40th Annual Symposium
October 27, 2016
Macromolecules & Innovation: From Discovery to Product

Featuring Invited Talks By:
Dr. Valeriy V. Ginzburg
Professor Jessica R. Kramer
Professor Milan Mrksich
Professor Timothy F. Scott
Professor Nicole F. Steinmetz

Symposium Committee:
Professor Theodore Goodson III, Committee Chair
Professor Mark Banaszak Holl
Professor Nicholas Kotov
Professor Ronald Larson
Harry van der Laan, Doctoral Candidate
8:00 – 8:50  Check In & Breakfast
8:50 – 9:00  Welcome
9:00 – 9:40  Professor Milan Mrksich  
            Northwestern University  
            Preparation of Megamolecules and Synthetic Antibodies
9:40 – 10:00  Kevin Golovin  
              University of Michigan  
              Designing Durable Icephobic Surfaces
10:00 – 11:20  Poster Session & Coffee Break (Even numbers present)
11:20 – 12:00  Dr. Valeriy V. Ginzburg  
               The Dow Chemical Company  
               Modeling Anisotropic Self-Assembly of Isotropic Objects: from Hairy Nanoparticles to Methycellulose Fibrils
12:00 – 1:30  Lunch – The Original Cottage Inn
1:30 – 2:10  Professor Jessica R. Kramer  
              University of Utah  
              Synthetic Polypeptides: From Drug Delivery to the Cancer Glycocalyx
2:10 – 2:30  Jihyeon Yeom  
              University of Michigan  
              Paramagnetically Enhanced Optical Activity of Chiral Nanoparticles
2:30 – 3:50  Poster Session & Coffee Break (Odd numbers present)
3:50 – 4:30  Professor Timothy F. Scott  
              University of Michigan  
              Exploiting Reversible Covalent Bonds in Polymeric Materials
4:30 – 5:10  Professor Nicole F. Steinmetz  
              Case Western Reserve University  
              From Black-Eyed Peas to Nanotechnology: Engineering Plant Virus-Based Therapeutics
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 industrial 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.

P&G Team Innovation Award
Generous support from Procter & Gamble has allowed for the creation of a new award at the 2016 Macro Symposium. This award will be given to a multidisciplinary research team that presents work at the symposium. Work will involve at least three students across two or more research groups. The award will be based on the utility of research to society, creativity and novelty, and context for discovery and application or the work.

Professor and Mrs. Albert Yee Poster Awards
Support from Macro Professor Emeritus Albert Yee and Mrs. Jessica Yee make possible five awards to outstanding student researchers. Awards are given to the top Polymer Science and Polymer Engineering posters, two to students with Macro affiliation and two to others from U-M or other institutions. Another award is given to the top poster presented by a non-Macro student. These funds also support a series of leadership awards given to Macro students.
Looking Back: A History of the Macro Symposium

Now in its 40th year, the first Macro Symposium was held on October 13th, 1977. *Current Contributions in Polymer Science* brought together nearly 150 people from academia and industry. Pioneers of polymer chemistry Professors Harry Allcock, Paul Flory, James Guillet, and Herman Mark gave invited talks. Twenty Michigan engineering and chemistry students presented their research to attendees.

The Macromolecular Research Center was founded nine years prior in 1968 by Professor Charles G. Overberger, Chair of the Chemistry Department and a former ACS President. Professor Overberger and the Macro faculty hosted an annual meeting to share recent advances and plan future collaborations with industrial sponsors.

When Ph.D. and Master’s students began to enroll in the mid 1970s the faculty and students expressed an interest in developing a separate event that would allow students to showcase their work and connect with leaders in industry and academia. For many years the symposium continued to be held over two days in conjunction with the sponsor’s meeting. The events eventually merged and offered a full day of invited talks and poster presentations that could appeal to a wide audience of students and professionals.

In recent years the symposium has continued to grow and bring together students, faculty, and industry professionals. We are thrilled to celebrate this milestone event today with participants from over thirty institutions, and hope you will continue to join us for many years to come!

**Speaker Profiles: The First Macro Symposium**

**Professor Harry Allcock** is the Evan Pugh Professor of Chemistry at Pennsylvania State University. He is credited with the discovery of both polyphosphazenes and clathrates and has authored over 600 papers during his distinguished career. Dr. Allcock has received many high honors from the American Chemical Society and his work continues to push forward new advances in the field.

**Professor Paul Flory** was a pioneering polymer chemist and winner of the 1974 Nobel Prize in Chemistry for “his fundamental achievements, both theoretical and experimental, in the physical chemistry of macromolecules”. Dr. Flory made several advances to the understanding of polymer behavior in solution, including the Flory-Huggins Theory and the Flory exponent.

**Professor James Guillet** led an acclaimed career as a polymer chemist investigating the ways in which polymers react with light. In the 1970s he developed photodegradable polymers and for several decades continued to conduct some of the world’s premier photochemical research.

**Professor Herman Mark** was a pioneer of polymer science research and education. In 1946 he established the Polymer Research Institute, the first research facility dedicated solely to polymers. His research contributed towards accurately measuring molecular weights of polymers (Mark-Houwink equation) and the commercialization of polystyrene and PVC.

*Special thanks to former Macro coordinators Mrs. Ruther Gerler and Mrs. Nonna Hamilton, whose meticulous record keeping made this summary possible.*
Preparation of Megamolecules and Synthetic Antibodies

Professor Milan Mrksich

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This talk will describe an approach to prepare molecules that have molecular weights in excess of 1 Million Dalton, and sizes in excess of 100 nm, yet that are structurally perfectly defined. The approach is based on the tethering of fusion proteins by linkers having irreversible ligands for specific enzymes. In this way, fusion proteins comprising the enzyme partners react efficiently and rapidly with the linkers to produce the conjugated adducts. The talk will show several examples of megamolecules prepared using this strategy, and will focus on megamolecules that mimic the bivalent display of Fab domains in antibodies. This work provides a new approach to prepare megamolecules with sizes and molecular weights that go far beyond what is possible with current chemical or biological approaches.

Dr. Milan Mrksich is the Henry Wade Rogers Professor of Biomedical Engineering at Northwestern University, where he also holds appointments in Chemistry and Cell & Molecular Biology. The interests of Professor Mrksich’s group overlap with chemistry, biology, and engineering with an emphasis on the design and synthesis of materials that are biologically active. They seek to discover applications of these materials to relevant problems in the biological and medical sciences. The group has pioneer the design of ‘dynamic substrates’ that present ligands whose activities can be switched on and off in response to the electrical or optical signals, particularly for studies that address the responses of adherent cells to changes in the extracellular matrix.

Professor Mrksich earned his Ph.D. in Chemical Biology from the California Institute of Technology and was an American Cancer Society Postdoctoral Fellow at Harvard University. In addition to his position at Northwestern Mrksich is a founder and inventor at SAMDI Tech, Inc., a contract research company that offers label-free assay development, high throughput screening, and peptide substrate discovery.
Modeling Anisotropic Self-Assembly of Isotropic Objects: from Hairy Nanoparticles to Methylcellulose Fibrils

Dr. Valeriy V. Ginzburg
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Spontaneous symmetry breaking and formation of anisotropic structures from apparently isotropic building blocks is an exciting and not fully understood topic. I will discuss two examples of such self-assembly. The first example is related to the assembly of “hairy” nanoparticles in homopolymer matrices\(^1\). The particles can assemble into long strings (they can also form other morphologies, as well) even though the shape of each particle and the distribution of ligands on the particle surface is spherically symmetric. Using the approach developed by Thompson, Ginzburg, Matsen, and Balazs\(^2\), we show that presence of other particles can re-distribute the ligands and effectively “polarize” the particle-particle interaction, giving rise to the formation of 1d particle strings\(^3\). In the second example, we consider aqueous solutions of methylcellulose (MC) polymers. It has been shown recently\(^4\) that at high temperature, the polymers form high-aspect ratio “fibrils” with diameter ~ 15 nm and length in the hundreds on nanometers. Using coarse-grained Molecular Dynamics (CG-MD), we propose that the “fibrils” are result of one-dimensional self-assembly of single molecule “rings”. Each MC polymer chain is forced into a ring because of the balance between internal chain rigidity (favoring more expanded configuration) and unfavorable polymer-water interactions (favoring more collapsed conformation). We also develop a theory predicting rheology and phase behavior of aqueous MC, and validate it against experimental data\(^5\). Both examples show that anisotropic self-assembly can show up in unexpected places, and various theoretical tools are needed to successfully model it.


Dr. Valeriy Ginzburg is a Senior Research Scientist at The Dow Chemical Company with expertise in theoretical Polymer and Materials Science. He received his B.S. and Ph.D. (Physics) from Moscow Institute of Physics and Technology (Russia), followed by postdoctoral fellowships at the University of Colorado (1993-97) and University of Pittsburgh (1998-2000). Since early 2001, Dr. Ginzburg has been member of the Corporate R&D at The Dow Chemical Company in Michigan. His research interests include theory, modeling, and simulation of polymers, composites, and nanocomposites. As part of the Core R&D Materials Science team, he uses the power of computer simulations to design new advanced materials. Dr. Ginzburg is a Fellow of American Physical Society (2014), has authored or co-authored more than 60 publications, including several papers in Science, Physical Review, and other prestigious journals, as well as 6 book chapters.
Synthetic Polypeptides: From Drug Delivery to the Cancer Glycocalyx

Professor Jessica R. Kramer

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Synthetic polypeptides are uniquely poised to harness the structure and function of native proteins with the synthetic advantages of chemically produced polymers. Polypeptides have diverse applications as biomimetic structures and as materials with tissue engineering, drug delivery, and therapeutic applications. Advances in the polymerization of amino acid N-carboxyanhydride monomers to produce polypeptides, and techniques for post-polymerization chemical modification will be discussed. The synthetic polypeptides were applied as components in bioactive block copolymer nano-carriers for drug delivery and as components of glycoprotein constructs. Chemically prepared glycosylated polypeptides are particularly valuable since their biologically produced counterparts are heterogeneous and difficult to characterize. Native cell-surface glycoproteins collectively form the glycocalyx, which plays essential roles in diverse cellular interactions and disease. Strategies to engineer the glycocalyx with chemically defined glycopolypeptides may shed light on the role of glycans in cancer and open doors for advances in diagnostics and therapeutics.

Dr. Jessica R. Kramer obtained an Honors B.S. in Chemistry from the University of Utah in 2004 and performed undergraduate research in the lab of Prof. C. Dale Poulter. She then worked in industry for 3 years at Echelon Biosciences synthesizing phosphoinositide and isoprenoid compounds. In 2007, Jessica began National Science Foundation funded graduate studies in the lab of Prof. Tim Deming in UCLA’s Chemistry Department. She obtained her Ph.D. in 2012 with a dissertation titled Functional Polypeptides for Biomedical Applications. In 2013, Jessica joined the lab of Prof. Carolyn Bertozzi at UC Berkeley as a National Institute of Health (NIH) Postdoctoral Fellow and as a UC Chancellor’s Postdoctoral Fellow. She now continues her work on cell-surface engineering with synthetic mucin glycoproteins as an NIH Fellow in the Bertozzi lab at Stanford University. Jessica will begin her independent career at the University of Utah in the Department of Bioengineering in January 2017.

For more information, visit: http://www.eng.utah.edu/~jessicak/index.html
Exploiting Reversible Covalent Bonds in Polymeric Materials

Professor Timothy F. Scott

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Covalently cross-linked polymer networks find utility as structural materials across a wide variety of applications where in situ polymerization, dimensional stability, environmental resistance, and permanence are required. Additional chemical functionality can be readily introduced to these networks by incorporating desired functional groups in the monomeric precursors employed for material fabrication; however, once set, the recycling, reuse, and post-polymerization manipulation of these covalently cross-linked networks are, as suggested by their common description as ‘thermosets’, limited. To address this shortcoming, strategies to afford adaptability in cross-linked polymers have focused on incorporating reversible covalent bonds within the network backbone of these otherwise intractable materials; thus, networks which contain a sufficient number and topology of ‘dynamic’ covalent bonds enable the cross-linked structure to respond chemically to an applied stimulus. This response, generally a change in the stress and/or shape (i.e., strain) of the material, is achieved without necessitating any irreversible network structure degradation by maintaining the cross-link density while allowing rearrangement of the connectivity. Here, I will discuss the potential of polymeric materials which, upon irradiation, are able to rearrange their connectivity to alleviate shrinkage stress and undergo rapid, photo-mediated healing. Further, I will detail the development of sequence-specific oligomers that employ dynamic covalent interactions to effect hybridization between strands of complementary sequences, mimicking the self-assembly commonly observed in complementary nucleic acid strands.

Dr. Scott is an Assistant Professor of Chemical Engineering at the University of Michigan, where he also holds an appointment in the Macromolecular Science & Engineering Program. Research in the Scott group is focused on exploiting the attributes of radicals for unique polymer fabrication and manipulation strategies to yield materials for biomedical devices, membrane separators, and energy capture and storage media. Current projects cover issues in in situ polymerization, polymer mechanochemistry, and dynamic covalent self-assembly. Professor Scott earned his Ph.D. in Materials Engineering from Monash University in Australia and shortly after began as an Assistant Professor and the University of Colorado, Boulder. He joined the faculty at Michigan in 2011.
Nanoscale engineering is revolutionizing the way we prevent, detect and treat diseases. Viruses are playing a special role in these developments because they can function as prefabricated nanoparticles naturally evolved to deliver cargos to cells and tissues. My laboratory has developed a library of plant virus-based nanoparticles; through structure-function studies we are beginning to understand how to tailor these materials appropriately for biomedical applications. Through synthetic biology, we have developed virus-based delivery system carrying contrast agent and/or therapeutic cargo enabling therapeutic applications targeting cancer and cardiovascular diseases. Another avenue is the development of virus-like particle platforms for cancer immunotherapy. The idea pursued is an “in situ vaccination” immunotherapy strategy to manipulate tumors to overcome local tumor-mediated immunosuppression and subsequently stimulate systemic anti-tumor immunity to treat metastases, and most importantly induce immune memory to protect patients from recurrence of the disease. In this lecture, I will highlight engineering design principles employed to synthesize the next-generation nanotherapeutics and I will discuss the evolution of such in preclinical models.

Dr. Steinmetz is an Associate Professor of Biomedical Engineering at Case Western Reserve University School of Medicine, Cleveland, OH, where she is leading a research laboratory interfacing bio-inspired, molecular engineering approaches with medical research and technology development. Dr. Steinmetz holds secondary and trainer appointments in the Departments of Radiology, Materials Science and Engineering, Macromolecular Science and Engineering, Pathology, Pharmacology, Molecular Virology, and Division of General Medical Sciences-Oncology; she is a member of Case Center for Imaging Research and Case Comprehensive Cancer Center.

Dr. Steinmetz trained at The Scripps Research Institute, La Jolla, CA where she was a NIH K99/R00 awardee and AHA post-doctoral fellow (2007-2010); she obtained her PhD in Bionanotechnology from the University of East Anglia where she prepared her dissertation as a Marie Curie Early Stage Training Fellow at the John Innes Centre, Norwich, UK (2004-2007). Her early training was at the RWTH-Aachen University in Germany, where she obtained her Diploma (Masters) in Molecular Biotechnology (2001-2004) after completing her pre-Diploma from the Ruhr University Bochum, Germany (1998-2001).
Designing Durable Icephobic Surfaces

Kevin Golovin

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Ice accretion remains a costly, hazardous hindrance worldwide. Icephobic materials reduce the adhesion between ice and a surface. However, only a handful of the icephobic systems reported to-date reduce the ice adhesion sufficiently for the facile removal of ice under its own weight or by mild winds. The majority of these amply-icephobic surfaces have relied on sacrificial lubricants, which may be depleted over time, drastically raising the ice adhesion. In contrast, here we show that surfaces utilizing interfacial slippage to lower their adhesion to ice may remain icephobic indefinitely (including after severe mechanical abrasion, acid/base exposure, 100 icing/de-icing cycles, thermal cycling, accelerated corrosion, and exposure to Michigan wintry conditions over several months). By tailoring the crosslink density of different elastomeric coatings, irrespective of material chemistry, we are able to design a library of extremely durable icephobic systems. Moreover, we propose a new, universally applicable and theoretically consistent model that accurately predicts the adhesion of ice to surfaces exhibiting interfacial slippage. This model allows one to rationally engender icephobicity in essentially any polymeric system. As such, we present several new, extremely icephobic systems, fabricated from a wide range of materials including common engineering plastics and sustainable natural oils. These environmentally friendly, icephobic systems may significantly reduce ice accumulation on airplane wings, wind turbine blades, car windshields or boat hulls.

Kevin Golovin is an NDSEG fellow and 5th year doctoral candidate in Professor Anish Tuteja's research group, studying materials science and engineering. Kevin's research focuses on understanding interfacial mechanics to engender specific properties to coatings and surfaces. His work has been featured in Science, The Wall Street Journal and The London Telegraph, and he has won numerous awards including the Patagonia Eco Innovation Case Competition and the Gore Fellows Award.
Chirality is a property unifying both electromagnetic waves and matter that typically manifests in light-matter interactions as the difference in absorption left- and right circularly polarized light, known as circular dichroism (CD). Although the studies of chiral effects associated with the magnetic component of light have long history and date back to M. Faraday, our sense is that the nexus of magnetism and chirality represents an underexplored area of science.

Despite importance for fields of multiferroics, skyrmions, spintronics, and homochirality of Earth’s life, magnetooptical effects are generally much weaker than their electrooptical analogs. Although the use of this effects in memory, optoelectronics, information processing devices, and catalysis has much technological appeal, the requirements of temperatures around $T=5-7$ K and magnetic fields of $B = 1.2-7.5$T complicates their implementation. Difficulties of molecular design of traditional chiral materials capable of combining chiral and magnetic centers or long-distance coupling of magnetic spins also hinders exploring of the effects.

Emergence of the new field of inorganic chiral nanoparticles (NPs) provides new opportunities for materials design of magnetooptics. Magnetic NPs can enhance both local magnetization of the chiral “centers” and their interaction with photons without externally applied magnetic fields. Here we demonstrated highly enhanced optical activity of NPs by synthesizing them using transition metal components. The chiral paramagnetic NPs exhibited $\sim 10x$ stronger optical activity compared to conventionally synthesized NPs. The tunable strong optical activity of NPs should contribute to chiral catalysis, chromic filters and display devices.

Jihyeon Yeom is a Ph.D. candidate in the Macromolecular Science & Engineering program, working in the research group of Professor Nicholas Kotov. Jihyeon’s research focuses on synthesizing metal and semiconductor nanoparticles, in particular the chiral self-assembly of nanoparticles. Her work as a researcher and student has been recognized within the U-M community and beyond. Jihyeon received the MRS Gold Award at the Spring 2015 MRS meeting and has been awarded several College of Engineering and Rackham Graduate school research prizes. Most recently she was selected as a recipient of the prestigious Rackham Graduate School Barbour Fellowship.
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