Nanotechnology & Wood Composites: Impact & Opportunity

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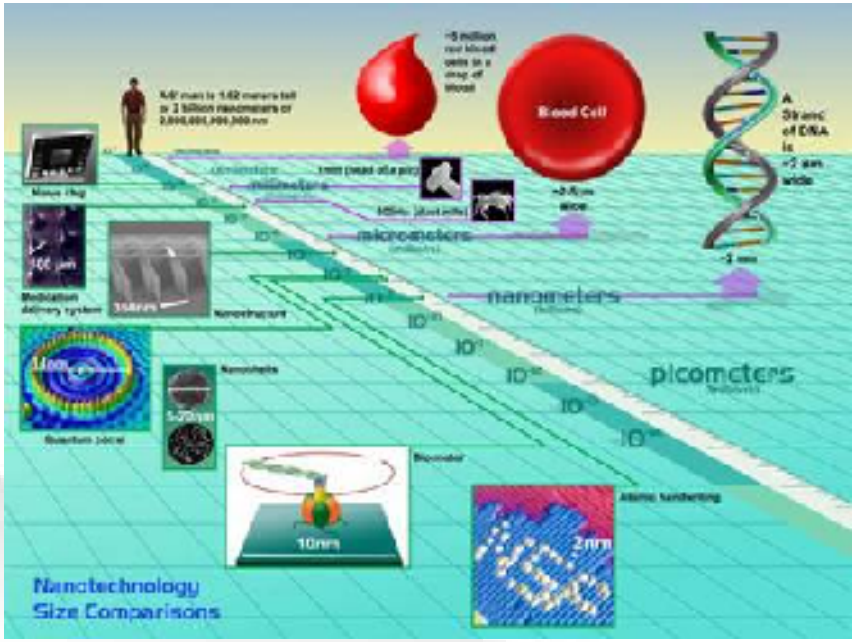
Forest Products Center

A random walk…

- Nanotechnology materials *(real and imagined)*
- Benefit of advanced analytical methods
- Biomimicry (giving something back)
- Final thoughts

Defining nanoscience and engineering…

- In the range of 1-100 nm
- Displays unique material behavior
  - Surface properties
  - Electrical properties
  - Optical properties
  - Mechanical properties
- Often addresses ordered systems



Wood/Resin systems…

- Nanoscale reinforcement of resins
  - High surface area
  - Low levels of addition
- Modified clays most common (A. Ragauskas, GA Tech)
- Promising direction for:
  - Bacterial cellulose
  - Nanocrystalline cellulose

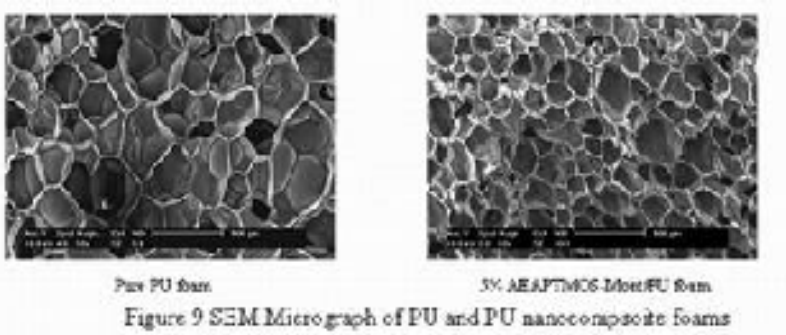
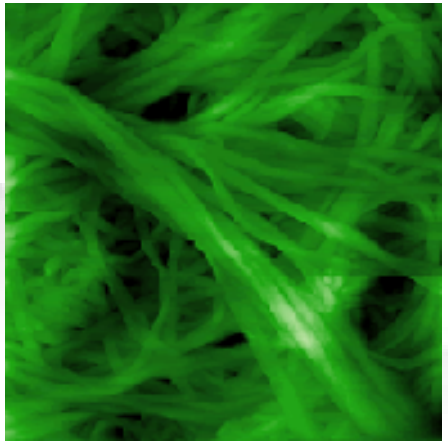


Figure 9 SEM Micrograph of PU and PU nanocomposite foams

http://www.chbmeng.ohio-state.edu/facultypages/leeresearch/3ThermosetNano.htm

T. Kondo (Tokyo U.); M. Brown (Texas A&M)



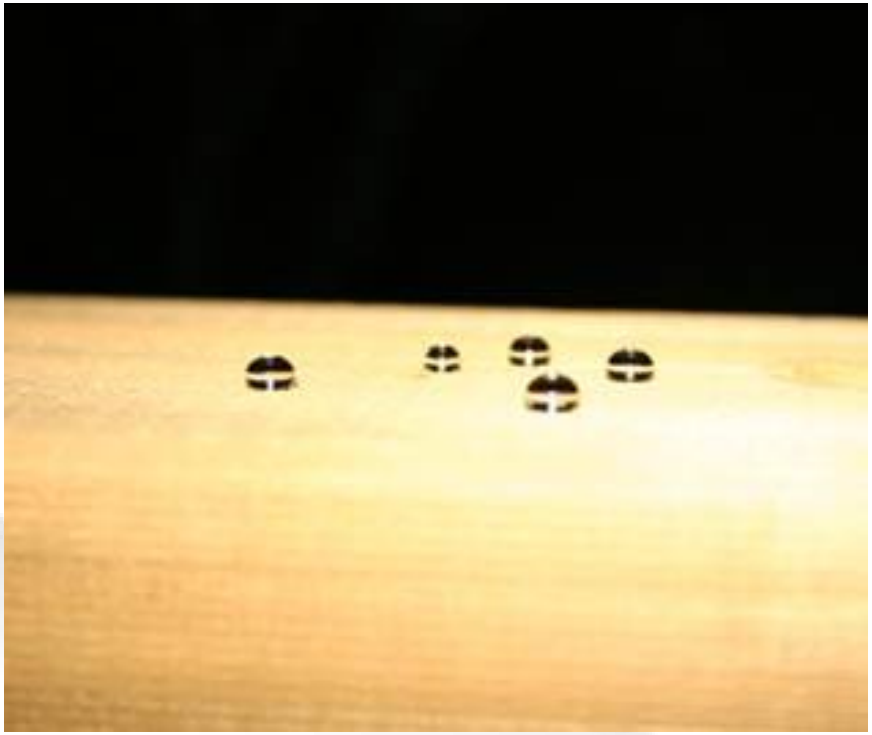
S. Morris, University of Bristol
Bacterial Cellulose

J. Simonsen (OSU); D. Gray (McGill U.); W. Winter (SUNY); M. Roman (VTU)

Architectural coatings…

- Notable nano success in coatings (improved tennis balls; sunscreen)
- Similar opportunities for wood:
  - Optical clarity
  - Moisture resistance
  - Environmental remediation

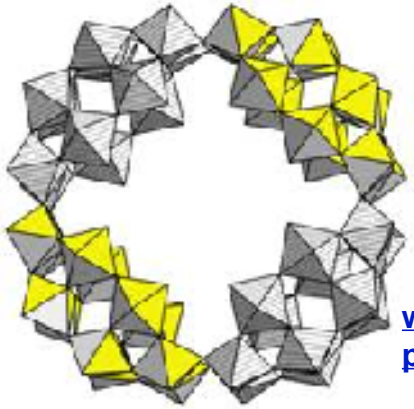
Innovative wood protection…



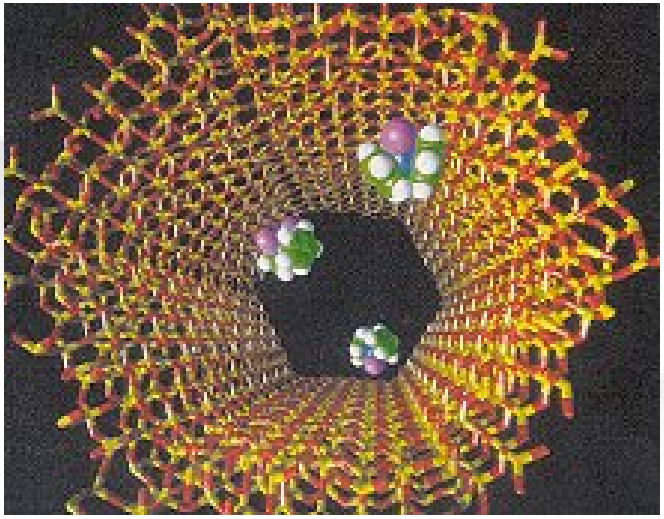
Nanoseal Wood… self-assembling hydrophilic/hydrophobic system imparting long-lasting protection to wood *(www.nanotech.com.au)*

Chemical processes…

- Pulping
  - Polyoxymetalates offer environmentally benign process (FPL)
- Biorefinery
  - Directed breakdown of carbohydrate and/or lignin components
- Bioremediation

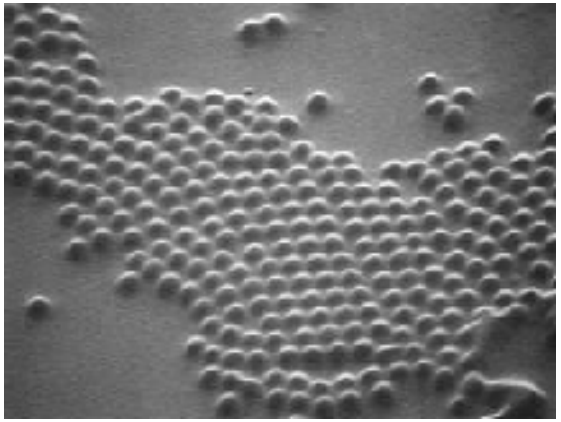


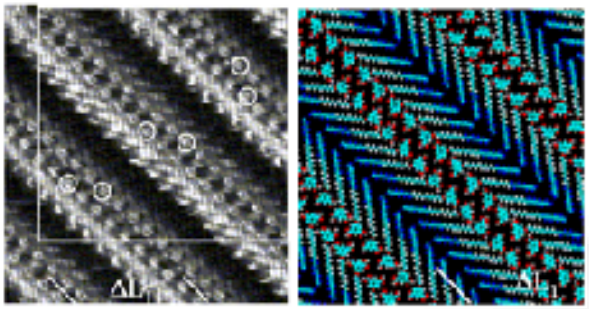
www.georgetown.edu/ faculty/ popem/poster.htm



Self assembling polymers…

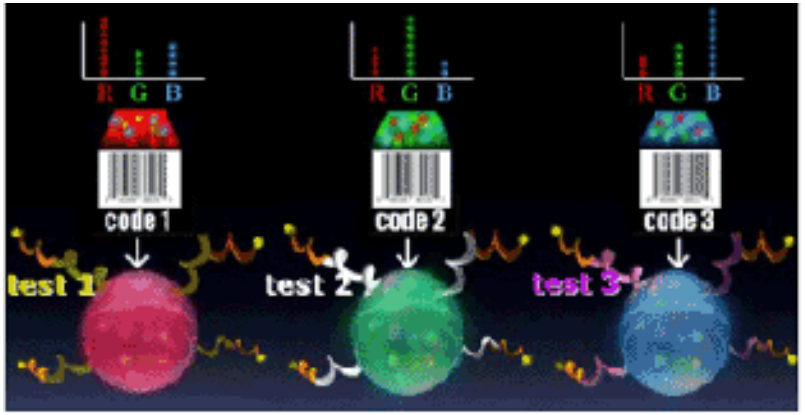
- Creates order at the nanoscale
  - Cost effective
- Membrane technologies
  - Filters and separation devices
- Coatings
- Derived from biobased monomer systems (?)



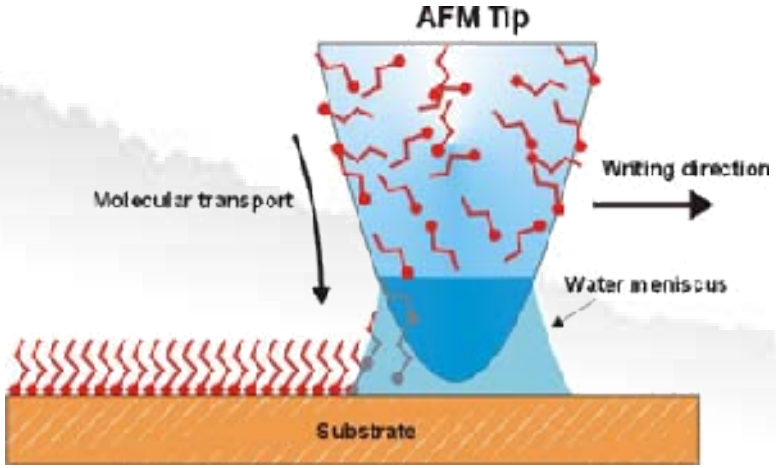


Room for innovation…

- Quantum dots
  - Absorb light and emit light at a shorter wavelength dependent on particle size
  - Tag with functionality or enzyme
- Dip-pen lithography
  - Deposition of sensors and labels
  - Form arrays of detectors (Bio or chemical sensors)
  - Assemble molecules
- Micelle carriers
  - Tailor electrostatic charge and hydrophobic/hydrophilic nature



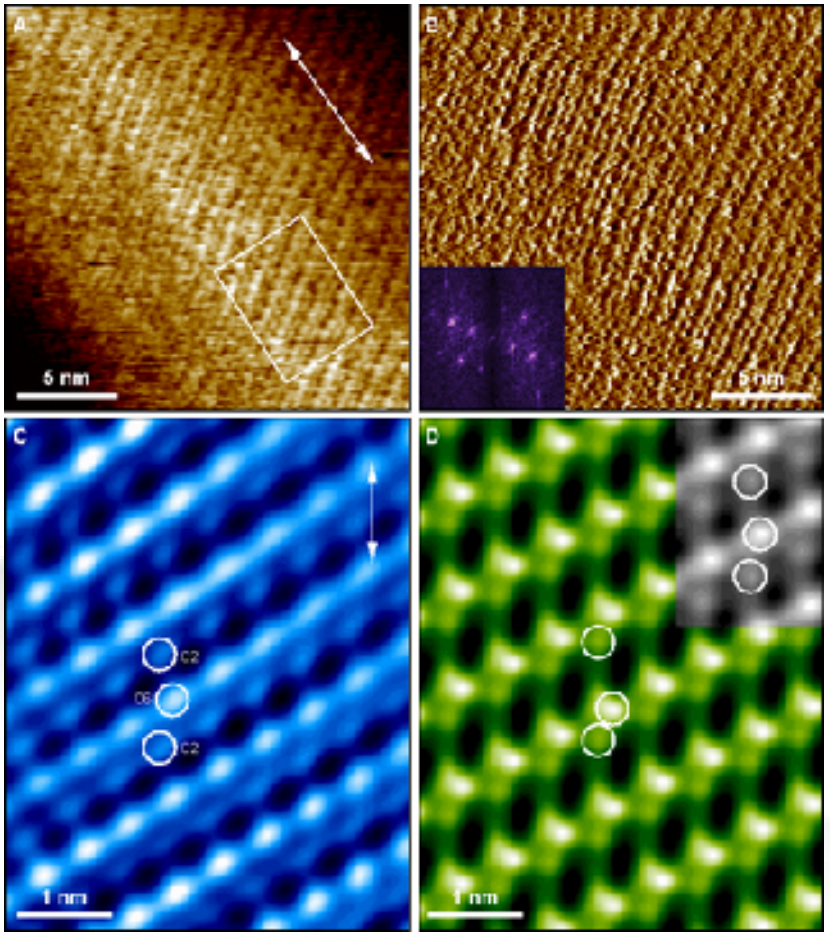
http://www.qdots.com



Chemical Image

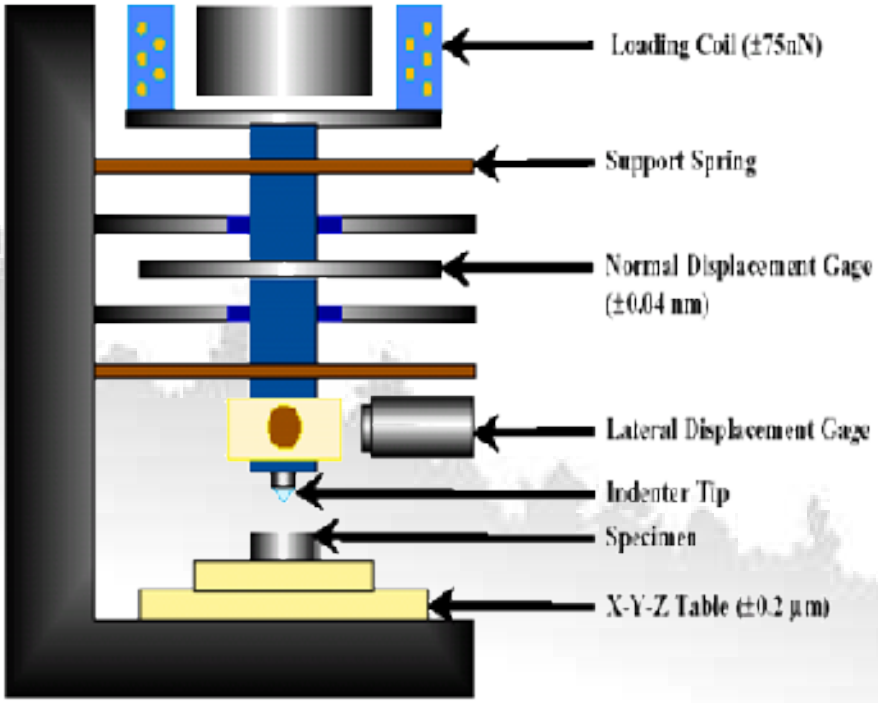
Analytical advances…

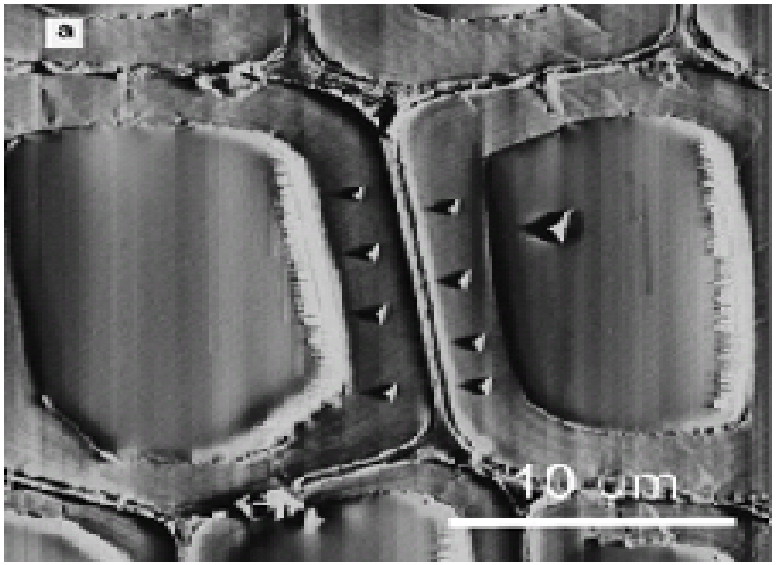
- Atomic force microscopy (AFM/SPM)
- Surface plasmon resonance spectroscopy
- Neutron scattering & diffraction
- Spectroscopic imaging (FTIR, NIR, SIMS, etc.)

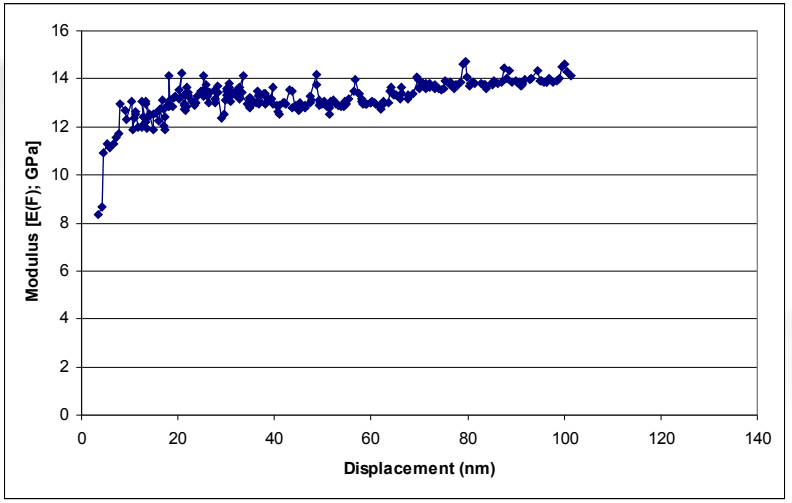


A. Baker, *http://spm.phy.bris.ac.uk/research/cellulose/cellulose2.html*

Wood cell wall properties…

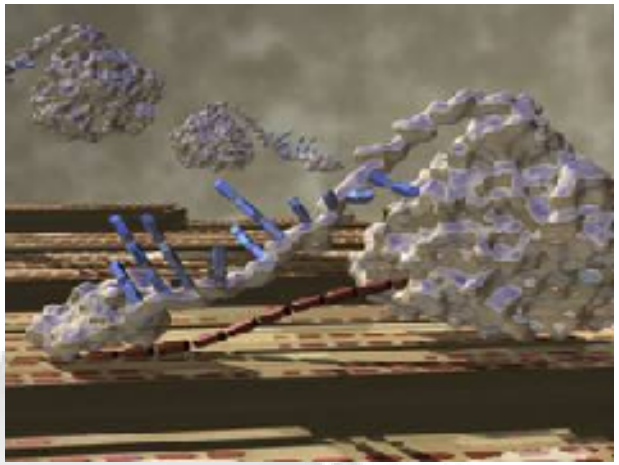


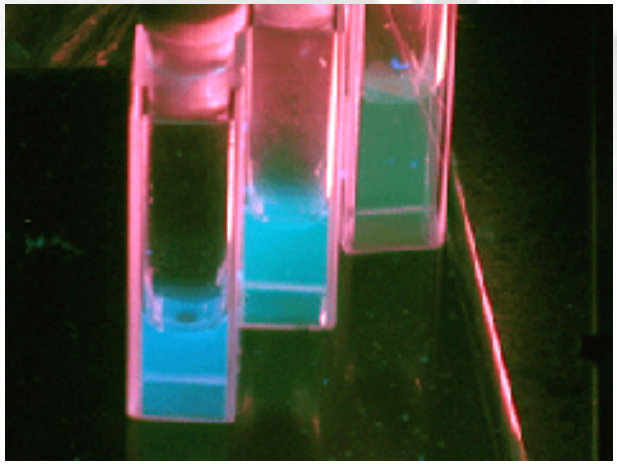




Gindl, et al, BOKU, Vienna, Austria
Wang, et al, Univ. of Tennessee

Quantum dot array sensors…

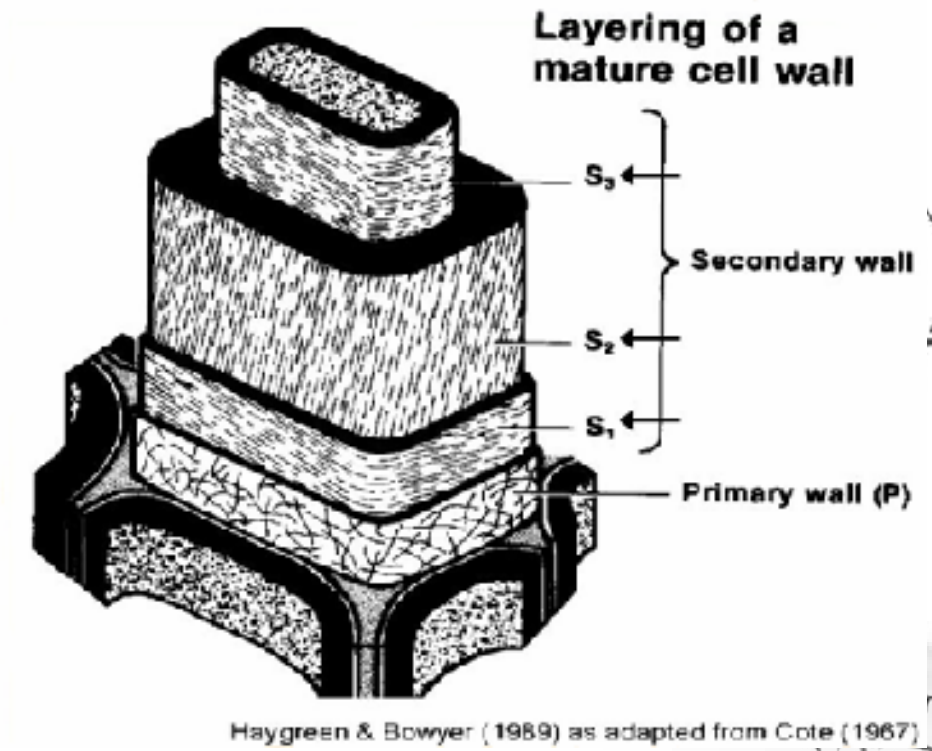




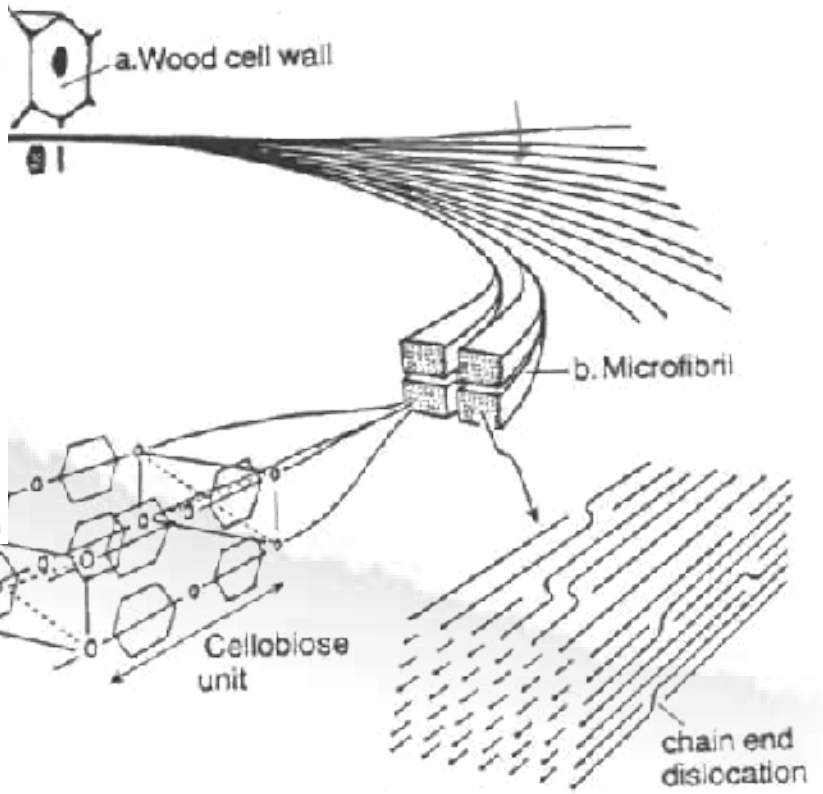
- Functionalized dots attached to cellulase binding domain
- Interacts only with cellulose
- Conventional microscopy with filters to identify

M. Himmel, National Renewable Energy Laboratory, Golden, CO

Hierarchical order of wood…

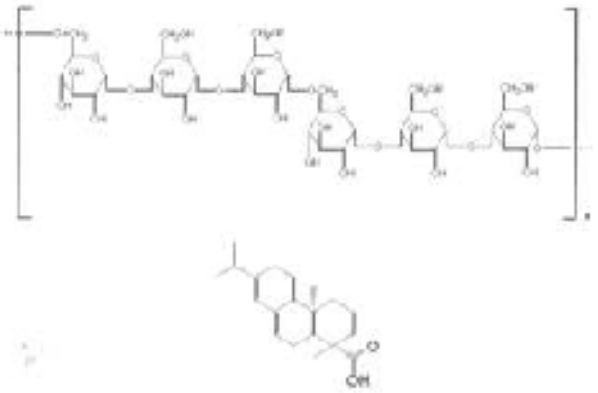


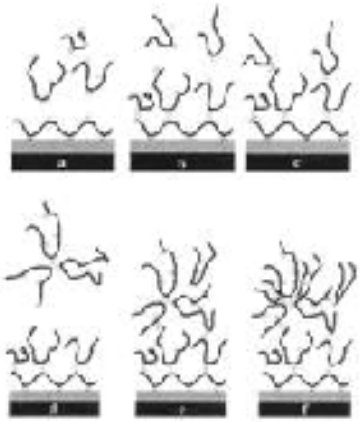
Haygreen & Bowyer (1989) as adapted from Cote (1967)



Wood – A biomimetic guide

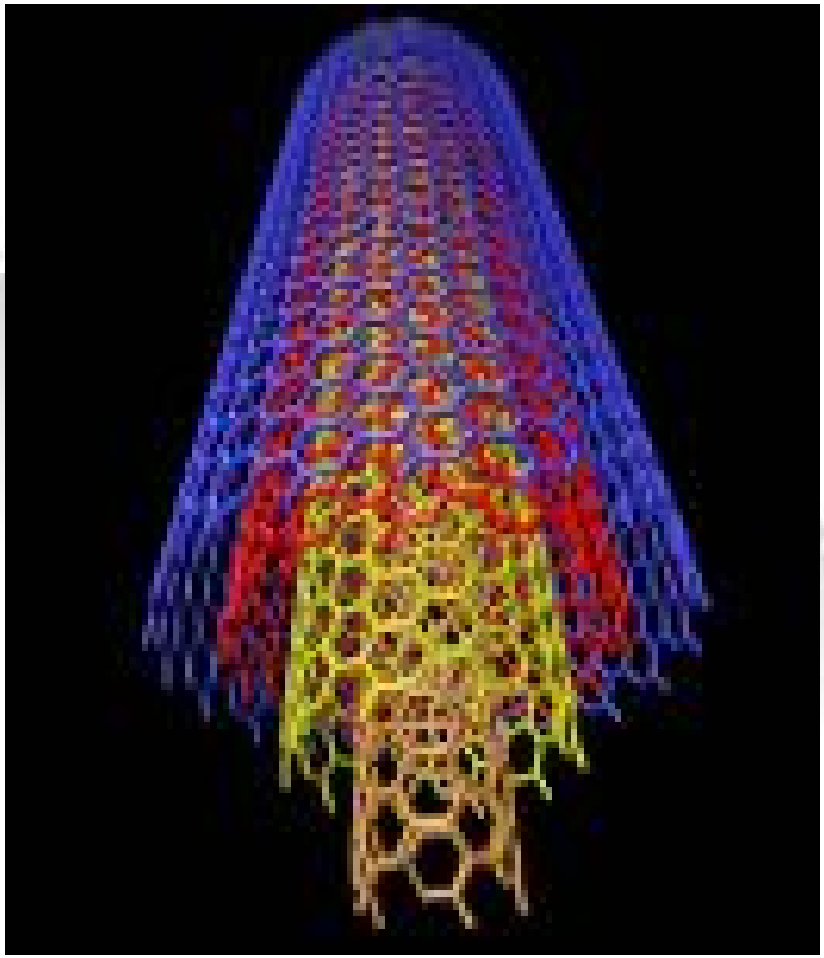
- Lyocell fiber substrate
- Self-assembly of carbohydrate on surface
- Subsequent sorption of lignin model
- Much improved strain in composite materials





Gradwell, et al, *Plant Biology & Pathology* (2004).

Nanoscience pitfalls…



- Toxicity
  - Toxic nanoparticles
  - Unkown health risks
- Scaling
  - Production of carbon nanotubes
  - Produce small parts on large scale
- Cost
    - Qdots ~ $400/g
    - Low cost carbon nanotubes ~ $0.40/g in bulk quantities

Beyond baby steps…

- New opportunity for real innovation into new materials and new markets
- Obligation to pursue, vigorously, this new direction
- Cooperative research is critical element
- FPI support is vital for substantive progress

Thanks go to…

- Dr. David Harper, Univ. of Tennessee
- Dr. John Simonsen, Oregon State Univ.
- Dr. Wolfgang Glasser, Virginia Tech
- Dr. Maren Roman, Virginia Tech