COLLEGE OF ENGINEERING
MACROMOLECULAR SCIENCE & ENGINEERING
UNIVERSITY OF MICHIGAN

43rd Annual Symposium

October 24, 2019

Polymer Design Interfaces

Featuring Invited Talks By:

Professor Jodie Lutkenhaus
Professor Kirk Schanze
Professor Kenneth Wagener
Professor Gerard Wong

Symposium Committee:
Professor Jinsang Kim, Committee Chair
Shamalee Goonetilleke, Doctoral Candidate
Violet Sheffey, Doctoral Candidate
Muru Zhou, Doctoral Candidate

Rackham Graduate School
University of Michigan

Sponsored By:

PPG sponsorship supported student travel grants, poster awards for Polymer Engineering, and provided additional support to symposium events.

BASF provided general support for the symposium.

Macro would also like to thank PPG and 3M for their support of Macro student fellowships in 2019.

Thank You!

Polymer Design Interfaces

8:30 – 9:00 **Check In & Breakfast**

9:00 – 9:40 **Professor Kirk Schanze –** University of Texas at San Antonio
Conjugated Polyelectrolytes in Biosensing and Distinction

9:40 – 10:00 **Jayan Karunarathna –** Bowling Green State University
Iron(III)–Polyuronate Photochemistry for Greener Applications in Surface Modification of Soft Materials and Controlled Plant Nutrient Delivery

10:00 – 11:20 **Poster Session** (Even numbers present)

11:20 – 12:00 **Professor Jodie Lutkenhaus –** Texas A&M University
Emergent Properties and Applications of Polyelectrolyte Complexes

12:00 – 12:30 **Lunch**

12:30 – 1:50 **Poster Session** (Odd numbers present)

1:50 – 2:10 **Catherine Snyder –** University of Michigan
Fabrication of Non-Spherical and Multiphasic Particles with Independent Control of Particle Size, Shape, and Chemistry

2:10 – 2:50 **Professor Gerard Wong –** University of California, Los Angeles
Nucleic Acid Complexes in Innate Immunity and Autoimmunity

2:50 – 3:00 **Break**

3:00 – 3:40 **Professor Kenneth Wagener –** University Florida
The ADMET Story

3:40 – 4:00 **Closing & Awards Presentation**

Macro Symposium Poster Awards

At the symposium we are pleased to recognize outstanding student research and contributions to the Macro program with a series of awards. These awards, detailed below, are made possible by the generosity of our alumni & friends, faculty, students, and industry partners.

Frank E. Filisko Award
The Frank E. Filisko Award is given to the top poster presented by a Macro student at the symposium. The award seeks to recognize both excellence and clarity in research and is named in honor of former Macro Professor and Director Frank E. Filisko. Professor Filisko's work on electrorheological fluids was widely cited and paired with an unwavering commitment to supporting his students' learning and research.

Nonna L. Hamilton Student Service Award
The Macro program is fortunate to have an exceptionally involved group of students who continually work to support their peers, the program, and the College of Engineering. This award recognizes the outstanding contributions a student has made to the Macro program. The award was first given in 2012 and is named for longtime Macro Coordinator Nonna Hamilton, who helped guide over two decades of Macro students through the program.

Overberger Student Research Award
Macro's top student research award is named for program founder Charles G. Overberger. The winner is selected by a faculty committee that aims to highlight excellence and innovation in doctoral research. In addition to serving as Macro Director for twenty years Professor Overberger chaired the Michigan Department of Chemistry and was Vice President for Research.

PPG Polymer Engineering, Professor Albert & Mrs. Jessica Yee Polymer Science, and Best Overall Awards
Support from PPG, Professor Albert & Mrs. Jessica Yee, and Macromolecular Science & Engineering make possible six awards to outstanding student researchers. The top Polymer Science, Polymer Engineering, and best overall posters presented by students with Macro affiliation will each receive awards. Additionally, the same awards will be granted for the top posters presented by students from other institutions or programs at U-M.

Speaker Abstracts & Bios

Conjugated Polyelectrolytes in Biosensing and Disinfection

Professor Kirk Schanze

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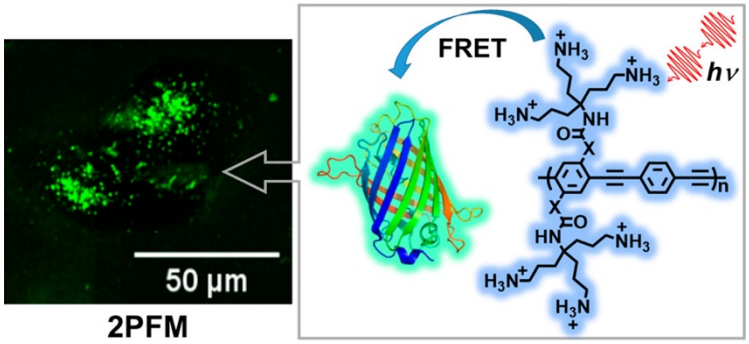
Conjugated polyelectrolytes (CPEs) featuring poly(phenylene ethynylene) and poly(thiophene) backbones substituted with ionic solubilizing groups are water soluble. These materials display a variety of interesting properties, including self-assembly into nanoscale aggregates, ability to process into nanostructured layer-by-layer films and optical/stimuli responsive behaviour in the presence of ions, surfactants and biomacromolecules. We have explored the use of cationic CPEs as fluorescent sensors for polyphosphates (pyrophosphate, ATP and ADP). In addition, cationic CPEs exhibit profound light-activated biocidal activity vs. a broad spectrum of bioagents, including bacteria, virus particles and spores. The talk will give a high-level overview work in this area, including recent work concerning the interactions between cationic CPEs and mammalian cells.



Kirk Schanze is the Robert A. Welch Distinguished University Chair in Chemistry at the University of Texas in San Antonio. He received his B.S. in Chemistry from Florida State University and his Ph.D. in Chemistry from the University of North Carolina, Chapel Hill. His research group focuses on the interaction of light with small molecules, polymers, and materials.

Dr. Schanze has published 320 peer-reviewed papers and given close to 300 national and international lectures and seminars. He is the founding Editor-in-Chief of the American Chemical Society journal *ACS Applied Materials & Interfaces* and was Associate Editor of the scholarly journal *Langmuir* for 10 years. Dr. Schanze has patented technology including new light-activated polymer-based antibacterial, materials and devices for producing near-infrared light emission for wound healing, low-cost plastic solar cell technology, and coatings for accelerated engineering testing of prototype structures.

Emergent Properties and Applications of Polyelectrolyte Complexes

Professor Jodie Lutkenhaus

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Charged assemblies bearing opposite or complementary charges span natural (proteins, enzymes, DNA) to synthetic materials (surfactants, synthetic polyelectrolytes). Assembly is facilitated by electrostatic attraction and entropic release of counterions, and most often occurs in aqueous media. Here, we discuss emergent properties that are mediated not only by electrostatics, but also by water. Notably decades ago, Michaels described synthetic polyelectrolyte complexes as brittle when dry but "leathery or rubberlike" when wet, which points to the strong effect of water on the mobility of a charged assembly. This talk will discuss the molecular origin of the glass transition in polyelectrolyte assemblies, revealing a generalized relationship that connects the glass transition to water content and the number of intrinsic ion pairs in the assembly. This further connects to the dynamics of the polyelectrolyte assembly, as shown using time-temperature-water superpositioning of the assembly's dynamic mechanical behavior. These findings emphasize the important, and often overlooked, role of water in an assembly's dynamic behavior. Turning toward applications, we leverage electrostatic charge to assemble polyelectrolytes and MXene nanosheets, which are an emerging class of 2D nanomaterials. Here, the nature of polyelectrolyte-2D nanomaterial assemblies is investigated as thin films. A reversibly stretchable MXene/polyelectrolyte strain sensor and humidity sensor is demonstrated, and the origin of this response is discussed. These results show that polymer-nanoparticle assemblies can be leveraged to create functional thin film coatings, conforming to a variety of surfaces of complex shapes.

Jodie Lutkenhaus is the William and Ruth Neely Faculty Fellow and Professor in the Artie McFerrin Department of Chemical Engineering at Texas A&M University. Lutkenhaus received her B.S. in Chemical Engineering in 2002 from The University of Texas at Austin and her Ph.D. in Chemical Engineering in 2007 from Massachusetts Institute of Technology. Following a postdoctoral position at University of Massachusetts Amherst, she joined the faculty at Yale in 2008. In 2010, she moved to Texas A&M University and was promoted to Associate Professor in 2015. Current research areas include polyelectrolytes, redox-active polymers, energy storage, and functional coatings. She has received recognitions including World Economic Forum Young Scientist, Kavli Fellow, NSF CAREER, AFOSR YIP, 3M Non-tenured Faculty Award. She is the 1st Vice Chair of the AICHE Materials Engineering & Sciences Division. Lutkenhaus is the Deputy Editor of ACS Applied Polymer Materials. She also serves on the Editorial Advisory Boards for ACS Macro Letters, Macromolecules, ACS Applied Nano Materials, Molecular Systems Design & Engineering, and Materials Today.

Nucleic Acid Complexes in Innate Immunity and Autoimmunity

Professor Gerard C. L. Wong

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It is a commonplace notion that specific binding plays critical roles in the immune system. The recognition of "pathogen associated molecular patterns" (PAMPs) by immune receptors has been one of the paradigmatic examples of specific binding in molecular biology. This is exemplified by the recognition of pathogen nucleic acids by Toll-Like Receptors (TLRs) of innate immunity, the 'first responders' to infection. We show that TLRs recognize and respond not to just chemical patterns on individual ligand nucleic acids they are designed to detect, but also to the nanocrystalline ordering of such nucleic acids with new antigens they are *not* designed to detect, thus vastly increasing their recognition repertoire with both beneficial and detrimental implications. Since the immune receptors are detecting crystalline arrangements of dsDNA and dsRNA in a multivalent manner, the resultant immune response can be highly amplified, leading to a broad range of health outcomes, including inflammation induced by heart disease, neutrophil apoptosis, and autoimmune diseases.

Gerard C. L. Wong is a Professor in the Department of Bioengineering and Department of Chemistry & Biochemistry at the University of California Los Angeles. Wong received his B.S. and Ph.D. in physics at Caltech and Berkeley. He joined the Materials Science Department and Physics Department at the University of Illinois at Urbana-Champaign in 2000 and was recruited to UCLA in 2009. His research recognition includes a Beckman Young Investigator Award and an Alfred P Sloan Fellowship. He is a Fellow of the American Physical Society, a Fellow of the American Academy of Microbiology, and a Fellow of the American Institute for Medical and Biological Engineering.

The ADMET Story

Professor Kenneth Wagener

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The story begins with Kenneth Wagener's oral examination for the Ph.D. degree, where "metathesis" was just being explored. Metathesis interest grew at a reasonable pace, with both small molecule and polymer chemistry creating opportunity. The ADMET reaction - Acyclic Diene Metathesis - was attempted with "classical" catalysts with no success, though the early experiments left a 'clue' to the problem at hand. Two mechanisms were competing with one another. This can't be if step chemistry (ADMET) is to succeed. The advent of the first defined catalyst (Schrock's catalyst) led to a prime experiment that opened the door to productive mechanistic, synthetic and structure analysis ADMET chemistry. This story will conclude with the latest work bulk metathesis (no catalyst) at temperatures as high as 175 C.

Kenneth Wagener is the George B. Butler Professor of Polymer Chemistry and Director, Center for Macromolecular Science and Engineering at the University of Florida. He earned a B.S. in Chemistry at Clemson University, 1968 and a Ph.D. in Organic and Polymer Chemistry with George Butler at the University of Florida, 1973. Kenneth has held various positions with the company Akzo Nobel from 1973 to 1984, leading to Technical Director of blood oxygenator project, now commercially used in heart/lung machines in surgery. Research group has included 160 people over the years of all types - PhD and Masters students, visiting scholars, and a large number of PhD students visiting from the Max Planck Institute for Polymer Research in Mainz, Germany; awards include the 2019 Tosoh Lifetime Achievement Award, the 2016 ACS Paul Flory Polymer Education Award, the 2013 Herman Mark Polymer Chemistry Award, the 2007 Alexander von Humboldt Senior Research Prize, also elected as a Fellow in the American Chemical Society, the Polymer Division, and the PMSE Division, and received the University of Florida's oldest award, given to only one faculty member a year, in 2000.

Iron(III) – Polyuronate Photochemistry for Greener Applications in Surface Modification of Soft Materials and Controlled Plant Nutrient Delivery

Jayan Karunarathna

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The Iron(III)–carboxylate photoreaction occurs in nature with the help of sunlight and it plays an important role in iron cycling in the natural environment. During this photoreaction, electron transfer from carboxylate to iron(III), generates a radical and iron(II). We have shown this reaction occurs in carboxylate-containing polysaccharides (polyuronates), where a carbon dioxide radical anion (CO_2) was generated, and eventually degraded the polymer chain. We used this radical generation to initiate polymerization of methyl methacrylate on materials such as hydrogels and cotton fabrics. By controlling the areas of light irradiation, we were able to photo-pattern these materials. Polymerization of poly(methyl methacrylate) changed the material properties such as mechanical strength and hydrophobicity compared to the starting material. In addition to using this photoreaction for surface modification, we prepared hydrogel beads with Fe(III) and alginate polymers. These gels also showed the photoreaction similar to solution phase and degraded the gel bead upon light irradiation. We showed that these gel beads can uptake phosphate ions from aqueous solutions for the wide pH range of 4.0 – 9.0 that we studied. Phosphate uptake was more than 80% for all the different gel bead formulations studied. Interestingly, upon light exposure, the photodegradation of the alginate chains slowly released the phosphate ions to the environment. We used these plant nutrient loaded hydrogel beads as a controlled release fertilizer system for tomato plants. Compared to the control plants, the tomato plants treated with fertilizer beads showed significant changes in their plant growth and fruit formation. Therefore, we have shown the ability to use natural polyuronates and the iron(III) photoreaction for greener applications in surface modification and controlled release of plant nutrients.

Jayan Karunarathna received his B.S. in Chemistry from the University of Sri Jayewardenepura in 2013 and is currently a fifth-year doctoral candidate in the Photochemical Sciences Program at Bowling Green State University. His main research interests are natural polymers and soft materials. His dissertation work with advisor Dr. Alexis D. Ostrowski is on polyuronate based hydrogel materials. This work focuses on understanding Fe(III) – carboxylate photochemistry and applying this into materials for greener surface modification reactions as well as responsive materials for plant nutrient release.

Fabrication of Non-Spherical and Multiphasic Particles with Independent Control of Particle Size, Shape and Chemistry

Catherine Snyder

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Cancer is the second leading cause of death and current treatments have low survival rates. Nanoparticle drug delivery has shown promise as a treatment method however, challenges still exist in overcoming physiological barriers in the body. To better understand the pharmacokinetics of nanoparticles in vivo, nanoparticle characteristics need to be varied in a systematic study to identify ideal formulations. Current fabrication methods are unable to make monodisperse, multiphasic, nonspherical and spherical particles, and to independently alter each parameter. We have developed a polymeric particle synthesis technique, Wettability Engendered Templated Self-assembly (WETS), and have demonstrated the ability to control size, shape and composition independently. The WETS methodology uses surfaces with patterned wettability to self-assemble discrete, monodisperse polymer particles in an array after dip-coating in a polymer solution. These particles can have dimensions ranging from 25 nm -150 μm, and can have a variety of non-spherical, planar geometries such as squares, triangles and hexagons. Additional dip-coating layers of other polymers on top of previous polymer layers allows for the fabrication of multiphasic particles with each phase able to encapsulate a different therapeutic. Single and multiphasic spherical particles are formed from the reconfiguration of nonspherical particles in a predictable manner. Multiphasic spherical particles can be tuned to create Janus or core-shell morphologies based on reconfiguration parameters. With the WETS fabrication method, we have demonstrated the ability to have systematic and independent control over the size, shape and composition of polymeric particles in a predictable manner which will allow for the identification of ideal nanoparticle formulations through a systematic study of nanoparticle pharmacokinetics in vivo.

Catherine Snyder received her B.S. from the University of Florida in 2015, and a M.S. from the University of Michigan in 2018. She is a fifth-year doctoral student in Materials Science and Engineering and is co-advised by Anish Tuteja and Geeta Mehta. Her research interests include studying and designing materials for medical applications and her thesisw work focuses on designing polymer nanoparticles for cancer drug delivery.

Posters

Polymer Engineering

#	Name	Institution & Title
1	**Taeyong Ahn**	University of Michigan *Hierarchical Nature of Nanoscale Porosity in Bone Revealed by Positron Annihilation Lifetime Spectroscopy*
2	**Ramin Ansari**	University of Michigan *Improving Color Purity in Thermally Activated Delayed Fluorescence Emitters*
3	**Bernardo Barea Lopez**	University of Southern Mississippi *Effects of Volumetric Shrinkage in Glassy Polymer Networks on Cure-Induced Strain For Fiber Reinforced Composites*
4	**Abhishek Dhyani**	University of Michigan *Low-interfacial toughness (LIT) materials for effective large-scale deicing*
5	**Yasmine Doleyres**	University of Michigan *Characterization and evaluation of 2-methylene-13,6-trioxocane (MTC) hydrogels as a biomaterial for tissue engineering and drug delivery applications*
6	**Kalani Edirisinghe**	Bowling Green State University *Reversible Photoreduction in Vanadium(V)-tartrate tetramers.*
7	**Erin Farrell**	The University of Akron *Surfactant Free Emulsion Templated Polyimide Aerogels*
8	**Jaehyun Jung**	University of Michigan *High strength epoxy nanocomposites reinforced by epoxy functionalized aramid nanofibers*
9	**Peng-Kai Kao**	University of Michigan *Anisotropic Colloids for Self-assembled Crystals and Gels*
10	**Dukhan Kim**	University of Michigan *Exploring insoluble redox polymers as storage materials with flowable mediators*
11	**Akshata Kulkarni**	The University of Akron *Development of a Hierarchical Porous Structure in Syndiotactic Polystyrene Aerogels Via Pickering Emulsion*
12	**Zoe Li**	Carnegie Mellon University *Synthesis and Characterization of Dopa-bearing ABA triblock copolymer as surgical sealants*

13	**Jayan Karunarathna**	Bowling Green State University *Iron(III) – Polyuronate Photochemistry for Greener Applications in Surface Modification of Soft Materials and Controlled Plant Nutrient Delivery*
14	**Chenchen Mou**	Carnegie Mellon University *Flexible Adhesive Hydrogel-Integrated Electrode For Selective Stimulation In Rat Vagus Nerve*
15	**Ayse Muniz**	University of Michigan *Single cell analysis reveals the instructive role of 2D and novel 3D engineered microenvironments in altering stem cell and stem-like cell behavior*
16	**Renato Navarro**	University of Michigan *Rapid in situ Regeneration of a Small Diameter Neoartery Through Heparin-Conjugated Bilayered Biomimetic Nanofibrous Scaffolds*
17	**Caymen Novak**	University of Michigan *Ovarian Cancer Cells Under Shear Stress Increase Proliferation, Invasion, and Chemoresistance*
18	**Renuka Patil**	University of Akron *Fabrication of pH responsive membranes using 248 nm Krypton FluorideExcimer Laser*
19	**Julie Rieland**	University of Michigan *Ionic liquid selection for cellulose processing*
20	**Joshua Seylar**	University of Akron *Progress Towards Helicene-based polymers*
21	**Wenhao Shao**	University of Michigan *Development of Novel Strategies for Solution Processable Multilayer Organic Light Emitting Diodes*
22	**Catherine Snyder**	University of Michigan *Fabrication of non-spherical and multiphasic particles with independent control of particle size, shape and chemistry*
23	**Harini Sridharan**	University of Akron *Orthogonally superimposed shear deformations with thermal gradients*
25	**Ben Swanson**	University of Michigan *Rational Design of Macroporous Tissue Engineering Scaffolds Guides the Fate of the Cranial Suture Mesenchyme*
26	**Alyssa Travitz**	University of Michigan *Multiscale Modeling of Polymer-Mediated Colloidal Interactions in Waterborne Coatings*

27	**Shannon Wetzler**	University of Michigan *Real-time measurement of analyte and interior polymer brush kinetics of using silicon photonic microring resonators*
28	**Thomas White**	University of Michigan *Impact of Design Modifications on Microfabricated Push-Pull Sampling Probes Intended for In Vivo Brain Chemistry Experiments*
29	**Tianyu Yuan**	University of Michigan *3D Printing of Reprocessable Self-Healing Thermoset with High Strength*
30	**Yichun Zhang**	University of Michigan *Cavitation induced printing of cell-laden hydrogel*

Polymer Science

31	**Kailash Arole**	Texas A&M University *Tunable Polyacetals*
32	**Rajani Bhat**	University of Michigan *Balancing the positive and negative charges of methacrylate copolymers for their antimicrobial and hemolytic activities*
33	**Takunda Chazovachii**	University of Michigan *An Industrially Practicable Method to Repurpose Sodium Polyacrylates Based Super-Absorbent Materials*
34	**Ankit Dara**	Bowling Green State University *Real-time Viscosity Monitoring in Adhesives using Luminescent Coordination Complexes as Molecular Sensors.*
35	**Mira Diab El Harakeh**	University of Michigan *Preparation of liquid crystal polymer -networks (LCNs) and -elastomers (LCEs) for self-folding origami structures*
36	**Keili Diaz**	Florida International University *Synthesis of 2-Purine Nucleosides Modified with a N-unsubstituted 1,2,3-Triazol-4-yl Moiety*
37	**Derek Frank**	University of Michigan *Inhibiting or accelerating crystallization of pharmaceuticals by manipulating polymer solubility*
38	**Travis Green**	Bowling Green State University *Towards photoresponsive materials: Photochemistry of poly(vinyl alcohol) hydrogels with indigo derived chromophores*
39	**Jun Guan**	University of Michigan *Potential semiconducting behavior of double-decker silsesquioxane polymers*
40	**Arushi Gupta**	University of Michigan *Compatibility Study Between LLZO Ceramic Electrolyte and Liquid Electrolytes with Potential to Enable Hybrid Electrolyte Batteries*
41	**Carina Haddad**	Bowling Green State University *Photoresponsive bioplastics that feature metal-polysaccharide complexes.*
42	**Justin Harris**	University of Michigan *Cellulose-Based Hydrogels for Water Remediation*
43	**Nisha Hollingsworth**	University of Michigan *Experimental Salt- and pH-Induced Swelling of Poly(Acrylic Acid) Brushes & Comparison to Theoretical Prediction*

44	**Naihsuan Hu**	Bowling Green State University *In-situ Formed Methyl-co-(bis-R) Silsesquioxane Based Polymer Networks with Solvent Controlled Pore Size Distributions and High Surface Areas*
45	**Ayaka Idomoto**	Nara Institute of Science and Technology *Structureand properties of domain-swapped myoglobin dimers with metal binding sites*
46	**Chamika Lenora**	Bowling Green State University *Thermally Stable Fluorogenic Zn(II) Sensor Based on Bis(benzimidazole) Functionalized Silsesquioxane Oligomer*
47	**Ting Lin**	University of Michigan *Probing Biological Molecule Orientation and Polymer Surface Structure at the Polymer/Solution Interface in Situ*
48	**Cong Liu**	Texas A&M University *Self-curing high-k epoxy containing metal-organic-framework-decorated carbon nanotubes*
49	**Tianyu Liu**	University of Michigan *Effect of Defective Microstructure on the Reflective Structural Color of Colloidal Films*
50	**Shahrea Mahbub**	Bowling Green State University *Beads on a Chain(BoC) Fluorescent Polymeric Materials: Interactions of Conjugated Organic Cross-linkers with Silsesquioxane Cages and their Spectroscopic Properties*
51	**Yuma Mitsuyoshi**	Nara Institute of Science and Technology *Fragmentation of lipid bilayer by zwitterionic amphiphilic polymers toward formation of lipid nanodiscs*
52	**Emily Mueller**	University of Michigan *Stabilizing higher efficiency organic photovoltaics with a fullerene-functionalized P3HT copolymer additive*
53	**Buddhima Rupasinghe**	Bowling Green State University *Fluoride Catalyzed Polysiloxane Depolymerization*
54	**Jack Queenan**	University of St. Thomas *Pancreatic Polymersomes: Acid Sensitive Nanoparticles for Glucose-Responsive Insulin*
55	**Patricia Rodriguez**	Florida International University *Guanylurea Modified Poly(ethylenimine) for Gene Delivery*
56	**Abhishek Shandilya**	Rensselaer Polytechnic Institute *Trap state distribution in polymer nanocomposite interphases using first principles*

57	**Jonathan Sun**	University of Michigan *Frustrated Diamidophosphorane Octa-Ruthenium Supramolecules with Photoelectric Release Mechanism for Ultraefficient CO2 Sequestration*
58	**Yasumichi Takase**	Nara Institute of Science and Technology *Structure elements are closely related to intramolecular residue-residue contacts*
59	**Jessica Tami**	University of Michigan *Mechanochemical Degradation of Polystyrene*
60	**Kelly Wang**	University of Michigan *Quasicrystal growth from misoriented seeds*
61	**Duleeka Wannipurage**	Wayne State University *Main Group Metal Alkoxide Complexes for Ring Opening Polymerization of lactide /Copolymerization of CO2-epoxide and epoxide -anhydride*
62	**Da Seul Yang**	University of Michigan *Controlled alignment of polymer chains*
63	**Mengjie Yu**	University of Michigan *Oxysilylation of diepoxides: a route to hybrid nanocomposites*
64	**Lisha Zhang**	University of Michigan *Isocyanurate transformation for healing of the isocyanurate-oxazolidone polymers*
65	**Xinyu Zhang**	University of Michigan *A New Approach to Epoxy Resins, Oxysilylation of Epoxides*

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