SUSTAINABLE BIOMATERIALS RESEARCH

"A SNAPSHOT OF ACTIVITIES AT VT"

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DEPARTMENT OF SUSTAINABLE BIOMATERIALS

MORE PEOPLE, MORE DEMAND FOR ENERGY, NUTRITION, AND SUSTAINABLE MATERIALS

Providing for 9 billion by 2050

Current World Population

7,174,738,958

view all people on 1 page >

154,030	Births today	**90,410,132**	Births this year
63,555	Deaths today	**37,304,306**	Deaths this year
90,475	Population growth today	**53,105,826**	Population growth this year

Top 20 Largest Countries by Population (live)

1	China	1,386,836,530	11	Mexico	122,559,010
2	India	1,254,498,295	12	Philippines	98,656,735
3	USA	320,442,046	13	Ethiopia	94,472,592
4	Indonesia	250,320,801	14	Vietnam	91,813,750
5	Brazil	200,620,212	15	Germany	82,714,930
6	Pakistan	182,604,587	16	Egypt	82,262,033
7	Nigeria	174,372,663	17	Iran	77,605,064
8	Bangladesh	156,891,261	18	Turkey	75,072,506
9	Russia	142,777,158	19	Congo	67,799,255
10	Japan	127,121,160	20	Thailand	67,043,153

Population clock as of 8/26/13
http://www.worldometers.info/world-population/

CARBON CYCLES FOR ENERGY

Comparison life cycle CO_2 emissions

Gasoline:

98 kg CO_2 per million Btu

Corn ethanol:

62 kg CO_2 per million Btu

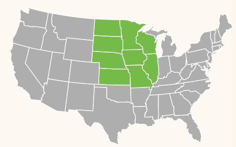
Sugarcane ethanol:

45 kg CO_2 per million Btu

SWITCHGRASS
(Panicum virgatum)

Type: Perennial bunchgrass

Region: Midwestern prairie states



Land-use impact: Displaces primarily soybeans and wheat and to a lesser extent hay, rice, sorghum, and cotton

Yield: ▨ ▨ ▨ ▨ ▨
Up to 5 dry tons per acre

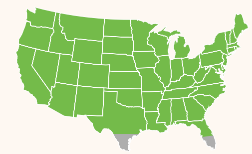
Life cycle CO_2 emissions:

13 kg CO_2 per million Btu

HYBRID POPLAR
(hybrid of *Populus* genus members)

Type: Fast-growing hardwood

Region: All of the continental U.S. except for the southern tips of Texas and Florida



Land-use impact: Small; poplar plantations are currently grown for paper pulp and lumber

Yield: ▨ ▨ ▨ ▨ ▨ ▨ ▨ ▨ ▨ ▨
10 dry tons per acre

Life cycle CO_2 emissions:

9 kg CO_2 per million Btu

Volume 91 Issue 32 | pp. 11-15
Issue Date: August 12, 2013
Seeking Biomass Feedstocks That Can Compete
Chem. & Eng. News

Wood is good

SNAPSHOT OF VT'S EFFORTS IN SUSTAINABLE BIOMATERIALS

Wood

Cellulose, cellulose nanoparticles, and derivatives, lignin-based materials, xylan

Shell

Coconut, walnut, and other nut shells

Other Biomass

Spent barley grains, bamboo, switchgrass, canola seed, corn cob

Aquatic derived biomaterials

Chitin and chitosan from crustaceans, alginic acid from seaweed, algae

Fermentation of sugars or degraded lignin products into

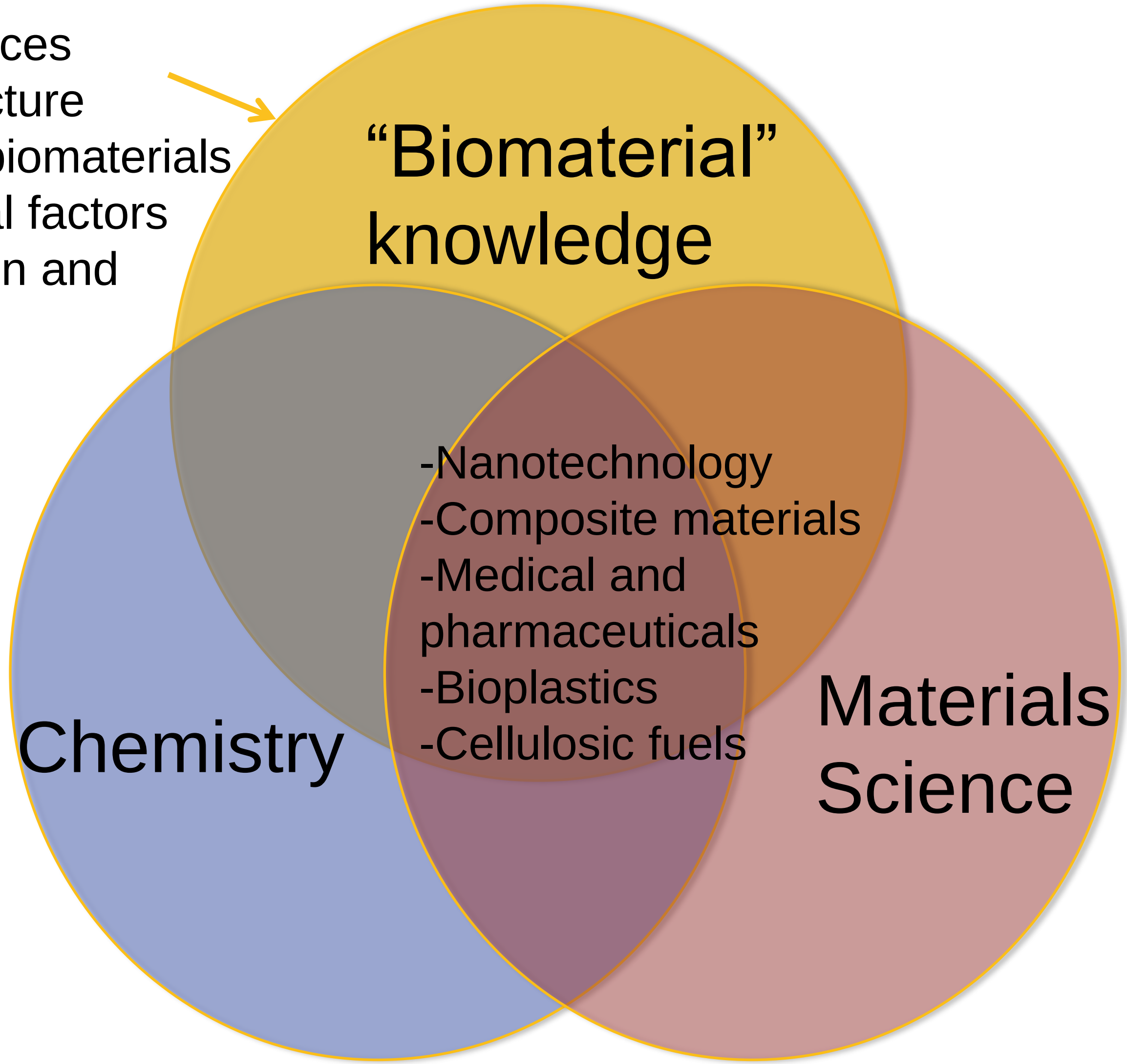
Polymers like bacterial cellulose and monomers such as urushiol oil or PDC,

Commercial Bioplastics

Cellulose acetate, polylactic acid, and starch

FROM UNDERSTANDING MOLECULAR PLANT WALL STRUCTURE TO IMPROVING RENEWABLE PRODUCTS

-Biomass sources
-Cell wall structure
-Variability of biomaterials
-Environmental factors
-Deconstruction and conversion



-Polymer
-Physical
-Analytical
-Organic

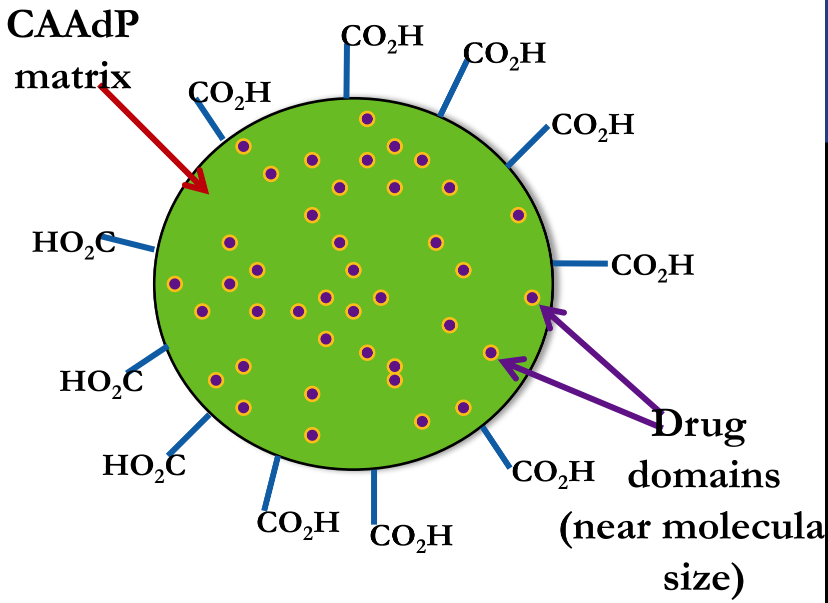
-Structure
-Physics
-Mechanics
-Composites
-Processing

RENEWABLE BIOMATERIALS AND HUMAN HEALTH

KEVIN J. EDGAR LABORATORY

Dissolving bricks; polysaccharides in drug delivery:

- 50% of marketed drugs poorly soluble, this means they can't get into bloodstream
- Wastes money, drugs get into wastewater (resistant organisms), harms patients
- We have carried out extensive synthesis and structure-property studies (with Lynne Taylor, Purdue) to identify some of the best polymers ever seen for enhancing drug solubility (novel cellulose esters including CAAdP) by making nanodispersions of drug in polymer; further improvement if we make nanodispersion particles < 250 nm diameter

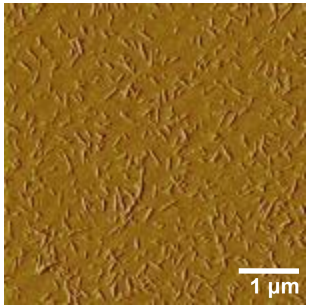


Delivering the undeliverable; cells, proteins:

- Developed first-ever solvents for alginate (from renewable seaweed)
- Solvents help us make new alginate derivatives that make great nanogels for delivery of cells and other delicate things
- Artificial pancreas for diabetics, protein drugs for cancer; protection from immune system and effective delivery

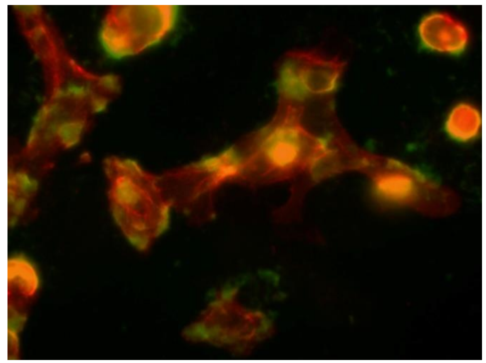
edgarresearch.org

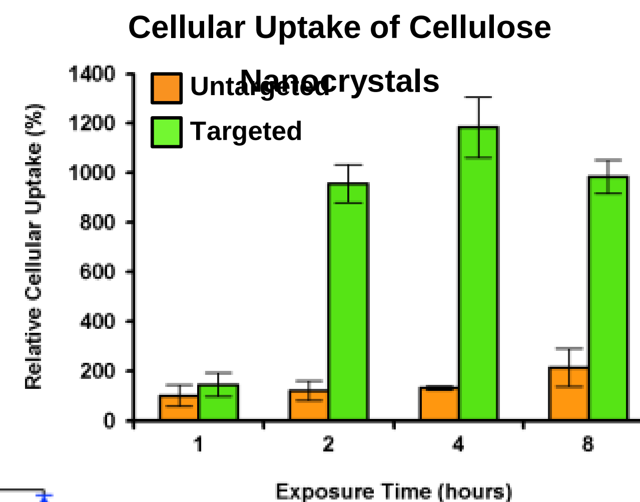
Virginia Tech Invent the Future



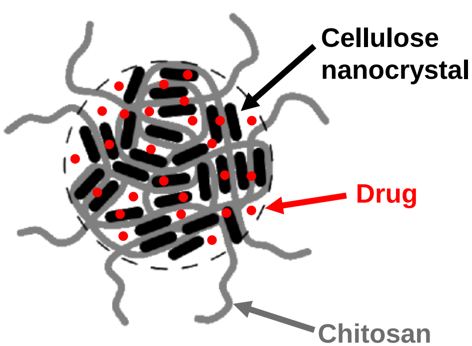
Cellulose Nanocrystal Mediated Bioimaging and Drug Delivery

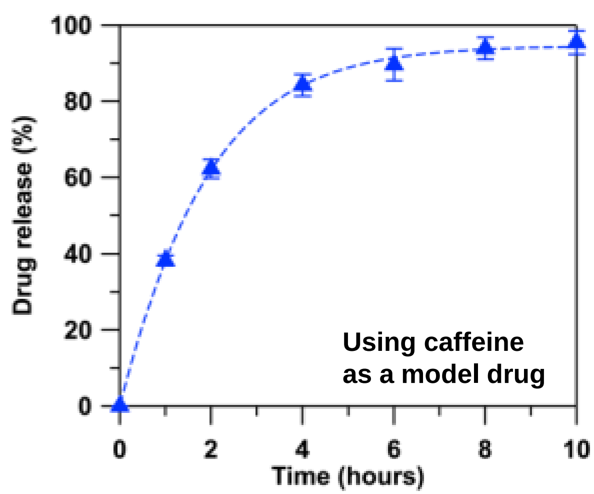
1. Targeted Intracellular Drug Delivery

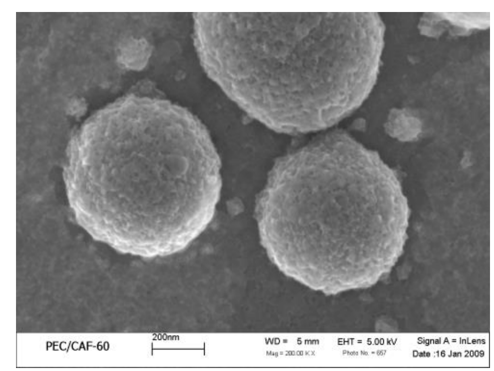


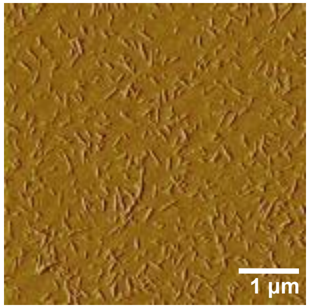


2. Oral Drug Delivery



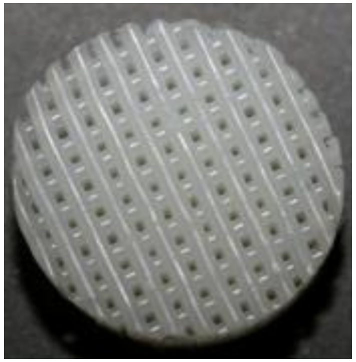




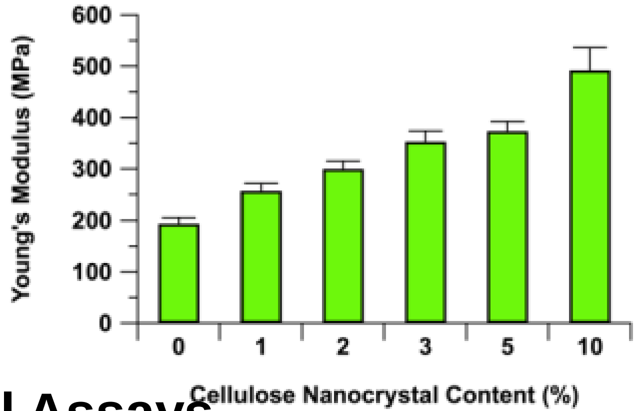


Cellulose Nanocrystal Applications in Medical Devices

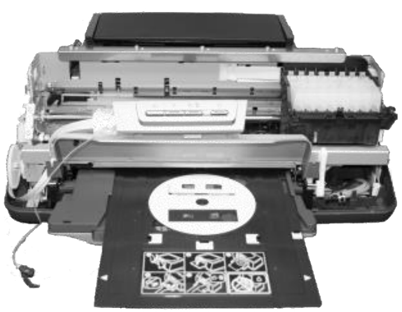
1. Cellulose Nanocomposites for Bone Scaffolds

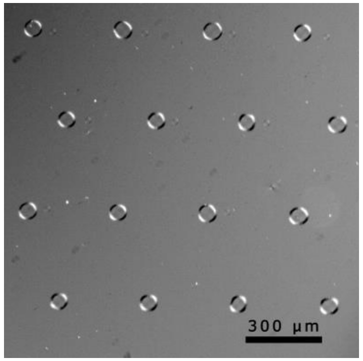


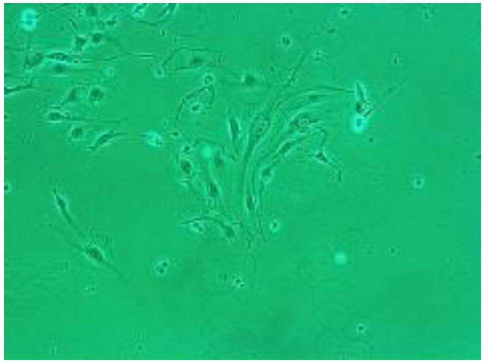
Polycaprolactone Nanoreinforcement



2. Inkjet Printed Micropatterns for Biological Assays

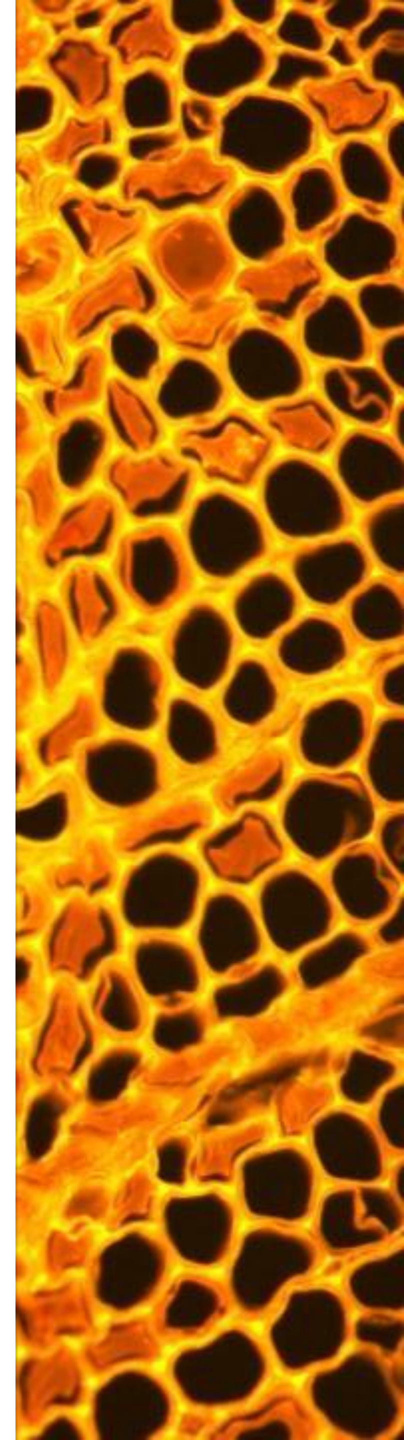






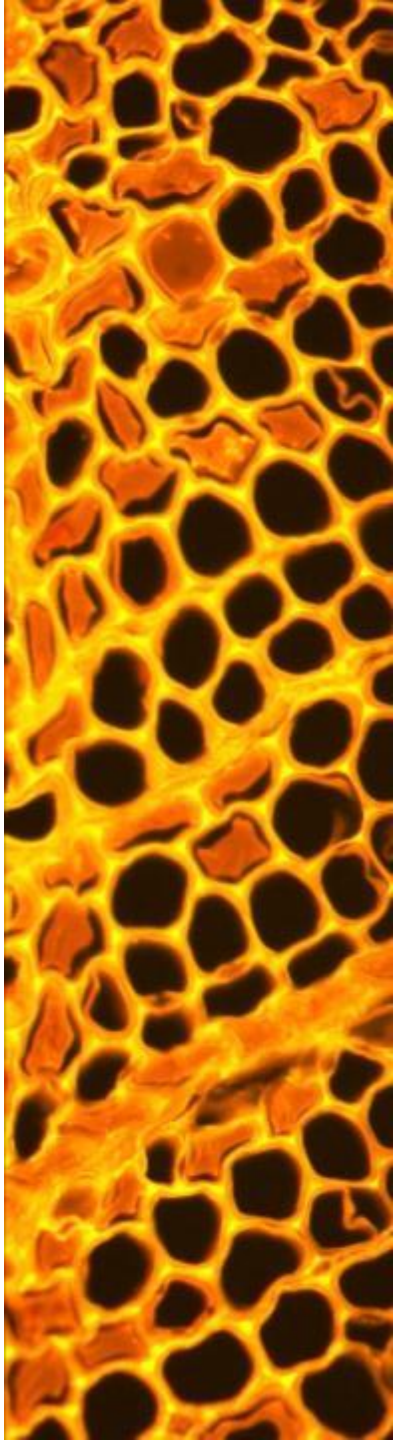
FRAZIER: SPECIFIC RESEARCH ACTIVITIES

1. Impact of filler properties on phenol-formaldehyde adhesion.
   - Corn cob residue, Alder bark & walnut shell fillers.
   - Filler particle size effects.
   - Filler surface chemistry.
2. Native-wood formaldehyde emissions.
   - New emission regulations limit release near levels of natural emission.
   - Natural emission poorly documented, not understood.
   - Measuring emissions as a function of thermal & chemical processing, & lignin chemistry.
3. Adhesion Fundamentals in Spotted Gum (*Corymbia sp*.).
   - Compare surface chemistries of spotted gum and Gympie messmate (*Eucalyptus cloeziana*).
   - Compare sensitivities to heat-induced surface deactivation.



FRAZIER: SPECIFIC RESEARCH ACTIVITIES

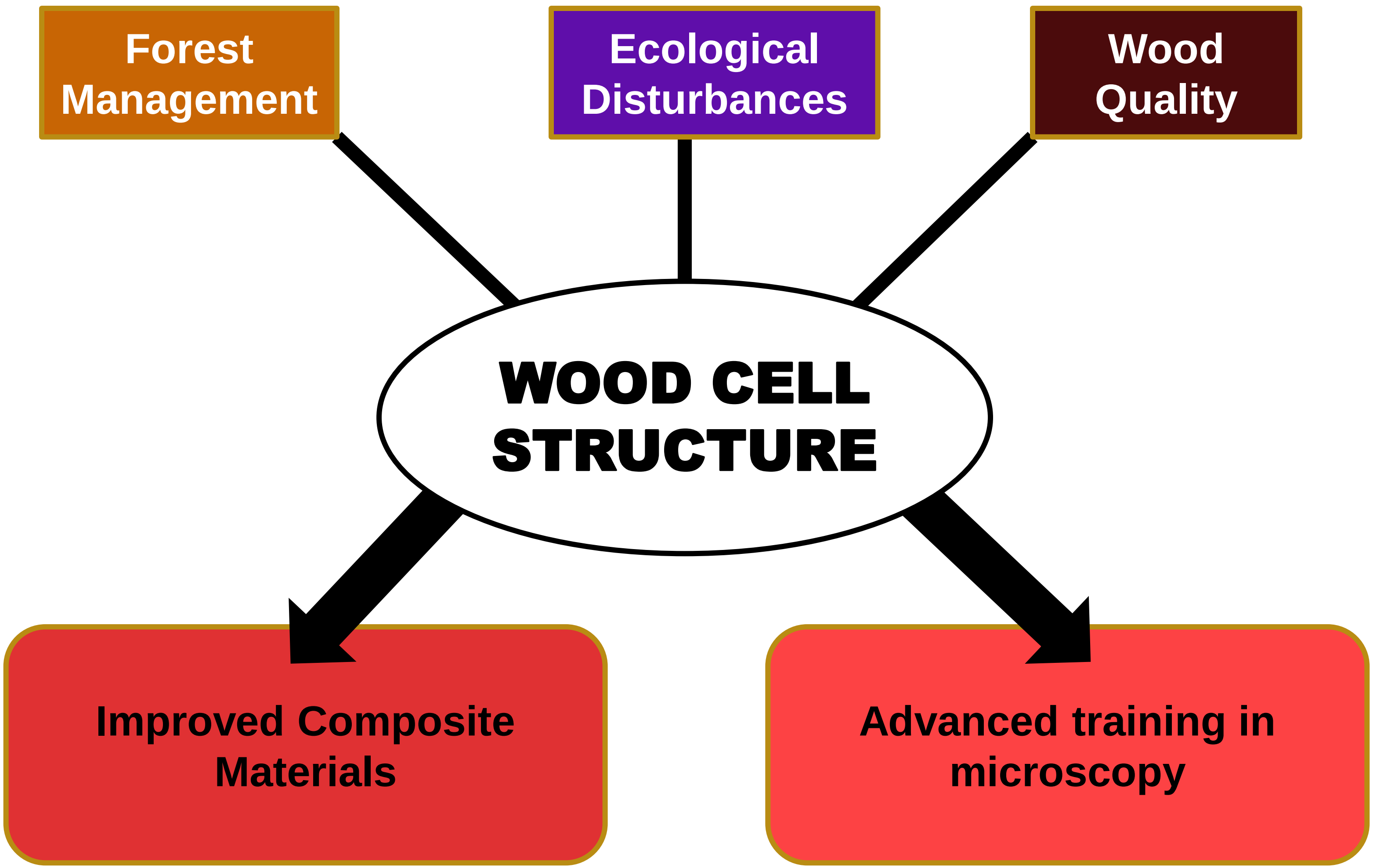
4. Urushiol (poison ivy oil) as a reactive monomer.
   - Collaboration w/ John Jelsesko, Plant pathology & Hong Leigh (visiting scholar).
   - Clone poison ivy oil genes; express via fermentation.
   - Study chemistry of urushiol as a reactive monomer in thermosetting adhesives.
5. Switchgrass rheology
   - Collaboration w/ Bingyu Zhao, Horticulture.
   - Genetically modified plants for enhanced liquid fuels yield.
   - Studying the glass transition in the altered plants.
6. Bamboo rheology
   - Collaboration w/ Fangli Sun (visiting scholar).
   - Fundamentals of bamboo cell wall organization.
   - Studying the glass transition as a function of pH.



Quantitative Wood Anatomy

Audrey Zink-Sharp, Professor

QWA: Connects anatomical structure to improvement of composite materials and advances training in light and scanning electron microscopy



EXAMPLE: RELATING FOREST MANAGEMENT AND ECOLOGICAL DISTURBANCES WITH WOOD QUALITY AND VARIABILITY

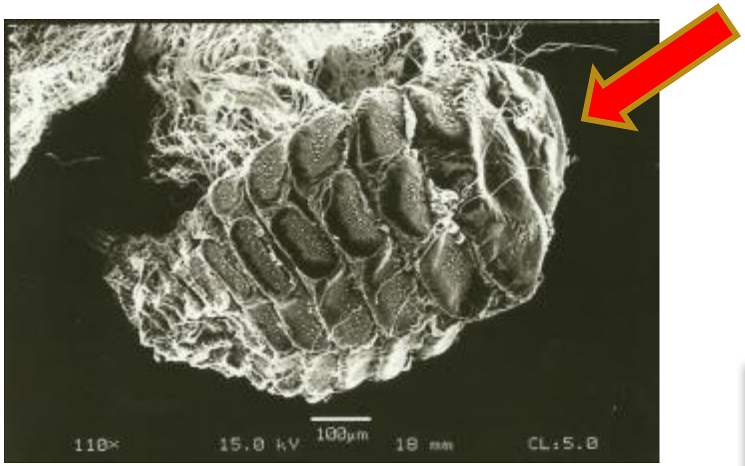


Figure 1 –Immature hemlock woolly adelgid. Arrow indicates insect's head.

Radial growth response of eastern hemlock to infestation of hemlock woolly adelgid

David M. Walker, Carolyn A. Copenheaver, Audrey Zink-Sharp

submitted to Annals of Forest Science, July 2013

Figure 2 – Healthy hemlock (left) vs. hemlock heavily defoliated by hemlock woolly adelgid (right).

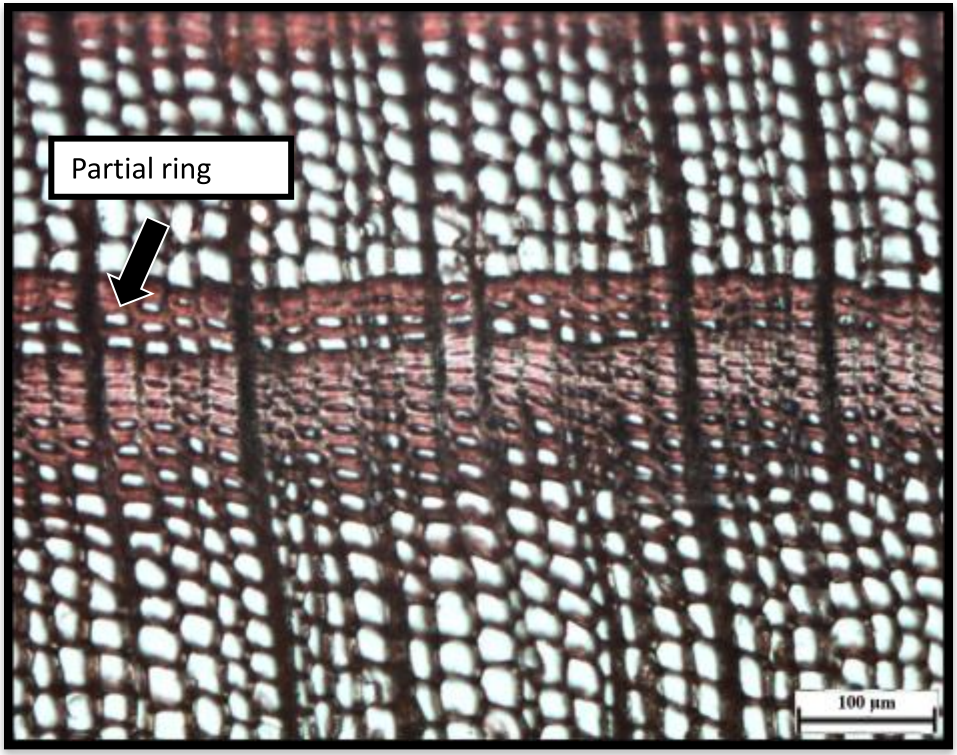
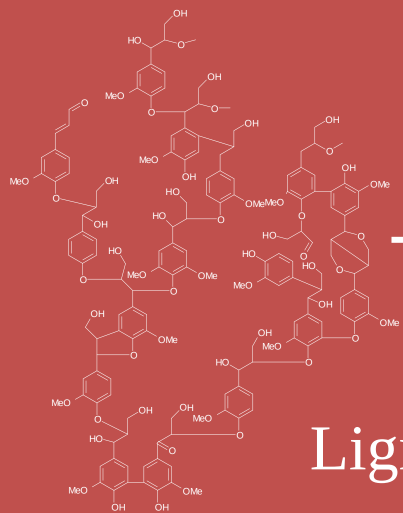


Figure 3 – Partial growth ring from an eastern hemlock infested with hemlock woolly adelgid.

Goodell: Production of a novel polymer-based materials from crude low molecular weight lignin via bacterial synthesis.

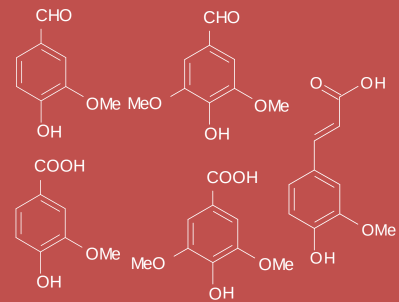
Collaboration w/ Otsuka, Nakamura – FFPRI-JAPAN. Renneckar, Y-T Kim, T. Long at VT.



Lignin

Decomposition

(8-50%)



… and other mono- or di-aromatic compounds

Fermentation (1000 L)

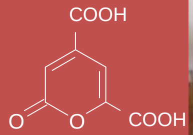
(ca. 100%)

PDC accumulation (100 g/L)

PDC

Purification

(ca. 80%)



Polymerization

Modification

Chemical industry

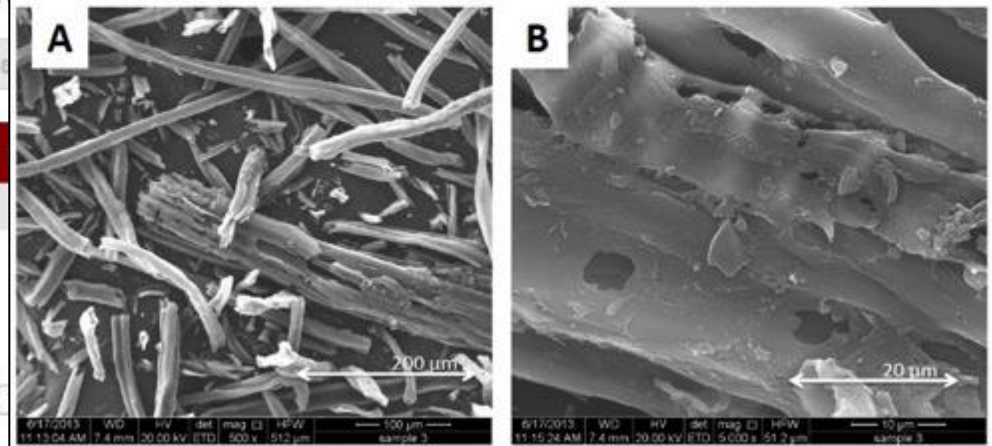


Figure 6: A and B are SEM images of carbonized wood fiber.

Virginia Tech researchers forging ahead to solve 300-year-old mystery

Posted: Jul 08, 2013 7:56 AM EDT
Updated: Jul 22, 2013 7:56 AM EDT
By Tim Ciesco, Reporter - **email**

BLACKSBURG, VA - Researchers at Virginia Tech are trying solve a centuries old mystery that could hold the key to creating new wave of stronger, lighter, more energy efficient metals.

As far back as the Crusades, soldiers in the Middle East had swords that were very strong, very sharp, yet lightweight made from a metal called Damascus steel. The last known maker of Damascus steel died 300 years ago, but never passed on its secret. To this day no one has been able to replicate it.

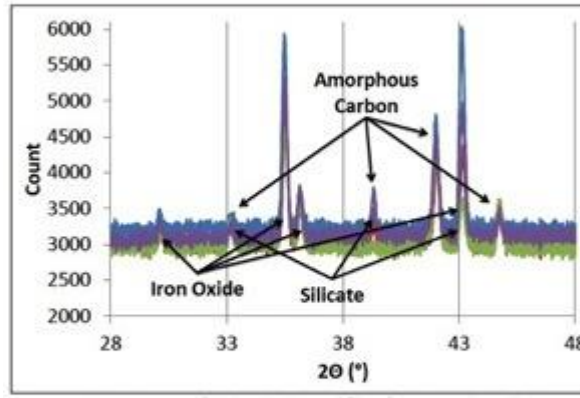


Figure 4: XRD spectra of carbonized wood fiber from sample replicates remains show peaks for amorphous carbon[5] with iron-oxide[6] and silicates[6], but not CNTs.[8]

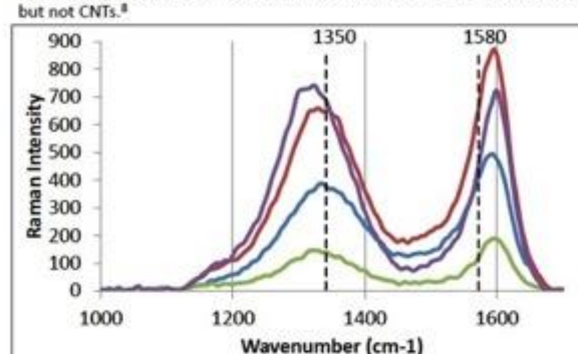


Figure 5: Raman spectra of carbonized wood fiber from sample replicates; a peak at ~1350 cm^{-1} is the D peak and indicates disorder in the structure, a peak at ~1580 cm^{-1} indicates sp^2 bonding between the carbon atoms[8]

SUSTAINABLE BIOMATERIALS

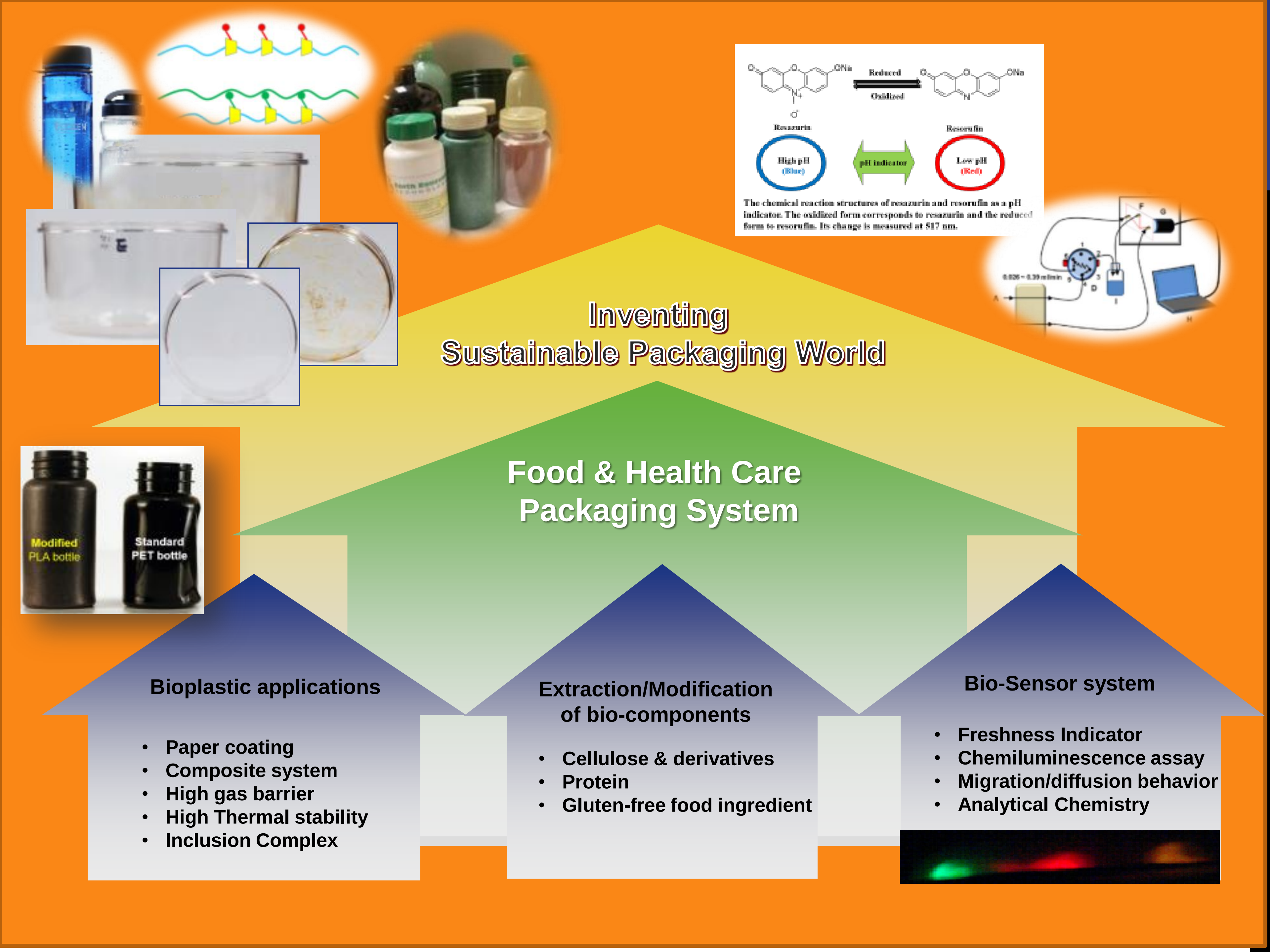
PKG | PACKAGING SYSTEMS + DESIGN

DR KIM'S SUSTAINABLE PACKAGING LAB

- Improvement of BioPlastics and their Applications
- Utilization of bio-components from biomass for packaging system
- Development of bio-sensor system using Chemiluminescence assay

YOUNG TECK KIM, PH.D

www.packaging.sbio.vt.edu ytkim@vt.edu

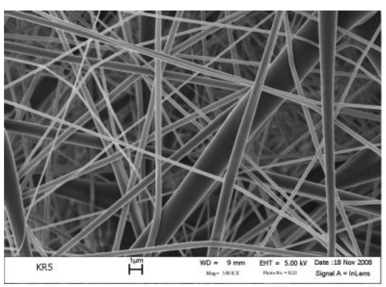


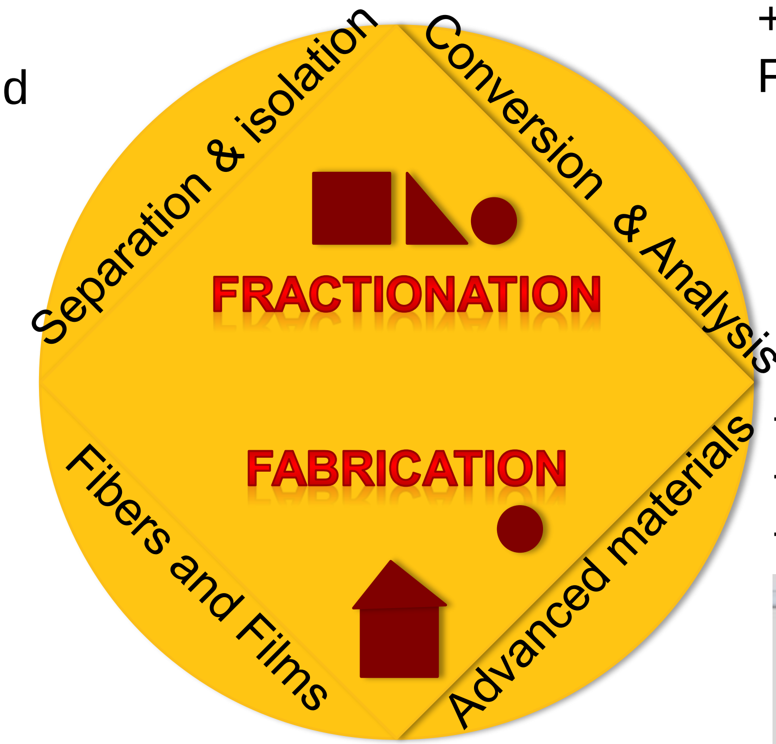
Inventing
Sustainable Packaging World
Food & Health Care
Packaging System
Bioplastic applications
Paper coating
Composite system
High gas barrier
High Thermal stability
Inclusion Complex
Extraction/Modification
of bio-components
Cellulose & derivatives
Protein
Gluten-free food ingredient
Bio-Sensor system
Freshness Indicator
Chemiluminescence assay
Migration/diffusion behavior
Analytical Chemistry
Modified
PLA bottle
Standard
PET bottle
Reduced
Oxidized
Resazurin
Resorufin
High pH
(Blue)
pH indicator
Low pH
(Red)
The chemical reaction structures of resazurin and resorufin as a pH indicator. The oxidized form corresponds to resazurin and the reduced form to resorufin. Its change is measured at 517 nm.

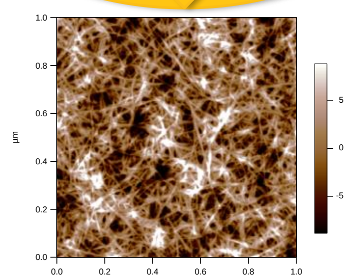
CONVERT ALL COMPONENTS OF BIOMASS INTO USEFUL MATERIALS

+Processes to recover biopolymers and sugars in high yield and purity

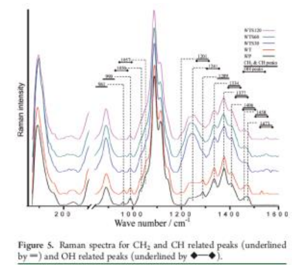
+Renewables for existing markets







+Structure & Functionality



+Nanocoatings
+Biocompatible materials
+Laser bonded wood

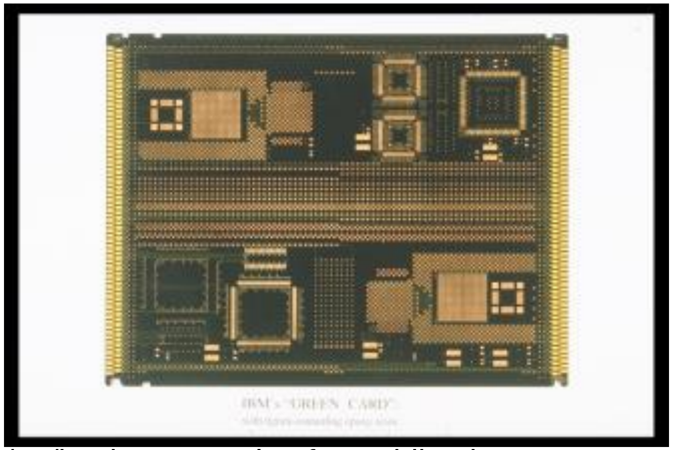
ENERGY: GASIFICATION OF WOOD CHIPS INTO ELECTRICITY

1 kilowatt hour for every 1.2 kilograms of dry biomass, is capable of generating 10 kilowatts, enough to power 100 100-watt light bulbs.

WE CAN MEET MANY OF OUR NEEDS USING WOOD IN SOME FORM OR ANOTHER

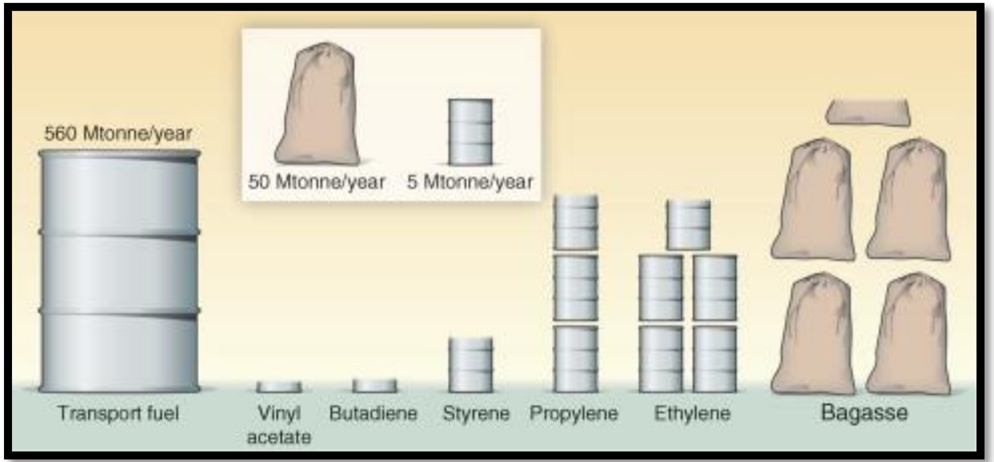
http://www.nytimes.com/2010/08/15/business/15unboxed.html?_r=0

Kevin P. Casey for The New York Times



Example of epoxidized lignin courtesy, W. Glasser

APAwood.org



Valorization of Biomass: Deriving More Value from Waste. C.Tuck, E. Pérez, István T. Horváth, Roger A. Sheldon, and Martyn Poliakoff. Science 10 August 2012: 337 (6095), 695-699.

EXAMPLES OF INDUSTRY THAT PARTNER, COLLABORATE, AND HIRE OUR STUDENTS

PPG, Dow Chemical, Owens Corning, Weyerhaeuser, Rust-Oleum, Celanese, Eastman Chemical Company, MeadWestVaco, Samsung Fine Chemicals, Ashland, Georgia Pacific Chemicals, Momentive, Arclin, Ashland

Industry is attracted to the most long term stable (lowest risk) and lowest cost solutions. Biomaterials from biomass can fill this role.