Nanotechnology Workshop for the Forest Products Industry

October 17 -19, 2004

Ted Wegner
Phil Jones
Nanotechnology Organizing Committee
Institutions Represented

• National Science Foundation
• DuPont
• Georgia Pacific Resins
• TAPPI
• DOE Pacific Northwest National Laboratory
• Western Michigan University
• International Paper
• PAPRICAN

• Weyerhaeuser
• IPST@ Georgia Tech
• Sappi Fine Paper
• University of Tennessee
• Iowa State University
• USDA Forest Products Laboratory
• Washington State University
• North Carolina State University
• IMERYS

112 People Registered
Nanotechnology initiative comes out of Agenda 2020 Focus for the Future

**Positively Impacting the Environment**
- Significant Reduction in Greenhouse Gases
- Decreased Ecological Footprint

**Advancing the Forest “Bio-refinery”**
- Sustainable Forest Productivity
- Extracting Value prior to Pulping
- New Value from Residuals & Spent Liquors

**Breakthrough Mfg. Technologies**
- Major Manufacturing Cost/Capital Reduction
- Significant Enhancement in Product Properties with Existing Assets
- Substantial Improvement in Energy Efficiency for Existing Processes

**Next Generation Fiber Recovery and Utilization**
- Recycled Fiber Indistinguishable from Virgin Fiber

**Technologically Advanced Workforce**
- From Workforce to Knowledge Workers in 7 years

**Advancing the Wood Products Revolution**
- Improved Building Systems
- Reduced System Costs
Nanotechnology, “The Next Industrial Revolution”

Dr. R. Siegel,

Nanotechnology:

1 to 100 nm

Source: ten Wold 1998
## U.S. National Nanotechnology Initiative

(Budget authority, US dollars in millions)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>2001</th>
<th>2005</th>
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<tr>
<td>National Science Foundation</td>
<td>150</td>
<td>305</td>
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<td>Defense (DOD)</td>
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<td>Energy (DOE)</td>
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<td>National Institutes of Health</td>
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<td>Commerce (NIST)</td>
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<td>NASA</td>
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<td>Agriculture (USDA)</td>
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<tr>
<td>Justice</td>
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<tr>
<td>Homeland Security</td>
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<td><strong>TOTAL</strong></td>
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<td>982</td>
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Why Nanotechnology?

- Less space, faster, less material, and less energy
- Novel properties and phenomena
- Most efficient length scale for manufacturing
- Intersection of living/non-living

Source: G McCarty 2003
Why the Forest Products Industry Sector?

- Forest products are a renewable resource
- Lignocellulose is among Nature’s most abundant self-assembling materials
- Its use and functionality for nanomaterials is largely unexplored
- At a fundamental level we have nanodimensional cellulose fibers
- Applications for nanomaterial use abound throughout forest products processing and products
- The Forest Products Industry Sector is largely a mature commodity industry and, as a traditional industry, offers the fastest way to commercialize nanotechnology
- Many products in the Forest Products sector are composite in nature and will benefit from the learnings from the Nanotechnology program
Nanofibers in Wood

Images of differentiating xylem cells from C. Haigler
Cellulose Synthesis and Material Production: Nature Working Across a Length Scale $>10^{10}$!

Candace Haigler and Larry Blanton, *Cellulose: “You’re surrounded by it, but did you know it was there?”*
Workshop Objectives

• Develop a vision for nanotechnology in the Forest Products Industry

• Develop a roadmap for nanotechnology in the Forest Products Industry (identify potential applications and uses, identify knowledge gaps and the research needed)

• Foster cooperation and collaboration among industry, academia, and government to fill knowledge gaps
  – Nanotechnology is cross-disciplinary

• Interest federal funding entities in nanotechnology for the Forest Products Industry
Nanotechnology Workshop
Concurrent Sessions

1. Polymer Composites & Nano-reinforced Materials
   (Ragauskas/Joyce)
   - Fiber composites/materials
   - Polymer composites

2. Self-assembly & Biomimetics
   (Glasser/Gray/Lancaster)

3. Cell Wall Nanostructure
   (Atalla/Haigler)

4. Nanotechnology in Sensors, Processing, & Process Control
   (Deng/Zhu)

5. Analytical Methods for Nanostructure Characterization
   (Beecher/Rials)
Follow Up Actions
Workshop Outputs

• Mihail Roco has enabled a powerful reception
  – We have the opportunity to be on the National Agenda

• Breakout Sessions, Information/Plenary Presentations to be on TAPPI Website (30 days)

• Roadmap Write-up (60 days)

• Monograph (90 days)

• Articles
  – TAPPI Solutions & Other Industry Publications
  – Invited by M Roco to submit article to Journal of
Visit to NSF and NNCO
National Science Foundation & National Nanotechnology Coordination Office

• Well received; with the following results:
  – High level of interest
  – Invited to follow up with presentation to Program managers and Clayton Teague
  – Interest in potential NSF sponsored workshops on specific topics
  – Interest in broader aspects of Forest Products industry
Building Support for Nanotechnology R&D in the Forest Products Sector

- Industry
- Federal Agencies/Departments (to include National Labs)
- University Community
- International
Building Support for Nanotechnology R&D in the Forest Products Sector

• We need Research Consensus on Highest Priority R&D Areas and Define Funding Needs
  – Industry—Agenda 2020 CTO Committee
  – Basic Research—NSF/DOE Basic Energy Sciences
  – Applied/Mission Oriented
    • USDA CSREES
    • USDA Forest Service
    • US DOE
  – University Community
    • PPERA
    • SWST
    • Others
  – State Agencies
Building Support for Nanotechnology R&D in the Forest Products Sector

• Form Linkages with the Broader Nanotechnology Research Community
  – NSF
    • National Nanotechnology Initiative
      – Nanoscience, Engineering & Technology (NSET)
      – Program Directors-Engineering Directorate
      – Grantees meeting Dec. 13-15 at NSF
        » Poster and participation on panel
  – DOE National Laboratory Centers
  – University Centers
  – Technical Societies
    • Linkages with MRS, ASME, ACS & AIChE
    • Linkages of TAPPI & FPS with the above
  – Consider Establishing a Website on Nanotechnology for the Forest Products Sector
  – Follow up workshop(s) with appropriate Nanotechnology R&D Groups
Building Support for Nanotechnology R&D in the Forest Products Sector

• Explore the Concept of a Steering Liaison Committee Involving:
  – Industry
  – Universities
  – Federal Agencies/Departments (to include National Laboratories)
  – Technical Societies
Nanotechnology has arrived at Forest Products Industries

• Government has reached out
• We must respond
Back up
Self-assembling Lignocellulosic nanomaterials & Forest Products Incorporating Nanomaterials
Current Nanomaterial Research & Development

Discovery-based Lignocellulosic Science & Product Development

Discover novel nanostructures, nanoparticles, & nanomaterials through investigator-initiated exploratory research

Determine nanomaterial properties (chemical, physical, and biological)

Identify potential uses of value

Assess commercial viability

Nanomaterials enter markets
Future Nanomaterial Development

Application-based Problem Solving

Existing needs, problems, or challenges in end-uses

Design, produce, and scale up nano-based materials with the exact properties needed

Diverse products based on Nanomaterials By Design rapidly enter and succeed in multiple markets
Subcommittee Workshop
Polymer Composites and Nano-Related Materials: Paper Related

Efficient Manufacturing Process
- Enhanced papermaking process
- Same phase water removal
- Eliminate re-wet phenomena
- Improve processing of residual
- Self assembling coatings - coating eliminate,
- Material science to increase machinery lifetimes by 100% - Reduced Corrosion
- Use non-woven in manufacturing platform to use less water
- Catalyst for pulping and bleaching operations
  reduced operating capital costs, improved performance)
Multifunctional Intelligent Paper

- Functional tissue/towel, packaging
- Integration of electronics into paper (signature safety security)
- Stronger light weight packaging
- Moisture stability of fibers/Sheet/Composites
- Smart Paper
  - Responsive to signal, hydrophobic/hydrophilic properties
  - Electronic paper with electric and magnetic properties,
  - Physical stress response, self cleaning, temp/moisture indicator, audio response
- Security paper, Controlled release, Self assembling (surface, internal, lumen)
Innovative Cellulosics Composites

- Healthy building material, less VOC
- Stronger light weight wood composites
- Environmental/Biological stability
- Moisture Stability of Composites
- Stronger than steel and more durable
- Optical properties
What other nanotechnologists seek to create, we seek to understand and manipulate, either *in vivo* or in engineered systems.

Functional nanodevices synthesize high surface area materials, some of which act as dispersions and coatings, to form a consolidated material—the plant cell wall.
Sensors, Processing and Process Control

- Develop Food Packaging Sensors
- Develop Intelligent Papers
- Develop Medical Packaging Sensors
- Develop Sensors for Paper Identification
<table>
<thead>
<tr>
<th>Individual Goals</th>
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<tr>
<td>On existing l/c substrate create novel, functional, self-assembling surfaces.</td>
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<tr>
<td>Develop a fundamental understanding of molecular recognition in plant growth and cell wall self-assembly in FP.</td>
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<tr>
<td>Learn to characterize self-assembled natural and synthetic material.</td>
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<td>To integrate micro &amp; nano scale organization in products</td>
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