Nanoelectronics Undergraduate Research Fellowship (NURF)
2010 Project Summary

Student name: Thomas Tokoly
Faculty mentor name: Dr. Abhijit Biswas
Project Title: **Synthesis and Characterization of Multi-Component Nanocomposite Membranes for CO_2 Capture**

Problem / problem area

Capturing carbon dioxide (CO_2) emitted by heavy industry including power plants is critically important apart from reducing use of fossil fuels to mitigate climate change. Scientists and engineers are facing a major challenge to develop a low-cost and energy-efficient technology that helps capture CO_2 effectively to reduce the greenhouse gas concentrations in the atmosphere. Conventional technologies used to remove or capture CO_2 are not energy-efficient. This is due to the fact that existing technological processes such as the cryogenic distillation of air, condensation to remove condensable organic vapors from gas mixtures, and amine absorption require a gas-to-liquid phase change in the gas mixture, which adds a significant energy cost to the capture process. Polymer-based membranes could provide both an energy-efficient and cost effective approach for the capture of CO_2. It has been found that thin film nanocomposite membranes made of polyimide (PI) and fibrous polyethylene glycol (PEG) have the ability to filter out certain gases such as CO_2 from a gaseous mixture. The fibrous matrix is advantageous as the voids produced in the cooling of these fibrous membranes allow absorption of gases, increasing the solubility of the membrane. **Present research has focused on discovering ways to enhance the carbon dioxide capture function of the membranes.** By combining one of these polymer solutions with metal oxide nanoparticles such as silica, one can increase the CO_2 capture ability of the membrane. A number of other metal oxides have been used in an attempt to increase gas capture efficiency without sacrificing the other membrane functions.

Activities & Results

Our work focuses on developing membranes with original combinations of metal oxides to create a membrane with superior ability to capture CO_2. We used both PEG and PI to form our polymer matrices. For our metal oxides, we tried SiO_2, MgO, CuO, and ZrO_2. Our goal is to fabricate a membrane with increased CO_2 affinity beyond the capabilities of other membranes produced. Additionally, we aim to create a membrane with high thermal stability to withstand the high temperatures at which fossil fuel gases are emitted. These membranes have potential to make a way into a wide range of applications. **Because of the liquid nature of the nanoparticle solutions, one could load the composite into a bottle for use as a sprayable coating for large area applications.** Figure 1 schematically illustrates the synthesis route for the fabrication of nanocomposite membranes.

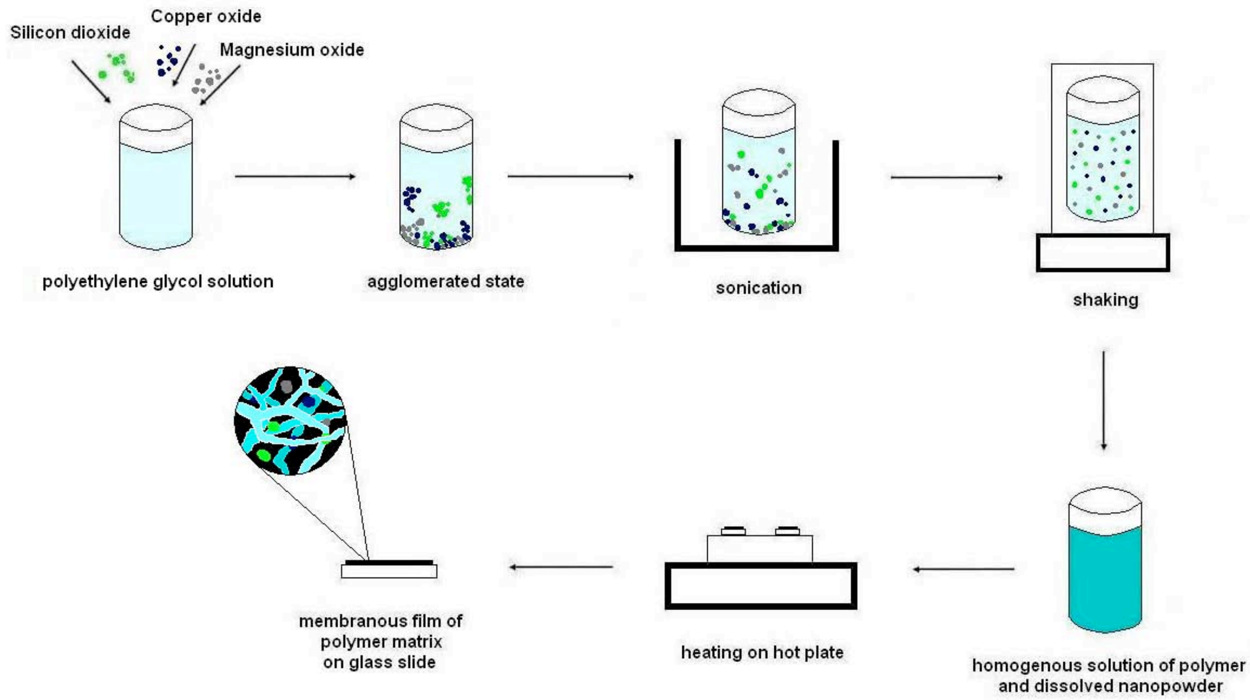

Figure 1. Schematic illustration of the synthesis procedure to create polymer nanocomposite membrane.

The simple synthesis procedure developed in this NURF project allows homogeneous mixing and dispersion of multiple inorganic and organic materials uniformly throughout the solution. A homogenous solution is desired so that the membrane's properties are constant all along its surface. Even with more complex membranes containing various nanoparticles, this homogeneity is easily produced using the simple process pictured above. The method allows developing membranes in both solid-state as well as solution forms. This provides an added advantage of coating various surfaces using liquid sprayable membrane materials for large-area applications.

Figure 2 shows SEM images along with the corresponding EDX data of the control sample (PEG) and nanocomposite membranes consisting of PEG/SiO_2 and PEG/SiO_2+CuO+MgO combinations. The SEM images show fibrous-type networks for all three samples. Networks of high-density carbon fibers offer excellent mechanical properties, high surface area, large pore volumes, high absorption and permeability. The employed method allows us to generate fine fibers of diameter ~ 1 µm (Figure 2).

The EDX data show elemental profiles of the three samples. The embedded tables show elemental compositional percentages (weight and atomic) of pure polymer (PEG) and the two membrane composite samples (Figure 2 a, b and c).

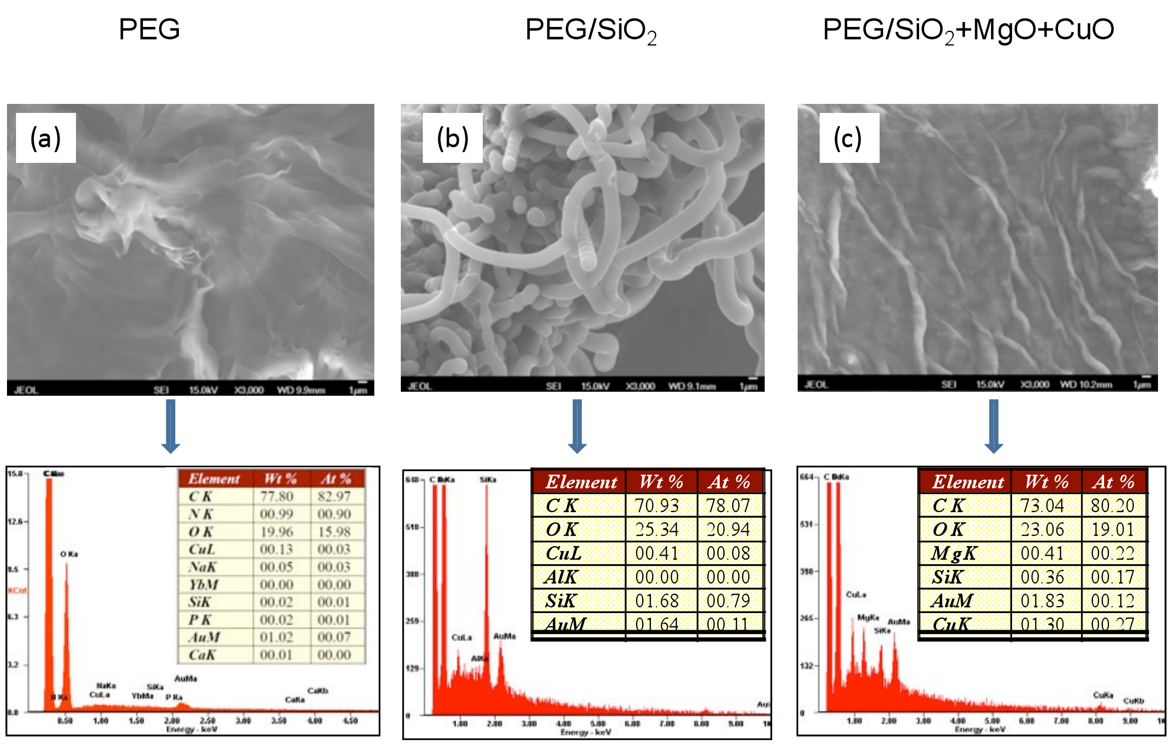

Figure 2. SEM images of three different types of PEG samples analyzed. SEM micrograph (a) is a control sample of PEG, (b) is PEG plus concentrated SiO_2, and (c) is PEG with a combination of SiO_2, CuO, and MgO. All three samples developed the fibrous-type network necessary for functional membranes. The Au signal is due to the coating of samples.

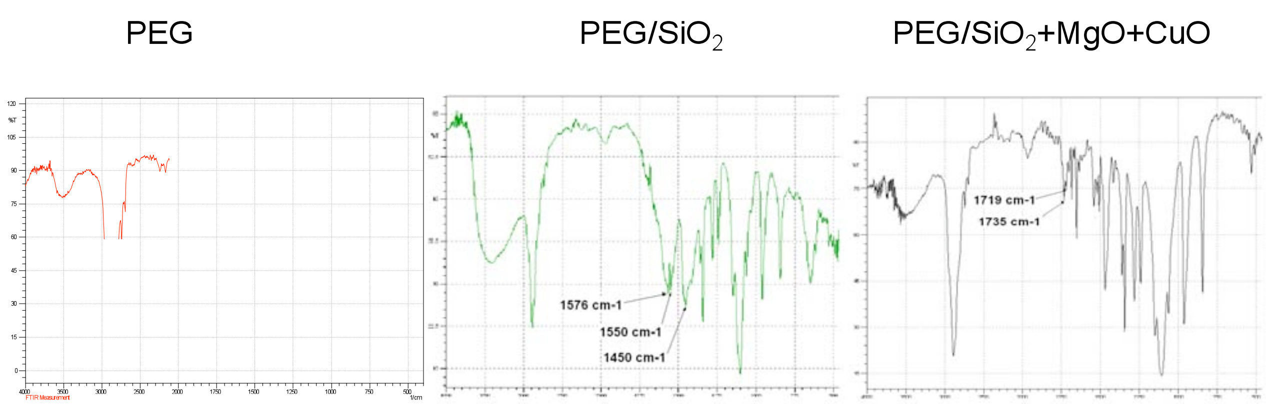

Figure 3: Fourier Transform Infrared (FTIR) spectra of PEG, PEG/SiO_2 and PEG/SiO_2+MgO+CuO samples. New peaks were observed at around 1735 cm^{-1}, 1719 cm^{-1}, 1576 cm^{-1}, 1550 cm^{-1} and 1450 cm^{-1}. This may be due to the reaction of CO_2 with the components. The new peaks are indicated above.

FTIR analysis of the membrane samples showed appearance of new peaks upon CO_2 purging at room temperature and at a pressure of 300 psi (Figure 3). The fibers provide the membranes with a large surface area, increasing opportunities for contact with gases to be absorbed as evidenced by the emergence of the new peaks. Future work will involve further IR analysis of the CO_2 absorption capabilities of the membranes. Also, other polymers such as the more temperature resistant polyimide (PI) will be studied in detail.

Acknowledgement

The NURF fellowship is gratefully acknowledged.

List of papers / posters

[1] A manuscript is under preparation for submission to an international journal.

[2] Posters to be presented at the ND Science and Engineering Summer Research Symposium - August 6, 2010, and MIND Annual Workshop, University of Notre Dame, August 10, 2010.

References

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