greenUp

2015 MICHIGAN GREEN CHEMISTRY AND ENGINEERING CONFERENCE

Advancing Toward a Safer and Sustainable Future

NOVEMBER 4, 2015

University of Michigan, North Campus Research Complex | Ann Arbor, Michigan

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DEAR 2015 MICHIGAN GREEN CHEMISTRY & ENGINEERING CONFERENCE ATTENDEES,

It is my great pleasure to welcome each of you to the University of Michigan for the 2015 Michigan Green Chemistry and Engineering Conference. We are thrilled to host GreenUp this year, and are glad you have joined us. It is an exciting time for the science and technology of green chemistry as we continue to advance the disciplines to prevent pollution, reduce hazards, and create more efficient processes. Industry is confronting an increasingly rapid rate of change, and new market pressures are driving more demand for solutions. The world of green chemistry and engineering is a stimulating area in which to work, study and create, and the University of Michigan will continue to bring inspired people together in events like this, to drive positive change, and to create a better world for future generations. In order to align ourselves with the changing environment, UM has designed and is currently teaching 400+ courses on sustainability. While the Graham Sustainability Institute is carrying out cutting edge research in this area, the Department of Chemistry has eliminated toxic materials from their teaching curricula, and introduced safer and microscale methods that result in less hazardous waste generated. Our research laboratories also embrace green chemistry and engineering principles in day-to-day research. To date, we have been successful in engaging 150 labs across the campus to practice sustainable chemistry and engineering in their operations.

Today, you will have the opportunity to hear from well-regarded experts, including our own Prof. Andy Hoffman, Director of the Erb Institute for Global Sustainable Enterprise. Additionally, representatives from the Department of Environmental Quality will join us to present this year's Governor's Green Chemistry award. We are also glad to have several representatives from the United States EPA join us including Stephen Devito, PhD and Dr. Rejender Varma. We are also joined by many green chemistry and engineering leaders during the breakout sessions and you're all invited to visit the poster competition and meet with our exhibitors.

In closing, I would like to thank you for attending our conference, and for bringing your expertise to our gathering. As leaders, you have the vision, the knowledge, the wherewithal, and the experience to help us pave our way to a sustainable, greener future. Throughout this conference, I ask you to stay engaged, stay proactive, and help us shape the future of chemistry and engineering at the University of Michigan, the great state of Michigan, and beyond. To borrow from our Planet Blue team here at the University, "Go Blue, Think Green!"

Sincerely,

Bart M. Bartlett
Associate Director for Science and Technology
University of Michigan Energy Institute

Conference Agenda

The objective of the Michigan Green Chemistry Program is to foster the adoption and development of chemicals and products that reduce or eliminate the use or generation of hazardous substances, while producing high quality products through safe and efficient manufacturing processes. This is our seventh annual conference, and the second GreenUp hosted by the University of Michigan. It is an ideal place to celebrate and discuss ways to advance toward a safe and sustainable future. The innovative spirit of the people and organizations of Michigan are on display at this event.

We encourage you to talk with the poster presenters and exhibitors, ask questions of speakers and panelists, and network with your fellow leaders at this event. Ultimately, we hope the principles of green chemistry and the ideas and applications discussed today will stay with you when you go back to school or work. The power is in your hands to cultivate the next generation of sustainable solutions.

7 a.m.	Registration, posters, and continental breakfast	
8 a.m.	Welcome *Professor Peter J. H. Scott, PhD, Department of Radiology, U-M Medical School*	
8:10 a.m.	Opening Remarks and Green Chemistry Governor's Awards *Jack Schinderle, Chief, Office of Environmental Assistance, Department of Environmental Quality*	
8:30 a.m.	Morning Keynote *Introduction: Sudhakar Reddy, PhD, Office of Campus Sustainability, University of Michigan* *Keynote Speaker: Andy Hoffman, P.h.D., Education Director, Graham Sustainability Institute, University of Michigan*	
9:15 a.m.	Plenary Panel, Stories Behind TRI Reductions *Steve Devito, United States Environmental Protection Agency; John Bradburn, General Motors; and Russell Brynolf, FTS Technologies* *Moderator: Clinton Boyd, Steelcase*	
10:45 a.m.	BREAK – *move to concurrent sessions*	
Breakout Sessions	**Green Chemistry Perspectives**	**Green Energy Technology, Part 1**
11 a.m.	Greener Pathways to Organics and Nanomaterials: Sustainable Applications of Nano-Catalysts *Dr. Rajender S. Varma, United States Environmental Protection Agency, Cincinnati, Ohio*	Design principles for green energy storage systems *Maryam Arbabzadeh, University of Michigan* Electrodeposition of crystalline Si nanowires at low temperatures *Luyao Ma, University of Michigan*
12 p.m.	NETWORKING BREAK	
12:15 p.m.	Lunch and Keynote Speaker *Introduction: Jeff Gearhart, Research Director, Ecology Center* *Keynote Speaker: Dr. Deborah Mielewski, Senior Technical Leader of Sustainable Materials and Plastics Research, Ford Motor Company*	
1:15 p.m.	Dessert, student poster award presentation, poster session, exhibitors and networking	

Breakout Sessions	Green Chemistry in Policy and Practice	Green Energy Technology, Part 2	Bio-materials in Michigan
1:45 p.m.	Reducing Chemical Use on University of Michigan's Campus *Anya Dale and Kenneth Keeler, University of Michigan Office of Campus Sustainability* West Michigan Green Labs Pilot: Bringing Pollution Prevention to Scale *Daniel Schoonmaker, West Michigan Sustainable Business Forum*	Hydration and the mechanical properties of anion exchange membranes for fuel cells *Matthew Liberatore, University of Toledo* Improving the Stability and Selectivity for OER of WO3 Photoanodes with an FeOOH Catalyst *Charles Lhermitte, University of Michigan*	Bio-Based Materials for Sustainable Production and a Circular Economy *Silvia Leahu-Aluas, Sustainable Manufacturing Consulting; Brandon Pitcher, Hemp Circle Industries LLC* Farm-to-Factory: Manufacturing Bio-based Automotive Materials in Michigan *Valerie Sathe Brugeman; Joshua Cregger, Center for Automotive Research*
2:45 p.m.	NETWORKING BREAK		
Breakout Sessions	**Safer Chemicals Policy**	**Industry Partnership for K-12 Green Chemistry Education**	**Green Technology Development**
3 p.m.	U.S. Environmental Protection Agency (U.S. EPA) Safer Choice Program *Bridget Williams, U.S. EPA* The Chemical Footprint Project *Mark Rossi, Clean Production Action*	Green Chemistry Connections: Inspiring students with innovation *Kaitlyn Babcock, Steelcase; Kate Anderson, Beyond Benign*	Performance-driven green chemistry *Adam Emerson, Resinate Materials Group* The 2014 U.S. Nanotechnology Commercialization Readiness Study: Implications for Michigan's Manufacturers *Manish Mehta, M-Tech International LLC*

ALL DAY - Posters, Exhibitors and Networking

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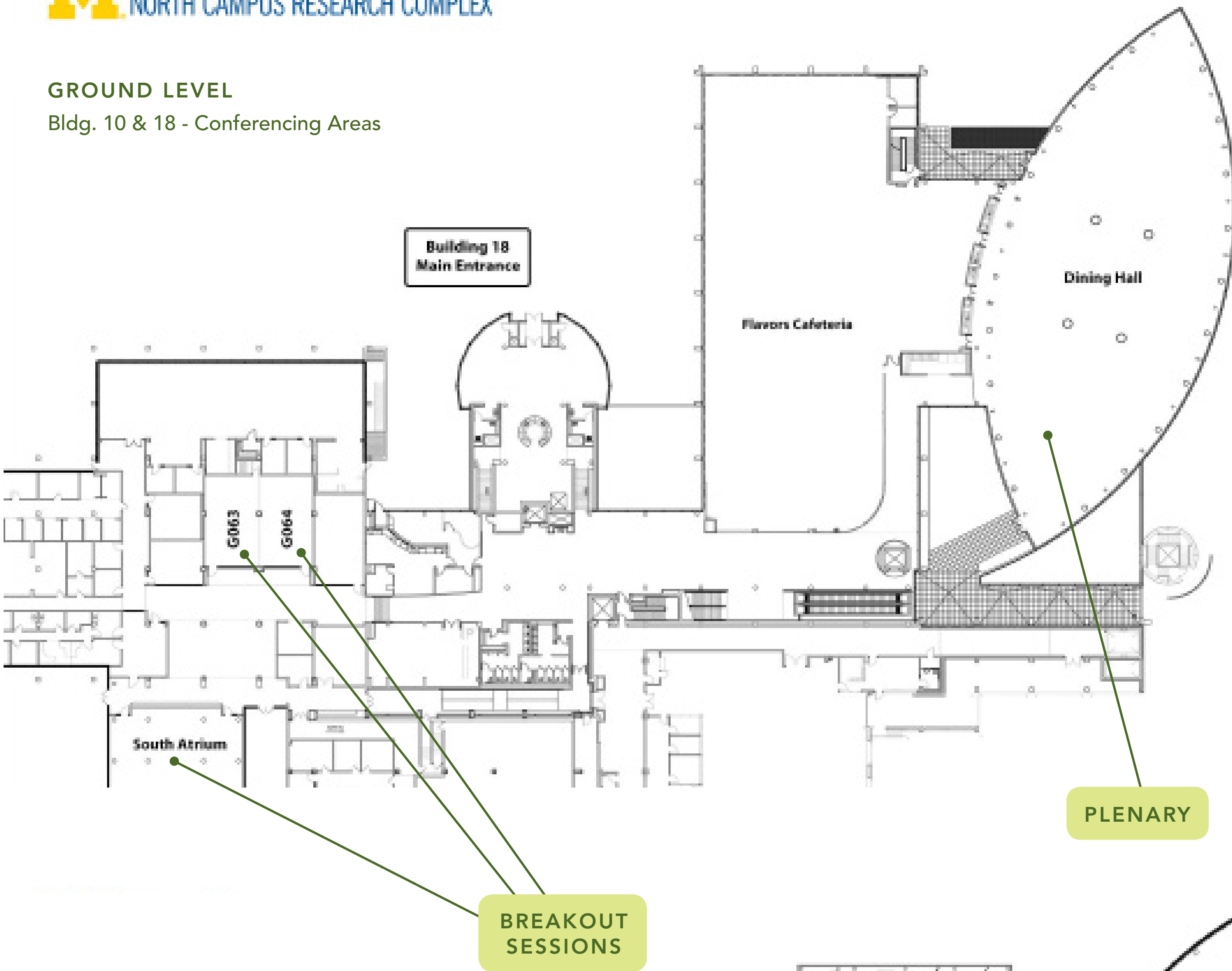

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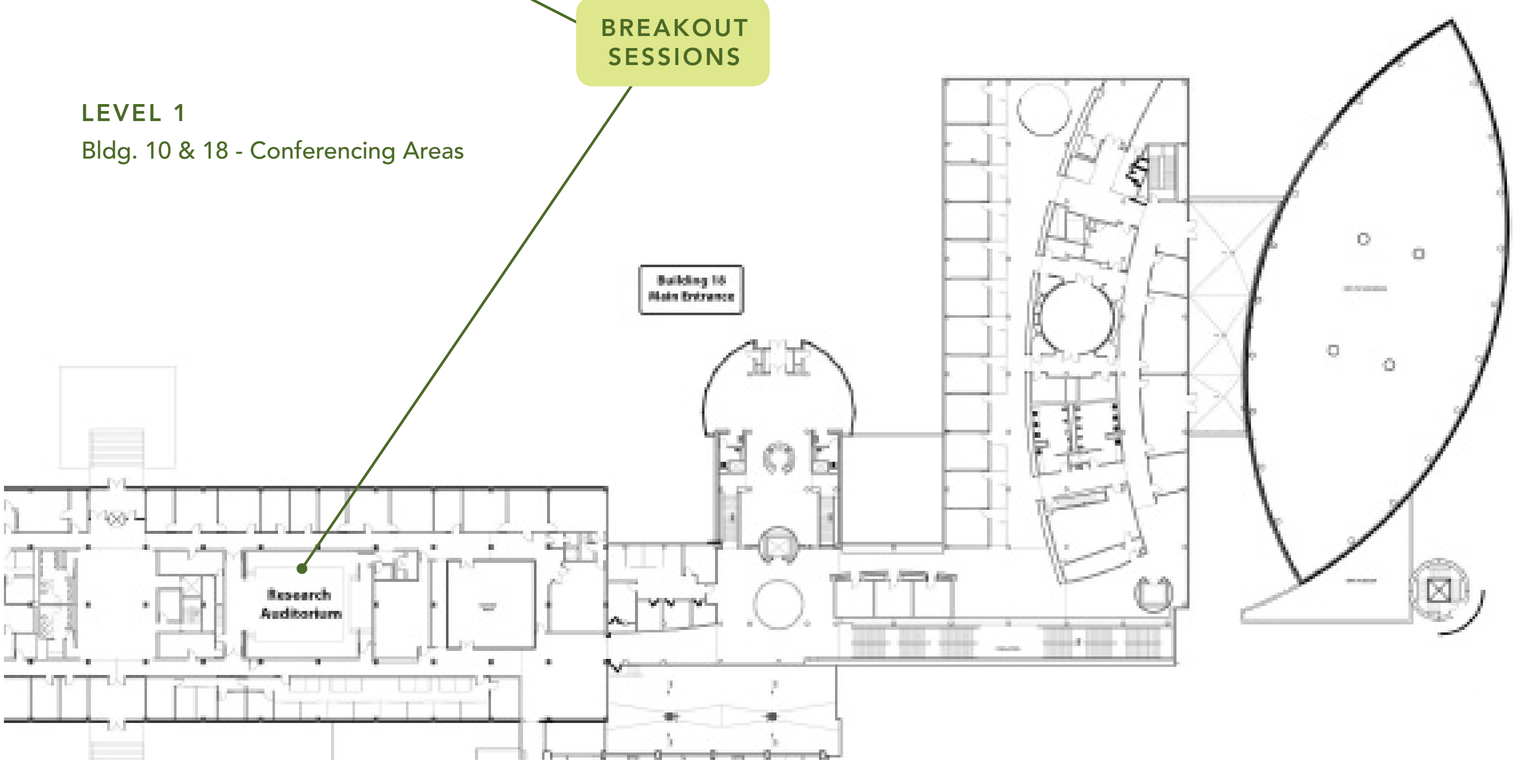

MICHIGAN GREEN CHEMISTRY GOVERNOR'S AWARDS

The Michigan Green Chemistry Governor's Awards recognize advances that incorporate the principles of green chemistry into chemical design, manufacturing, or use. The awards acknowledge efforts to design, implement, and promote safer and more sustainable chemicals, processes, and products.

The Awards program, which is Michigan specific, is guided by the following focus areas:

- **Greener Synthetic Pathways**
  This focus area involves implementing a novel, green pathway for a new chemical product or material. It may also involve using a novel, green pathway to redesign the synthesis of an existing product.

- **Greener Reaction Conditions**
  This focus area involves improving conditions other than the overall design or redesign of a synthesis.

- **Design of Greener Chemicals and Materials**
  This focus area involves designing and deploying chemical products or materials that are less hazardous than the products or technologies they replace.

- **Design and Implementation of Greener Processes**
  This focus area involves designing and deploying a process where hazardous and/or toxic chemicals are reduced or eliminated such that the resulting process will be environmentally benign, economically sound, and implementable, while still ensuring product quality.

- **Education or Advocacy of Green Chemistry**
  This focus area involves educating or advocating for the advancement of green chemistry in Michigan.

GREEN CHEMISTRY GOVERNOR'S AWARD WINNER

Mayaterials, Inc.
Tailored Silicas and Silicon Based Chemicals

Contributors: Professor Richard M Laine; National Science Foundation; Riceland Inc.; USDA

Liquid Silica from Bio- and Industrial Waste, Sustainable and Green

"Transforming ag-waste into value added products"

Richard Laine (CEO and CTO)

Mayaterials has learned to depolymerize silica at < 200 degrees Celsius using more sustainable resources including rice hull ash (RHA), diatomaceous earth (DE), and others. Importantly, the researchers realized an objective explored unsuccessfully multiple times over the past 85 years satisfying one of the "grand challenges" of silicon chemistry. Mayaterials can use RHA and DE, and likely other agricultural waste to produce alkoxysilanes, especially Si(OEt)4 [TEOS], at costs estimated to be about 10 percent of TEOS currently produced (at scale).

Traditionally, most Si compounds and materials derive from metallurgical grade silicon, made by carbothermal reduction of silica, with carbon in a high temperature, capital, equipment, and energy intensive process. Likewise, precipitated SiO2 is made by stoichiometric reaction of SiO2 with Na2CO3 at 1300° Celsius forming Na2SiO3 and one mole of CO2. Na2SiO3 is treated with H2SO4 to produce one mole of Na2SO4/mole of SiO2. These processes are equipment and energy intensive, costly, and have a significant carbon footprint.

Thus, beginning in 1930, repeated attempts were made to develop low temperature, low cost methods of depolymerizing SiO2 to generate alternate routes to Si compounds as well as precipitated SiO2. The success of such a process can be considered a "grand challenge" for silicon chemists. Researchers at Mayaterials working with researchers at the University of Michigan have now succeeded in effecting such a reaction. The Mayaterials process claims to be more sustainable and have a very low carbon footprint.

The Mayaterials process eliminates all high temperature steps, CO2 production, and uses Ag-waste or DE as sustainable, green starting materials. The discovery of several routes to effecting this reaction may provide a paradigm shift in silicon chemistry given that we can avoid energy and equipment intensive carbothermal reduction as well as the intermediacy of corrosive, toxic and polluting chlorosilanes and HCl.

Additionally, the base is recycled, and the process completely escapes producing metallurgical grade silicon. The intent is to completely supplant production of TEOS from metallurgical grade silicon by using RHA, DE, or other agricultural wastes at costs that allow them to compete in the market and move to high purity precipitated SiO2 for electronic and optical products applications.

Mayaterials plans to scale the process to a sub-pilot plant in Michigan to 50-100 kg TEOS per week and explore using Michigan agricultural waste sources. If scale up is successful, the process will change the way high purity alkoxysilanes and precipitated and fumed silica are produced worldwide, because there are multiple sources of biogenic silicas everywhere.

If Mayaterials can greatly reduce the cost of producing TEOS and related products, then the opportunity exists to also produce lower cost but higher quality precipitated silica for applications ranging from food grade silica for toothpaste for example to precipitated silicas for use as extenders and fillers for polymers including for example lower cost, lighter weight tires.

THE TWELVE PRINCIPLES OF GREEN CHEMISTRY*

1. **Prevention**
   It is better to prevent waste than to treat or clean up waste after it has been created.

2. **Atom Economy**
   Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. **Less Hazardous Chemical Syntheses**
   Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. **Designing Safer Chemicals**
   Chemical products should be designed to effect their desired function while minimizing their toxicity.

5. **Safer Solvents and Auxiliaries**
   The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

6. **Design for Energy Efficiency**
   Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

7. **Use of Renewable Feedstocks**
   A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

8. **Reduce Derivatives**
   Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

9. **Catalysis**
   Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. **Design for Degradation**
    Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

11. **Real-time analysis for Pollution Prevention**
    Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. **Inherently Safer Chemistry for Accident Prevention**
    Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

* Anastas, P. T.; Warner, J. C.; Green Chemistry: Theory and Practice, Oxford University Press: New York, 1998, p.30. By permission of Oxford University Press.

THE TWELVE PRINCIPLES OF GREEN ENGINEERING*

1. **Inherent Rather Than Circumstantial**
   Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently nonhazardous as possible.

2. **Prevention Instead of Treatment**
   It is better to prevent waste than to treat or clean up waste after it is formed.

3. **Design for Separation**
   Separation and purification operations should be designed to minimize energy consumption and materials use.

4. **Maximize Efficiency**
   Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.

5. **Output-Pulled Versus Input-Pushed**
   Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.

6. **Conserve Complexity**
   Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.

7. **Durability Rather Than Immortality**
   Targeted durability, not immortality, should be a design goal.

8. **Meet Need, Minimize Excess**
   Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.

9. **Minimize Material Diversity**
   Material diversity in multicomponent products should be minimized to promote disassembly and value retention.

10. **Integrate Material and Energy Flows**
    Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.

11. **Design for Commercial "Afterlife"**
    Products, processes, and systems should be designed for performance in a commercial "afterlife."

12. **Renewable Rather Than Depleting**
    Material and energy inputs should be renewable rather than depleting.

* Anastas, P.T., and Zimmerman, J.B., "Design through the Twelve Principles of Green Engineering", Env. Sci. and Tech., 37, 5, 94A-101A, 2003.

THANK YOU

Green Chemistry Roundtable Members

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Dr. Yinlun Huang, Wayne State University
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Mr. John Dulmes, Michigan Chemistry Council
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Ms. Tracey Easthope, Ecology Center
Dr. Sudhakar Reddy, University of Michigan, Office of Campus Sustainability
Dr. Sarah A. Green, Michigan Technological University
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