Novel Isolation/Directed Production of Nano-lignocellulosic Structures
# Novel Isolation/Directed Production of Nano-lignocellulosic Structures

- Identify Key Opportunities

<table>
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<tr>
<th>Cellulose</th>
<th>Lignin</th>
<th>Hemicelluloses</th>
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<tr>
<td>• Fibrils</td>
<td>• Spheres</td>
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<td>• Whiskers</td>
<td>• Rods</td>
<td>• Films</td>
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<td>• Spheres</td>
<td>• Cylinders</td>
<td>• Electrospun fibers</td>
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<td>• Regenerated nano-particles</td>
<td>• Carbon nanostructures</td>
<td>• Self-associated structures</td>
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Cellulose, Lignin, Hemicellulose Nanostructures

• Need to determine and model fundamental properties to establish unique
  – Morphological
  – Mechanical
  – Chemical
  – Optical
  – Magnetic
  – Electronic
  – Transport

properties and resulting opportunities attributed to nanoscale
Goal Statement

Develop fundamental knowledge for the separation, processing, and reassembly technologies needed to address both high value and high volume applications for nano-lignocellulosic polymers and structures.
Objectives

- Systematically identify fundamental properties of association of biopolymers and how to disaggregate this association.
  - Recognizing that separation technologies are oftentimes coupled to the intended application.
- Elucidate of the unique properties of nanolignocellulosics for innovative applications.
- Develop modeling capabilities to explain and predict properties of nanolignocellulosic structures.
Benefits

• Large scale, low cost nanostructures of cellulose, lignin, hemicelluloses
• Environmentally benign nanostructures
• Use superior properties of cellulose over synthetic polymers
• Sustainable and renewable alternative to petroleum based products
Potential Separation Technologies

• What’s needed is a systematic program to identify fundamental properties of association of biopolymers and how to disaggregate this association.

• Separation technologies are coupled to the intended application.
Potential Separation Technologies

- Acid hydrolysis
- Dissolving solvent extraction methodologies
- Enzymatic/biological treatment
- Mechanical/ milling/ grinding
- Ionic liquids
- Near supercritical extraction
- Steam explosion
- High pressure homogenization
- Surface acetylation of fiber- can you release nanocrystals by surface derivatization?
- High Shear
Identify Key Applications

• Specialty High Value
  – Utilize structure and benign nature of nanocellulosics for the development of biomedical devices and pharmaceuticals
  – Utilize 50% or more of the intrinsic strength
  – Utilize the natural self-assembly recognized in the growth of the cell wall to create self-assembled structures for specific purposes
Identify Key Applications

• High Volume
  – Water purification system
  – Papermaking components
    • Strength enhancers
    • Dimensional stability
  – Novel imaging technology built into paper
  – Use nano-lignocellulosics to create tunable hydrophillic/hydrophobic surfaces
  – Wood based composites
    • Strength enhancers
    • Creep control
    • Moisture control
    • Dimensional stability
Barriers

• Current laboratory separation technologies are often inadequate for nanolignocellulosic systems.
• Separation science is not fully developed for nanoscale systems.
• Separation technologies currently used in laboratory are often not viable processes on the industrial scale, such as
  – Separate nanoparticles from product stream- nanofiltration? centrifugation?
  – Drying
  – Size fractionation
• Metrology and characterization tools are inadequate.
• Principles of disassembly and reassembly are not sufficiently advanced.
• Difficult to advance the underlying science if one or more applications are not readily apparent.
• Particular value of nanolignocellulosics and their contributions for sustainable development is not widely understood in the materials science community
R&D and Related Needs

- Identify structure of available lignocellulosic nanomaterials from wood
- Characterize, measure, and model properties making full use of available biological research and techniques
- Engage separations research community and prepare inventory of potential separation processes and effective models for application and scale-up
- Develop library of properties of nanolignocellulosics
- Establish uniqueness and benefits of nanolignocellulosics compared to other nanomaterials
- Identify relationships between separation and purification technologies, nanomaterial properties, and end use applications
- Investigate economic viability of nanomaterials as application opportunities arise
R&D and Related Needs

• Engage separations research community and prepare inventory of potential separation processes and effective models for application and scale-up
  – Host joint sessions or symposia of AIChE Forest Products and Separations Divisions, American Filtration and Separation Society (AFS), ACS, ASME, and MRS
  – Benchmarking currently available separation technologies coordinated by professional societies and industrial sponsors
    • Tailored metrology techniques and analytical equipment
  – Elements of a research Program
    • Study flocculation and agglomeration and their effects on nanosystems
    • Fundamental principles of engineered reassembly
    • Elucidate efficient extraction of nanocellulosic ensembles
    • Study rheology, such as compressional and shear, gelation