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***

O_2

CO_2

Next Generation Fiber Recovery and Utilization

- ***Recycled Fiber Indistinguishable from Virgin Fiber***

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***

Technologically Advanced Workforce

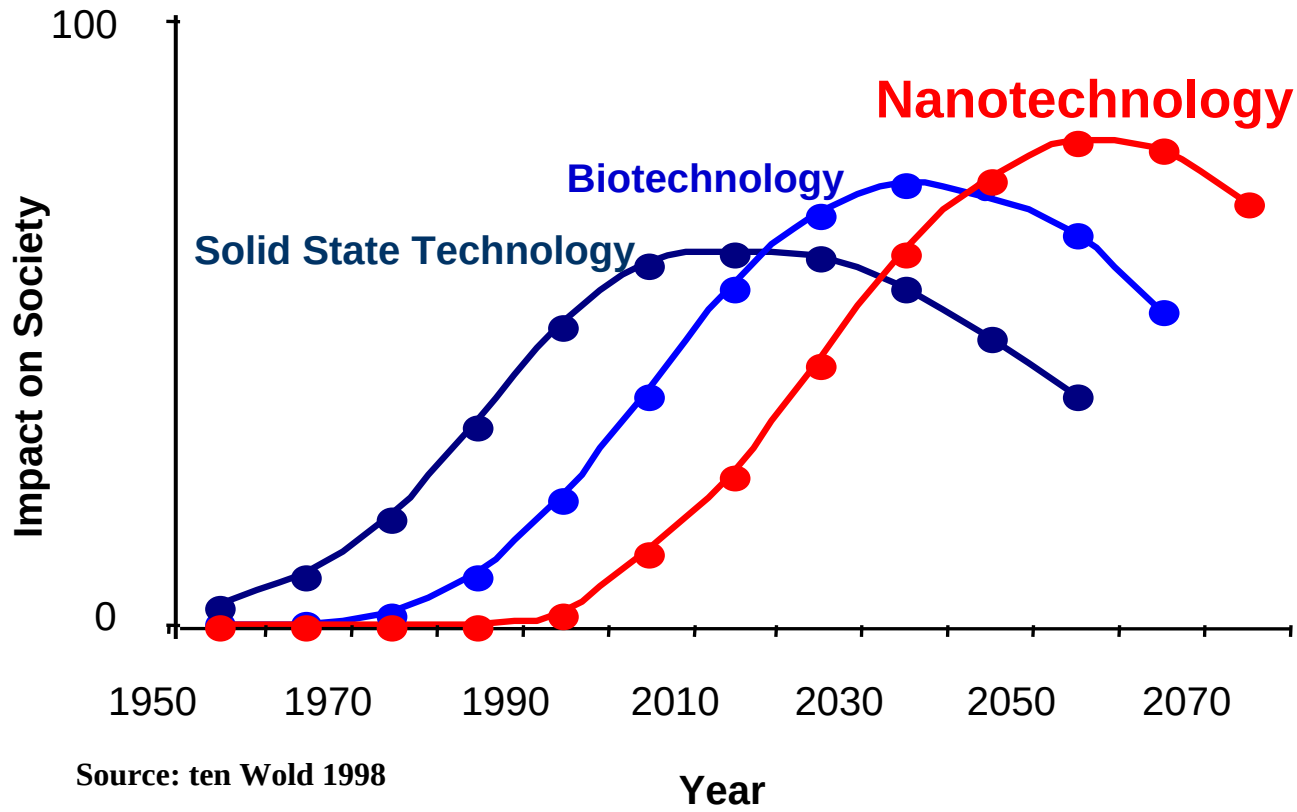
- ***From Workforce to Knowledge Workers in 7 years***

Advancing the Wood Products Revolution

- ***Improved Building Systems***
- ***Reduced System Costs***

Nanotechnology, "The Next Industrial Revolution"

Dr. R. Siegel,



Source: ten Wold 1998

Nanotechnology: 1 to 100 nm

U.S. National Nanotechnology Initiative

(Budget authority, US dollars in millions)

Fiscal Year	2001	2005
National Science Foundation	150	305
Defense (DOD)	125	276
Energy (DOE)	88	211
National Institutes of Health	40	89
Commerce (NIST)	33	53
NASA	22	35
Agriculture (USDA)	0	5
EPA	5	5
Justice	1	2
Homeland Security	0	1
TOTAL	464	982

Why Nanotechnology?

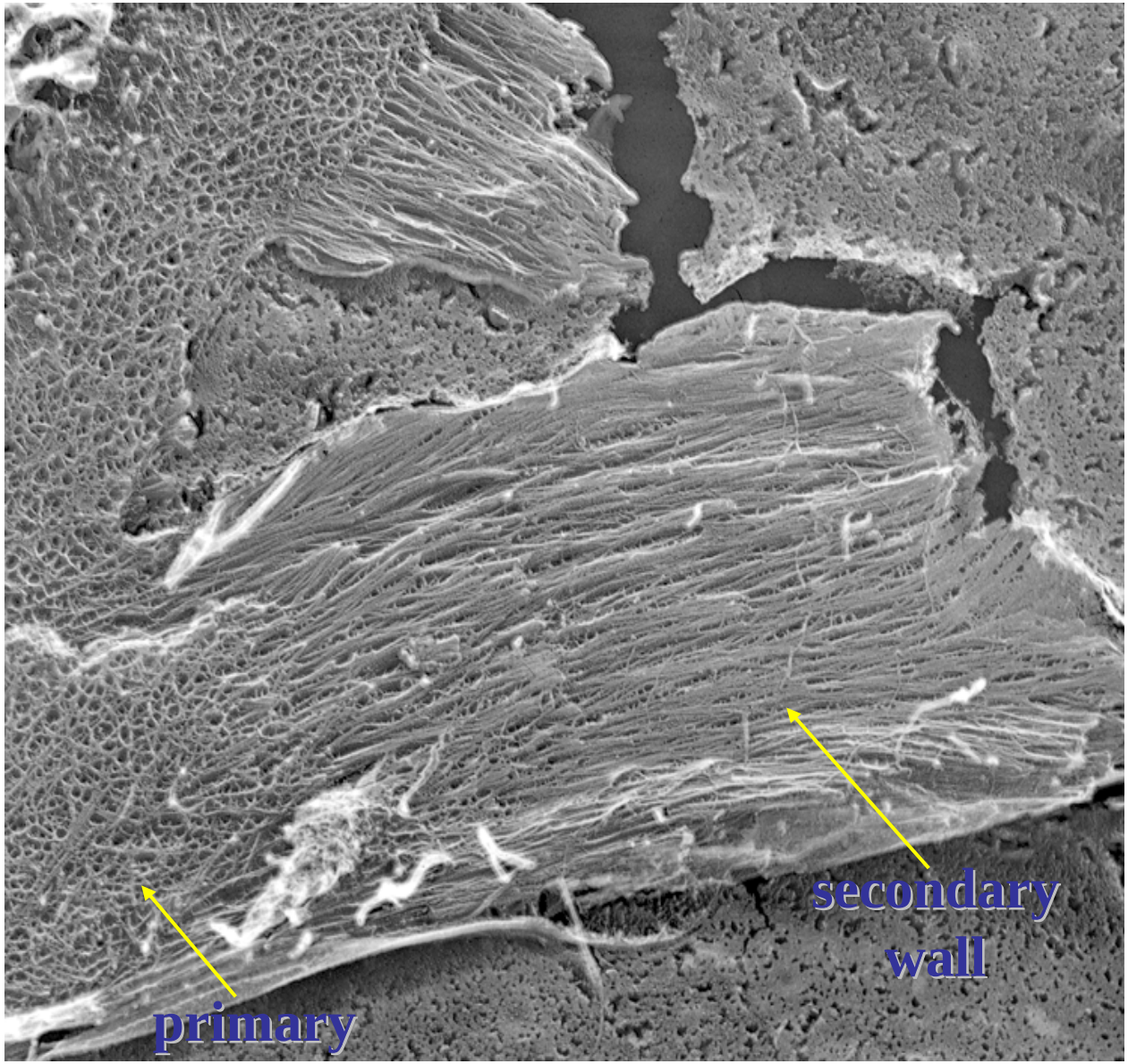
- **Less space, faster, less material, and less energy**
- **Novel properties and phenomena**
- **Most efficient length scale for manufacturing**
- **Intersection of living/non-living**

Source: G McCarty 2003

Why the Forest Products Industry Sector?

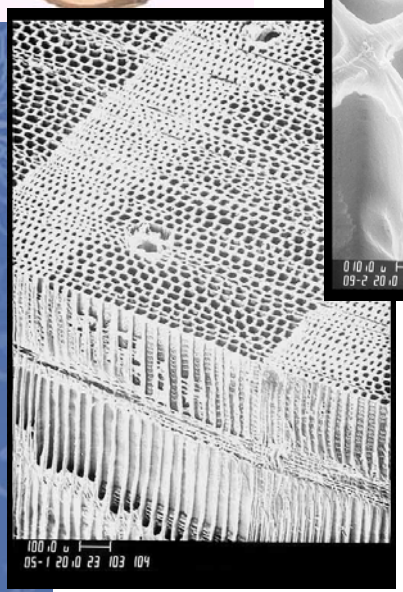
- **Forest products are a renewable resource**
- **Lignocellulose is among Nature's most abundant self–assembling materials**
- **Its use and functionality for nanomaterials is largely unexplored**
- **At a fundamental level we have nanodimensional cellulose fibers**
- **Applications for nanomaterial use abound through out 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**

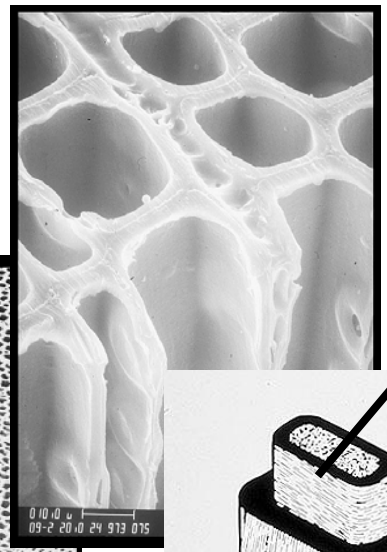
Nanofibers in Wood

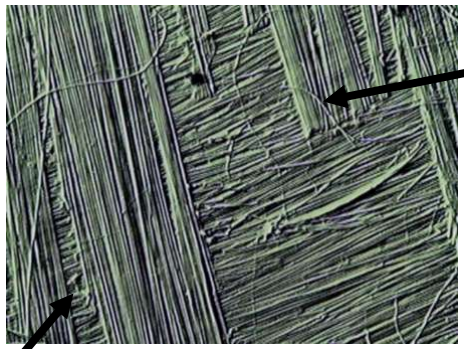


Images of differentiating xylem cells from C. Haigler

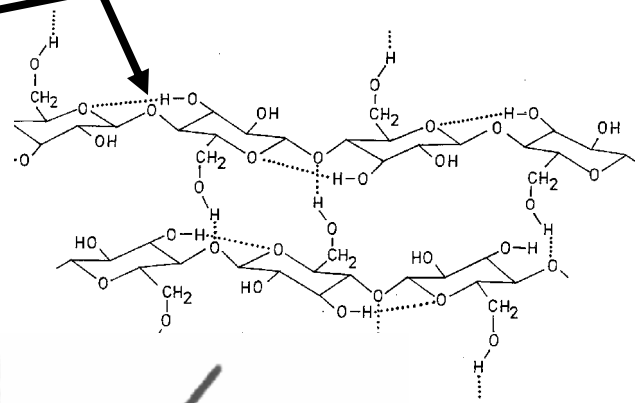
Cellulose Synthesis and Material Production: Nature Working Across a Length Scale >10^{10}!

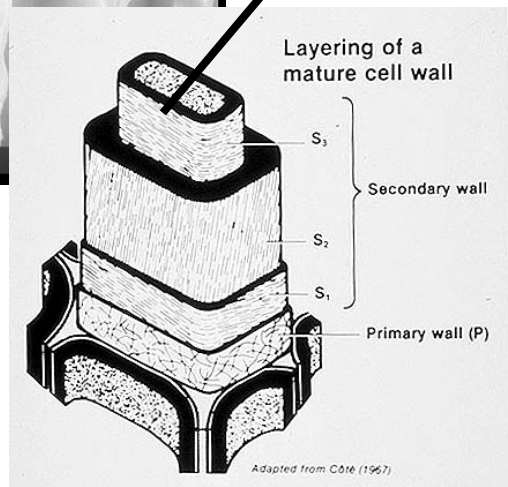


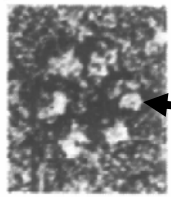




Cellulose nanofiber bundles







6 Assembly proteins (rosette) which produces cellulose nanofibers

www.ita.doc.gov/td/forestprod/

jupiter.phys.ttu.edu/corner/1999/dec99.pdf

Source: Jeffery Catchmark , Penn State University

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 mangers 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

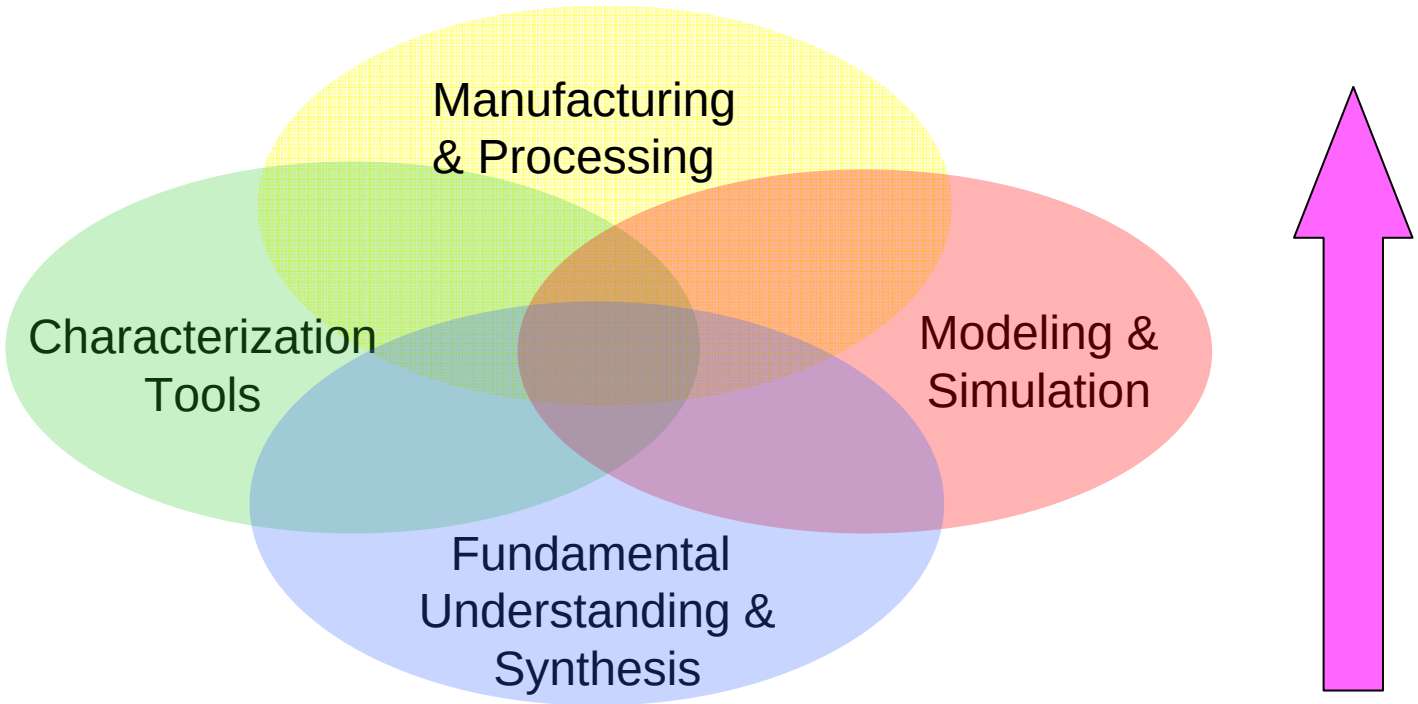
Nanotechnology has arrived at Forest Products Industries

- Government has reached out
- We must respond

Back up

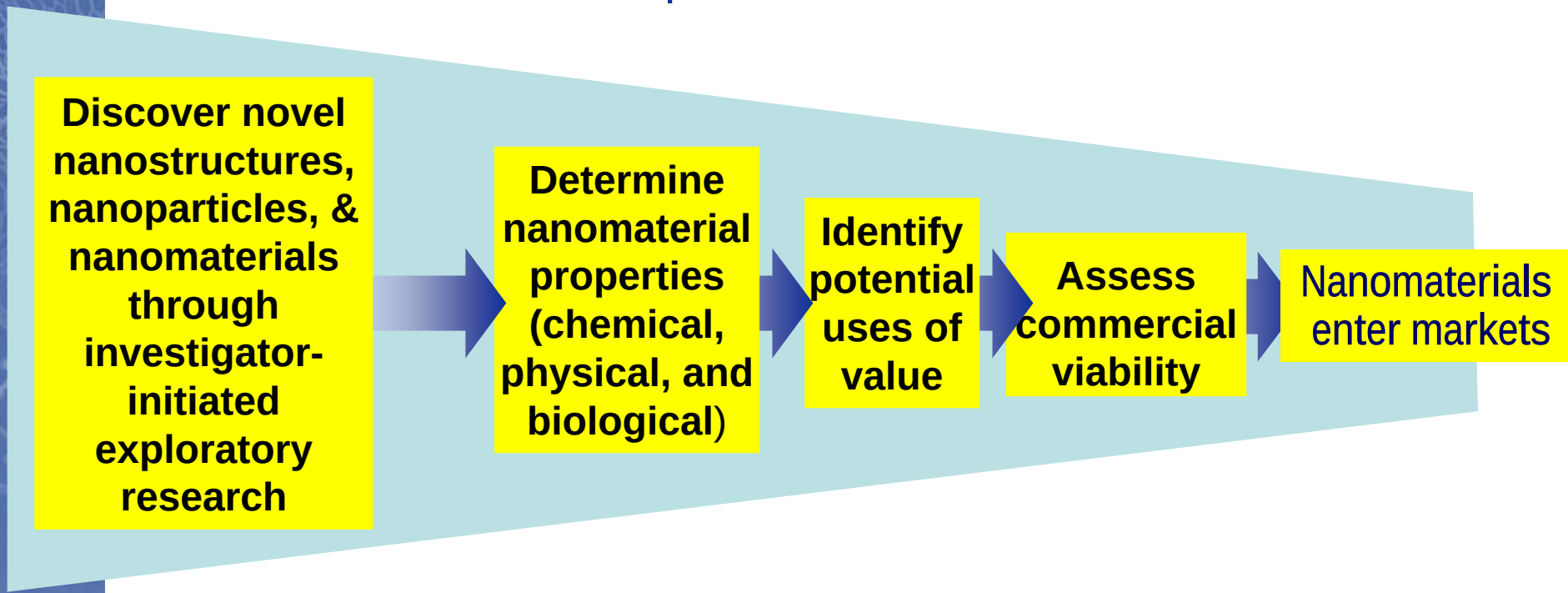
Self-assembling Lignocellulosic nanomaterials & Forest Products Incorporating Nanomaterials

Knowledge Gaps



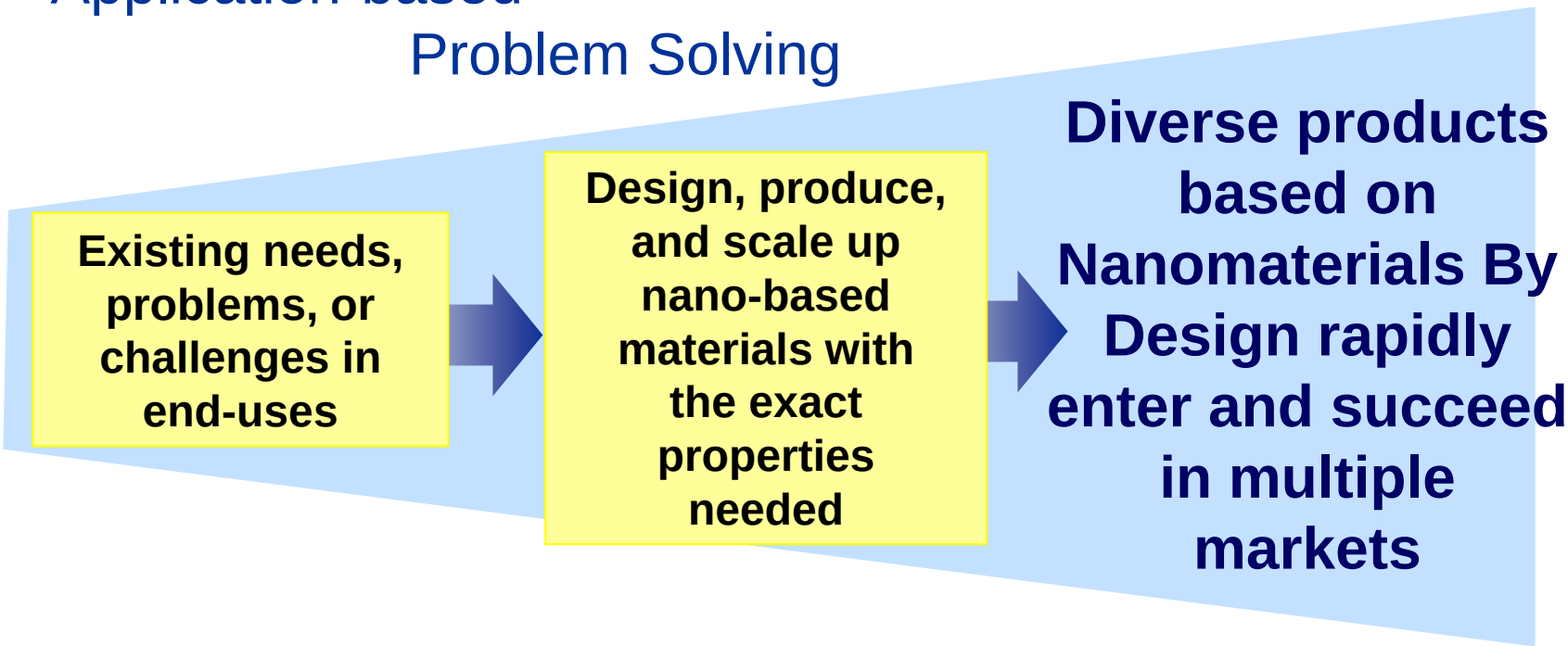
Current Nanomaterial Research & Development

Discovery-based Lignocellulosic Science & Product Development



Future Nanomaterial Development

Application-based
Problem Solving



Subcommittee Workshop

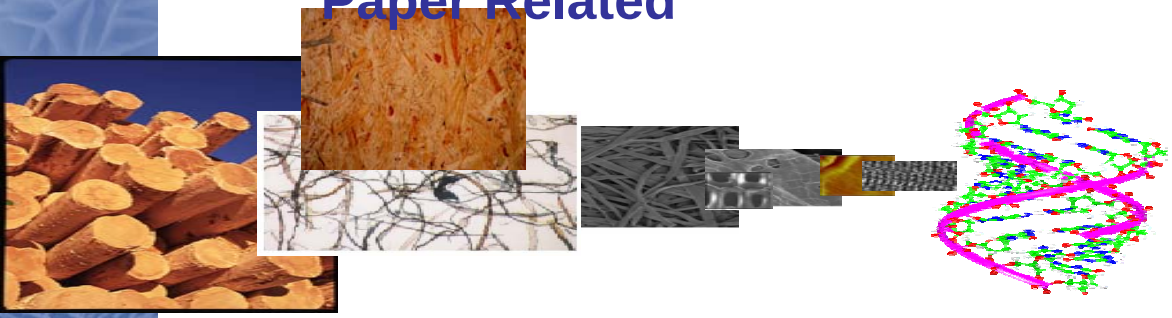
Polymer Composites and Nano-Related Materials: Paper Related

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)

Subcommittee Workshop

Polymer Composites and Nano-Related Materials: Paper Related

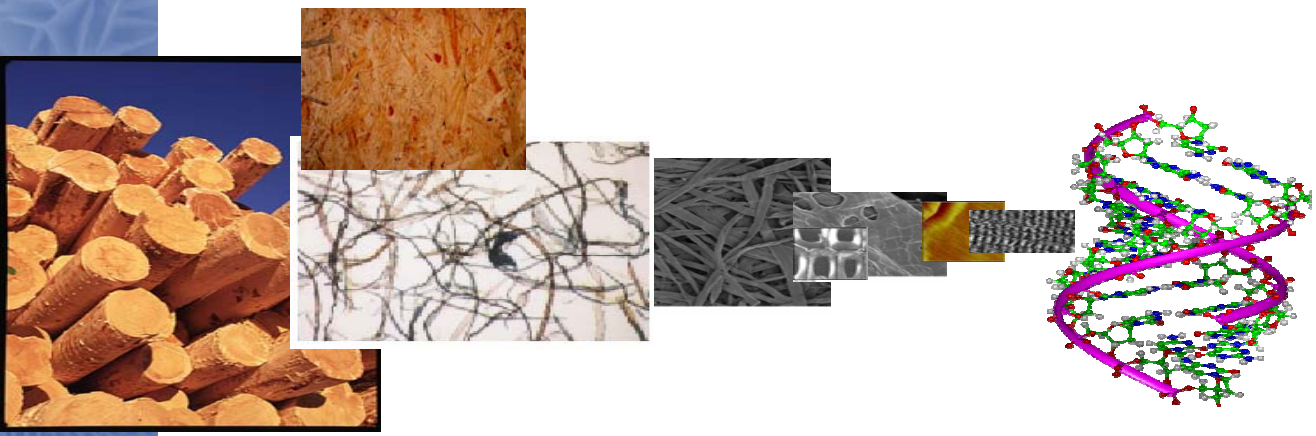


Multifunctional Intelligent Paper

- 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)

Subcommittee Workshop

Polymer Composites and Nano-Related Materials: Paper Related

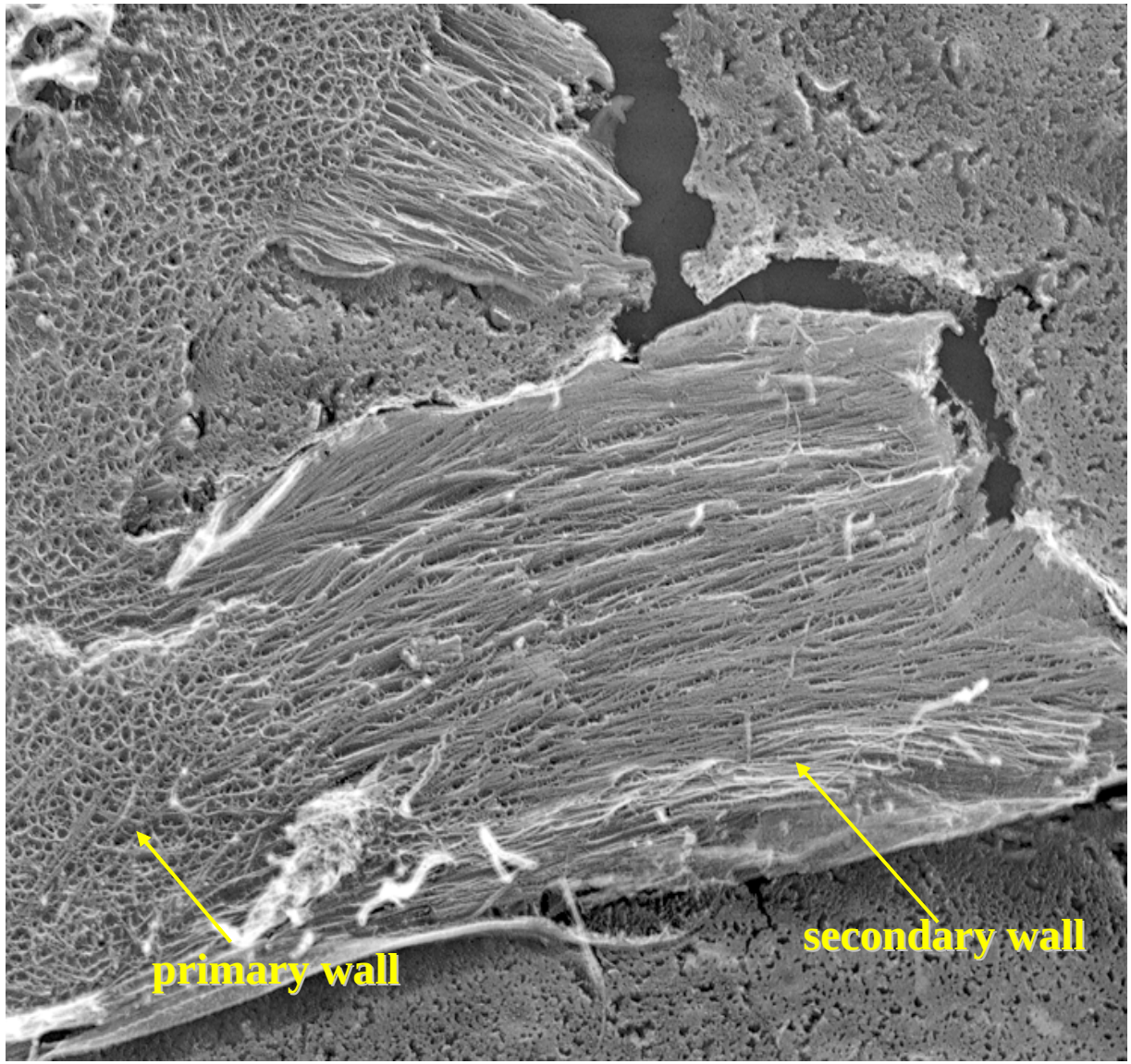


Innovative Cellulosics Composites

- 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

Self Assembling Systems Individual Goals

- On existing l/c substrate create novel, functional, self-assembling surfaces.
- Develop a fundamental understanding of molecular recognition in plant growth and cell wall

- Learn to characterize self-assembled natural and synthetic material.
- To integrate micro & nano scale organization in products