

RET Site for Polymer Engineering Research and Workforce Development

Sarah E. Morgan,¹ Marek W. Urban,¹ Veena Choudhary,² Paul J. Jones¹ and Kevin Rhudy¹

¹*School of Polymers and High Performance Materials, University of Southern Mississippi, Hattiesburg, MS, 39406.* ²*Centre for Polymer Science & Engg., Indian Institute of Technology, Delhi, Hauz Khas, New Delhi -110016, India.* E-mail: sarah.morgan@usm.edu

ABSTRACT: The IREE: Research Exchange in Nanoengineered Polymeric Materials supplement supported two doctoral students in polymer engineering at The School of Polymers and High Performance Materials at The University of Southern Mississippi to complete three-month collaborative research programs in residence at The Centre for Polymer Science and Engineering at The Indian Institute of Technology in Delhi, India. The two research projects involved rheological studies of polyhedral oligomeric silsesquioxane (POSS) polymer nanocomposites and the development of stimuli-responsive bioactive polymeric surfaces. The synergistic strengths of the two research institutions, including polymer synthesis and analysis expertise at Southern Miss and polymer processing and rheology capabilities at IIT Delhi, enhanced international collaboration and research progress. In addition to conducting collaborative research, students participated in cultural activities, attended international research conferences and visited international corporations with research centers in India. On returning from India, the graduate students participated in the RET Site for Polymer Engineering Research and Workforce Development summer research program, working with high school and community college teachers. The graduate students will visit teachers' classrooms during the fall semester to introduce high school students to their international research experience.

INTRODUCTION

The RET site for Polymer Engineering Research and Workforce Development (RET) at The University of Southern Mississippi School of Polymers and High Performance Materials (SPHPM) involves ten community college and high school teachers who perform summer research in polymer films, composites and nanocomposites under the direction of Polymer Science and Engineering faculty, and develop curricula and laboratory experiments to administer in their own classrooms. Graduate students are involved in the RET Site research and serve as research mentors for the teachers. Teachers present results of their research at technical meetings, including the American Chemical Society National meetings, and present results of education and curriculum development activities at education conferences, including the annual Mississippi Science Teachers Association conference. Activities developed by the teachers are posted on the RET website for use by other teachers across the nation. The goal of the program is to provide teachers the enthusiasm and tools to pass on to their students, thereby enhancing student interest in science and engineering careers.

The IREE: Research Exchange in Nanoengineered Polymeric Materials supplement provided support for two domestic graduate students to complete a three-month collaborative research program at the Indian Institute of Technology Delhi Center for Polymer Science and Engineering Centre (IIT). The goal of the research exchange was to stimulate, establish, and sustain an international collaborative research program between SPHPM and IIT, while providing graduate students with enhanced understanding of international

culture and scientific research endeavors between the two countries. Additionally, the program provided US students with an opportunity for collaborative international research at one of the premier engineering education and research institutes of India. The collaborative research programs were designed to build on the key strengths of the two institutes, incorporating SPHPM strengths in polymer synthesis and analysis with IIT expertise in polymer processing and rheology. Both research projects are expected to result in joint publications between the two institutions. In addition to performing research in IIT laboratories, students attended international conferences, visited local industrial research facilities and participated in cultural activities, allowing them to gain perspective on international research and collaboration. The researchers' international experience will enhance Mississippi high school and community college students science classes as well through participation in the RET program. The graduate students will visit the RET teachers' classrooms this fall to discuss their international research experience and cultural activities. The students are preparing a video of their experiences to share with the classes as well.

Paul J. Jones, graduate student, and Kevin Rhudy, graduate student, participated in the three month research experience. The students were chosen for the research exchange based on their academic standing, research interests and research experience. Jones works under the direction of PI Morgan and Rhudy works under the direction of co-PI Urban. Both students were chosen in their fourth year of graduate study, having completed required coursework, written and oral exams, with top grades and substantial research accomplishments and experience. Jones pursued a collaborative project based on processing and rheological analysis of POSS/polymer nanocomposites, while Rhudy pursued research involving biologically active stimuli-responsive polymer surfaces, in collaboration with Prof. Veena Choudhary of IIT Delhi. Jones and Rhudy performed research in India February 1, 2008 through April 30, 2008. Morgan and Urban visited India February 16 – 26, 2008. Choudhary visited SPHPM laboratories in U.S. July 22- 25, 2008.

The Indian Institute of Technology, Delhi (IIT Delhi) is one of the premier teaching, research and consultancy institutes of Asia. Centre for Polymer Science and Engineering (CPSE), established in December 1993, is a part of this world class teaching and research institution. It is a leading Centre in the country for teaching and research in the emerging area of polymers. The main objectives of CPSE are to provide education in Polymer Science and Engineering at the undergraduate and postgraduate levels, to foster interdisciplinary research on the frontiers of Polymer Science and to assist Polymer-related industries by solving problems and advising on developmental work. The principal thrust of the Centre is manpower development and research for enhancing the fundamental knowledge as well as developing polymeric materials. The changing needs of the industry are kept in view while designing and upgrading teaching and research Programs. The Centre is actively involved in research and development activities involving doctoral research and sponsored projects. The faculty of the Centre has the major role in teaching of interdisciplinary M.Tech programme in Polymer Science and Technology. The primary purpose of this programme is to train scientist and engineers to fulfill the constantly growing requirements of polymer based industry in the country. Research activities include Polymer synthesis, modification of polymers, smart micro/nano hydrogels, nano composites, high energy polymeric binders, glass fibre/carbon fibre reinforced composites, polymer blends and alloys, Polymer compounding, polymer processing, polymer products design and modeling and simulation in processing.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION

Two collaborative research programs were performed by the two students based on ongoing research in the PI and co-PI U.S. laboratories. In India, the students completed the research under the direction of Professor Veena Choudhary at IIT. The U.S. co-PIs visited India in February to review the project progress and tour the labs. The entire research team attended the International POLYCHAR 16: World Forum for Advanced Materials conference in Lucknow, India, February 17 – 21, where 292 participants presented research from 35 different countries. It is expected that joint publication will result from both research projects.

The first project, performed by Paul Jones (advisor Morgan) involved preparation and evaluation of polymer nanocomposites. High performance engineering polymers, polyphenylsulfones (PPSU), were blended with nanostructured polyhedral oligomeric silsesquioxane (POSS) compounds, and the effects on thermal characteristics and rheological properties were determined. POSS materials are nanostructured compounds that consist of a molecular silica cage linked by oxygen atoms. A large array of organic groups can be added to the corners of the cage in order to achieve a specific goal. In this study, dodecaphenyl POSS (Figure 1A, DP-POSS) and trisilanolphenyl POSS (Figure 1B, TSP-POSS) were evaluated in the polymer matrix at weight fractions between 0.5 and 10%. Blends were prepared by twin screw extrusion, and rheological and thermomechanical properties evaluated. Viscosity reduction in the blends was shown to be a function of POSS structure, blend composition and shear rate. Figure two shows torque experienced in the extruder as a function of POSS weight fraction in the blend. POSS additives resulted in a 50% reduction in torque.

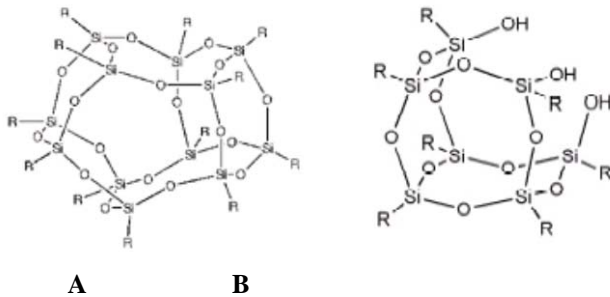


Figure 1. Structures of POSS nanostructured chemicals: 1A) dodecaphenyl POSS®, 1B) trisilanolphenyl POSS®; R represents phenyl.

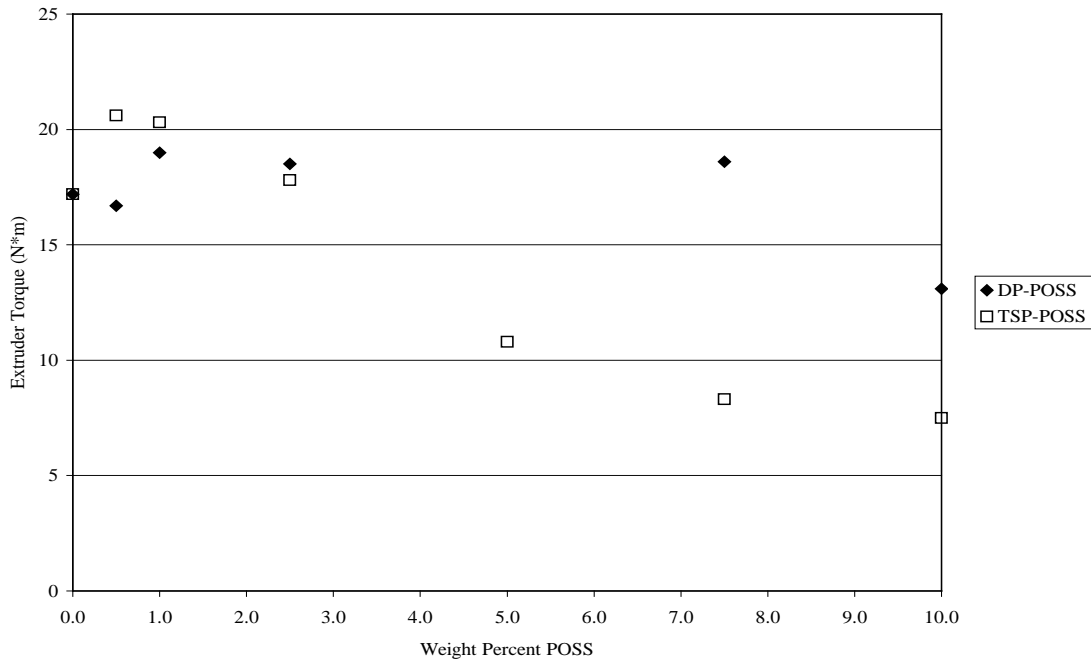


Figure 2. Extruder torque as a function of wt. % POSS in the polymer matrix.

The second research program, performed by Kevin Rhudy (advisor Urban) involved development of bioactive polymer surfaces. The goal of the collaborative research was to develop stimuli-responsive bioactive surfaces utilizing amino acids potentially capable of sensing DNA molecules. The rationale of this research is illustrated in Figure 3 below which takes advantage of the ionization of amino acids through pH changes creating environments susceptible for self-assembly of individual components during the coalescence of colloidal dispersions.

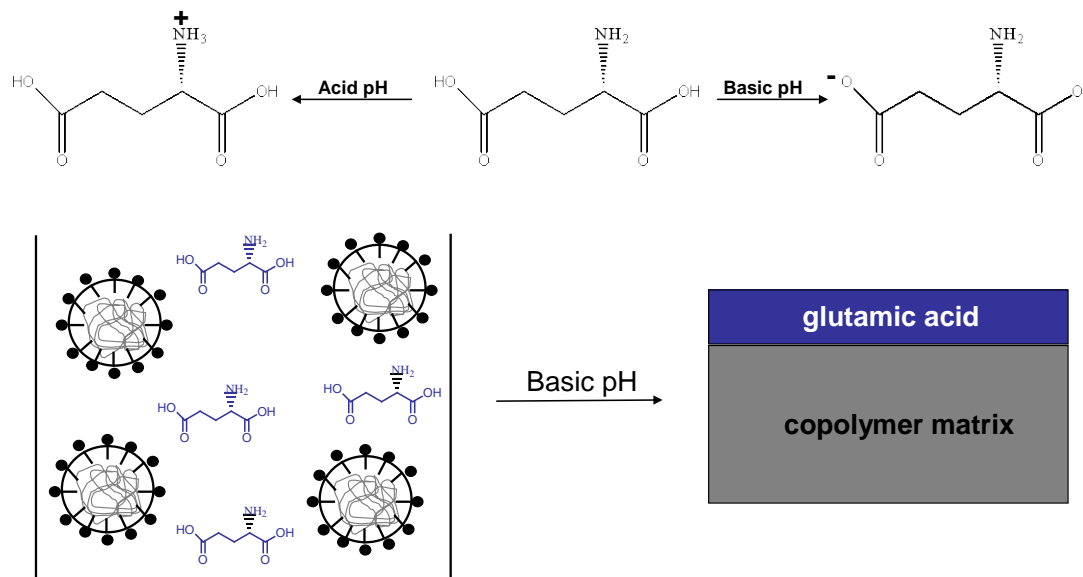
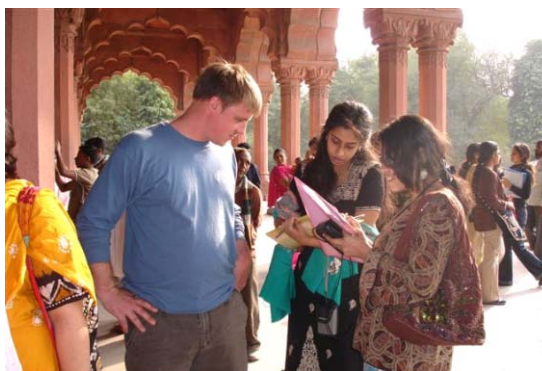


Figure 3. Stimuli-responsive bioactive surfaces.

As shown above, this was achieved by polymerizing methyl methacrylate and n-butyl acrylate in the presence of glutamic and aspartic acid (3 w/w %) and by altering the pH of the solution using pH buffers at pH 3-10. Molecular level analysis revealed that under basic conditions an enriched layer of amino acids are formed at the film-air (F-A) interface. Current, on-going research pertaining to the “sensing” capabilities of these surfaces is underway.

BROADER IMPACTS OF THE INTERNATIONAL COOPERATION

The goal of the IREE research exchange was to stimulate, establish, and sustain an international collaborative research program between SPHPM and IIT, while providing graduate students with enhanced understanding of international culture and scientific research endeavors between the two countries. The students gained understanding of Indian culture through living on campus and interacting with Indian students, visits to cultural sites and trips to global industry located in India. The program impacts not only the graduate students who travelled, but also impacts teachers involved in the RET site and their classrooms. The graduate students are preparing presentations and a video to share in high school and community college science classrooms of RET teachers this fall. The program will highlight the international component of scientific research, and broaden students’ understanding of the entire research process, and opportunities for researchers.



A key part of the student experience was living on campus with Indian students, who were both research colleagues and became close friends. The

U.S. students learned that Indian students share a strong sense of family values and a very intense desire to succeed. The competition for students to gain admission to IIT is so great that hundreds of thousands of students sit for the entrance exams, but only a few thousand of the country's best students will actually gain admission. The students at IIT work extremely hard but also take time to really celebrate. The students celebrated the Holi festival in which the entire country basically closes down for the festival of colors. During the festival people 'play Holi' by throwing colored dye on one another in celebration.

Cultural visits by students included the British residency, the Bara Imambara, and the Chhota Imambara in Lucknow. In Delhi, the students visited the Qutab Minar, which is the tallest brick minaret in the world standing at 72 meters high, the Red Fort and the Lotus temple. Red Fort was a fortress palace built by the emperor Shah Jahan but also contained the clothing, weapons, cooking supplies, and living accommodations that this 17th century emperor enjoyed. The Lotus Temple is a much more modern structure that was completed in 1986 and serves as a house of worship to approximately 4 million people per year. The massive structure resembles a flower just about to bloom and has received worldwide attention and architectural awards. Additionally, the students visited the city of Agra and toured the Taj Mahal, one of the Seven Wonders of the World, and Agra fort.

The research team travelled to Bangalore to gain appreciation of the high-tech business sector of India. GE scientists hosted a visit to the John F. Welch GE Global Research Center (JFWTC), with a tour of facilities, presentations on ongoing research and discussion of students research programs. JFWTC is GE's first and largest integrated, multidisciplinary Research and Development Center outside the US. 3,000 scientists, researchers and engineers work in JFWTC in areas like Electromagnetic Analytics, Composite Material Design, Color Technology, Additive Technology, Non-Destructive Evaluation, Corrosion Technology, MEMS, Molecular Modeling, Power Electronics, Analysis Technologies, Computational Fluid Dynamics and Engineering Analysis. The center is a \$120 million state-of-the-art facility.

The research program at IIT Delhi as well as the research exchange at GE Global Research in India have resulted in sustained, ongoing research partnerships with Southern Miss researchers. The cultural impact on the students is best summarized by a student quote: 'In my travels around Delhi and the country of India the main theme that I observed was one of contrasts. A modern high rise could be next to an ancient temple. Just outside the quiet, serene walls of IIT, a thriving city of over 10 million people was moving non-stop. Parents and families try to instill and retain old traditions in a country that is rapidly changing. However, there was one unifying characteristic that is present in India as well as the United States. Everybody searches and strives to achieve peace, success, and fairness against a world full of challenges.'

DISCUSSION AND SUMMARY

The IREE: Research Exchange in Nanoengineered Polymeric Materials resulted in significant advances in research projects in the area of nanostructured polymer composites and stimuli-responsive biologically active polymer surfaces. The research exchange has established research collaborations between scientists at the Indian Institute of Technology Delhi and the University of Southern Mississippi School of Polymers and High Performance Materials. A follow up visit by Indian researchers to the U.S. to sustain and expand the original research program has already been completed. Additionally, a research cooperation has been established between Southern Miss researchers and the GE Global Research site in Bangalore, India. Three GE India scientists have visited the Southern Miss laboratories, and discussions for formal collaborative research projects are underway. The students gained profound understanding of differences in global culture, while learning to effectively participate in the global research enterprise. They will share their experience to a broader audience through the RET program, visiting high school and community college science classes in the fall.

Best practices recommendations:

- U.S. advisors should visit the international host site during the student research period to ensure that students are progressing and help mediate "culture shock"

- Visits to local industry enhance the experience
- Adequate preparation with the U.S. university office of international programs helps to make the experience run smoothly
- Provide a video camera to the students to record the cultural experience

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- The NSF Award Number of current grant, and the name of your NSF program officer.

BRIEF BIOGRAPHIES OF RESEARCHERS

Paul Joseph Jones is a fourth year graduate student at The University of Southern Mississippi School of Polymers and High Performance Materials performing research under the direction of PI Morgan. He is the recipient of a Hearin Graduate Fellowship and in 2006 received an NSF Fellowship to attend the Nanomechanics and Nanomaterials Summer Workshop at Northwestern University. He is the author of three peer-reviewed journal publications and has presented results of his research at six national conferences, including the American Chemical Society and the Society of Plastics Engineers annual scientific meetings. He holds a B.S. in Chemical Engineering from the University of Mississippi, where he was named a NASA Space Grant Scholar.

Kevin Rhudy is a fifth year graduate student performing research under the direction of co-PI Urban. His current research is in the area of stimuli-responsive colloidal dispersions. He has a publication in *Langmuir*, and has presented results of his research at national meetings including the American Chemical Society and the Waterborne Symposium. He holds a B.S. in Polymer Science from The University of Southern Mississippi, where he received Polymer Science departmental awards.

Veena Choudhary, Professor, Centre for Polymer Science and Engineering, IIT Delhi, is the author of over 200 publications in scientific journals, has served as advisor for fifteen Ph.D. and fifty M.Tech graduates, serves as the Vice President for The Society of Polymer Science in India, and holds numerous research awards, including Humboldt Fellow, RWTH, Aachen, Germany. She obtained a Ph.D. in Polymer Chemistry, Indian Institute of Technology, Delhi, India (1977), M.Sc. Organic Chemistry, Punjab University, Chandigarh, 1973 Rank: First position in University and B.Sc.Chemistry, G.N.University, Amritsar, 1971. Her current research interests include synthesis and characterization of high performance polymers, development of thermoset and thermoplastic polymeric nanocomposites, smart /nano hydrogels: preparation, characterisation and its evaluation in biomedical field, and materials for fuel cell membranes.

Sarah E. Morgan, Associate Professor, School of Polymers and High Performance Materials, University of Southern Mississippi. She joined the Univ. in 2002, after a fourteen year career in industrial R&D in engineering thermoplastics. At GE Plastics she held R&D and management roles at GE locations around the world. Most recently she was Global Technology Manager for NORYL™ Resins and Global Sourcing Quality Leader at GEP headquarters. She holds a PhD from The University of Southern Mississippi (1988) and BA from Rice University (1980). Her current research interests are in the area of high performance materials, with specific focus on tribological, rheological and mechanical performance, including nanoengineered materials, high performance polymers, hybrid organic/inorganic nanocomposites, stimuli-responsive polymer surfaces and thin films. She serves as Education Director for the NSF MRSEC and Director for the RET Site for Polymer Engineering Research and Workforce Development.

Marek W. Urban, Professor of Polymer Science, is the Director of NSF Materials Research Science and Engineering Center (MRSEC) and National Science Foundation Industry/University Cooperative Research Center (I/U CRC) in Coatings at The University of Southern Mississippi School of Polymers and High Performance Materials. He received an M.S., Chemistry, 1981, from Marquette University, WI; a Ph.D., Chemistry and Chemical Engineering, 1984, Michigan Technological University, MI, and completed a postdoctoral fellowship at Department of Macromolecular Science, 1984-86, Case Western Reserve University, Cleveland, Ohio. His research interests include Stimuli-Responsive Polymeric Coatings; Surface/Interfacial Interactions in Organic Coatings and Film Formation; Stratification Processes in Polymeric Films; Film Formation in Organic Coatings; Nondestructive Characterization Methods; IR Imaging and Photoacoustics, Attenuated Total Reflectance, FT-IR Spectroscopy; Infrared and Raman Imaging; Molecular level Adhesion; Behavior of Small Molecules in Polymer Networks; Spectroscopy and Nonequilibrium.