Nanomaterials Research at the Forest Products Laboratory

Ron Sabo
Jerry Winandy
Ted Wegner

US Forest Service
Forest Products Laboratory
Madison, WI USA
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
    - Optical Properties
    - Piezoelectric Properties
    - Flexible Displays
  - Reinforced Composites
    - Adhesive Mechanics
    - Molecular Filters
    - 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
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/Nanoindenteter
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