NANOTECHNOLOGY FOR FOREST PRODUCTS, PART 2

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Editor's Note: This article is a result of the Forest, Wood and Paper Industry's Agenda 2020 program focused on providing the industry with technology for a robust and sustainable future. Nanotechnology is one of the key "platforms" discussed at Technology Summit II, held in May 2004. This article discusses the development of the Nanotechnology platform. Part 1 appeared in the July 2005 issue of *Solutions!* Other articles on nanotechnology have also appeared in *Solutions!* magazine. To access these and other nanotechnology resources type "nanotechnology" into the search field on www.tappi.org .

IN THIS ARTICLE, YOU WILL LEARN:

- Details on the roadmap for progress developed by industry experts.

ADDITIONAL RESOURCES:

- " Nanotechnology for Forest Products, Part 1," by Ted Wegner and Phil Jones, *Solutions!,* July 2005. Please go to www.tappi.org and click on the July 2005 issue.
- "Nanotechnology for the Forest Products Industry—Vision and Technology Roadmap", visit www.tappi.org or www.nanotechforest.org
- Home page of the National Nanotechnology Initiative, the multi-agency framework for federally-funded nanotechnology R&D: www.nano.gov

R&D FOCUS AREAS

In planning for the Nanotechnology for the Forest products Industry Workshop, we considered many different options for organizing technical focus areas for breakout discussion sessions. We felt the fallowing R&D focus areas provide the best path forward for a nanotechnology roadmap by identifying the underlying science and technology needed: also, they foster essential interactions among visionary, interdisciplinary research and technology leaders from industry, academia, research institutions, and government.

Below we provide a brief description and a list of research directions for each focus area.

Polymer composites and nano-reinforced materials—combining wood-based materials with nanoscale materials to develop new or improved composite materials with unique multifunctional properties.

- Develop and investigate novel materials with enhanced properties (e.g., films, coatings, fillers, matrices, pigments, additives, and fibers—especially lignocellulosic nanofibrils.
- Develop and investigate novel materials for processing equipment
- Develop and understand the interrelationships between nanoscale material characteristics and the resulting product end use property improvements.
- Determine the optimum way to implement new materials.
- Develop economic and life-cycle models for forest-based nanoscale materials and products.

Self–assembly and biomimetics—using the natural systems of woody plants as either the source of inspiration or the template for developing or manipulating unique nano-, micro-, and macro-scale polymer composites via biomimicry and/or direct assembly of molecules.

- Develop a technical platform enabling self-assembly of paper products and other lignocellulosic materials at the nano scale
- On existing lignocellulosic substrate create novel, functional, self-assembling surfaces.
- Develop a fundamental understanding of molecular recognition in plant growth and cell wall self-assembly in FP processes to create new or enhance existing products.
- Learn to characterize self-assembled natural and synthetic material.
- To fully integrate micro and nano scale organization in products

Cell wall nanostructures—manipulating the cell wall nanostructure of woody plants in order to modify or enhance their physical properties and create wood and wood fibers with superior manufacturability or end-use performance.

- Investigate the process of formation of cellulose nanofibrils. including genetic. biochemical, cellular, and biophysical regulation (see **Figure 1**).

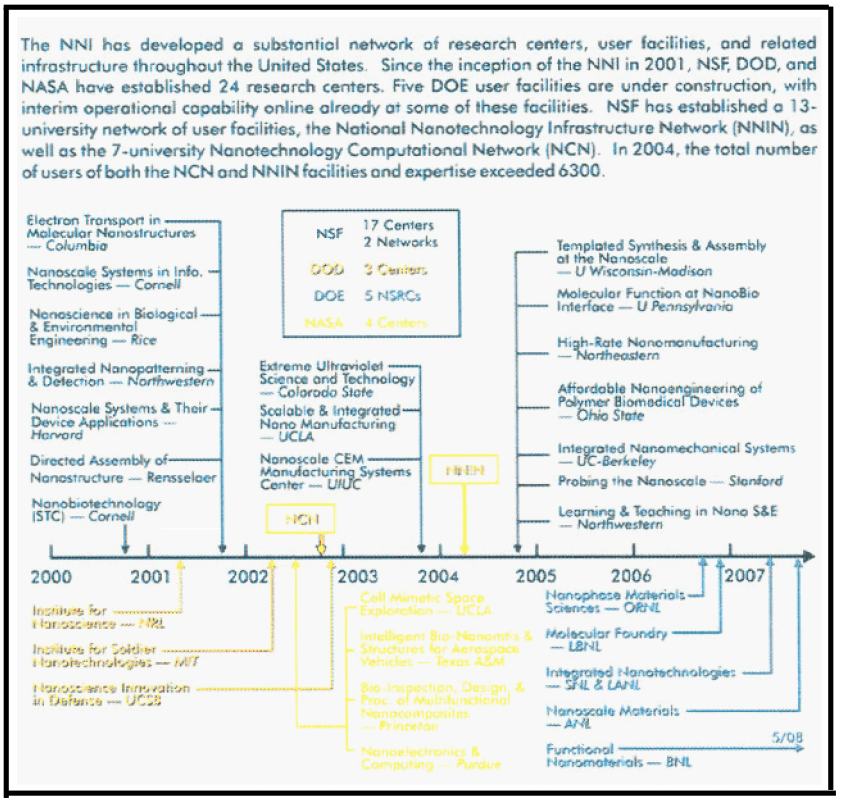


Figure 1: NNI Centers and Users Facilities with whom we need to network

- Characterize the processes that regulate the formation of the other constituents of the cell wall and the manner in which they are coupled with the deposition of cellulose.
- Determine the manner in which the processes of assembly and consolidation are guided by the expession of genomic information, the biophysical interactions of the synthesized molecules, and the emerging mechanical properties.
- Apply new instrumental methods to study the cell wall native state without significantly altering its structures.
- Develop cell walls as models and materials fur nanoscale assembly of new composites.

Nanotechnology in sensors, processing and process control—Using non-obtrusive, nanoscale sensors for monitoring and control during wood and wood-based materials processing, to provide data on product performance and environmental conditions during end use service, and to impart multifunctional capabilities m products.

- Identify microbial species or chemical/optical/physical agents that are unique fingerprints or signatures of food spoilage, medical contamination, or product degradation: develop methodologies for incorporating these agents into non-obtrusive, low-cost, robust nanosensors for food and medical packaging materials.
- Investigate genetic and chemical modifications of wood lignocellulose materials to enable basic sensing capabilities and self regulation (e.g., for moisture, temperature,VOCs).
- Investigate and develop paper and wood product coating technology and coating materials that an deploy nanosensors to these products through mechanical or chemical means.
- Investigate and develop fiber tagging techniques (e.g., through coating or fiber modification) to enable fiber separation and identification for recycling, counterfeiting, or forensic applications.
- Study and develop methods to synthesize data from multimillions of nanosensors in order to generate useful information for action or process control.
- Develop cast effective, efficient, environmentally-preferable and highly selective nanostructured catalysts for disassembling wood and lignocellulose
- Carry out research on the use of nanomaterials in conjunction with unit operations processing wood and wood-based materials.

Analytical methods for nanostructure characterization—Adapting existing analytical tools or creating new tools (chemical, mechanical, electrical, optical, or magnetic) that accurately and reproducibly measure and characterize the complex nanoscale architecture and composition of wood and wood based lignocellulosic materials.

- Create and maintain a compendium of available analysis tools.
- Develop techniques and tools to measure hemicellulose polymer structure and properties at the nanoscale.
- Develop techniques and tools to measure lignin structure and properties at the nanoscale.
- Develop methodologies and instrumentation to determine cell wall morphology and measure properties ai the nanoscale.

- Develop and deploy new collaborative strategies for analysis involving multiple techniques.

R&D collaboration to include the National Nanotechnology Initiative (NNI) and its centers—This emphasizes the importance of collaboration and cooperation among researchers from various disciplines and organizations, including universities, research institutes, National Laboratories, and several government agencies and departments.

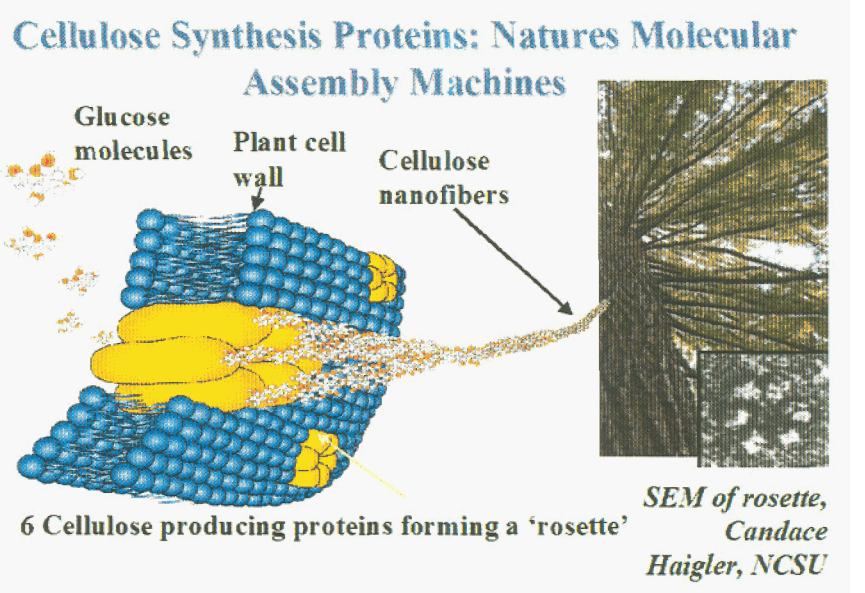
The forest products sector must create links between its research community and the broader community of nanotechnology researchers in order to capture synergies, enhance accomplishments, and avoid needless duplication of facilities and efforts. Research entities to engage include:

- Individual researchers
- Researchers with differing disciplines
- Basic and applied researchers and research teams
- Research institutions including universities, research institutes, and national laboratories
- Industry, universities, research institutions. and several federal agencies and departments
- All of the previous groups from countries around the world.

MOVING AHEAD

In moving ahead in the area of nanotechnology, the forest products industry must seize the opportunity to link with larger nanotechnology research and industrial communities such as the ongoing efforts of the National Nanotechnology initiative (NNI) (**Figure 2**).

The NNI is a visionary R&D program that coordinates the activities of 22 federal agencies and a host of collaborators from academia, industry, and other organizations. The total federal funding investment for the NNI is $988 million in fiscal year 2005 and a request of $1,052 million in fiscal year 2006.



Jeffrey M. Catchmark, Penn state University and NSF NNIN

Figure 2. Cellulose producing proteins.

The goals of the NNI are to maintain a world class research and development program aimed at realizing the full potential of nanotechnology; facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit develop educational resources, a skilled workforce. and the supporting infrastructure and tools to advance nanotechnology; and support responsible development of nanotechnology.

LINKING WITH COMMUNITIES

By linking with communities such as the NNI, the forest products industry will be able to expand its knowledge of nanotechnology, pool its resources with those of others pursuing common research and development goals, and advance its own agenda. SI

Editor's Note: For more infomation, read "Nanotechnology conference targets research options, "Solutions!, February 2005, by Jan Bottiglieri and Douglas Rooks. Access this article on www.solutionsmagazine.org by clicking on the February issue.

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