the resulting spectrum. Through the use of FTIR, Valerie showed that the chemical composition of all of the composite samples remained constant. This finding is shown in figure 3 below.

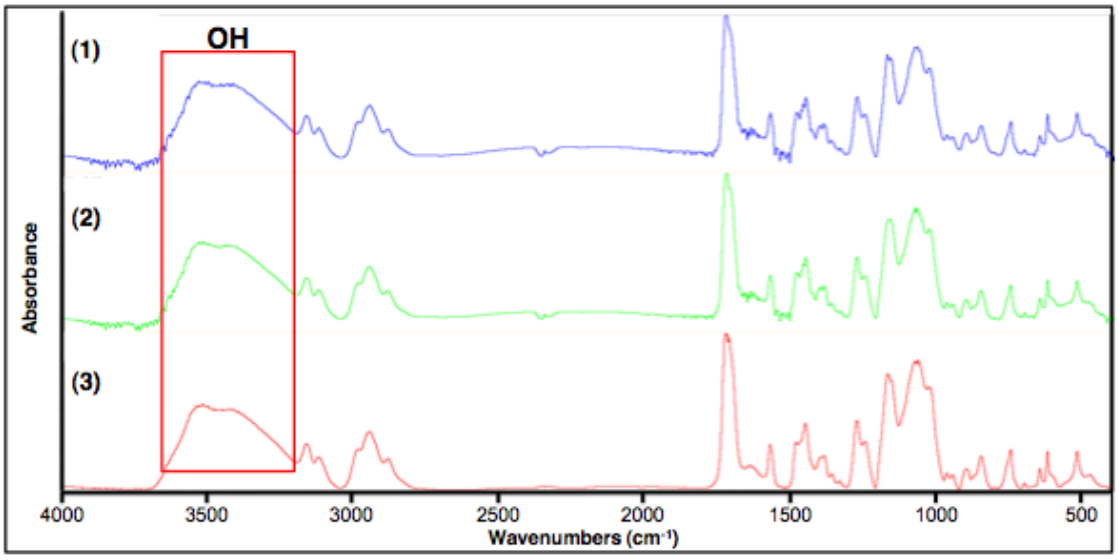

Figure 3: FTIR absorption spectra of aPHEMA-EMIM-BF4 composite with deposition at 45°C and 100 atm over a one week period.

The circled OH peak of sample does not shift suggesting that the hydrogen bonding within the composite does not change over time. Valerie explains that this was a significant finding because it shows that the chemical composition of the composite does not change over time even though the physical appearance of the composite readily changes.

CONCLUSION

Valerie's research shows that PHEMA-EMIM-BF4 composites synthesized from iCVD do maintain their chemical composition over long periods of time. This is very promising because it shows the stability of the composite. However, she says that more research needs to be done in order verify if the observed increased transparency of the samples does indeed mean the samples are just going to equilibrium. In the future, she plans to perform additional tests these polymer-ionic liquid composites and to characterize composites fabricated from other polymers and ionic liquids.

FUTURE IMPLICATIONS

The appeal of polymer-ionic liquid composites is that they provide applications in many areas that are seeking more environmentally friendly options. For example in the construction industry, harmful fiberglass insulations have been replaced with biorenewable polymer composite foams. Since these composites exist in a semi-solid state and contain the high ionic conductivity of an ionic liquid, they can be used as electrolyte membranes in fuel cells, acutators, electrolytes in batteries, and in many other chemical and optical applications.

Furthermore due to the ionic liquid properties, the composites can be recycled after use, cutting costs and saving the environment. Valerie is very excited about the technologically advanced possibilities these polymer-ionic composites can provide in the future. Even though Valerie's plans for the future do not directly lie within the chemical nanotechnology field, she realizes the importance of her work and the huge implications that this field of study can have upon the entire world. She hopes that as the revolutionary field of chemical nanotechnology unfolds, others will be motivated to seek hands on experience and become involved with nanotechnology research.