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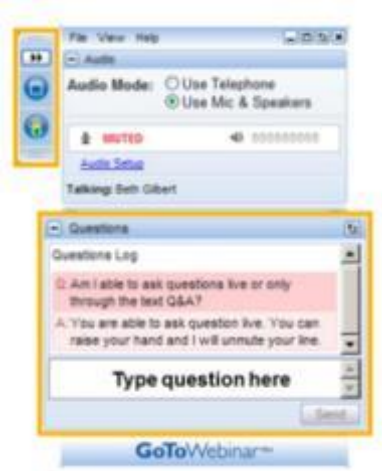

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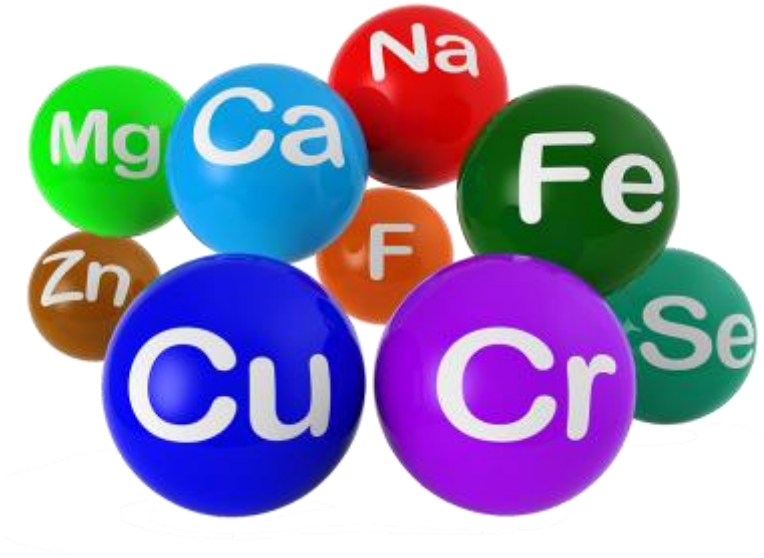

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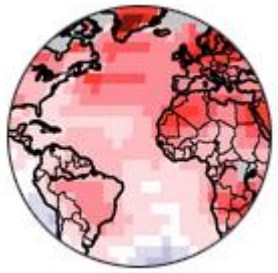

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2014 ACS Chemistry Champions Competition Runner-Up

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Dr. Ingrid Montes, ACS Junta de Directores y Profesora de Química Orgánica, Universidad de Puerto Rico, Recinto de Río

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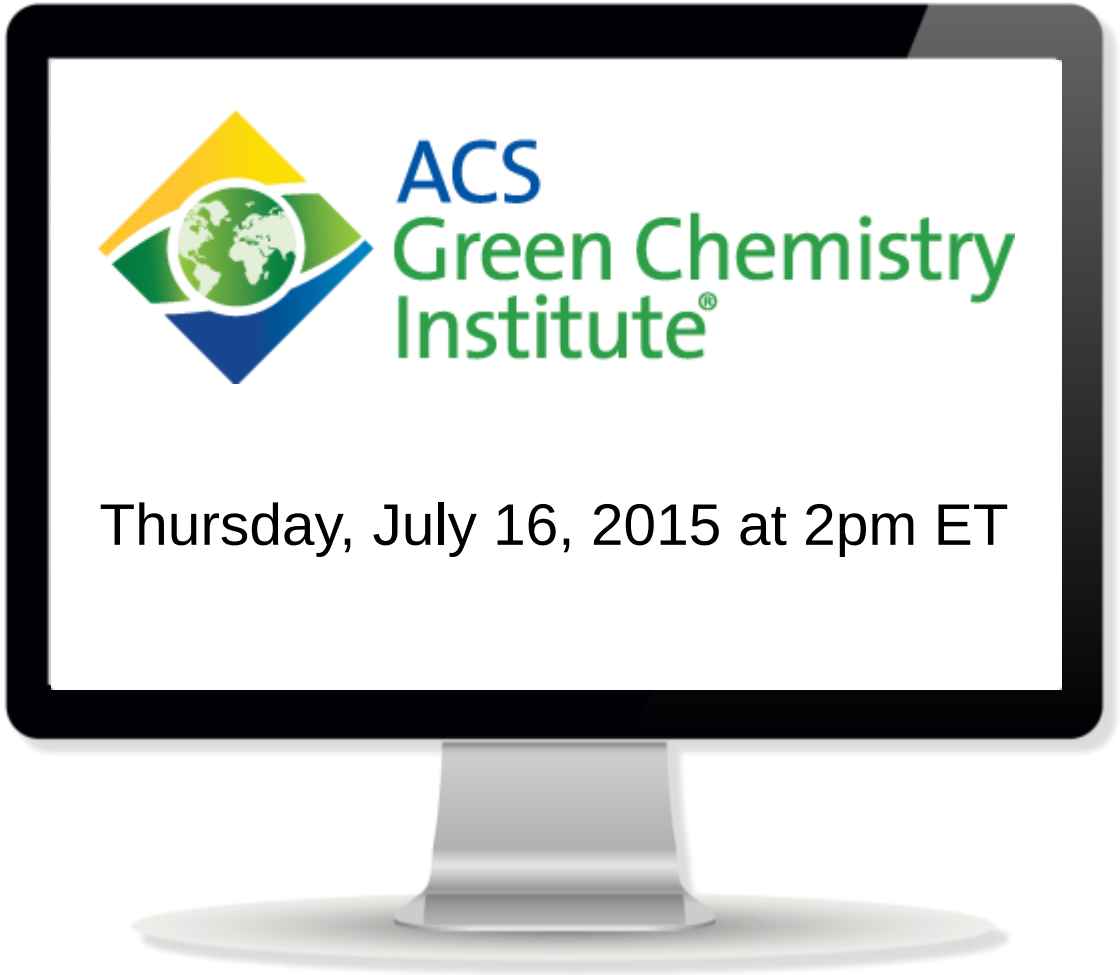

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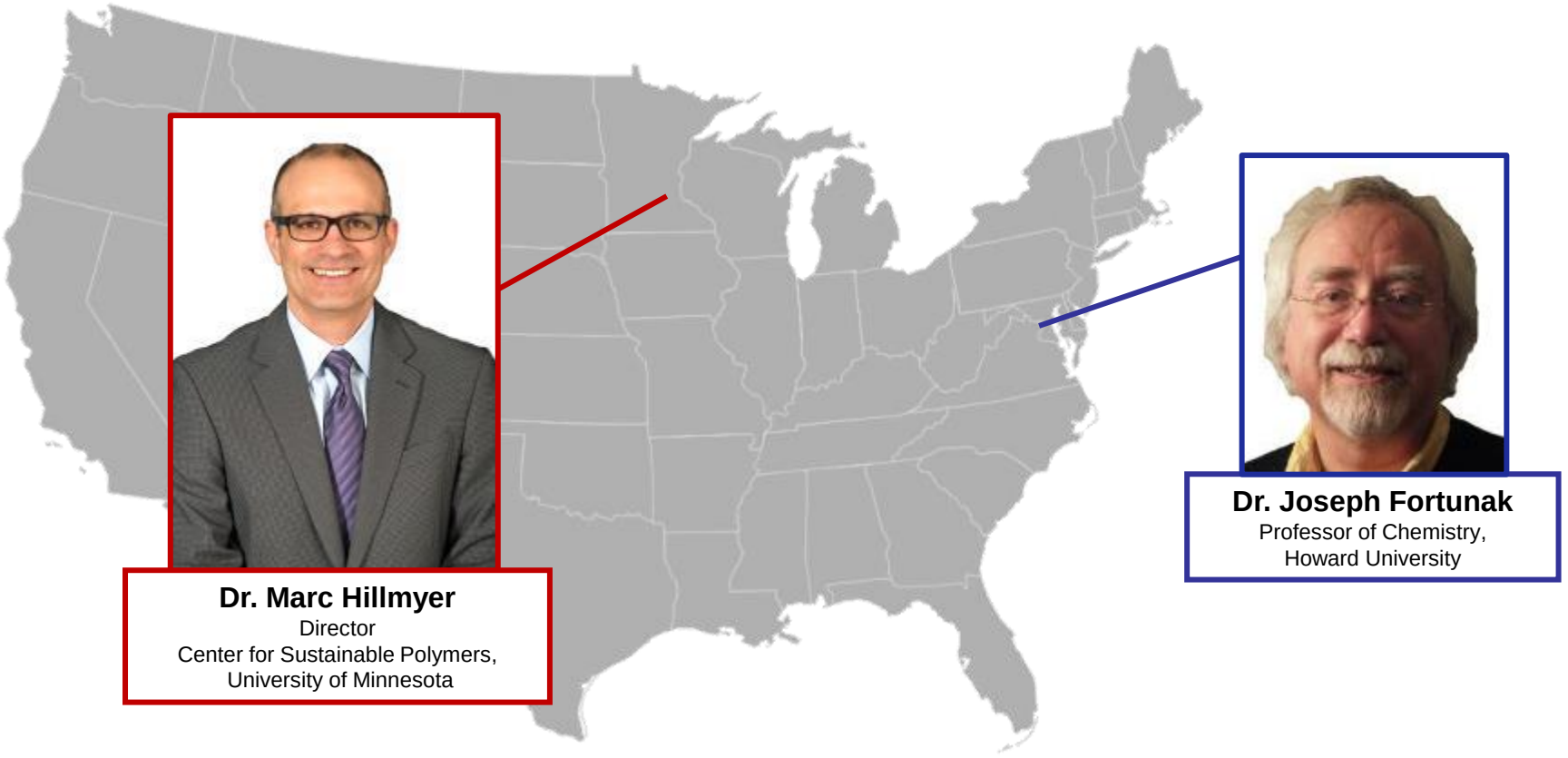
"Making Plastic Greener Through Next Generation Polymers"



Dr. Marc Hillmyer
Director
Center for Sustainable Polymers,
University of Minnesota

Dr. Joseph Fortunak
Professor of Chemistry,
Howard University

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Polymers are produced on the teragram scale. 1

The U.S. plastics industry creates nearly $400 billion in annual shipments. 2

Polymer production is largely based on finite feedstocks. 3

Polymer waste persists in the environment. 4

Making Plastic Greener Through Next Generation Polymers

Marc A. Hillmyer

UNIVERSITY OF MINNESOTA
Driven to Discover℠

Kechun Zhang | Frank Bates

Mingyong Xiong | Debbie Schneiderman

C&E News June 2, 2014

5

Susan Freinkel

A Toxic Love Story

"In a world of nearly seven billion souls and counting, we are not going to feed, clothe and house ourselves solely from wood, ore and stone; **we need plastics.** And in an era when we're concerned about our carbon footprint, we can appreciate that **lightweight plastics take less energy to produce** and transport than many other materials. Plastics also make possible green technology like solar panels and **lighter cars and planes that burn less fuel.** These "unnatural" synthetics, **intelligently deployed,** could turn out be nature's best ally."

New York Times 17 March 2011 6

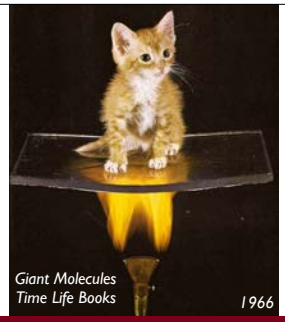
From "The end of cheap oil" National Geographic June 2004 7

lightweight

protective

strong

transparent



Giant Molecules
Time Life Books
1966

moldable

insulating

disposable

inexpensive

8

What could the future polymer industry look like?

Biomass (waste or non-nutritive)

↓ *bio, organic, & inorganic chemists*

Monomers (new and established)

↓ *polymer chemists & materials scientists*

Sophisticated materials (structure-controlled)

↓ *all stakeholders*

Sensible end-of-life solutions (recycling, incineration, compost)

integrated efforts by chemists, chemical engineers & materials scientists 9

REVIEW

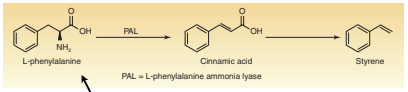
Valorization of Biomass: Deriving More Value from Waste

Christopher O. Tuck,[1] Eduardo Pérez,[1] István T. Horváth,[2]* Roger A. Sheldon,[3]* Martyn Poliakoff[1]*

Most of the carbon-based compounds currently manufactured by the chemical industry are derived from petroleum. The rising cost and dwindling supply of oil have been focusing attention on possible routes to making chemicals, fuels, and solvents from biomass instead. In this context, many recent studies have assessed the relative merits of applying different dedicated crops to chemical production. Here, we highlight the opportunities for diverting existing residual biomass—the by-products of present agricultural and food-processing streams—to this end.

Waste constitutes an enormous potential resource: hundreds of megatonnes (Mt)/year across the world.

(10^{11} kg or 10^{14} g)



from fermentation of biomass

How many billion kilograms in one teragram?

(a) 1

(b) 10

(c) 100

(d) 1000

Center for Sustainable Polymers

NSF Center for Chemical Innovation

University of Minnesota · Cornell University · Berkeley

- Established at UMN in May 2009
- Phase I NSF CCI September 2011
- Phase II CCI from the NSF August 2014

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Managing Director: Laura Seifert

Director of EO&D: Jennifer Henderson

CSP Grand Challenge

Discover efficient and precision conversions of renewable raw materials into innovative polymeric products that outperform the current suite of non-sustainable polymers from performance, environmental, and cost perspectives.

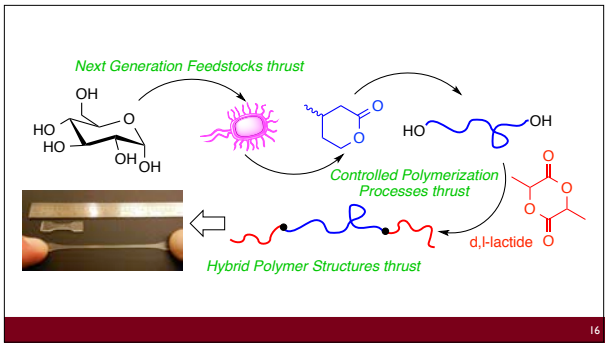
Integrative elements

- Center management
  Streamlined & lean approach that fosters creativity
- Innovation
  Effective engagement and partnerships with industry
- Education and Professional Development
  Train tomorrow's leaders in sustainable science and technology
- Informal Science Communication
  Capture the attention of kids and adults on a grand scale
- Broadening Participation
  Actively encourage diversity as a critical ingredient for success




3M, Arkema, Ashland, Aveda, BASF, Bayer, Biformix, Bostik, Bridgestone, Cambria, Cargill, Coca-Cola, Cortec, Cray Valley, Danimer, Dow, Eastman, Elevance, Fana Química, Franklin, General Mills, gevo, H.B. Fuller, Henkel, InterfacialSolutions, Kimberly-Clark, NatureWorks LLC, N, Novomer, Reluceo, Schlumberger, Segetis, Total, Wrigley

hillmyer@umn.edu 612-625-7834



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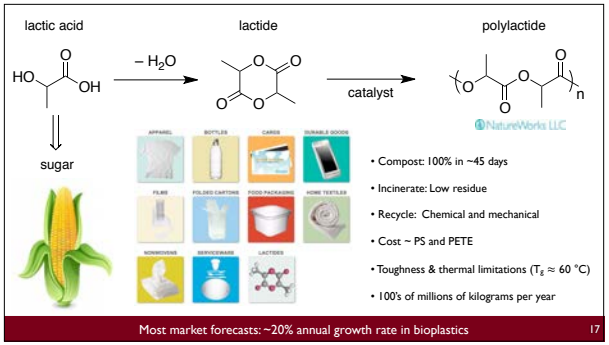
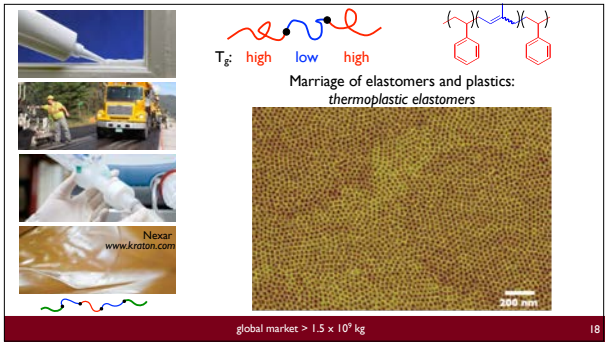


Most market forecasts: ~20% annual growth rate in bioplastics 17



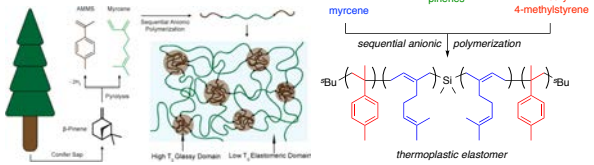
global market > 1.5 x 10^9 kg 18

ACS Macro Letters

Sustainable Thermoplastic Elastomers from Terpene-Derived Monomers

Justin M. Bolton,† Marc A. Hillmyer,* and Thomas R. Hoye*

Department of Chemistry, University of Minnesota, Minneapolis, Minnesota 55455-0431, United States

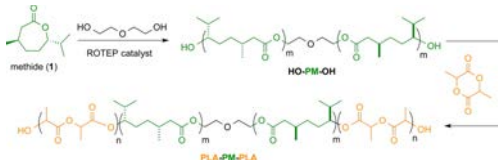


ACCOUNTS of chemical research

Aliphatic Polyester Block Polymers: Renewable, Degradable, and Sustainable

Marc A. Hillmyer* and William B. Tolman*

Department of Chemistry and Center for Sustainable Polymers, University of Minnesota, 207 Pleasant Street Southeast, Minneapolis, Minnesota 55455, United States



What is the approximate glass transition temperature of PLA?

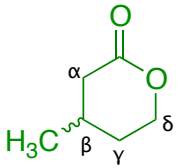
(a) –60 °C

(b) 0 °C

(c) 60 °C

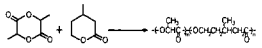
(d) 160 °C

β-methyl-δ-valerolactone



valeric acid found in the valerian plant
(Valeriana officinalis)

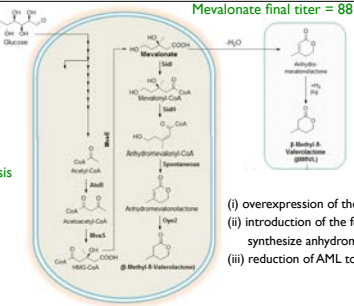
- Org. Syn. **1955**, *35*, 87
- Spicy-apple, sweet flavor in Turkish tobacco (*Tobac. Sci.* **1973**, *18*, 43)
- Cyclic ester susceptible to ROTEP
- ROTEP produces a low Tg polyester
- Early German & Japanese polymer patents (PUs)
- Extensive literature on use as synthon
- Very little in the literature on polymers



Scheme 1

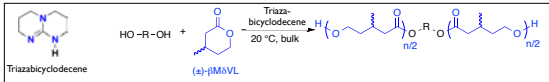
Mevalonate final titer = 88 g L^{-1}

Direct βMδVL biosynthesis

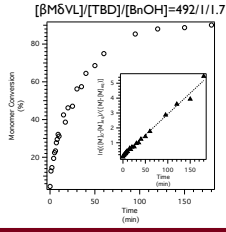


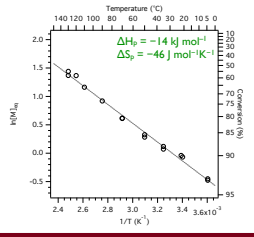
Semisynthesis: High yielding dehydration & hydrogenation

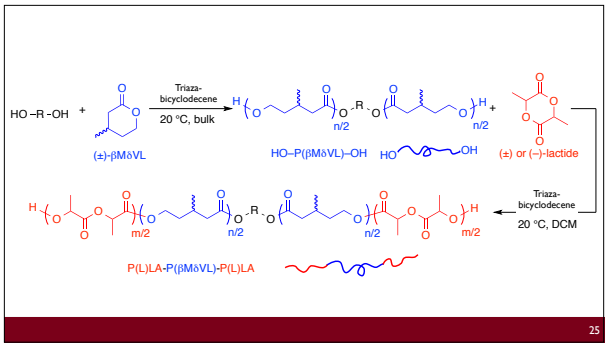
(i) overexpression of the mevalonate-producing enzymes
(ii) introduction of the fungal siderophore proteins to synthesize anhydromevalonolactone (AML)
(iii) reduction of AML to βMδVL by enolate reductases



[βMδVL]/[TBD]/[BnOH]=492/1/1.7







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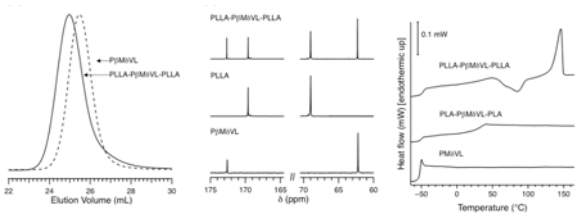
SEC NMR DSC



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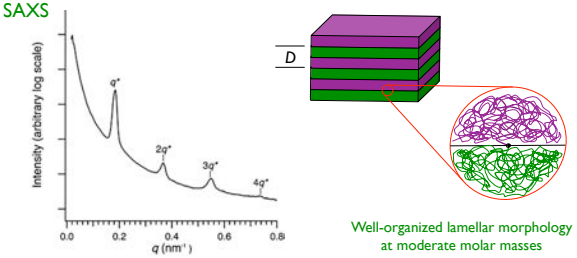
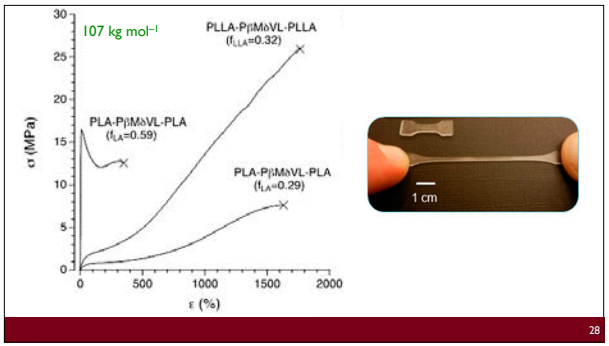
SAXS



Well-organized lamellar morphology at moderate molar masses

PLA–PβMδVL–PLA (16.2–20.0–16.2 kg mol^{-1})
(D = 33 nm)

27



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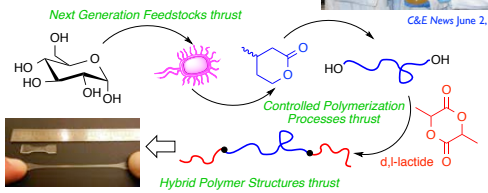
500 liter scale up on 5 March 2014

29

Discover efficient and precision conversions of renewable raw materials into innovative polymeric products that outperform the current suite of non-sustainable polymers from performance, environmental, and cost perspectives.

C&E News June 2, 2014



Xiong *et al. Proc. Natl. Acad. Sci.* **2014**, *111*, 8357.

30

How much does Prof. Hillmyer love sustainable polymers?

(a) not at all

(b) somewhat

(c) a lot

(d) a little too much

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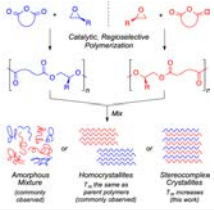
Poly(propylene succinate): A New Polymer Stereocomplex

Julie M. Longo, Angela M. DiCiccio, and Geoffrey W. Coates*
Department of Chemistry and Chemical Biology, Baker Laboratory, Cornell University, Ithaca, New York 14853-1301, United States



C&E News November 17, 2014

"It is relevant to the world of industrial polymers because it addresses issues with biodegradation, renewable raw materials, and the demands placed on modern plastics. In this case, that is the ability to crystallize quickly from the melt and have a melting point above 100 °C. In principle, this discovery could be a keystone of a new line of thermoplastic polymers." - Eric P. Wasserman, Dow Chemical

JACS spotlight
J. Am. Chem. Soc. **2014**, *136*, 15807−15808

J. Am. Chem. Soc. **2014**, *136*, 15897. (*ACS Editors' Choice*)

ChemComm
COMMUNICATION
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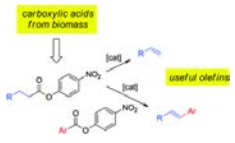
Olefins from biomass feedstocks: catalytic ester decarbonylation and tandem Heck-type coupling†

Alex John, Levi T. Hogan, Marc A. Hillmyer* and William B. Tolman*

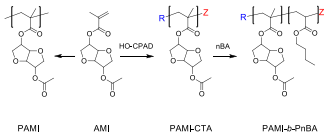
Cite this: *Chem. Commun.*, 2015, 51, 2731
Received 11th November 2014,
Accepted 3rd January 2015
DOI: 10.1039/c4cc09003a



Chem. Commun. **2015**, *51*, 2731.

Poly(acetylated methacrylic isosorbide) [PAMI]

James J. Gallagher, Marc A. Hillmyer,* and Theresa M. Reineke*
Department of Chemistry, University of Minnesota, 207 Pleasant Street SE, Minneapolis, MN 55455



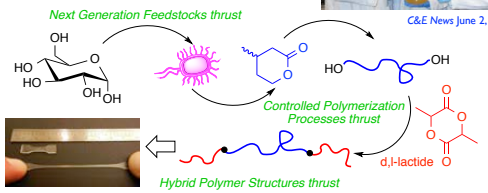
Thermally stable, high glass transition temperature polymethacrylate from sugar.

(isosorbide comes from the hydrogenation & dehydration of glucose)

ACS Sustainable Chem. Eng. in press **2015** (*ACS Editors' Choice*) 34

Discover efficient and precision conversions of renewable raw materials into innovative polymeric products that outperform the current suite of non-sustainable polymers from performance, environmental, and cost perspectives.

C&E News June 2, 2014



Xiong *et al. Proc. Natl.Acad. Sci.* **2014**, *111*, 8357. 35

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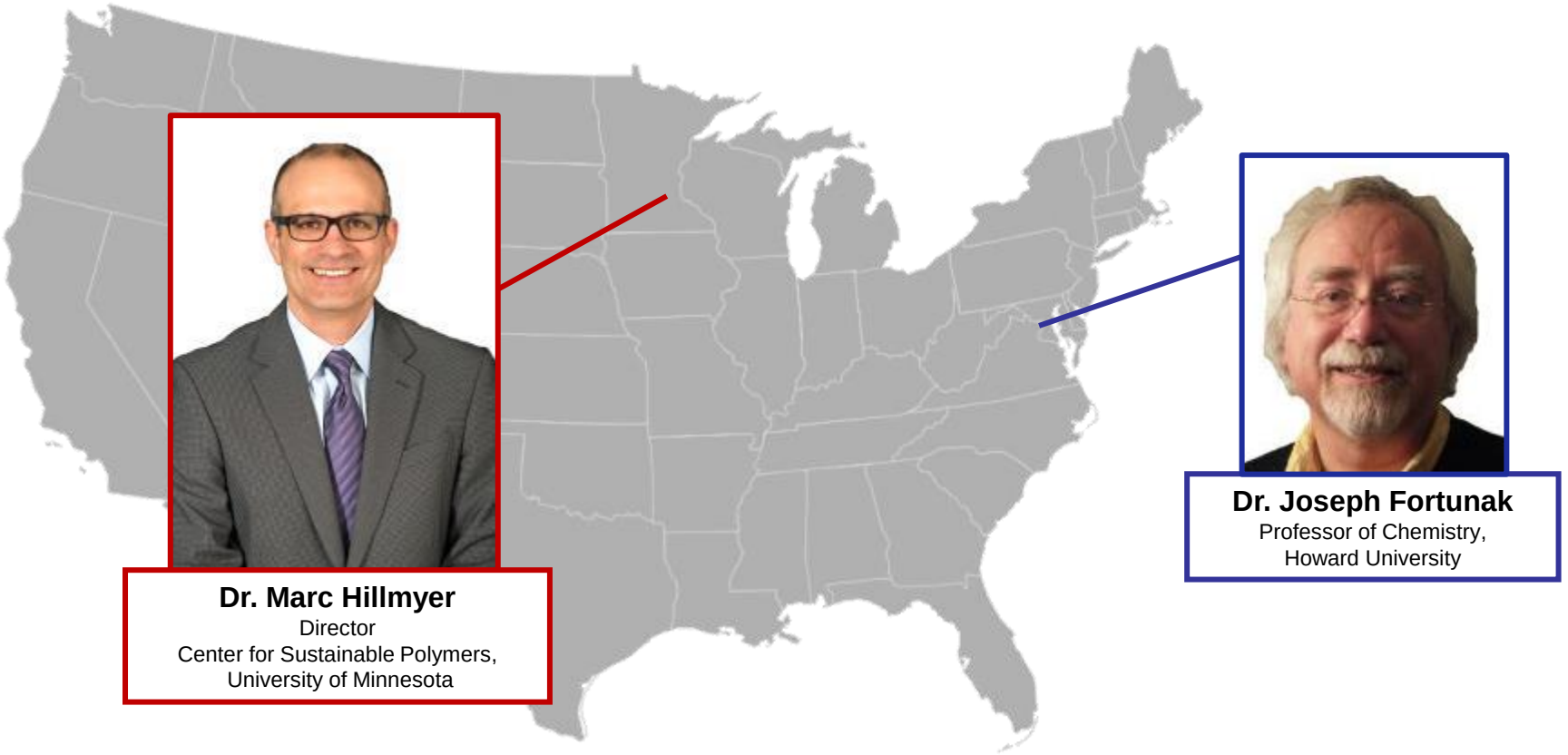

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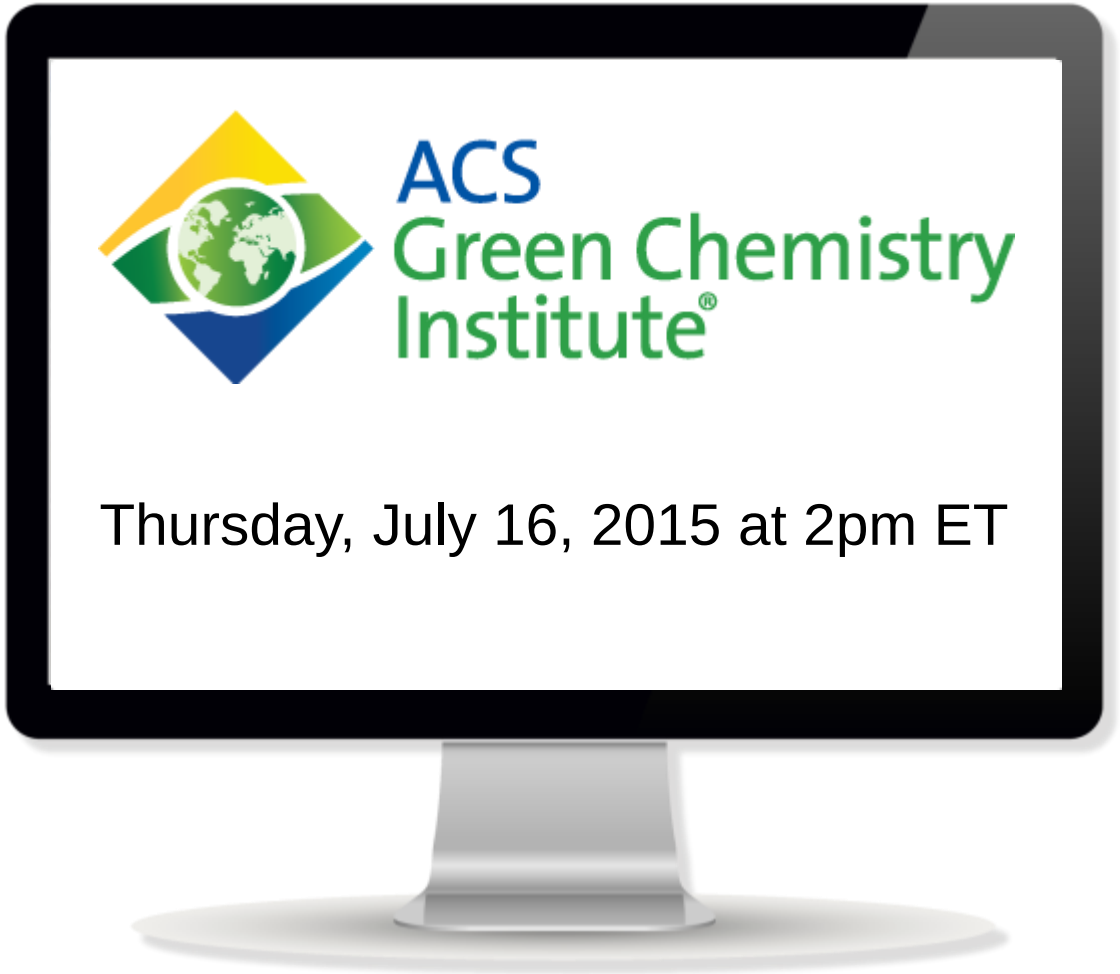

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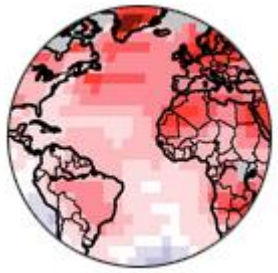

Thursday, March 12, 2015 at 2pm ET

"Bringing CO2 Monitoring to You: Communicating Atmospheric Chemistry"

Alexis Shusterman, PhD candidate, UC Berkeley
2014 ACS Chemistry Champions Competition Runner-Up

Dr. Darcy Gentleman, Manager, Engagement and Science Communications, The American Chemical Society

Wednesday, March 18, 2015 at 11am CST

"**Panorama Energético en la Era de la Sustentabilidad:** Energías Renovables y Dispositivos Emergentes"

Dr. Luis Echegoyen, Profesor de Química**,** Universidad de Texas, El Paso

Dr. Héctor D. Abruña, Profesor de Química**,** Universidad de Cornell

Dr. Ingrid Montes, ACS Junta de Directores y Profesora de Química Orgánica, Universidad de Puerto Rico, Recinto de Río

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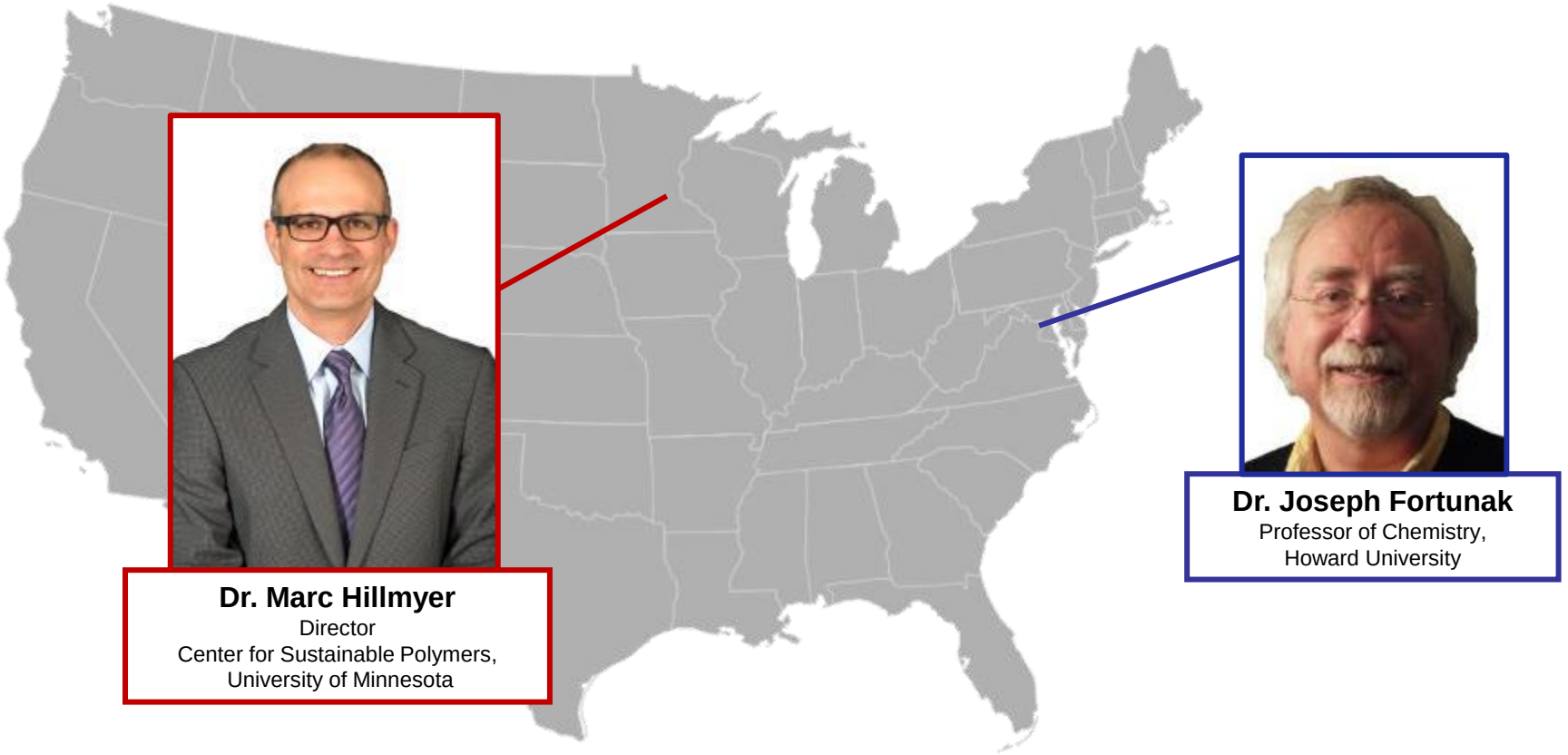

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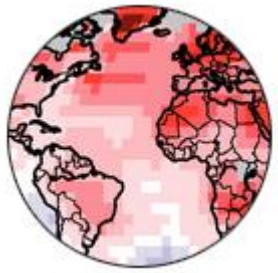

Thursday, March 12, 2015 at 2pm ET

"Bringing CO2 Monitoring to You: Communicating Atmospheric Chemistry"

Alexis Shusterman, PhD candidate, UC Berkeley
2014 ACS Chemistry Champions Competition Runner-Up

Dr. Darcy Gentleman, Manager, Engagement and Science Communications, The American Chemical Society

Wednesday, March 18, 2015 at 11am CST

"**Panorama Energético en la Era de la Sustentabilidad:** Energías Renovables y Dispositivos Emergentes"

Dr. Luis Echegoyen, Profesor de Química**,** Universidad de Texas, El Paso

Dr. Héctor D. Abruña, Profesor de Química**,** Universidad de Cornell

Dr. Ingrid Montes, ACS Junta de Directores y Profesora de Química Orgánica, Universidad de Puerto Rico, Recinto de Río

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