Nanomaterials Research at the Forest Products Laboratory

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USDA Forest Service

Mission

Sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

- **Manages 193 million acres of forest & grasslands**
- **155 National forests & 20 grasslands**
- **$4B total budget; ~$260M research budget**
- **~30,000 employees**
- **>500 research scientists**
- **5 research stations, the Int'l Inst. of Tropical Forestry, & the Forest Products Laboratory**
- **Research themes include fire, invasive species, recreation, water & air quality, wildlife & fish, and the analysis & use of forest resources**

Forest Products Laboratory

- Founded 1910
- ~200 employees
- ~$25M budget
- Research Areas Include
  - Nanotechnology
  - Advanced Composites
  - Advanced Structures
  - Bioenergy/Biorefinery
  - Forest Service Initiatives
    - Sustainability
    - Paper and paperboard recycling
    - Wood preservation
    - Engineered properties of wood

FPL Structure

Wood Fiber & Composites Research

- Fiber & Chemical Sciences
- Microbial & Biochemical Science & Technology
- Composites Science
- Forest Materials Modification

Wood Products Research

- Economics & Statistics
- Building Moisture & Durability
- Engineered Properties & Structures
- Center for Forest Mycology

Support/Administrative

- Support Laboratories (ACML, EML, PTL)
- Research Facilities Engineering

Nanotechnology & Forest Products

APPROACHES

1. Incorporate nanomaterials, nanosensors, etc. into current forest products
2. Exploit the nano-dimensional characteristics of wood

Focus Areas

- Improved strength, lighter weight materials
- Forest nanomaterials
- Water/lignocellulosic interactions
- Nanocomposites
- Photonic and electronic properties
- Reduced energy consumption

Modify Current Forest Products

- Improve Performance & Functionality
- Incorporate Nanomaterials into Products

Nanomaterials →

- Sensors
- Ink-Printing, E-ink
- Paper & Board Production
- Adhesive Mechanics
- Composite Panels
- Coatings
- Active Papers, E-paper
- Electronics on Wood/Paper
- Barriers
- Flexible Batteries

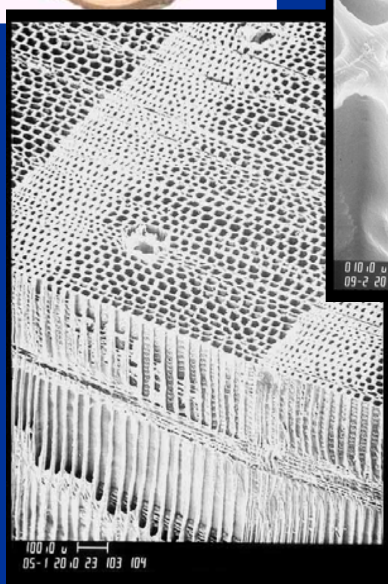
Wood-Derived Nanomaterials

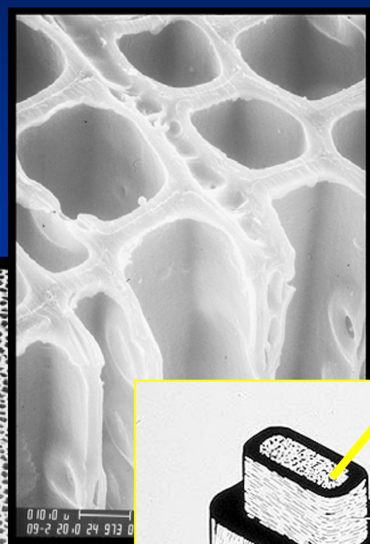
- New Applications & Products
- New Processing Routes
- New Characterization Techniques

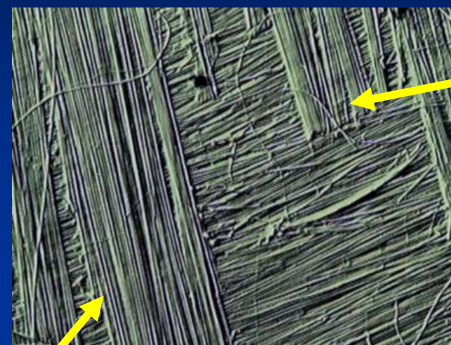
Cellulosic Nanomaterials

- Self Assembly
- Reinforced Composites
- Optical Properties
- Adhesive Mechanics
- Piezoelectric Properties
- Molecular Filters
- Flexible Displays
- Magnetic Field Alignment

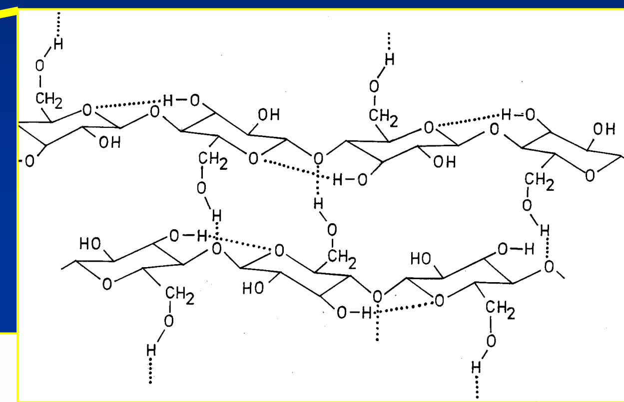
Cellulose Synthesis and Material Production: Nature Working Across a Length Scale >10^{10}!

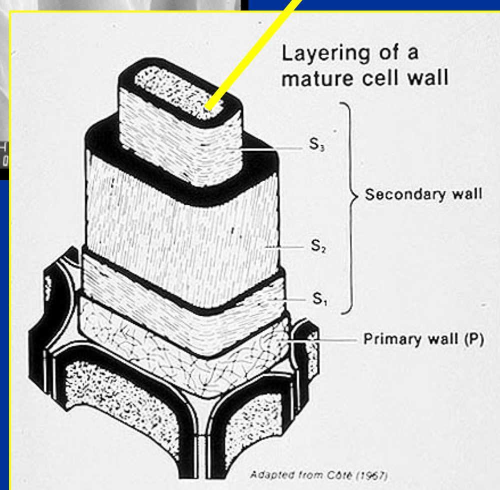


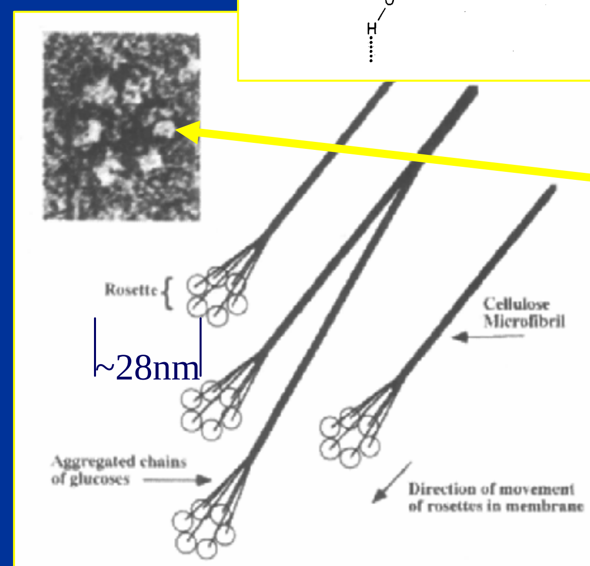




Cellulose nanofiber bundles







6 Assembly proteins (rosette) which produces cellulose nanofibers

Source: Jeffery Catchmark , Penn State University

Cellulose Nanocrystals

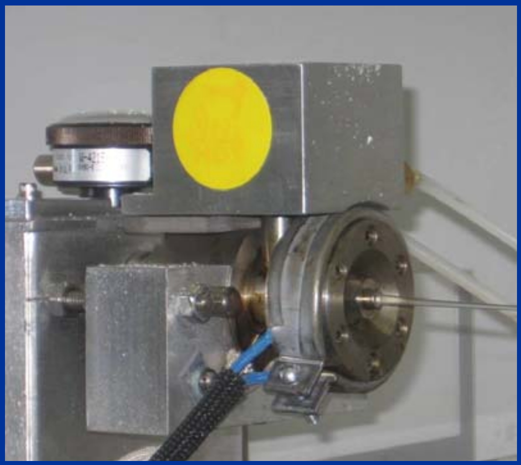
http://macromolecules.case.edu/group_weder.htm

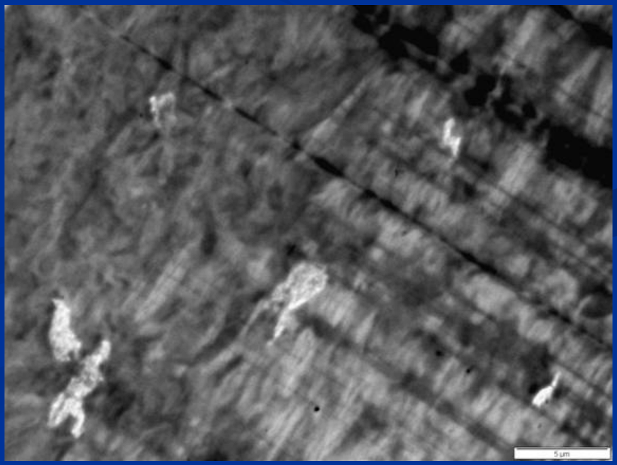
Cellulose Nanocrystals

- High-aspect crystallites from wood (~5nm x 100-300nm)
- High strength (~Kevlar fibers; 1/10 CNT's)
- Piezoelectric
- Commercial potential
  - Inexpensive (est. ~$5/lb)
  - Renewable & producible in bulk
  - Microcrystalline cellulose already used in food & pharmaceuticals
  - Currently ~100k ton/yr demand for MCC

Composites with CNC

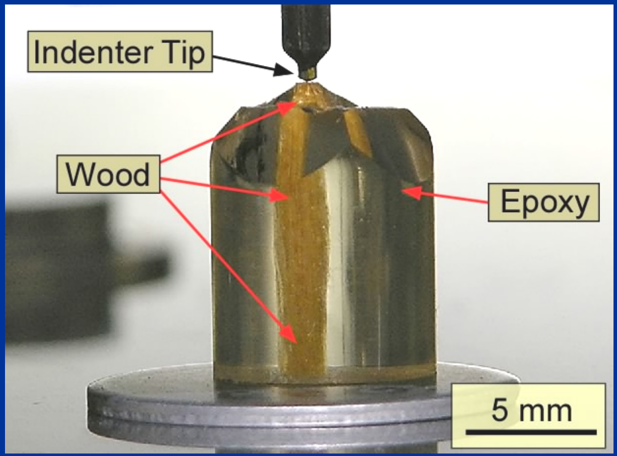
- CNC's have good reinforcement potential
- Use CNC's to enhance performance of commodity plastic composites
- Extruding plastic filaments
- Difficult to disperse in non-polar polymers such as polyolefins
- Preliminary results show modest strength increases with 2% CNCs in polypropylene



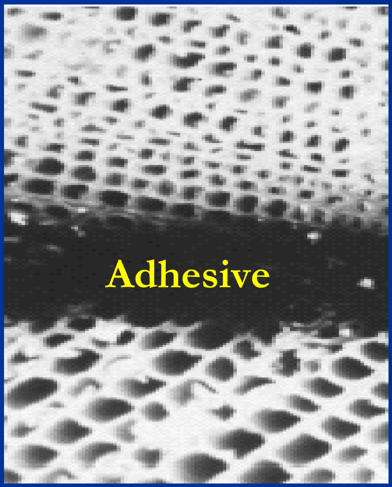


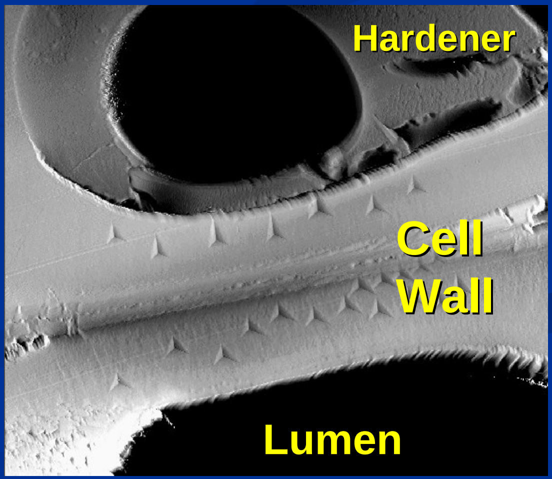
Nanoindentation at FPL

- Understanding properties & interactions at the micron & submicron level
- Correlating property changes to bulk performance
- Properties & applications
  - Wood ultrastructure
  - Interface between wood & polymers
  - Mechanical properties
  - Adhesive penetration & adhesion mechanisms
  - Failure mechanisms



AFM/Nanoindenter





FPL Nanotechnology R&D Objectives

- Delineate wood cell wall architecture
- Describe the wood–polymer interphase as it relates to adhesion, paint, and composites
- Evaluate approaches to producing and using cellulose nanocrystals
- Converting wood into new products
- Improving wood products with nanotechnology
- Characterize microbial decay at the nanoscale
- Nanoscale sensors for detection of decay, invasive species, etc.
- Economic & life-cycle evaluation of nanotechnology in forest products

Underlying Science Needs
Precompetitive Thematic Areas

- Surfaces / Interfaces
  - High strength, light weight
- Composites / Matrix / Bulk
  - Material, Photonic, Electronic
- Non-covalent Bonded Interactions
  - High strength, lightweight
- Separations and Fractionalizations
  - Nano cellulose
- Water Properties at the Molecular Level

Partnering & Working with FPL

- Needs to be consistent with Mission of Forest Service and Legal Authorities
- Can work with a variety of Partners
  - Industry
  - Universities
  - State & Federal
- Non-confidential Cooperation
- Confidentiality
  - Technology Transfer Act of 1986
  - Confidential Business Information
  - Intellectual Property

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