ND*nano* Undergraduate Research Fellowship (NURF)
2012 Project Summary

1) Student name: Michael Ashley
2) Faculty mentor name: Abhijit Biswas
3) Project title: Sprayable Nanocomposite Coatings for Large-Area Carbon Capture and Storage

4) Briefly describe any new skills you acquired during your summer research:

5) Please briefly share a practical application/end use of your research:
The greenhouse effect has established that emitting large amounts of carbon dioxide into the atmosphere produces a warming effect, potentially with devastating climate ramifications. The use of low-cost, easily fabricated materials for carbon dioxide capture and conversion into useful products could provide great help in maintaining our ecosystems given globally increasing carbon emissions.

Project summary:

As we enter a new era with changing views of the environment, cost-effective and easily available carbon capture technology will be necessary to curb global climate change. Because current carbon capture methods remain expensive and energy inefficient, this technology must be refined. Furthermore, carbon dioxide (CO_2) is a renewable feedstock which can serve both as a reagent in chemical synthesis and as an environmentally benign solvent system. At present, given the depleting petroleum feedstocks that we heavily depend on to produce industrially important chemicals, it is urgent that we develop novel uses for CO_2 in chemical synthesis and purification in order to curb global petroleum consumption. The major challenge, however, lies in activating CO_2 due to its thermodynamic stability. Thus, in order to achieve a sustainable energy future, a viable and low-cost technology needs to be developed that, in addition to capturing CO_2, would convert it into useful products or chemicals. Multi-component polymer-based nanocomposites could be the low-cost solution to carbon capture needs. The homogenous mixture of a polymer matrix with metal oxide nanoparticles has demonstrated its ability to bind CO_2 with high efficiency. Both the organic and inorganic components of this type of solution provide distinct benefits: the metal oxide catalysts offer high selectivity as well as mechanical and thermal stability, while the polymer phase offers flexibility and the possibility of a "sprayable" CO_2-absorbing membrane. In order for this technology to gain commercial popularity, several challenges must be overcome. Most importantly, we must be able to fabricate the nanocomposite on a large scale using low-cost materials. An additional challenge is the prospect of fabricating large quantities of nanocomposite while ensuring homogeneity and easy processability. Then, we must be able to spray this nanocomposite onto large areas of any surface.

My project goals were to design and synthesize multi-component nanocomposites using a drop-casting method. The samples contain combinations of MgO, CaO, CuO, SiO_2, TiO_2, RuO_2, and Fe_2O_3 nanoparticles dispersed in a polyethylene glycol (PEG) matrix. They were prepared by individually adding the metal oxides, using an alternating pattern of mechanical shaking and sonication in order to ensure homogeneity, a necessary quality for the functionality of the nanocomposites. The completed samples were analyzed for their CO_2 trapping capabilities, conversion into environmentally benign carbonate minerals on the surface of the nanoparticles, and the presence of methane, pure oxygen, methanol, and formic acid (for which data collection is still underway). Samples of different combinations of the metal oxide nanoparticles in PEG were produced; these samples range from simple to quite complex systems. Figure 1 shows a scanning electron microscope image of a complex sample, which contains 5 inorganic components. We have determined that the dispersion of catalytically active nanoparticles in a fibrous polymer matrix enhances CO_2 trapping and conversion, as shown by the presence of carbonate after reaction with CO_2. Additionally, a multicomponent system results in multifunctionality, combining the functions of each catalytically active component and improving capture properties when the nanocomposite membrane is exposed to a gas stream. Figure 2 shows a representative Fourier Transform Infrared (FTIR) image. It displays the post-reaction composition of our samples that includes carbonate.

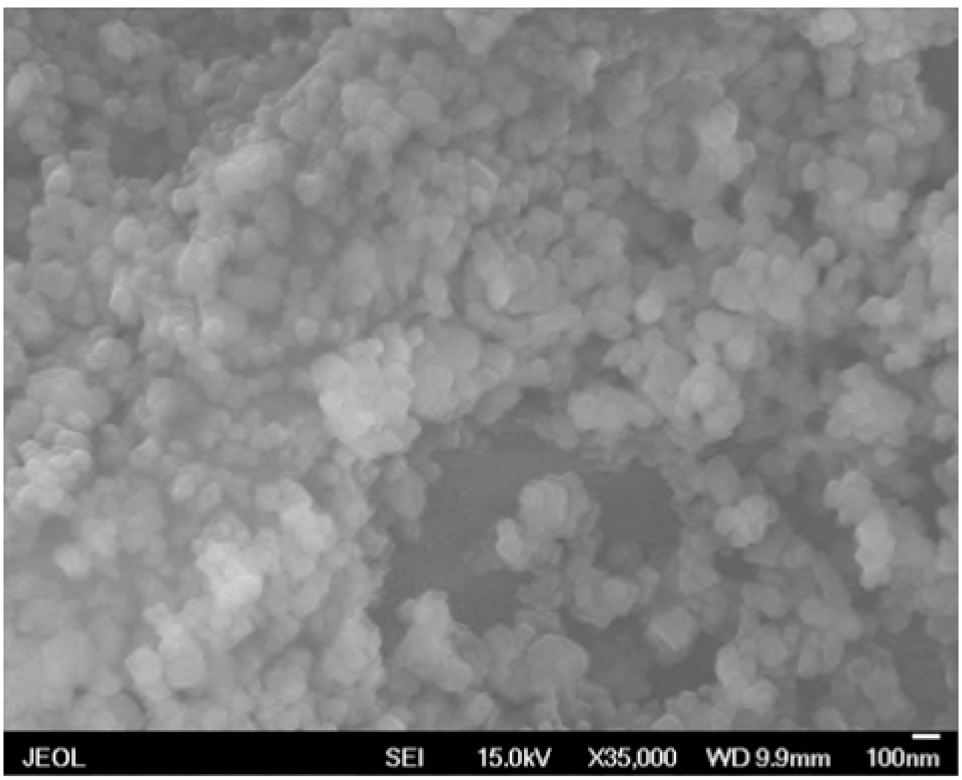

Figure 1: Scanning Electron Microscope (SEM) image of 5-component system (MgO, SiO_2, CuO, TiO_2, and Fe_2O_3 in PEG)

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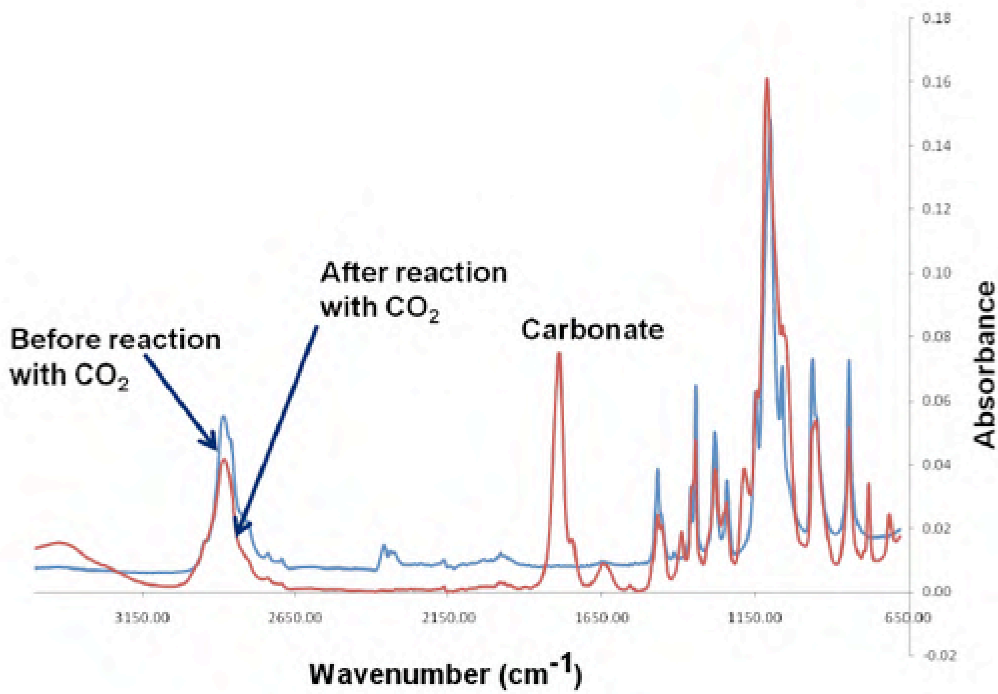

Figure 2: Representative FTIR data showing the presence of carbonate after reaction with CO_2

Publications (papers/posters/presentations):

[1] Michael Ashley, Enkeleda Dervishi, Alexandru Biris, Anindya Ghose, Mathew Labriola, Tao Wang and Abhijit Biswas, Solution Processable Polymer-Based Nanocomposite Coatings for Large-Area Carbon Capture and Conversion, to be published.

[2] Michael Ashley, **2011 SUMMER UNDERGRADUATE RESEARCH SYMPOSIUM**, August 5, 2011, Jordon Science Hall, Notre Dame, Poster Presented.

[3] Matthew Labriola, Michael Ashley, Ilker Bayer and Abhijit Biswas, Nanomedicine: Medical Applications of Nanotechnology, Vacuum Technology & Coating Magazine, Vol. 12, August, 2011.

[4] Michael Ashley, Matthew Labriola, Anindya Ghosh, Alexandru Biris, Ilker Bayer and Abhijit Biswas, Nanotech-Enabled Sustainable Energy: Green Nanoenergy, Vacuum Technology & Coating Magazine, Vol. 12, September, 2011.

[5] Michael Ashley, Charles Magiera, Punnamchandar Ramidi, Kerry Wilson, Anindya Ghosh, and Abhijit Biswas. Nanomaterials and Processes for Carbon Capture and Conversion into Useful By-Products for a Sustainable Energy Future, to be published.

[6] Michael Ashley, Punnamchandar Ramidi, Timothy Bontrager, Charles Magiera, Anindya Ghosh, Alexandru S. Biris, Ilker S. Bayer, and Abhijit Biswas. Engineered Nanocomposites for Capturing and Converting Carbon Dioxide into Useful Chemicals**.** MRS Proceedings 2012.