UIDP Webinar: Center for Bioplastics and Biocomposites

Moderator: Tony Boccanfuso, UIDP
Presenters: David Grewell, Iowa State University; Jason Locklin, University of Georgia; Vikram Yadama, Washington State University; and Deborah Mielewski, Ford Motor Company
Date: December 6, 2017

We will begin momentarily.
Disclaimer

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Center Vision

• CB² will **develop knowledge** about an array of high-value products from agricultural, forest feedstocks:
  – Plastics
  – Coatings
  – Adhesives
  – Composites

• **Compatibility** with current industrial manufacturing systems and **promotion of economic development** are paramount
Iowa State

- 37,001 Students (state’s largest)
  - 30,034 Undergraduate students
  - 5,096 Graduate students
  - 871 professionals
  - 118 countries
- Over 1,750 faculty
- A land grant institution
- Research institution (top 50)
- State GDP 18.6%* manufacturing
- Nearly 10,000* employed in the plastics industry

* CIRAS Report, Manufacturing in Iowa
Center organization

- NSF
  - Center Evaluator Marc Sokol
  - Industry Advisory Board
  - Center Coordinator Yijing Ding
  - University Policy Committee
    - Center Director David Grewell (ISU)
  - Site Co-Director Vik Yadama (WSU)

- 27 Faculty ISU
  - Research
    - Synthesis & Compounding
  - 20 Faculty WSU
    - Processing
    - Biobased Products
    - Modeling
    - Commercialization

- Feb 2017
Center organization
CB² project selection and management overview

- **January (JAN)**: Projects Initiated
- **May (MAY)**: 6 Month Review
- **November (NOV)**: Projects Review
- **December (JAN)**: Projects Initiated

**Project Selection:**
- Project Selection Initiated
- Call for Seed Concepts

**Project Selection Initiative:**
- Projects Initiated
- Project Selections
**CB² project selection**

- **MAY**
  - Call for seed concepts from IAB

- **JUL**
  - Proposals due, PIs (ISU, WSU)
  - Proposals sent to IAB

- **SEP**
  - Seed concepts due, prepared by IAB
  - Call for proposals, PIs (ISU, WSU)

- **OCT**
  - EARLY NOVEMBER
    - Revised final proposals due, PIs (ISU, WSU)
  - IAB vote of proposals
  - Final proposals for podium announced

- **NOV**
  - MID NOVEMBER
    - IAB meeting
    - Podium presentations
    - Final proposals selected for funding by IAB

- **JAN**
  - Selected projects start
CB² project management

- **JAN**: Selected projects start
- **MAR**: Quarterly reports due
- **MAY**: Bi-annual meeting
- **AUG**: Quarterly reports due
- **NOV**: IAB meeting

**MAY**
- Presentation by PIs on project status
- Review of center and project by IAB

**AUG**
- Review by IAB
- Review of center and project by IAB

**INTERNSHIPS AT IAB**

- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
- IAB Mentoring Meeting
Membership Justification

• Membership is a fraction of the costs for a full time employee with productivity matching that of an employee

• IP rights

• Company name is marketed on each of our communications
  • Emails
  • National and International presentations
  • Reports
  • Journal articles

• Project selection and mentoring
## 2016 Budget

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tangible</strong></td>
<td></td>
<td></td>
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<tr>
<td>Membership</td>
<td>$480,000</td>
<td></td>
</tr>
<tr>
<td>CIRAS</td>
<td>$30,000</td>
<td>Support from ISU Center for Industrial Research and service</td>
</tr>
<tr>
<td>College of Engineering</td>
<td>$18,178</td>
<td>WSU</td>
</tr>
<tr>
<td>College of Engineering</td>
<td>$10,322</td>
<td>ISU</td>
</tr>
<tr>
<td>College of Agriculture</td>
<td>$53,000</td>
<td>ISU</td>
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<tr>
<td><strong>Intangible</strong></td>
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<td></td>
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<tr>
<td>Members meeting costs</td>
<td>$112,500</td>
<td>20 at 2015 fall meeting; 25 at 2016 spring meeting. $2500/person.</td>
</tr>
<tr>
<td>Members mentoring costs</td>
<td>$25,920</td>
<td>24 mentors meeting 1 hour/month with 9 projects</td>
</tr>
<tr>
<td>In-kind center director time</td>
<td>$37,700</td>
<td>20 hours/month of in-kind support</td>
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<tr>
<td>In-kind site director time</td>
<td>$19,906</td>
<td>10 hours/month of in-kind support</td>
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<td>IDC waiver of membership</td>
<td>$240,000</td>
<td>waiver of indirect cost</td>
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<tr>
<td>3M hosting of spring IAB meeting</td>
<td>$10,000</td>
<td>Meals, rooms, tours</td>
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<tr>
<td><strong>Total</strong></td>
<td>$1,037,524</td>
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<tr>
<td><strong>NSF</strong></td>
<td>$202,500</td>
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<tr>
<td><strong>Leverage (non NSF funds: NSF funds)</strong></td>
<td>5.1</td>
<td></td>
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</table>
Funded projects (2017)

- Thermoplastics Starches Based Thin Films with Polyacrylated Glycerol as Plasticizer
- Production of Low Cost Lignin Composite Materials Using Bio Refinery Lignin
- Odor Control in Agave Fiber – Poly Propylene Biocomposites
- Develop Chitin Nano Fibers for High Performance Solvent Based Coatings and Films
Funded projects (2017)

- 9 total
- Fully Biobased Degradable Plastic with Insecticide Functionality
- Study on the Properties of Polyacrylated Glycerol Based Thermoplastic Elastomers as Self Tackified Biobased Pressure Sensitive Adhesives
- Develop Renewable Propylene Using Sugar Derived 1,2- Propanediol and Glycerol
- Interfacial Healing of Biopolymers
Funded projects (2018)

• Production of Low-Cost Lignin Composite Materials Using Biorefinery Lignin

• Increasing Interfacial Bonding in Agave Fiber-Polypropylene Biocomposites for Enhanced Properties

• Develop renewable propylene using sugar derived 1,2-propanediol and glycerol

• Consumer-safe bioplastic blister packs
Funded projects (2018)

• Towards Biobased ABS
• Biobased Transparent Waterborne UV Absorbing Coating
• PEN Polymers – Next Generation Bottles and Packaging Materials
• Vitrimerizing ester bond-containing thermoplastics for property improvement
Projects that may impact your company

• $30,000/year
  – $400,000/year research
  – $200,000/year IDC costs
  – $600,000/total
  – 35:1 leverage

• IP

• Networking
Next outreach

- **NPE**
  - 65,000 attendees
  - 10’x10’ booth (2016 40 x 40) - S19203
  - Orlando, May 7-11, 2018
Washington State University
BioProducts Research
Vikram Yadama, Site Co-Director

Webinar— December 6, 2017
National Science Foundation
Industry & University Cooperative Research Center
• Over 26,000 undergraduate, graduate, and professional students
• Founded in 1890 as the state of Washington’s land-grant university
• Research excellence in:
  • Engineering
  • Materials Science
  • Sustainable/Clean Technology
  • Agriculture
Composite Materials and Engineering Center (CMEC)

• ~50-year history of leadership in wood composite materials, polymeric materials (materials chemistry, materials processing, mechanics), and natural fibers.

• The 28,000 ft$^2$ facility houses equipment for:
  – Biomass processing equipment
  – Sorting, drying, blending and forming
  – Pelletizers
  – Pilot & commercial scale extruders
  – Hot presses for small & full size panels
  – RTM/VARTM
  – Injection molding equipment
  – Strong floor for structural testing
The Concept is to Foster Interdisciplinary Collaboration

- Air Quality
- Water Quality
- Materials and Biofuels
- Structural Systems
- Transportation Materials
Composite Materials and Engineering Center

✓ Material Characterization
  • Adhesive performance
  • Chemical, thermal and rheological behavior

✓ Composite Fabrication
  • CLT, and panel products
  • Polymer processing capacity
  • Raw material refinement

✓ Structural Engineering
  • Timber and wood framed structures
  • Mechanics and dynamic analysis
  • Reliability
  • Non-destructive analysis
  • ICC accredited Laboratory

✓ Environmental Exposure
  • Hygrothermal behavior of wall systems
Thrust Areas

- Feedstock Logistics
- Economics, Social Issues and Commercialization
- Synthesis and Compounding
- Composites
- Performance Evaluation and Engineering Design
Lignocellulosic Biomass

**Cellulose** 40-45%
- Crystalline
- Linear polysaccharide of glucose

**Hemicellulose** 25-35%
- Amorphous
- Branched polysaccharide of xylose

**Lignin** 15-35%
- Amorphous
- Highly branched aromatic polymer
- Phenylpropanols
5-Year USDA CAP (Co-PDs: Wolcott & Cavalieri)
NARA TEAM

Catchlight Energy
CLH
Cosmo Specialty Fiber
Facing the Future
Gevo, Inc.
Gevan Marrs, LLC.
Montana State University
Oregon State University
Pennsylvania State Univ.
Salish Kootenai College
Steadfast Management
TSI Inc.

University of Idaho
University of Minnesota
University of Montana
University of Washington
University of Wisconsin
USFS – Forest Products Lab
USFS – PNW Research Sta.
University of Utah
Washington State University
Western Washington Univ.
Weyerhaeuser
Characteristic Grinding Operations
Fuel Path

Feedstock
- Weyerhaeuser
- Confederated Salish & Kootenai Tribes
- Muckleshoot Tribe
- Cosmo Spec Fiber
- Lane Forest Products

Pretreatment
- Andritz
- ZeaChem

Fermentation/Separation
- ICM
- Whitefox

Alcohol to Jet
- South Hampton Refining
Fuel Distribution and Demonstration

**Fuel Certification**
- Alter Jet - ASTM D7566
- Blending
- Conv Jet – ASTM D1655
- Distribution to Wing
- Commercial Demonstration Flight

**Partners**
- Gevo Corp
- EPIC / SwissPort
- Alaska Airlines

**1st Commercial Cellulosic Biofuels Flight**
Seattle to DC
Valuable Lessons

Technical: *High recalcitrant nature of softwood species*

Feedstock supply risk: *Low quality, variability, logistics, etc*

Economic: *Overall cost of biofuels production is high*
Integrated Technologies To Facilitate Biorefinery

Hot water extraction (HWE) as a viable pretreatment step in an integrated process

Douglas fir/Ponderosa Pine/Hardwoods

Materials: Ponderosa pine

Small logs Undebarked

HWE

T = 160°C, t = 90 min

SUGARS (~67%)

ACETIC ACID + INORGANICS + OTHERS

WPC, Particleboard, MDF

Lignin Structure

Obstacles

- Highly branched structure
- Strong intramolecular force
- Low/no solubility in solvents

Potential feedstock for:
- Aromatic chemicals
- Polymer materials

Need

- Abundant hydroxyls
- Low accessibility of OH groups
- Low reaction efficiency and conversion

Need a simpler and greener modification method of lignin
Diverse Polymer Applications for Lignin

Waste cooking oil

Mild conditions
Easy treatments

Kraft lignin

Commercial Asphalt + Triepoxy + Lignin curing agent → Epoxy Asphalt

Professor Jinwen Zhang, Dr. Junna Xin & their team
Diverse Polymer Applications for Lignin

Waste cooking oil
Polymerization without solvent

Bio-asphalt  +  Lignin epoxy  →  Epoxy Bio-asphalt

Kraft lignin

Professor Jinwen Zhang, Dr. Junna Xin & their team

Commercial Asphalt  +  Triepoxy  +  Lignin curing agent  →  Epoxy Asphalt
Diverse Polymer Applications for Lignin

- **Lignin as feedstock for bioabsorbents**
  - Lignin-based adsorbent (LBA) for the selective removal of Cd(II) (ACS Sustainable Chemistry and Engineering 2017, 5, 4086)

- **Lignin as feedstock for hydrogels** (ACS Omega, 2017, 2 (1) : 251-259)

- **Lignin as feedstock for thermoplastics** (Chemistry Select 2016, 1, 3449)

- **Lignin as feedstock for epoxies**
  - Partially depolymerized lignin (PDL)-derived curing agents
  - PDL-derived epoxies (ACS Sustainable Chemistry and Engineering 2016, 4, 2754)
Mechanochemical Approaches to the Conversion of Cellulosic Wastes into Value-Added Products

Michael P Wolcott – Regents Professor
Mohammadali Azadfar – Post Doctoral Fellow
Max Graham – Undergraduate Student
Lang Huang – Graduate Student
Ball-milling of wood pulp: physicochemical modification of cellulose powder
Solvent-free method of activating cellulose powder: as reinforcing agent in PP matrix
Developing nano-chitin and chitin derivatives for transparent packaging film and coating applications
Michael P. Wolcott, Jinwu Wang, Hang Liu and Tuhua Zhong
Washington State University

Shrimp shell

Commercial chitin powder from shrimp shell

Chitin nanofibers dispersion in water


*TEM: Transmission electron microscopy


6 to 8 million tons of waste crab, shrimp and lobster shells were produced globally every year.

Chitin
(15-40%)

Protein
(20-40%)

Calcium carbonate
(20-50%)

Chitin propionate solution in 90% aqueous ethanol

Diameter: 8.2 ±3.3 nm
Length: 147.9±57.7 nm

Product #1

1.5 wt%

Product #2

1.8 wt%
Organo-soluble chitin propionate (CP) applications

Chitin propionate in 90% aqueous ethanol

Highly transparent CP film

Tensile strength test

Bio-based CP films

CP coated paper

Control

*Photo source: https://www.azom.com/article.aspx?ArticleID=510
Textile Research & Testing

Xenon Weather-ometer

Martindale Abrasion & Pill Tester

3-D Body Scanner

Capillary Flow Porometer

Hydrostatic Pressure Testing

Elmatear² Digital Tear Testing

Contact Angle Tester (VCA OPTIMA)
Low Environmental Impact Hemp Fiber Extraction & Applications
Post-Consumer Cotton Waste Recycling for Regenerated Fibers

- Environmentally Friendly solvents for textile waste dissolution
- Wet spinning for controllable high quality regenerated fibers
Vikram Yadama
Washington State University, Pullman, WA
vyadama@wsu.edu
509-335-6261
600+ products introduced to the marketplace

35 new products on the market in FY 2016

Top 5 among all US universities in new products reaching the marketplace 3rd consecutive year

Top 10 total licenses & options among all U.S. universities 9th consecutive year
NMI takes a **systems approach** to the challenges of design and disposal of new products and materials. Its goal is the development of new materials guided by **green engineering principles**: the design and use of processes and products in a way that minimizes pollution, promotes sustainability and protects human health—without sacrificing economic viability and efficiency.
Plastic waste inputs from land into the ocean in 2010

The 192 countries with a coast bordering Atlantic, Pacific, and Indian oceans, Mediterranean and Black seas produced a total of 2.5 billion metric tons of solid waste. Of that, 275 million metric tons was plastic, and an estimated 8 million metric tons of mismanaged plastic waste entered the ocean in 2010.

Mitigation options:
- Reduce plastic in waste stream
- Improve solid waste management infrastructure
- Increase capture

Generated by 2 billion people within 50 km (30 miles) of the coast

Estimated mass of plastic waste floating at the ocean surface: 6,350-245,000 metric tons

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*Plastics Europe, “Plastics—the Facts 2013” (2010 data)
**Ozier et al., 2014. Eriksen et al., 2014
Plastic to Microplastic

This

Becomes


http://marinedebris.noaa.gov/info/plastic.html

Problem solving... at the speed of business
1. Industry-led or reduce demand
2. Green Engineering, Circular Economy
3. Reusable items, Sharing/Collaborative Economy
4. Context-sensitive Solid Waste management Infrastructure
5. Litter Capture and Clean-up
The New Materials Institute will host a planning meeting for the proposed UGA CB² site addition on **February 6-7, 2018 in Athens, GA** to develop the implementation plan for the proposed UGA CB² site addition.

UGA will contribute new researchers, industry members, and projects in CB² toward the mission of **engineering more sustainable packaging**.

This involves developing alternative biodegradable plastics and novel recycling methodologies for the packaging industries, including coatings, foams, and thermoplastics with excellent barrier properties for films and sheet goods.
Current Planning Meeting Attendees
Building the Bio-based Automobile

Debbie Mielewski, Senior Technical Leader, Sustainable Materials, Ford Motor Company

Webinar—December 6, 2017
National Science Foundation
Industry & University Cooperative Research Center
Ford’s Rich History in Bio-based Materials
Our vision for the 21st century is to provide SUSTAINABLE transportation that is affordable in every sense of the word:

...while the automobile provided tremendous benefits to mankind in the 20th century, “it also had a major negative impact on the environment. To be considered a leader in corporate citizenship, an automobile company must demonstrate leadership in addressing environmental concerns.”

- Bill Ford
SUSTAINABLE MATERIALS STRATEGY

- Increasing our use of recycled materials
- Continuing to develop plant-based renewable materials
- Eliminating substances of concern
- Addressing end-of-life impacts through improved recyclability
- Working with environmentally and socially friendly suppliers
Bio-Materials: Why Now?

• Increased use of renewable feedstocks and agricultural products
• Use of recycled or waste products
• Reduce dependence on petroleum
• Improved LCA-better for the earth
• Improved performance in select functions
• Increased MATERIAL CHOICE
• Increased consumer awareness
• Some are LIGHTWEIGHT-FE
• Revenue for farmers
Sustainable Materials Technical Challenges

• Automotive environment
  - -40 °C to 85 °C to 130 °C
  - 10+ years / 120,000+ miles
• Appearance requirements
• New failure modes possible
• Multiple processing methods
• Natural Fibers are hydrophilic: Issues of compatibility with polymers
• Natural Fibers are hygroscopic i.e. sensitive to humidity: processability - porosity issues
• Limited thermal stability: Fiber degradation during processing.
Implementation of Soy Foam on 2008 Mustang

Seat supplier: Lear Corporation

Applications: seat cushion & back

Times Square, New York, July 2007
Success: 8 Renewable Materials

Renewable *feedstocks* in production at Ford today

- soy
- jute
- wheat straw
- kenaf
- castor beans
- rice hulls
- coconut
- cellulose
Ford and Heinz
You Say Tomato, We Say Tom-Auto

**OVERVIEW:** In the spring of 2014, Ford and Heinz began a collaboration to investigate the use of tomato fibers in developing sustainable, composite materials for use in vehicle. Specifically, the team was testing the material’s durability for potential use in wiring brackets or the storage bins in a Ford vehicle.

**PROCESS:** Thus far, we have learned how to grind and dry the materials. We have mixed them with poly(propylene) resins and generated injection molded, composite materials for testing. We continue to optimize both dispersion and mechanical properties of the tomato fiber plastic.

**MEDIA AWARENESS:** News of the collaboration garnered amazing results, with nearly 100 original U.S. articles and broadcast hits in the first week. Top placements include broadcast in NPR and Bloomberg’s “The Pulse,” and articles in the Wall Street Journal, TIME, Reuters, Fox Business, CNN Money, USA Today, Examiner, Popular Science, and syndication via the Associated Press. Even Jimmy Fallon picked up the news after we pitched his producer. To this day, we continue to receive inbound requests for sustainable materials interviews.
Sustainable Materials Research

Bio-based Foams
- castor
- soy
- palm
- algae

Recycled Materials
- jeans
- bottles
- money

Natural Fiber Composites
- Oat hulls
- wheat straw
- coconut
- cellulose

Bio-based Resins
- sugarcane
- bamboo
- corn
- dandelion

Fermentation
The Value of CB² to Ford

- Excellent networking opportunities
- Recruit students trained in the field of bioplastics and biocomposites (2 interns)
- Leverage research funds and increase company visibility through joint publications and conference presentations.
- Direct the research projects and mentor the following projects
  - Increasing Interfacial Bonding in Agave Fiber-Polypropylene Biocomposites for Enhanced Properties
  - Production of Low-Cost Lignin Composite Materials Using Biorefinery Lignin
Thank you for participating

www.uidp.org
info@uidp.net
(803) 807-3679

Sign up for information about UIDP news, webinars, projects, and more at uidp.org/newsletter-signup/