4bb Nanoporous and Nanostructured Materials for Biomimetic Sensor and Hydrogen Storage Applications

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My research interest is in the field of designing functional nanoporous and nanostructured materials using the science and technology of creating, manipulating and assembling materials at the nanoscopic level (1-100 nm). The goal is to develop a new class of advanced nanoporous materials for biomimetic sensor and hydrogen storage applications. My Ph.D dissertation was on designing nanoporous thermosetting polymers for selective-permeation membranes. During this time, I developed a novel synthesis technique based on a miscible system called the reactive encapsulation of a solvent (RES) technique. This technique unlike the conventional methods that are based on micro/macroscopic phase separation provided a facile way of tailoring the nanoporous morphology in polymeric systems. The RES technique along-with the chemical grafting methods was used to design perm-selective membranes. Currently, I am doing my post-doctoral research with BASF in University of Louis Pasteur, where I am developing polyurethane/polyurea based nanoporous polymers via sol-gel methods for thermal insulation applications. Based on my current and past experiences with thermosetting polymers, block copolymers, emulsions, semi-crystalline polymers, monomer and polymer synthesis, characterization and material design at the nanoscopic level; I would like to build a research program that would involve solving fundamental and practical problems in developing advanced materials for biomimetic sensor and hydrogen storage applications. These materials would find applications in homeland security issues of chemical/biological warfare agents, and renewable energy programs.

Nanoporous polymers for biomimetic sensors. Design of biomimetic sensors is basically motivated by the mechanisms found in biological systems, for example, design of electronic nose (EN) is based on our own sense of smell. An important application of these sensors is in detecting biological/chemical warfare agents such as anthrax, sarin and mustard gas in the battle field so that the soldiers get enough time to move to safety. Generally, these sensors are developed to reproduce or surpass the human senses. In this pursuit, the important parameters for which the sensor design is optimized are detection time, concentration levels and specificity in detecting an analyte. The choice of sensor material and its design are important steps that limit these parameters. Usually the sensor materials used are thin films of polymer or polymer-carbon black composite. The sensing mechanism is usually based on swelling of these materials by the analyte which in turn depends upon the diffusion and adsorption characteristics of the materials. The diffusion depends upon the micro and nanostructure of the polymer film and the adsorption depends upon the nature and extent of interactions between the polymer and the analyte. Thus, an intelligent design of sensor materials would entail optimizing the micro/nanostructures and interaction effects of the polymer film. Sol-gel techniques are widely used to design nanoporous polymers. Such techniques have been shown to be useful in designing materials with porosity and pore sizes between 0-80% and 1-50 nm [1]. Based on my experience with such systems, it is proposed that sol-gel techniques using polyurethane/polyurea, phenol-formaldehyde and epoxy-amine chemistries will be used to design nanoporous materials for sensing applications. The nanoporous morphology of these materials would be optimized by controlling the reaction, solvation and phase separation characteristics of the system. Subsequently, the pore activity of these materials will be modified using chemical grafting techniques based on sulfonation and esterification (amino acids) reactions. Such grafting techniques could impart hydrophilicity and bioactivity [2]. In effect functional nanoporous materials would be designed for sensing applications using sol-gel and subsequent chemical grafting techniques.

Nanoporous carbon xerogels and aerogels as hydrogen storage materials. One of challenges for the hydrogen fuel economy is to find a reasonably cheap, safe, compact, and reversible hydrogen storage media. Highly nanoporous carbon materials can be potentially used for this application. Nanoporous carbon materials can be designed by sub or supercritical drying the nanoporous gels designed using the

sol-gel techniques discussed above and subsequent carbonization at high temperatures. Carbon xerogels or aerogels would result depending on whether the drying was carried out in the sub or supercritical states. These materials would be subjected to surface activation steps and the resulting materials would be tested for their hydrogen storage capacities. High specific surface area (> 2000 m^2/g) [3] and nanoporous nature (pore size ~ 1-50 nm) of these materials could provide the desired hydrogen storage capacity.

1) Raman, V.I. and Palmese, G.R. Langmuir 2005, 21, 1539-1546

2) Mougenot, P.; Koch, M.; Dupont, I.; Schneider, Y.; and Marchand-Brynaert, J. Journal of Colloid and Interface Science 1996, 177, 162-170

3) Al-Muhtaseb, S.A. and Ritter, J.A. Advanced Materials 2003, 15, 101-114