

Nanozellulose und Nanotechnologie: neue Verwendungs- und Vermarktungsmöglichkeiten der forstlichen Ressource Holz

Albert-Ludwigs-Universität Freiburg

Prof. Marie-Pierre Laborie, PhD
University of Freiburg

Outline

1. Nanotechnology and the forest products industry
2. A vision to advance the forest products industry
3. Product diversification in the forest products industry
4. Concluding remarks

Outline

1. Nanotechnology and the forest products industry
2. A vision to advance the forest products industry
3. Product diversification in the forest products industry
4. Concluding remarks

Nanotechnology

- A nanometer is a billionth of a meter, or 80000 times thinner than a human hair
- Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale

Nanotechnology Industry Workshop

in VA, USA, (Oct 17-19, 2004)

- American Forest and Paper Association (AFPA), TAPPI, USDA, FPL
- “Nanotechnology is the most promising breakthrough towards production growth since the Internet—some say a second industrial revolution”.



Nanotechnology for the
Forest Products Industry

Vision and
Technology
Roadmap

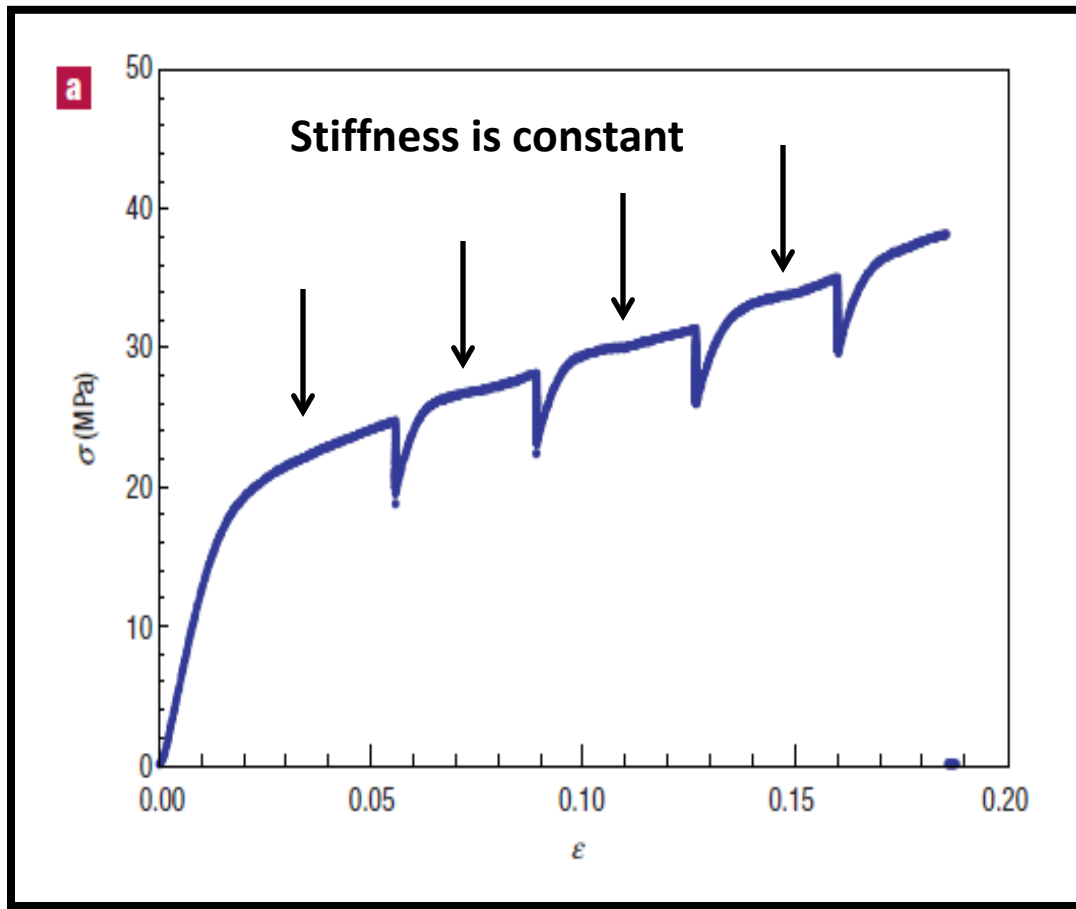
Forest Technology Platform

- Nanotechnology **will also become crucial** in the forest-based sector. Conventional woodworking relies mainly on the macro-scale properties of wood. Beyond that it is natural to start looking for nano-scale applications.
 - “Nanofibrillar cellulose”
 - “Self-healing and self-cleaning wood”
 - ...



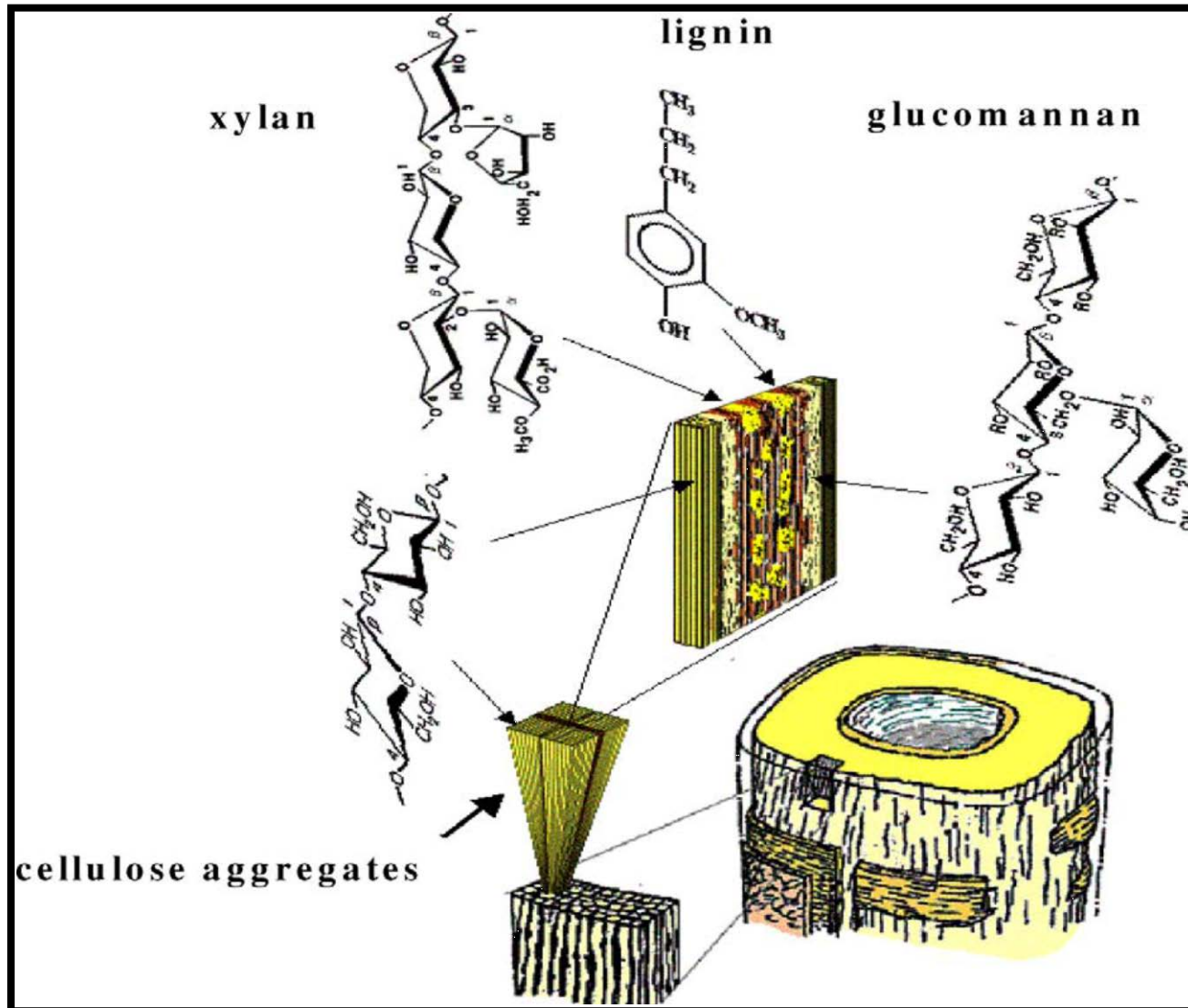


Stress-Strain Curve of Wet Wood Fiber



- A self-healing material
- Engineering of interfaces and **molecular interactions**
- Velcro mechanism in Wood

Wood from the Molecular Lens



Nanomanufacture
Bottom-up



The National Research Strategy Bioeconomy 2030

“ We must better understand and characterize the **complexity of the building blocks and blueprints of biological systems**, and **improve our predictions about their reactions to external influences**. Only then will we be able to better **exploit them technologically** for the benefit of mankind and the environment “



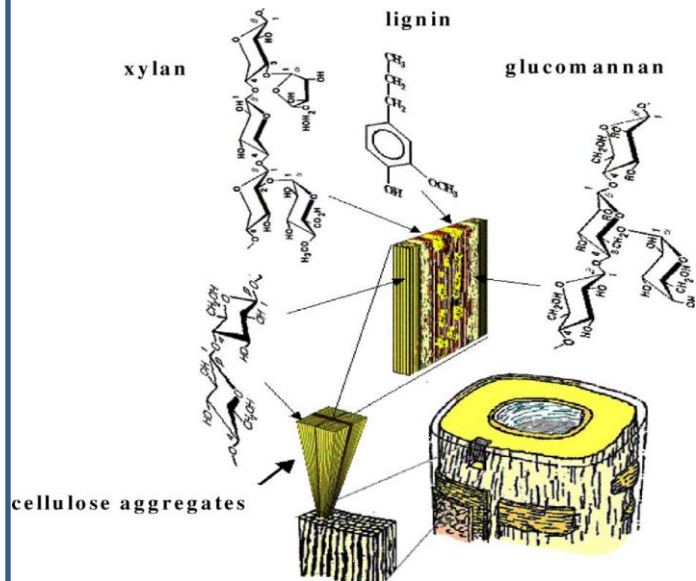
A handwritten signature in black ink, which appears to read 'Annette Schavan'.

Prof. Dr. Annette Schavan, Federal Minister for
Education and Research

Forest Biomaterials at the University of Freiburg

Forest Resources

1) Molecular modeling of wood structure & properties

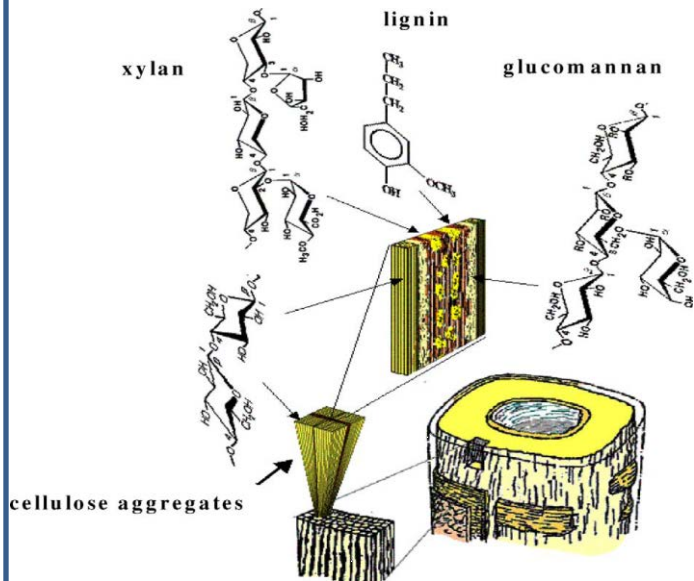


Cellulosic cell wall (Salmén et al., C.R. Biologies 2004)

Forest Biomaterials at the University of Freiburg

Forest Resources

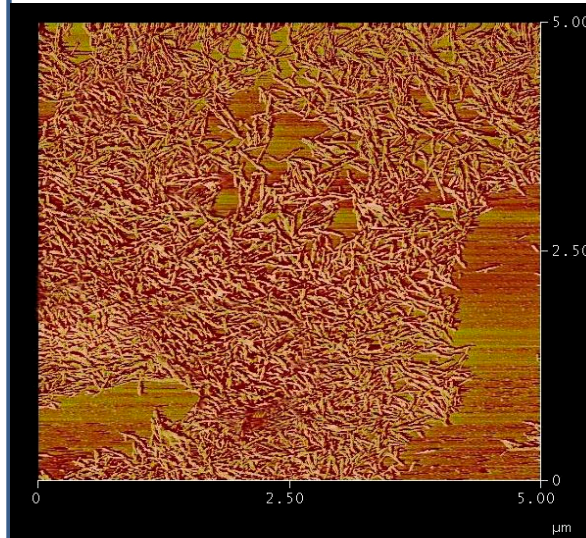
1) Molecular modeling of wood structure & properties



Cellulosic cell wall (Salmén et al., C.R. Biologies 2004)

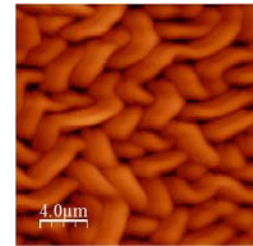
Novel Forest Biomaterials

2) Recovery of building blocks from processing waste streams



Nanocellulose

3) Engineering of novel biomaterials



Microstructured nanocellulose-based coatings

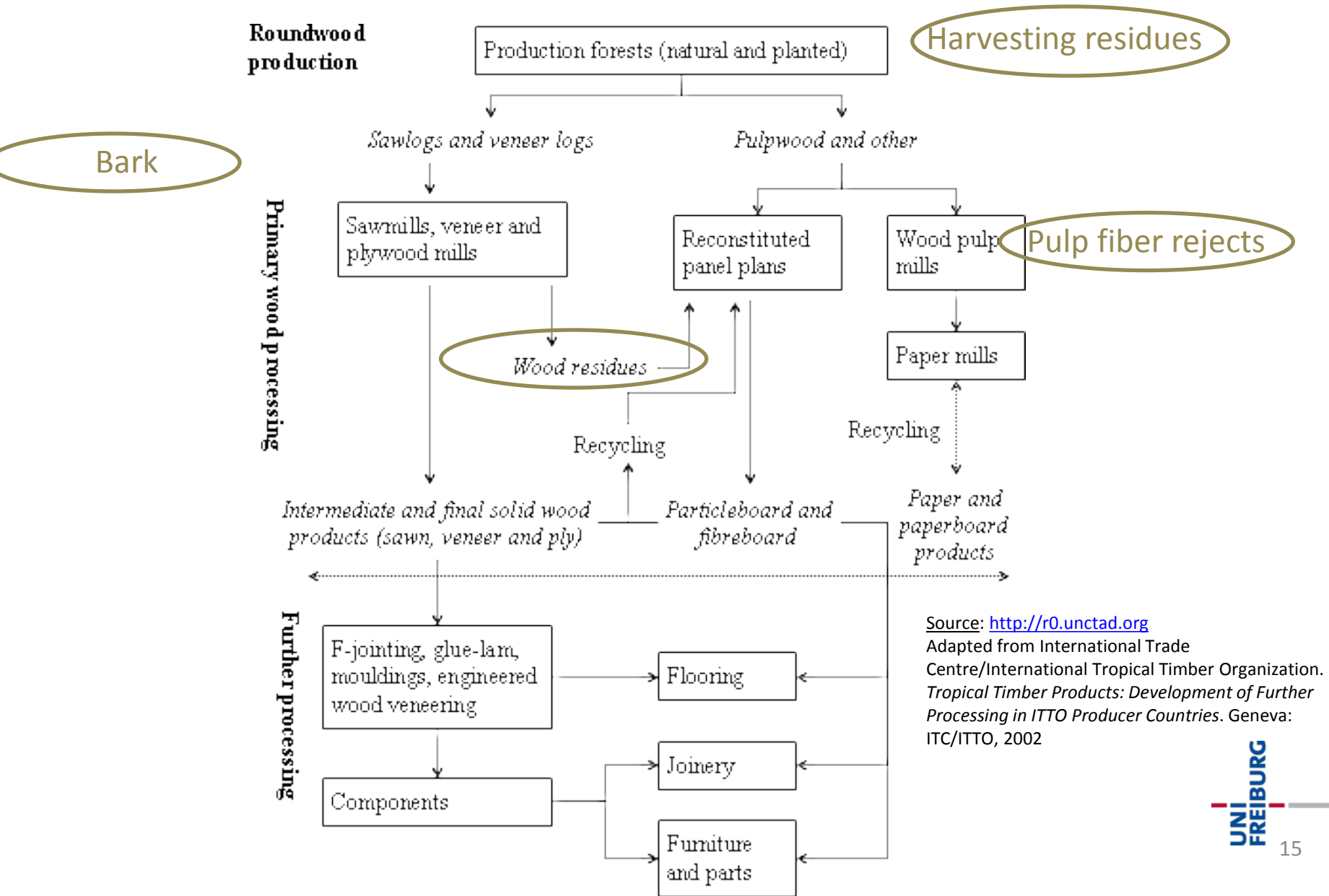


Tannin based foams

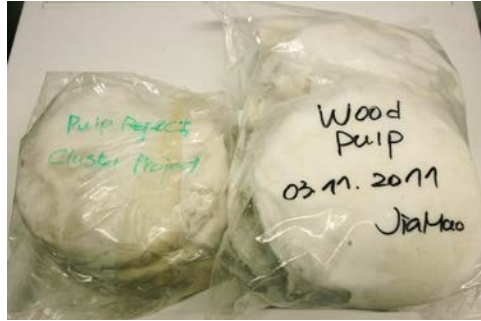
Outline

1. Nanotechnology and the forest products industry
2. A vision to advance the forest products industry
3. Product diversification in the forest products industry
4. Concluding remarks

How does this fit within the Wood Processing Industry?

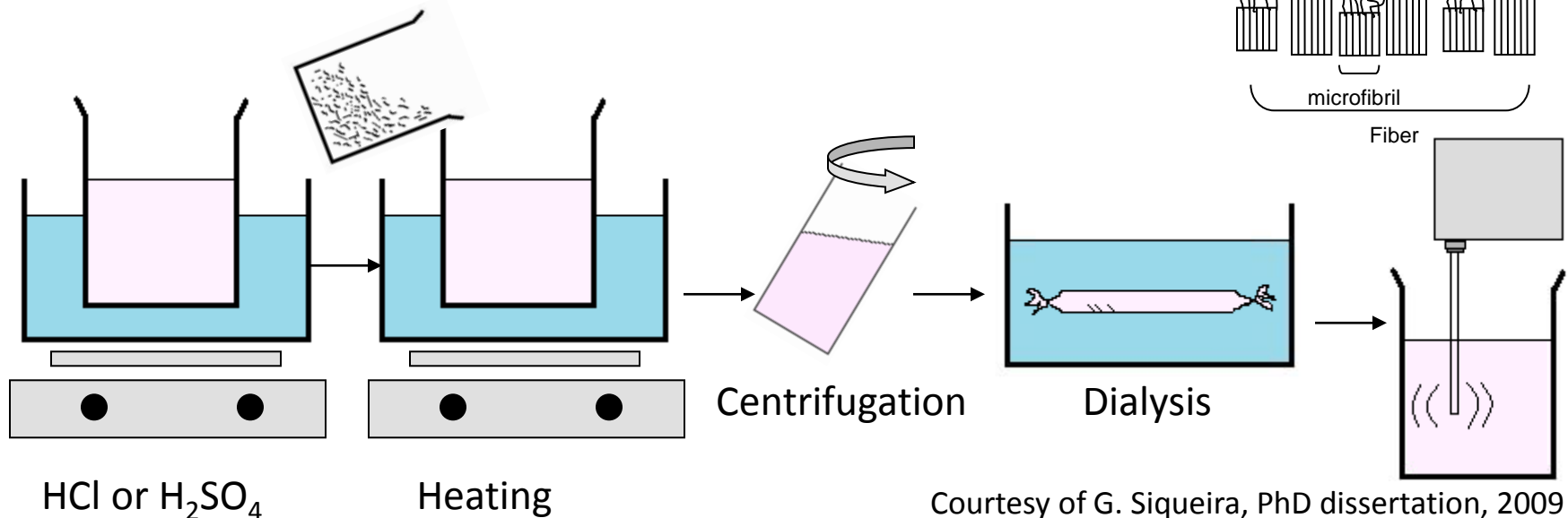
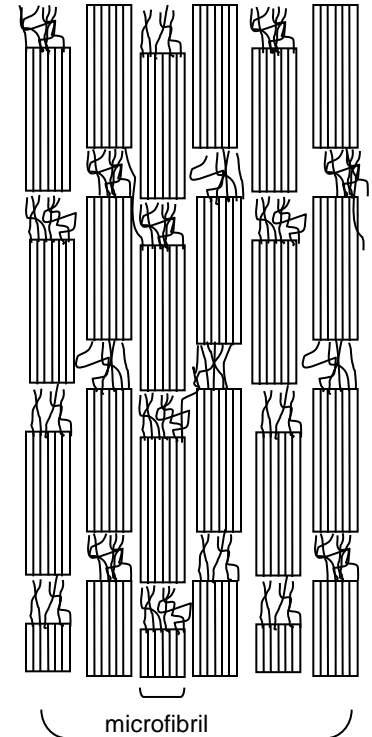
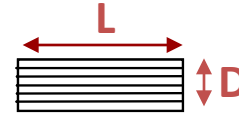


Nanocellulose from Pulp Fiber Rejects



*Bleached pulp from Sappi Fine Paper Europe (right)
And pulp reject from Stora Enso (left)*

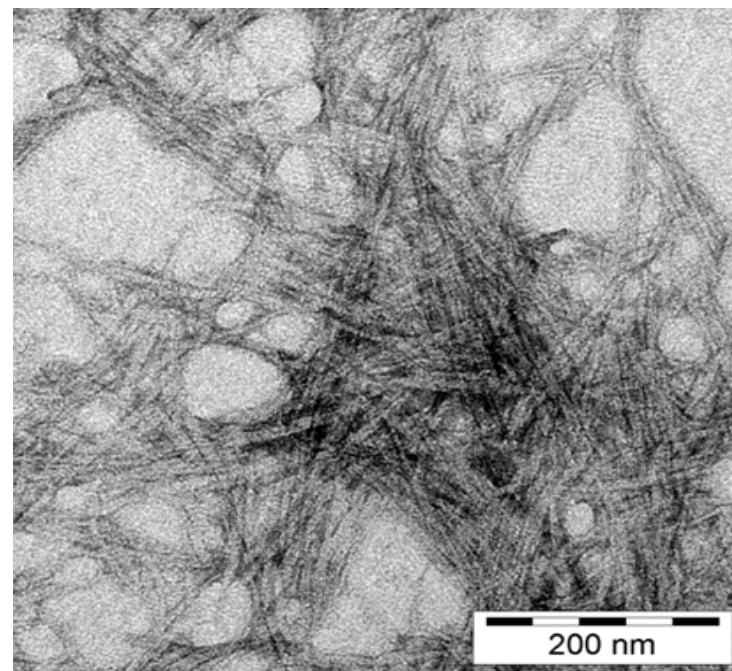
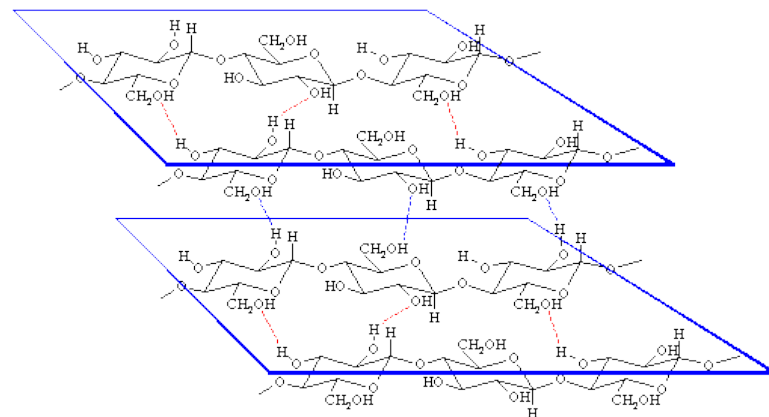
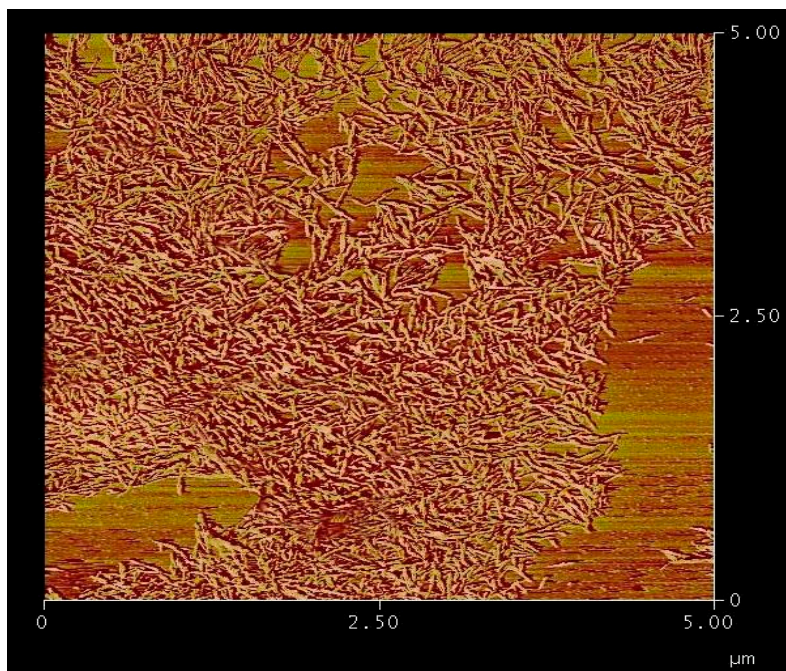
Aspect Ratio: 10 to 50



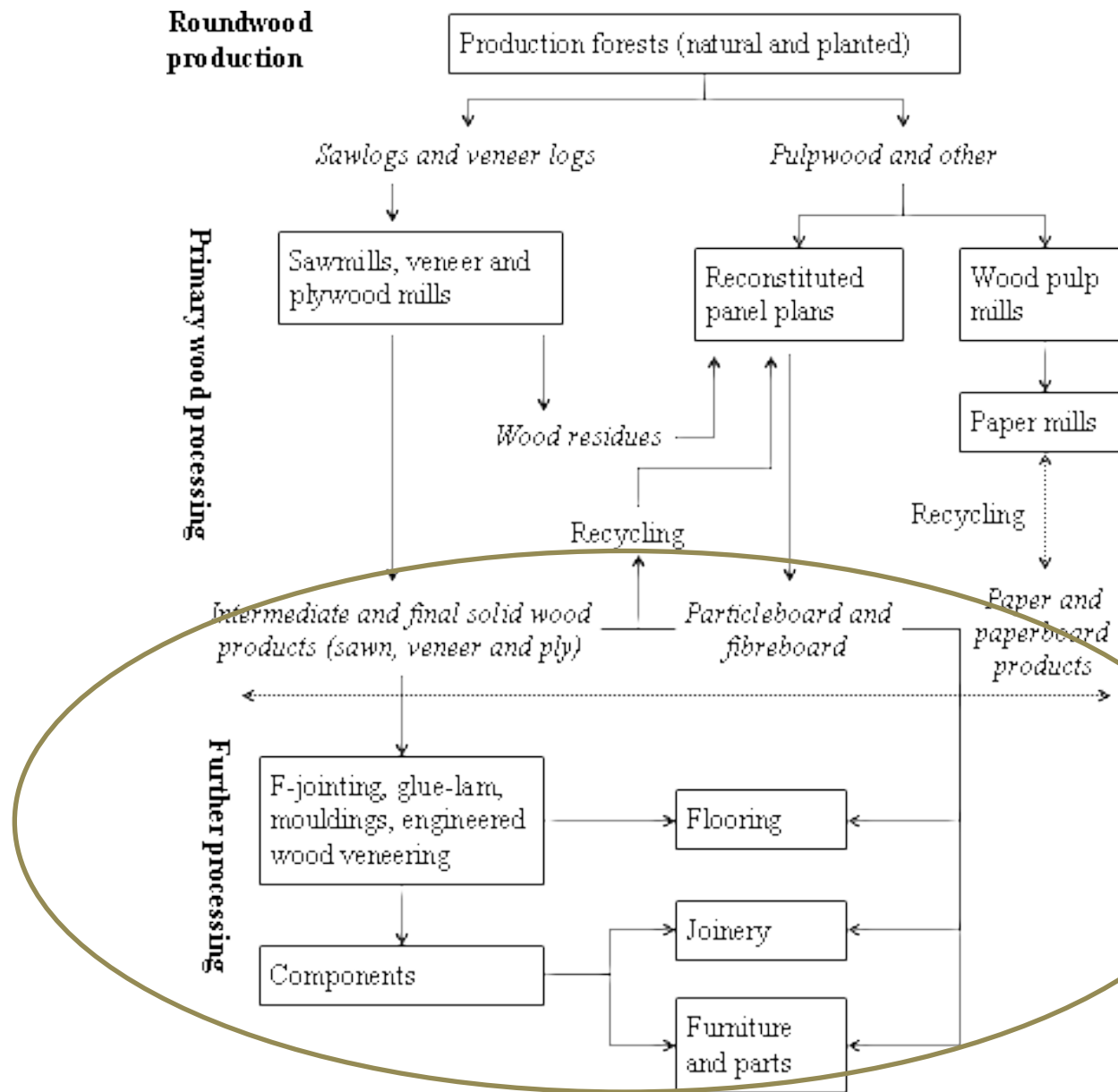
Courtesy of G. Siqueira, PhD dissertation, 2009

Cellulose Nanowhiskers

- Rod-like nanoparticles with stiffness estimated at 140 Gpa

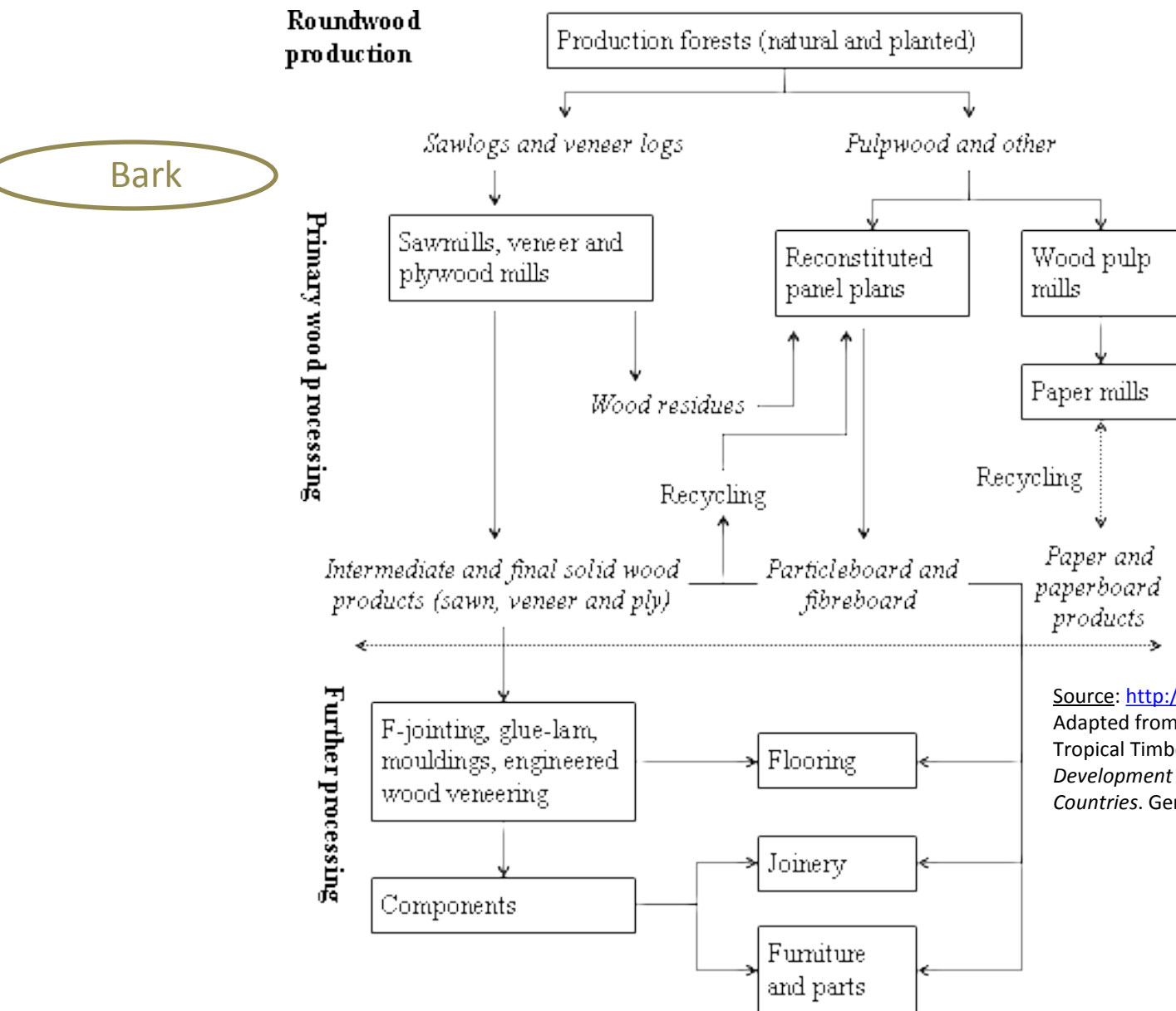


How does this fit within the Wood Processing Industry?



Source: <http://r0.unctad.org>
Adapted from International Trade Centre/International Tropical Timber Organization. *Tropical Timber Products: Development of Further Processing in ITTO Producer Countries*. Geneva: ITC/ITTO, 2002

How does this fit with the Wood Processing Industry?

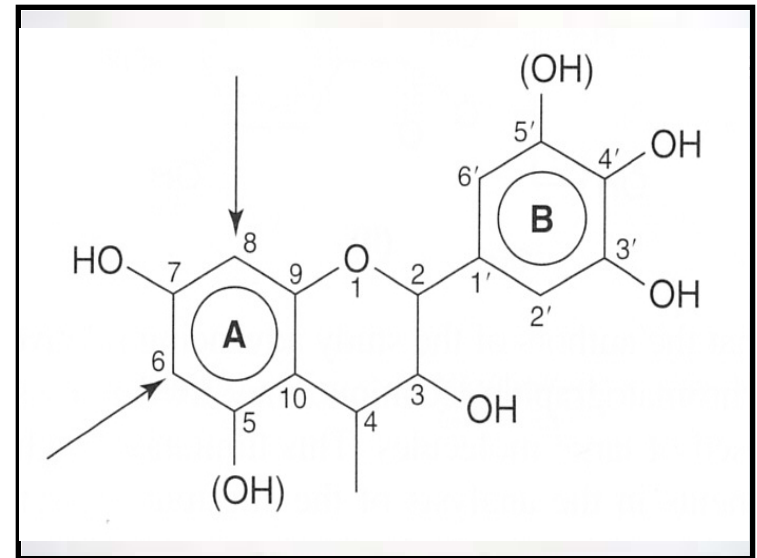


Source: <http://r0.unctad.org>

Adapted from International Trade Centre/International Tropical Timber Organization. *Tropical Timber Products: Development of Further Processing in ITTO Producer Countries*. Geneva: ITC/ITTO, 2002

Bark for Bio-based Building Blocks and Bio-based Polymers

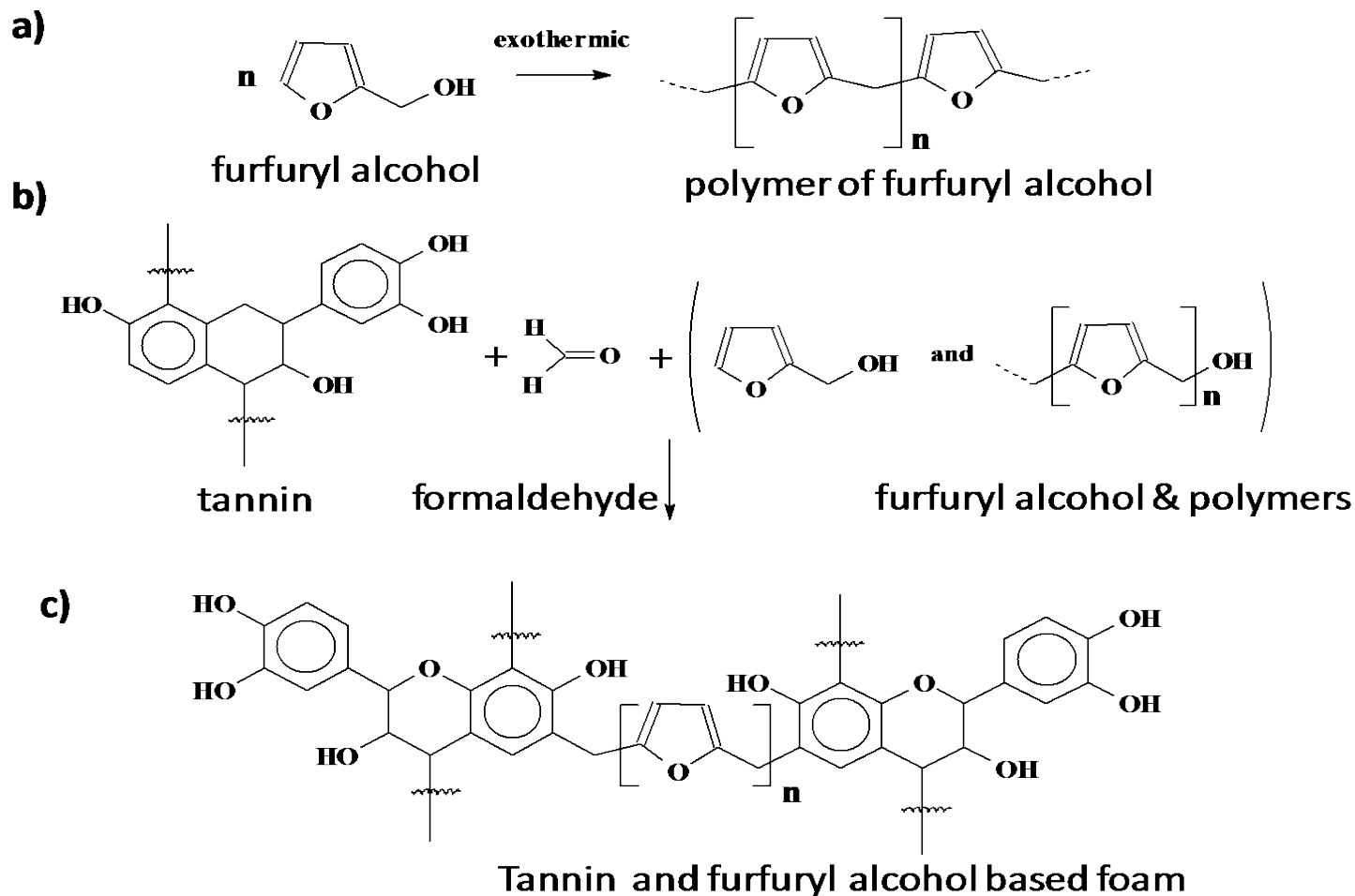
- Wood bark is already within the wood chain supply
- ca 12 Million m³ of bark is currently burnt for bioenergy purposes in Europe
- Estimated* harvest potential from only pine and spruce amount to ca. 38 Mm³



- Spruce (*Picea abies*)
- Radiata Pine (*Pinus radiata*)
- Maritime Pine (*Pinus pinaster*)

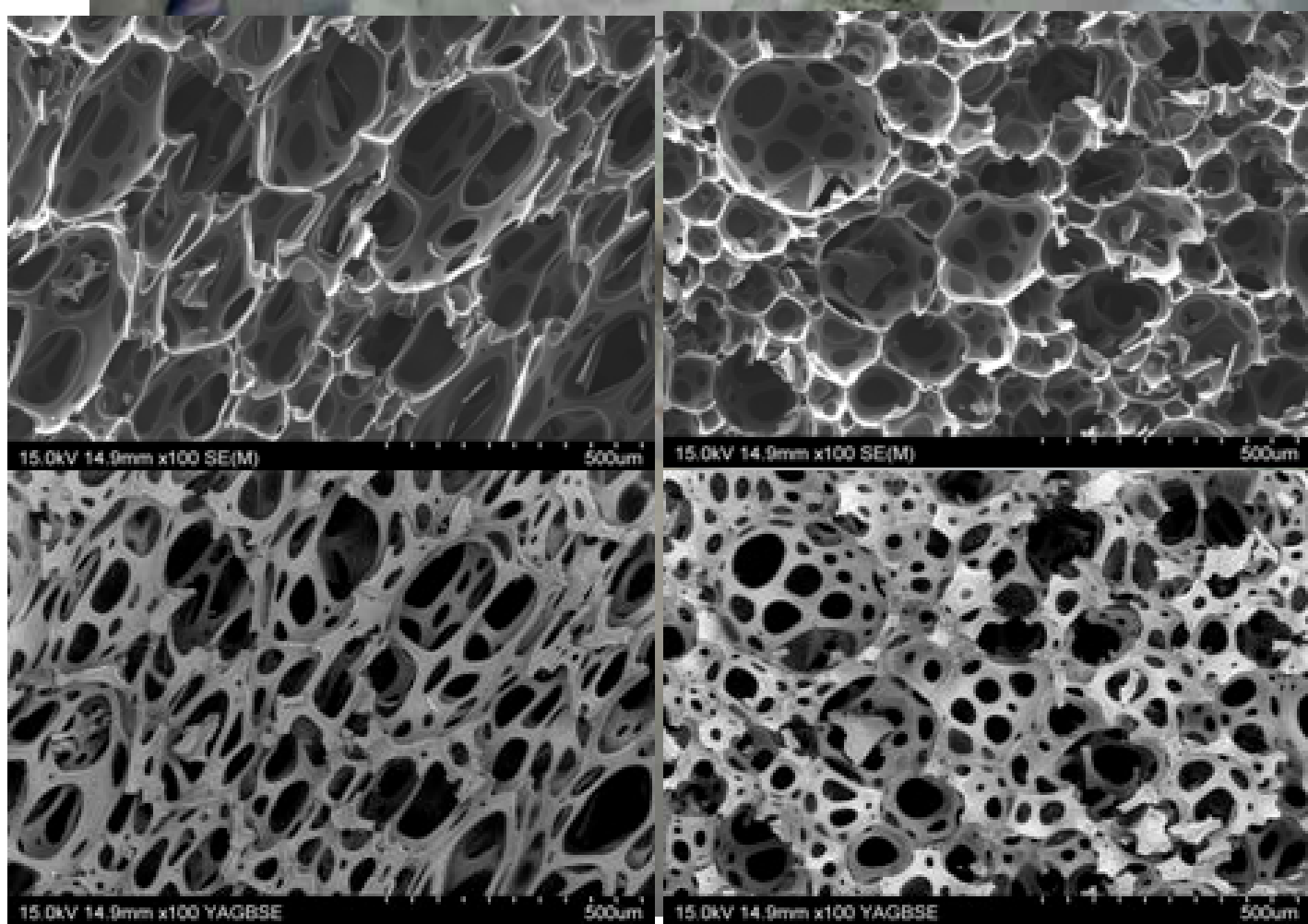
*Estimated after data from EFORWOOD Project

Tannin-based Polymers

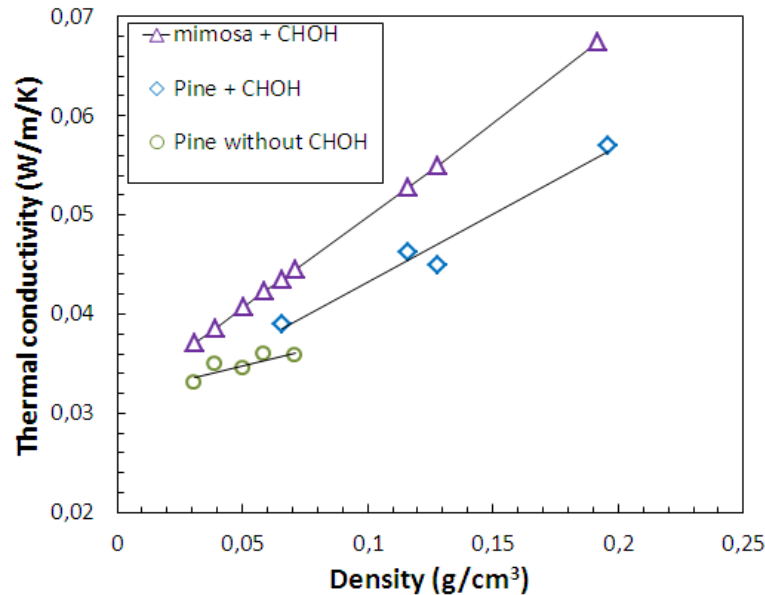


Reaction schemes for the synthesis of tannin foams, a) polymerization of furfuryl alcohol, b) condensation of tannins with formaldehyde and c) polymeric structure of resulting tannin/ furfuryl alcohol foams.

Tannin-based Foams



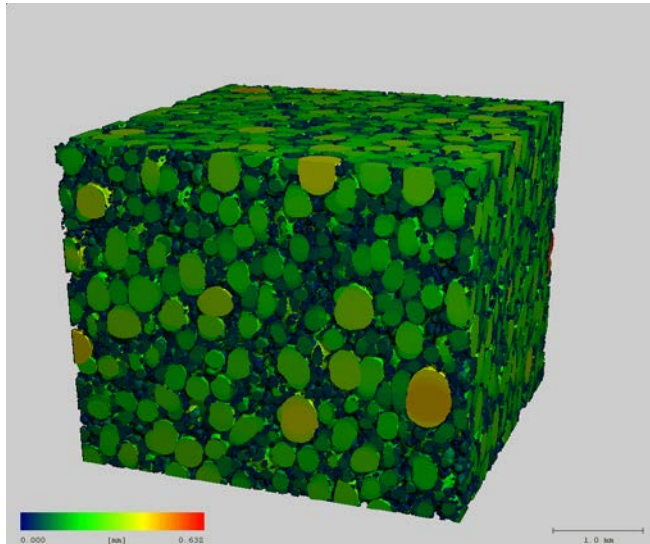
Insulating Foams from Tree bark Tannins



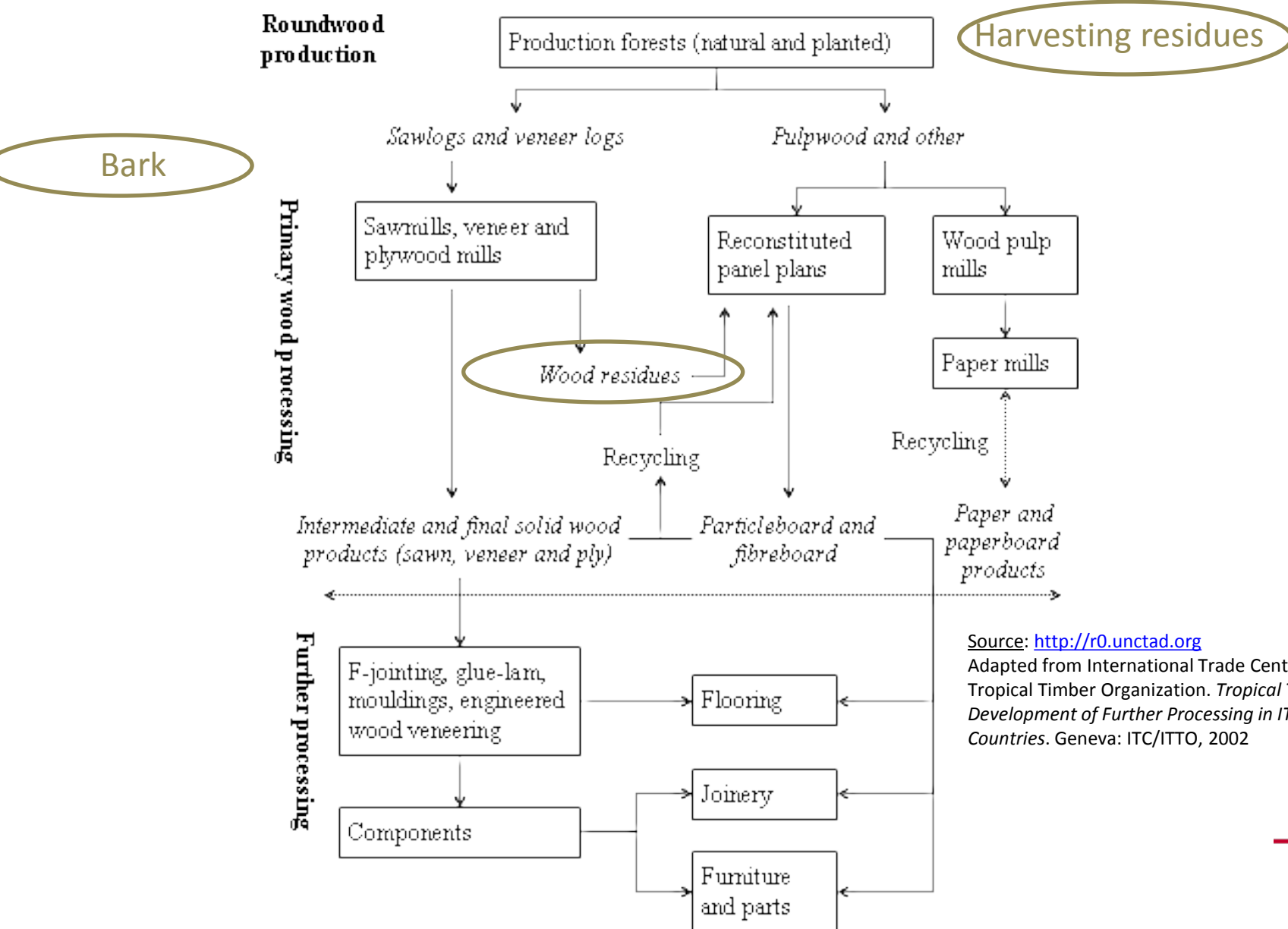
➤ Insulating properties are good but mechanical properties need to be improved

Mechanical Properties of rigid foams (Mpa)

Density (g cm ⁻³)	Pine without formaldehyde	Pine with formaldehyde	Mimosa foam ^a	Phenolic foams ^b
Elastic modulus				
0.035	0.18	-	1.91	
0.04	0.31	-	2.47	
0.05	0.29	0.41	3.79	
0.06	0.17	0.97	5.38	
0.07	0.21	1.49	6.69	
0.11	-	7.16	12.25	
0.14	-	20.4	16.42	
0.19	-	26	23.37	
Compression strength				
0.035	0.028	-	0.11	
0.04	0.034	-	0.14	
0.05	0.041	0.06	0.20	0.76
0.06	0.042	0.09	0.27	
0.07	0.058	0.12	0.33	
0.11	-	0.045	0.59	
0.14	-	1.03	0.78	2.17
0.19	-	1.75	1.10	



How does this fit with the Wood Processing Industry?



Designing Thermoplastic Lignin-based Materials with Fast Pyrolysis

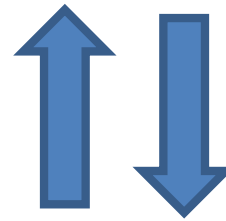
Room Temperature

- Lignin
 - Second most abundant bio-based polymer on earth
 - Only 2 % valorized

Storage modulus (GPa)



80°C



200°C



Outline

1. Nanotechnology and the forest products industry
2. A vision to advance the forest products industry
3. Product diversification in the forest products industry
4. Concluding remarks

Concluding Remarks

- The current forest product industry can be strengthened by the development of innovative forest biomaterials
- Nanotechnology and bio-inspiration are driving product innovations
- Cascade utilization of by-products: biomaterials and then bioenergy
- Industry and academia must be closely connected
- Highly interdisciplinary: botany, silviculture, materials science, nanotechnology, chemistry and physics...

Freiburg a Privileged Place for Innovative Forest Biomaterials

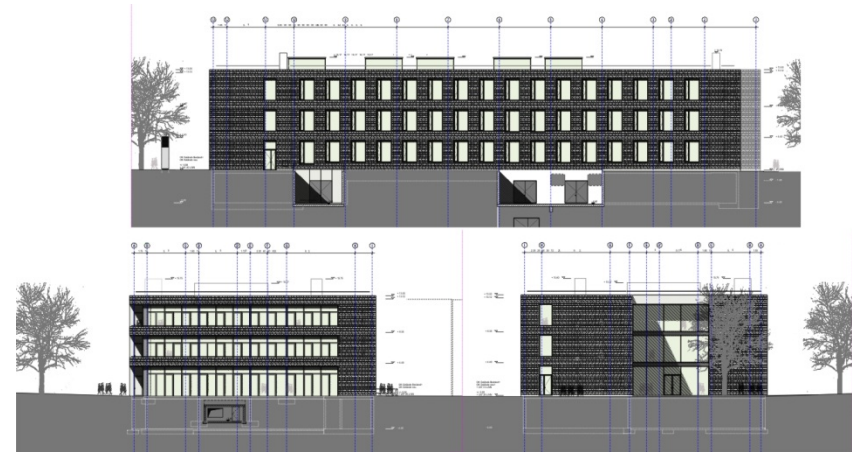


- **Tradition**

- Tradition in forest sciences
- Excellence in polymer / materials sciences and microtechnology

- **Innovations**

- Freiburg Center for Interactive Materials and Bio-inspired Technologies (FIT)
- New specialization in „Biomaterials and Bioenergy“ within the MSc in environmental Sciences



Acknowledgements

- All current and past students and collaborators

Nanocellulose



Tannin-based Foams



Danke für Ihre Aufmerksamkeit

Fragen?