Renewable Composite Interfaces: Strategies for Making Opposites Attract

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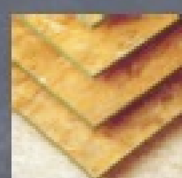
Renewable Composite

- Materials where one of the major constituents is derived from a renewable source
- Examples of renewable sources: wood, agricultural fibers, polymers derived from biomass (cellulose, hemicellulose, lignin), regenerated fibers (e.g. rayon), etc.
- Wood is bonded in over 70% of its applications



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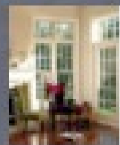
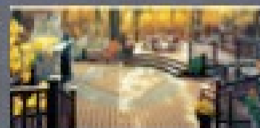
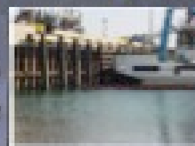
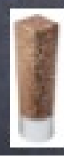
Polymer Composites

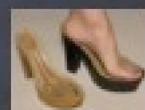
- Polymers are long chain molecules
- Polyethylene, polypropylene, PVC, polystyrene, ABS, bioplastics
- 45-75% wood or ag fiber (~0.150 mm in diameter)
- 25-55% polymer
- 1-25% other (lubricants, **coupling agents**, talc, biocides, fire retardants, etc.)











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Why add natural fibers to plastic?

- Reinforcement
  - 12GPa wood vs. 1 GPa PP
- Cost
  - $0.0125/lb wood vs. $0.90/lb PP
- Density (specific gravity)
  - 1.4 cell wall vs. .96 PP vs. 2.6 glass
- Durability - slows moisture diffusion
  - Biological deterioration requires water

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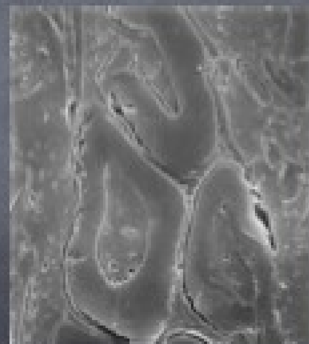
Why is it important for composites?

- Wood is polar and very hydrophilic
- Most polymers are nonpolar and hydrophobic
- Wood and plastic have very little interaction
- Continuity of strain and the transfer of stress across an interface



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Adhesion

The tendency of dissimilar molecules to cling together because of attractive forces impacts everyday life.

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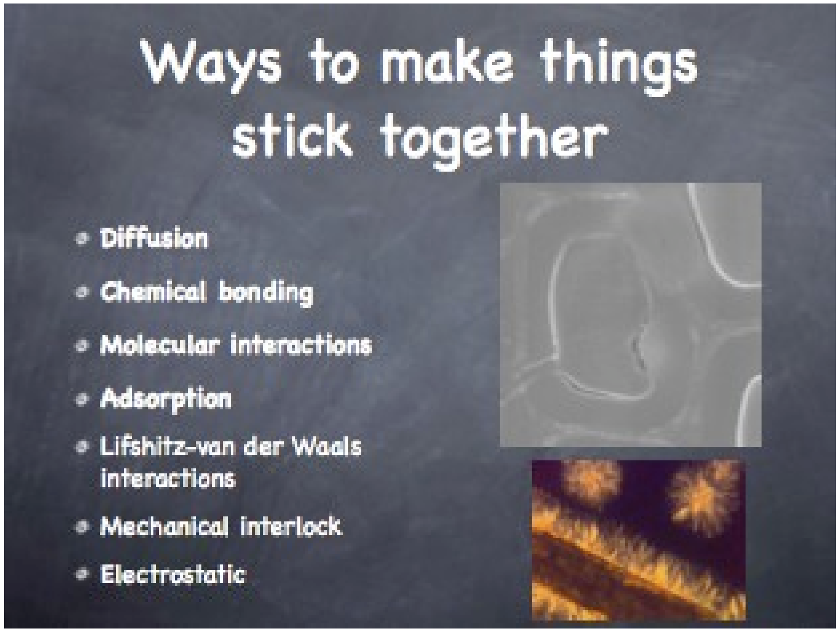
Ways to make things stick together
Diffusion
Chemical bonding
Molecular interactions
Adsorption
Lifshitz-van der Waals interactions
Mechanical interlock
Electrostatic

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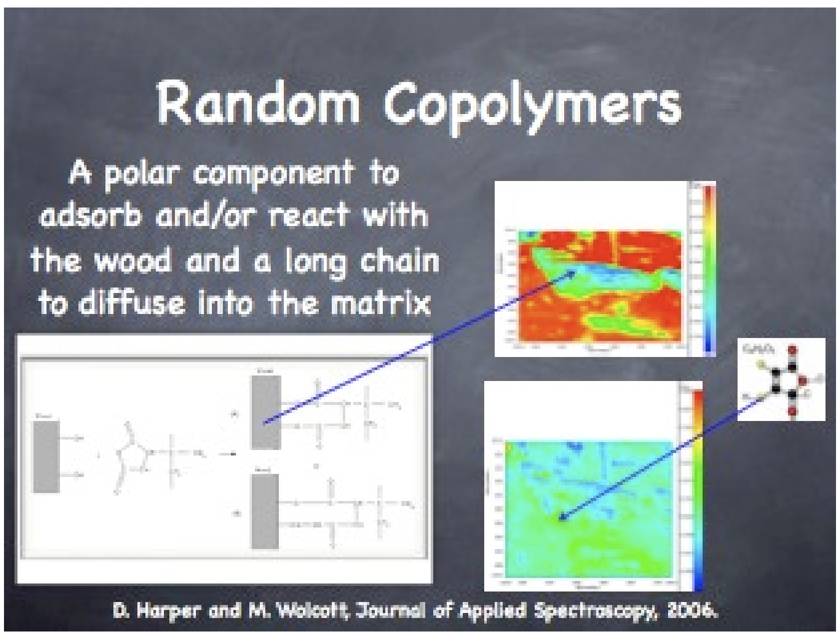
Random Copolymers
A polar component to adsorb and/or react with the wood and a long chain to diffuse into the matrix
D. Harper and M. Wolcott, Journal of Applied Spectroscopy, 2006.

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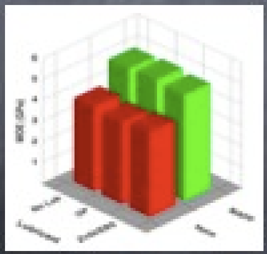
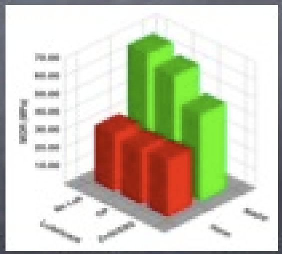
Mechanical Properties

Addition of 5% copolymer improved strength by more than 100% and elastic modulus by nearly 50%





D. Harper and M. Wolcott, Composites A, 2004.

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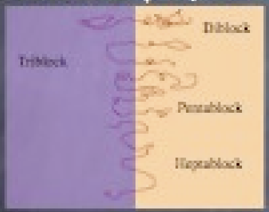
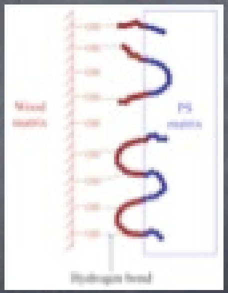
Molecular Velcro®

Block Copolymers



Eastwood and Dadmun, Macromolecules, 2002.



Tingaut et al., Macromolecular Chemistry and Physics, 2008.

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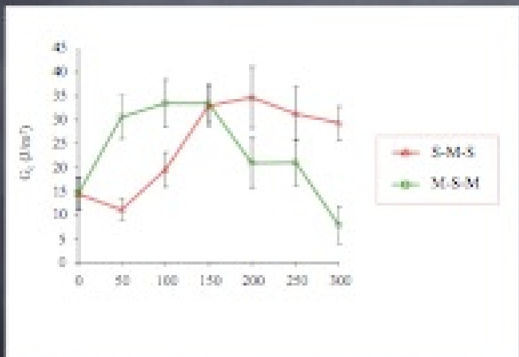
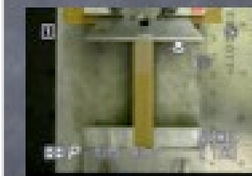
Copolymer architecture





Tingaut et al., Macromolecular Chemistry and Physics, 2008

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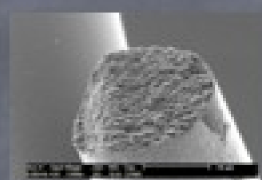
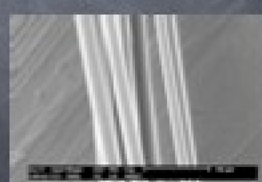
Carbon Fibers

- Uses a low value byproduct of cellulosic Ethanol production as a Feedstock
- Most lignin is burned for power generation
- Current worth is ~ $0.02/lb.
- Current research aimed at adding value to lignin
- Current price of medium grade carbon fiber >$8/lb.
- Current price of most plastics ~$.90/lb.
- Development of rural economies
- Possible $4 billion industry that would increase worldwide carbon fiber production 1500%





Carbon fibers have the potential to reduce fuel consumption in transportation applications by reducing weight by up to 2/3.

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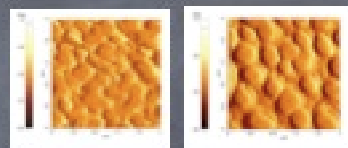
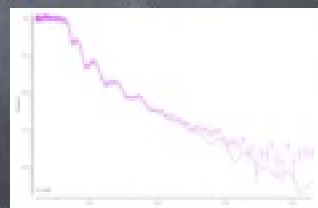
Lignin Polymer Blends

- Lignin-synthetic blends as precursors for carbon fibers
- Melt extruded fibers
- Exploring copolymers as coupling agents
- Neutron reflectivity at the SNS showed decreasing in interfacial width





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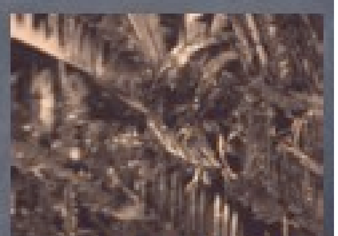
Self assembled structures

Bolaform amphiphilics: Hydrophilic headgroup/Hydrophobic core

Glucal C12 bolaform



20% bolaform 80% cellulose

Goal: Improve dispersion and interaction of lignocellulosics
Bolaforms offer a renewable source of surfactants
Hydrophilic reinforcement (cellulose) + Hydrophobic matrix (polypropylene) is used as a model system

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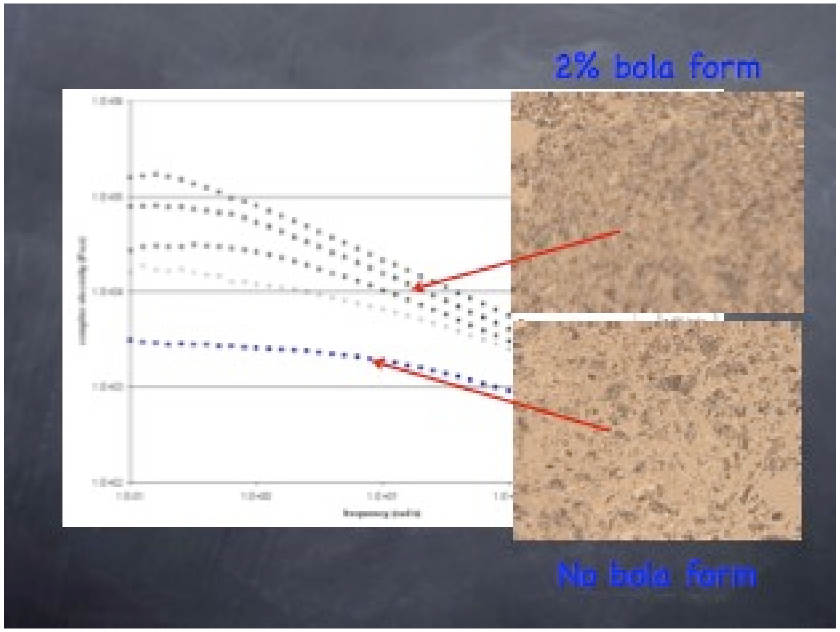
2% bola form
No bola form

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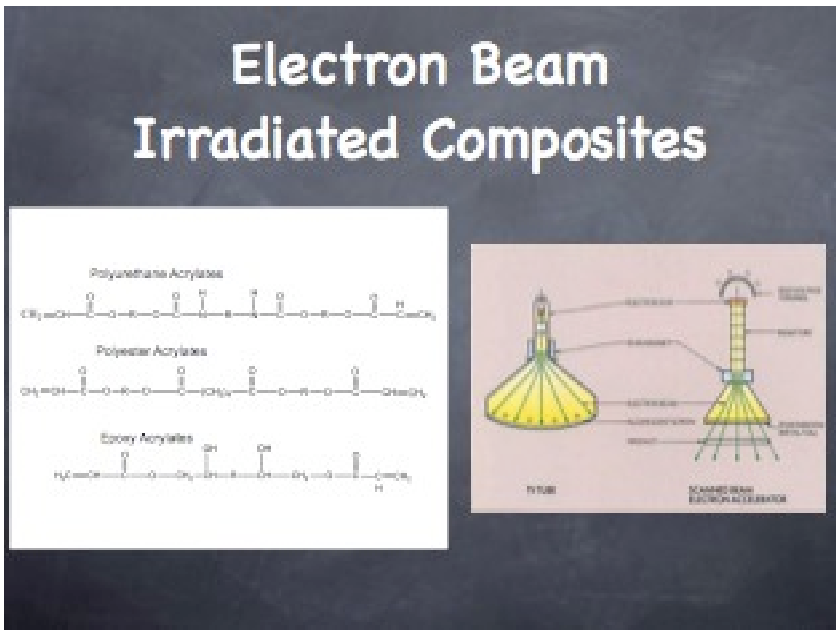
Electron Beam
Irradiated Composites
Polyurethane Acrylates
Polyester Acrylates
Epoxy Acrylates

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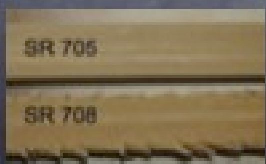
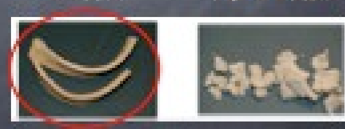
Electron Beam Irradiated Composites

- Matrix for initial study was LDPE
- Irradiated at 80 kGy
- Formulated with di- and tri- functional acrylates and methacrylates



E-beam No E-beam



Toughness and creep

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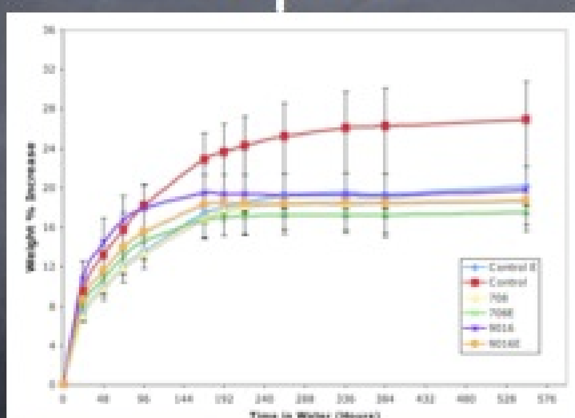
E-beam Composite Water Sorption



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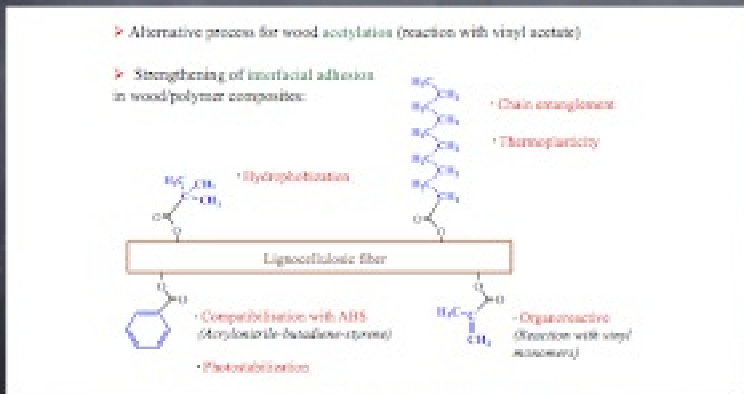
Modification of the fiber surface



Courtesy of Dr. Gilles Sèbe

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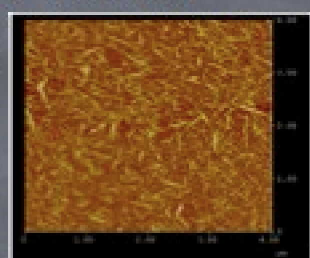
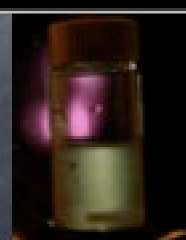
Nanocellulosic fibers

- Nanocrystalline cellulose fiber (less than 100 nm in diameter)
  - Produced by acid hydrolysis of cellulose pulp
  - Tendency to aggregate and difficult to disperse
- Grafted hydrophobic vinyl acetate groups on the surface
- Dispersed grafted fiber in THF (tetrahydrofuran)





Photos courtesy of Dr. Nihat Çetin

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Summary

- Renewable materials are of growing importance to for economy and stewardship of resources
- Interfaces between materials govern performance
- Strategies covered:
  - Controlled interfacial architecture
  - Coupling agents to bridge the surface and matrix
  - Modify the surface to look like matrix
  - Self assembly of adsorbed materials

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Acknowledgements

- Dr. Joe Bozell (TFPC) - bolaforms
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- Dr. Gilles Sebe (University of Bordeaux) - wood modification
- Dr. William Griffith and Dr. Alicia Compere (ORNL) - electron beam and carbon fibers

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Thank You!

Interest, comments, and questions direct to:

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