Nanoindentation for Characterizing Wood & Related Systems

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Department of Material Sciences and Process Engineering

Nanoindentation – basic principle
DSI depth sensing indentation

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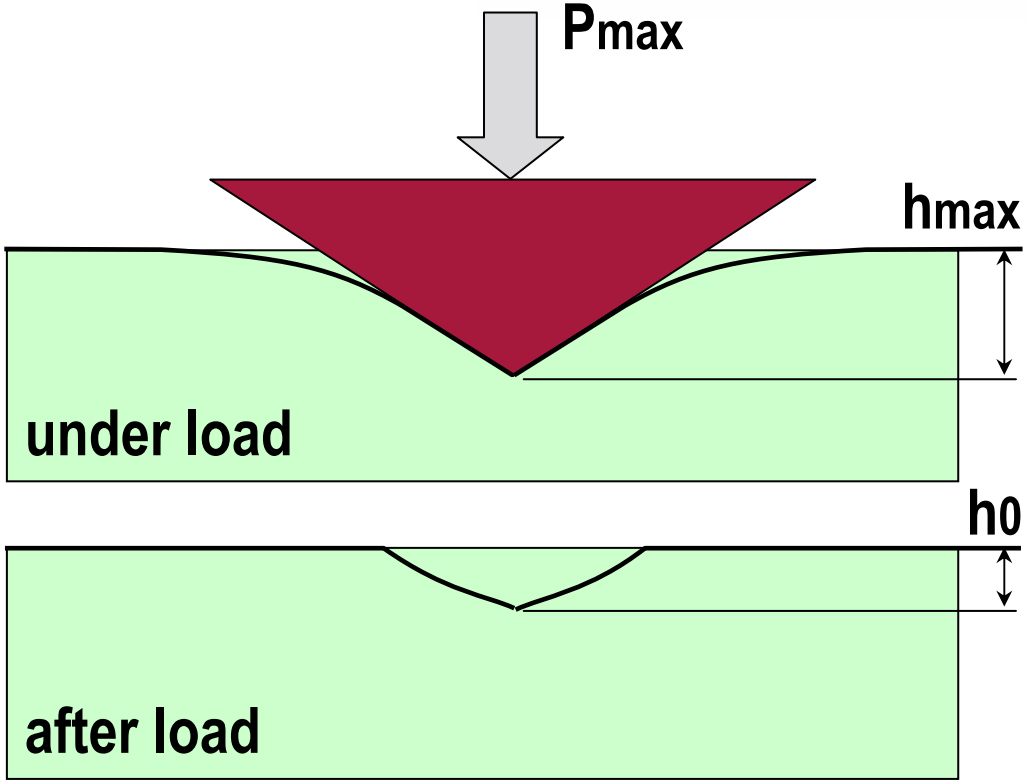

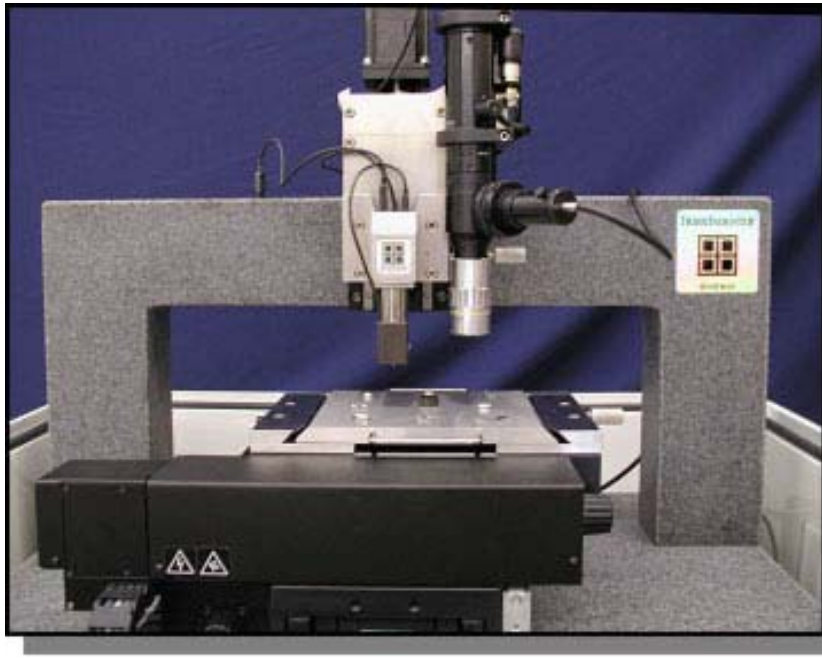

Nanoindentation tips
Microscope images

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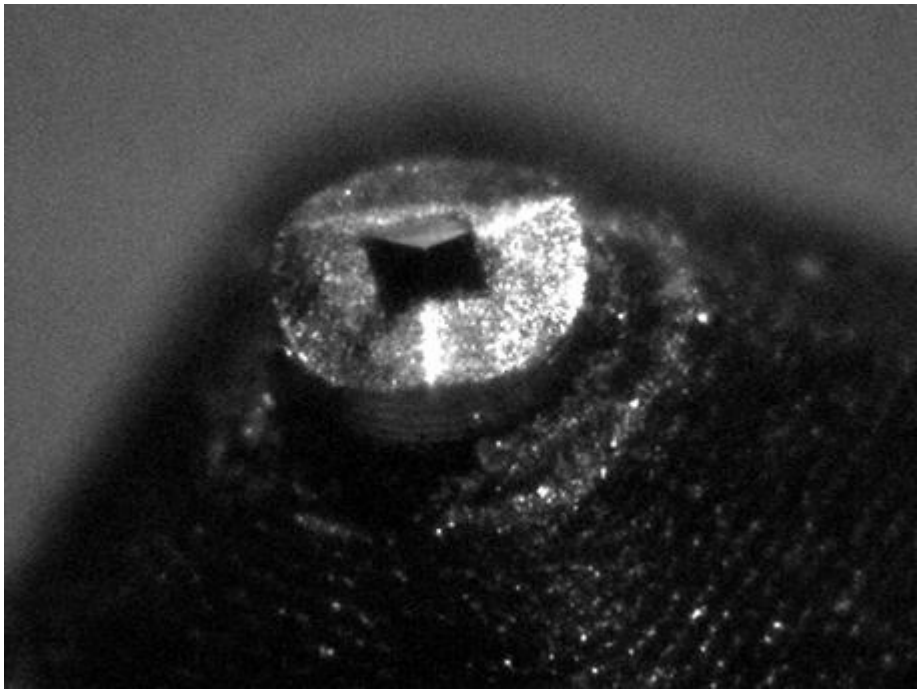
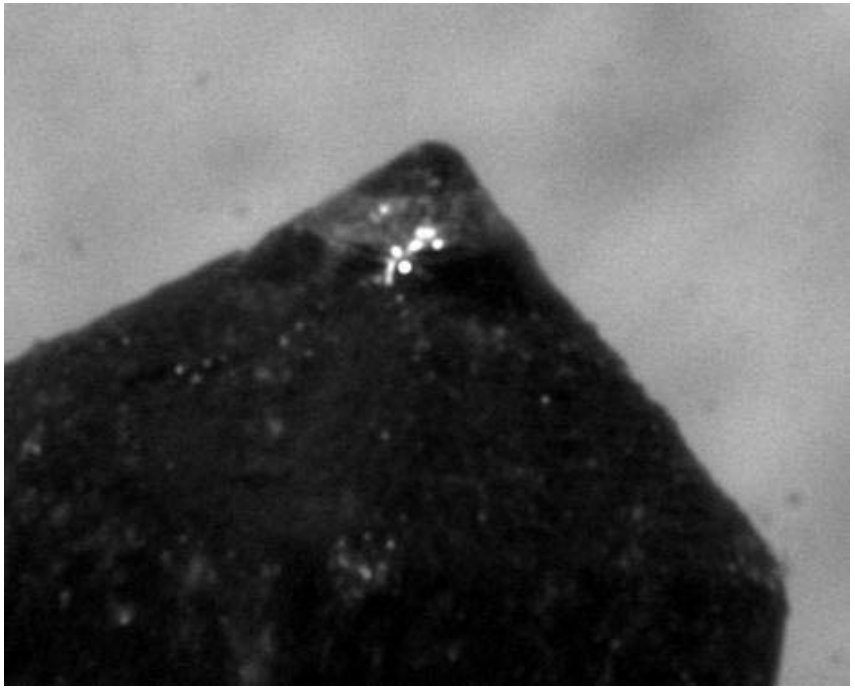
Berkovich
Three-sided pyramidal tip



Conospherical tip



Nanoindentation – data analysis

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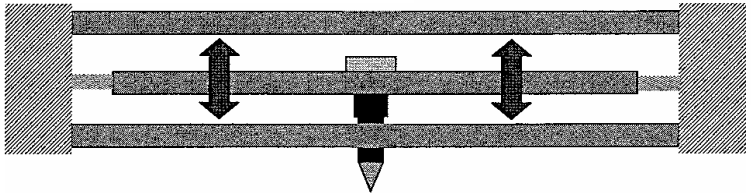

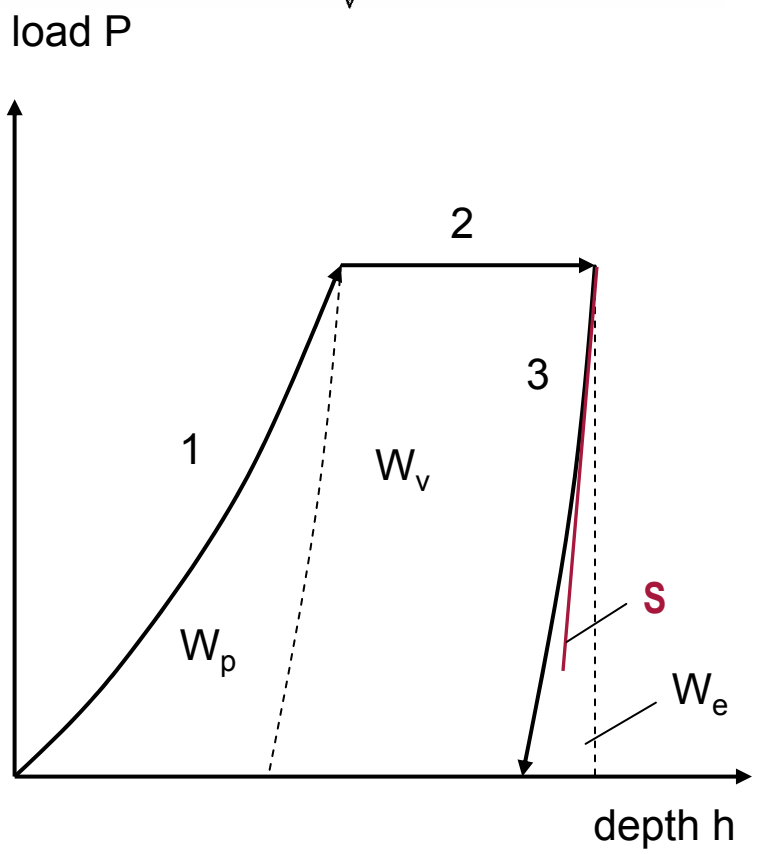

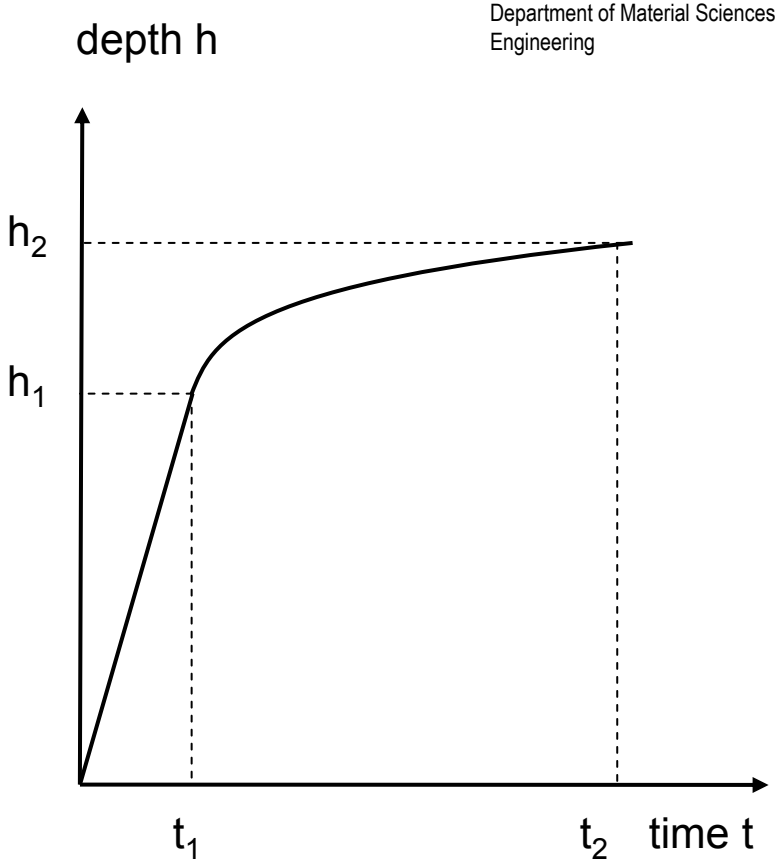

Nanoindentation – data analysis

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$$H = \frac{P_{\max}}{A}$$

Hardness

$$E_r = \frac{1}{2}\sqrt{\pi}\,\frac{S}{\sqrt{A}}$$

Reduced Modulus of Elasticity
Oliver & Pharr (1992)

$$\frac{1}{E_r} = \left(\frac{1-\nu_m^{\,2}}{E_m}\right)_{material} + \left(\frac{1-\nu_i^{\,2}}{E_i}\right)_{indenter}$$

E_i=1140GPa
Poisson's ratio ν_i=0.07

$$C_{IT} = \frac{h_2 - h_1}{h_1} \times 100$$

Indentation Creep

Nanoindentation
sample preparation - surface roughness

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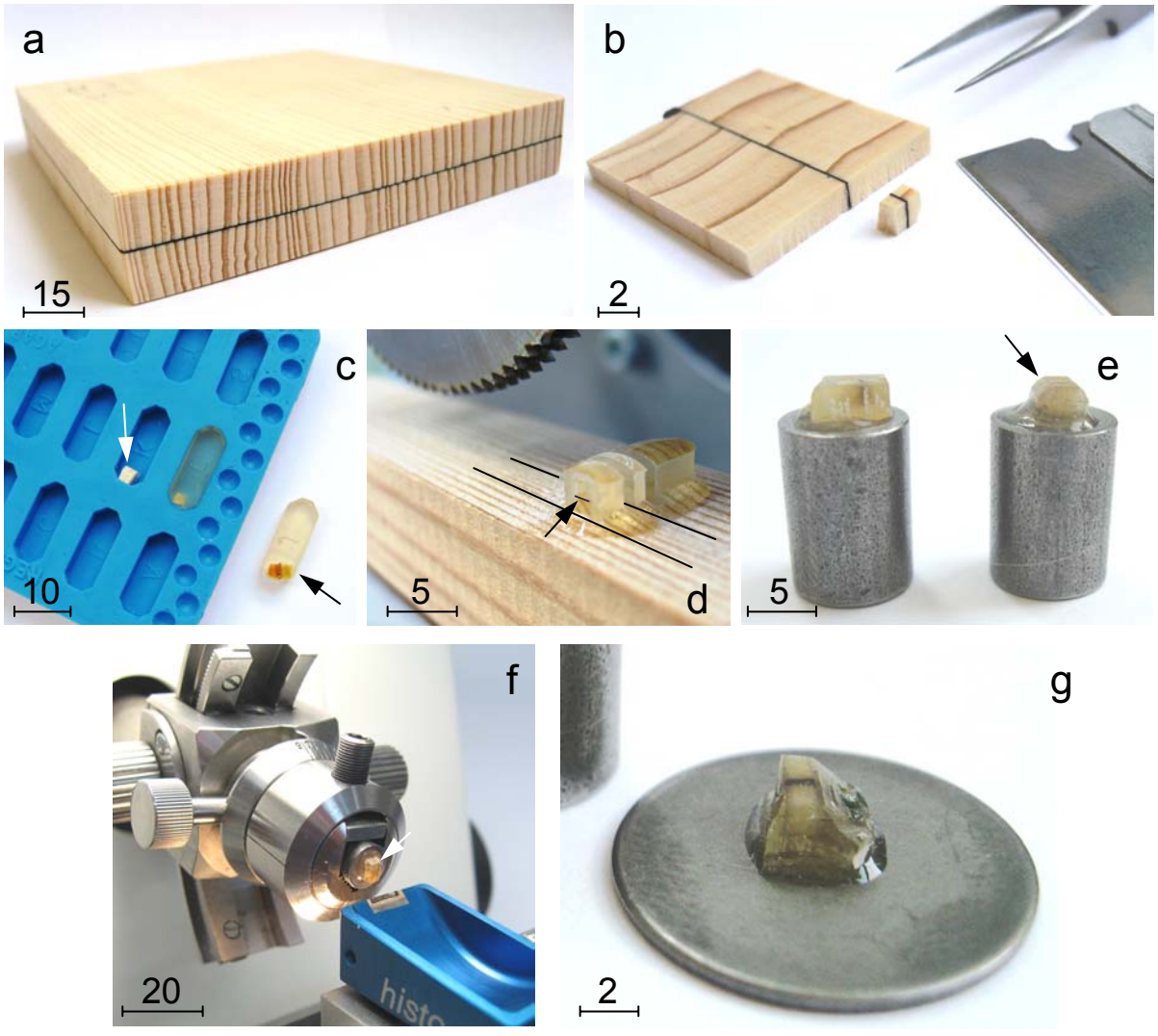
Indenter

Surface

Indenter

Surface

Nanoindentation – Sample preparation



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Nanoindentation on Wood
Scales in Wood-Adhesive bonds

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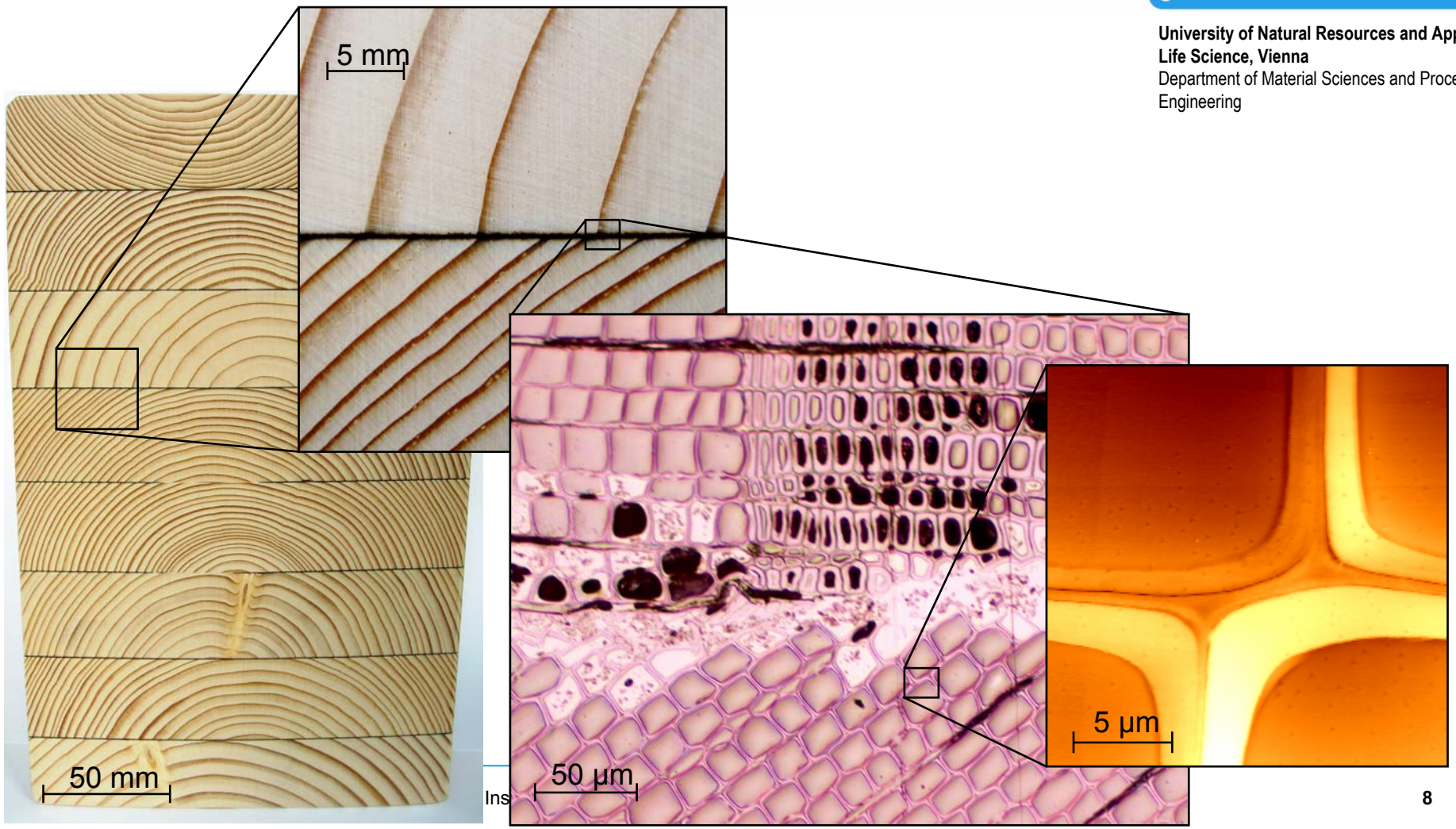

Mechanical properties of Adhesive Films
Tensile Test

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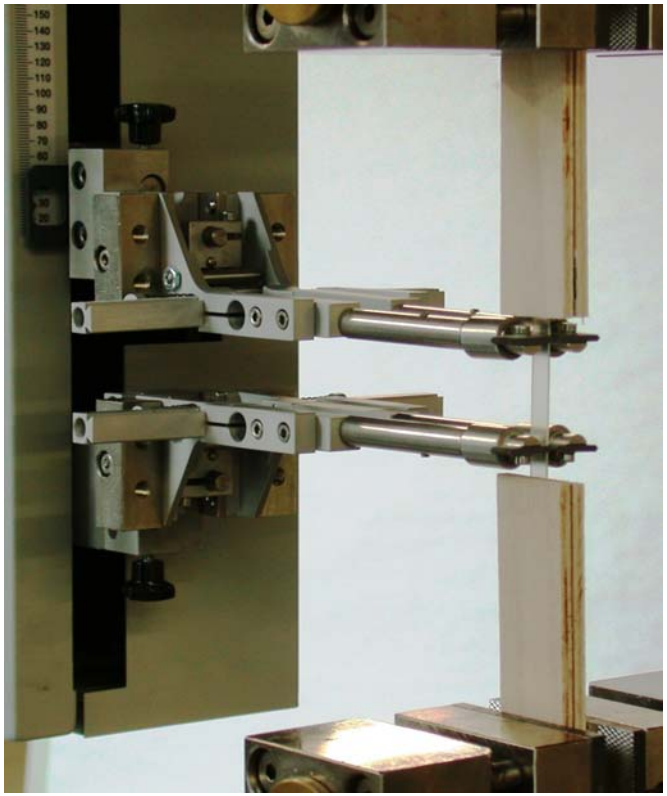
macro



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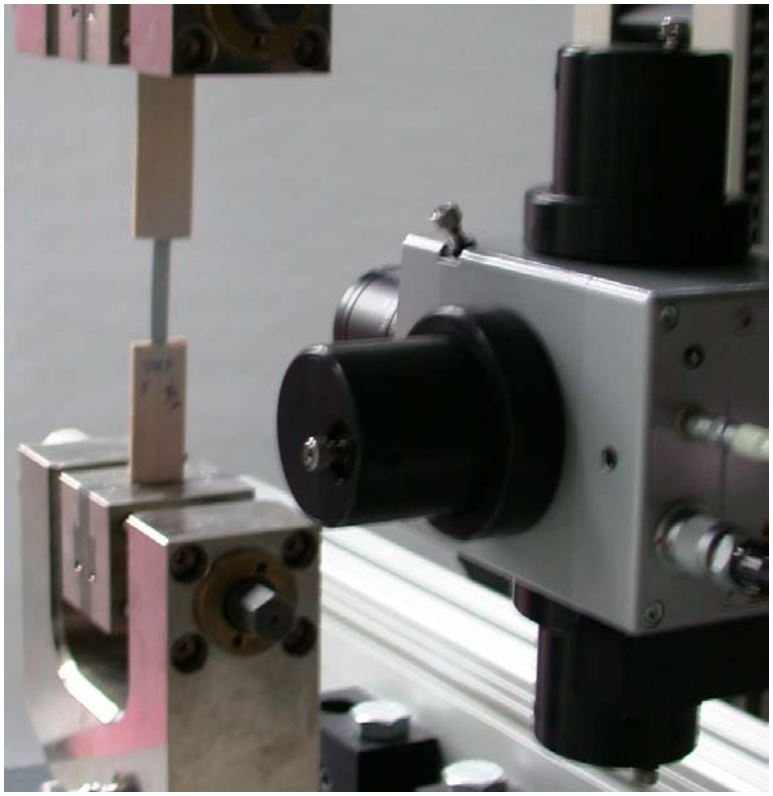
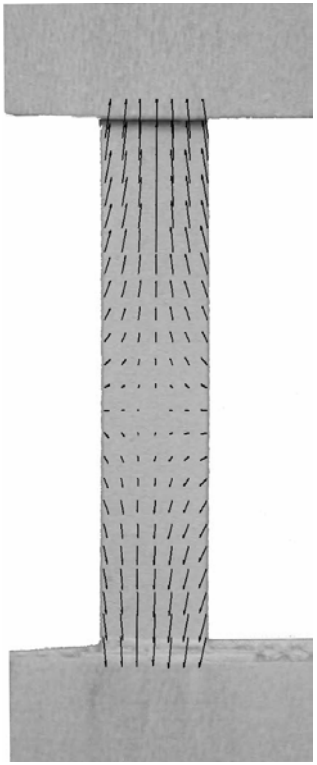
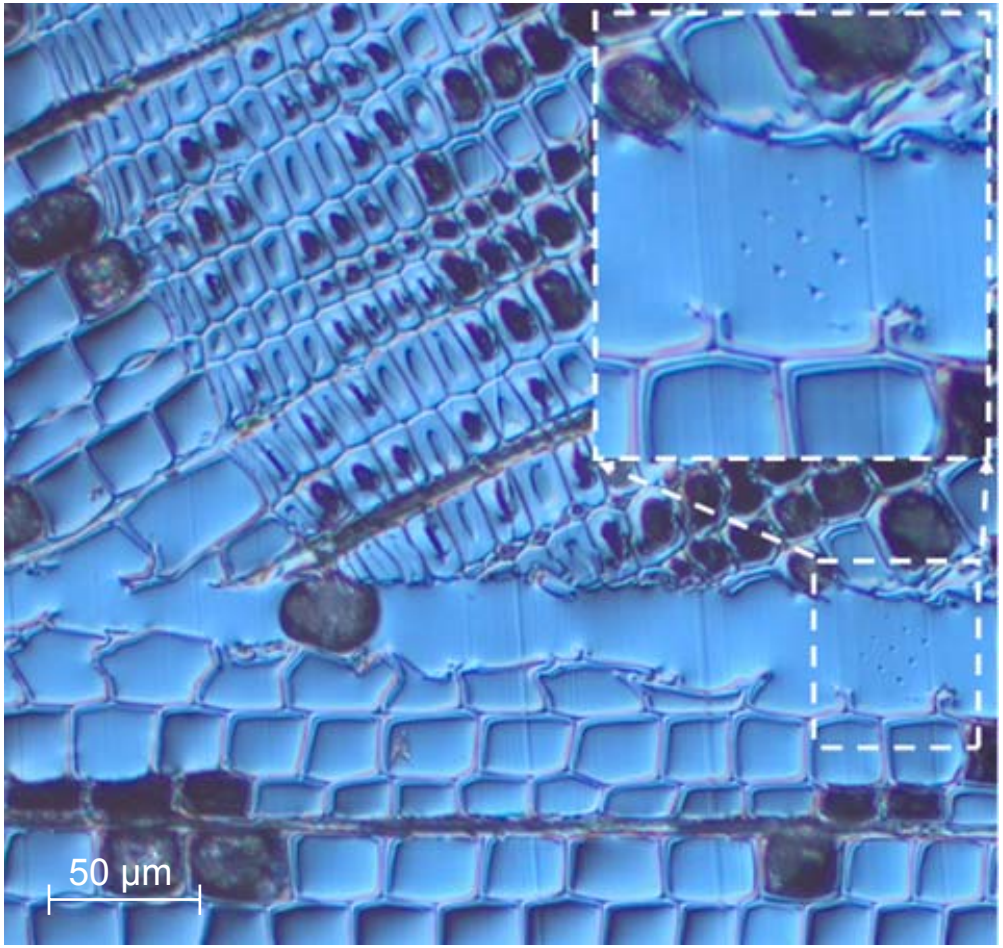




Mechanical properties of Adhesives in the bond line



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Mechanical properties of Adhesives

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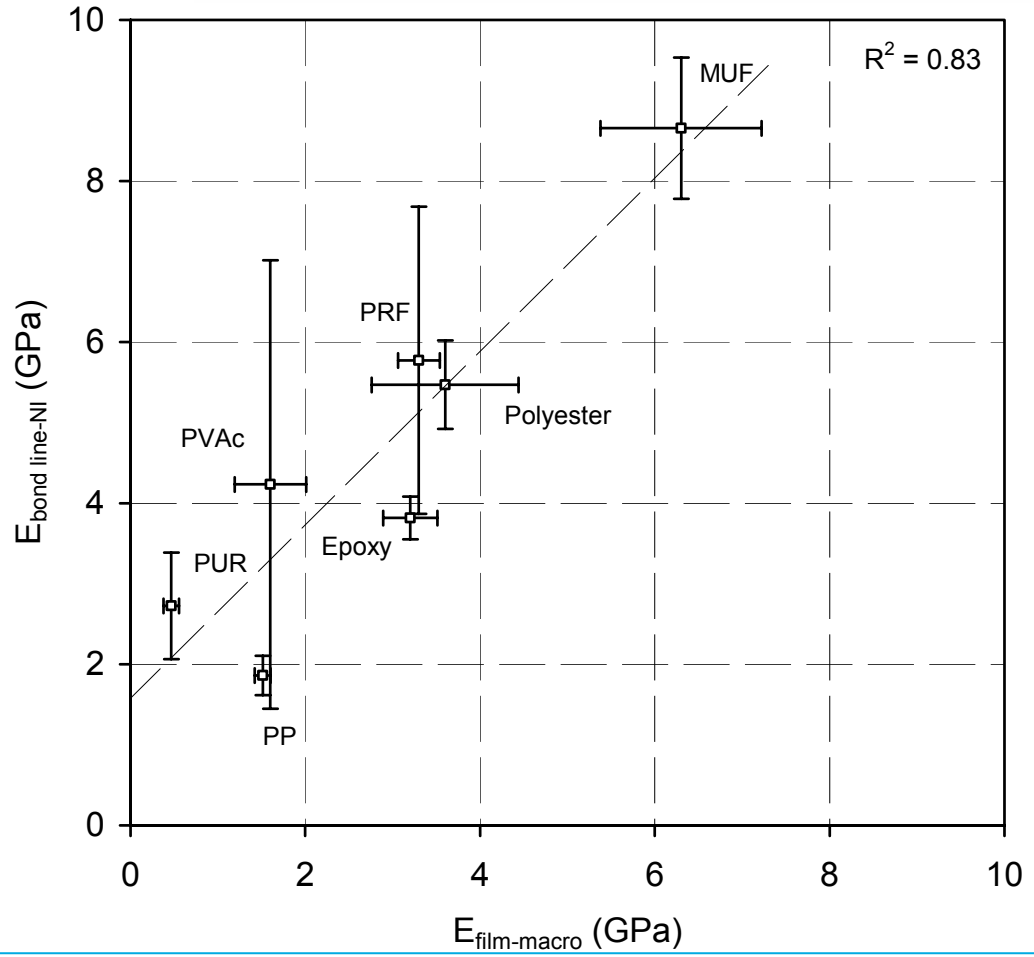

Mechanical properties of Adhesives
Nanoindentation – Deformation Work

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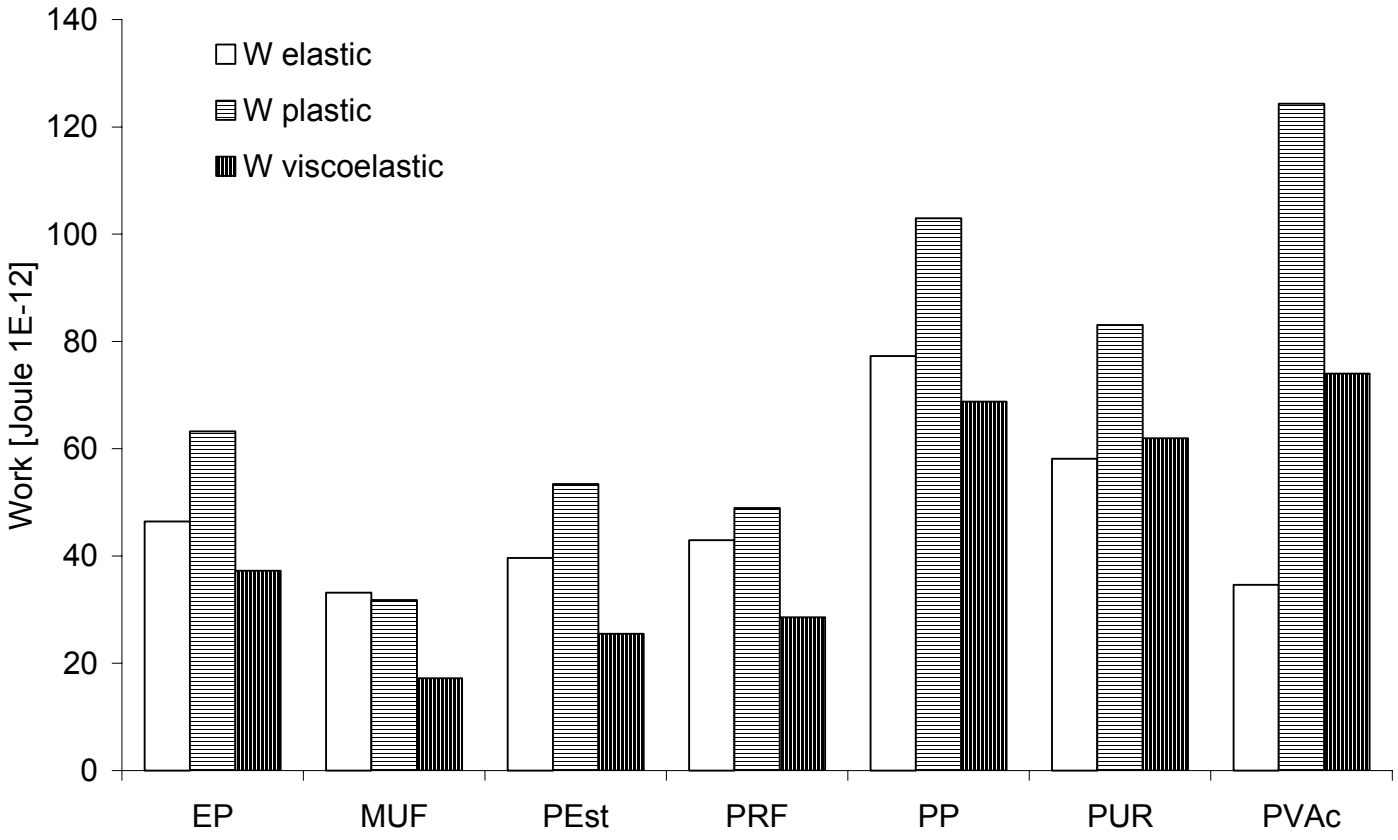

Mechanical properties of Adhesives
Nanoindentation – Creep

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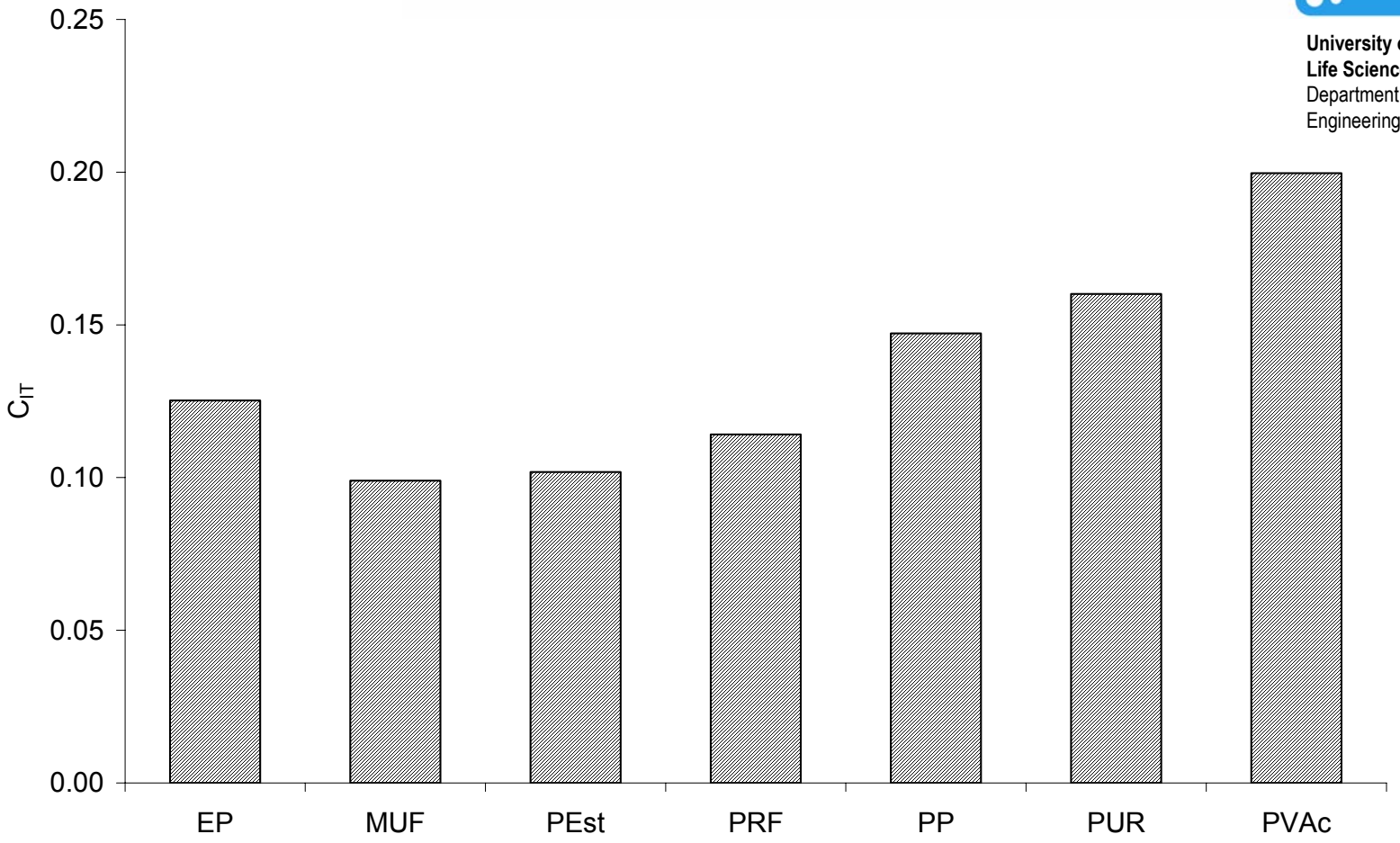
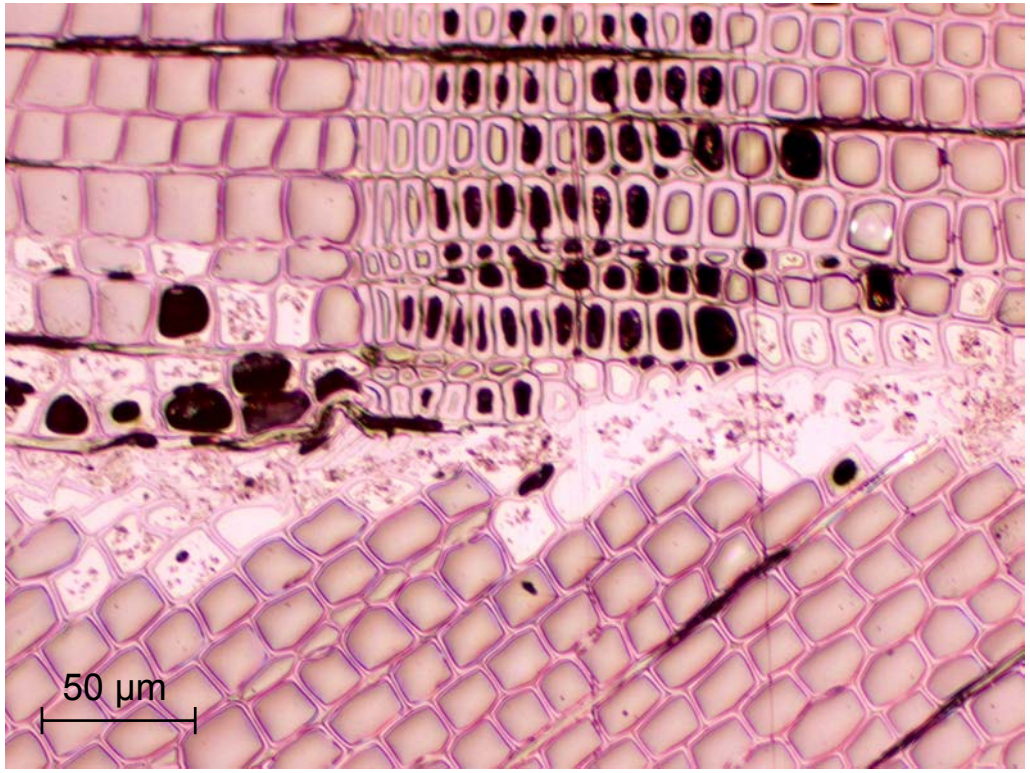
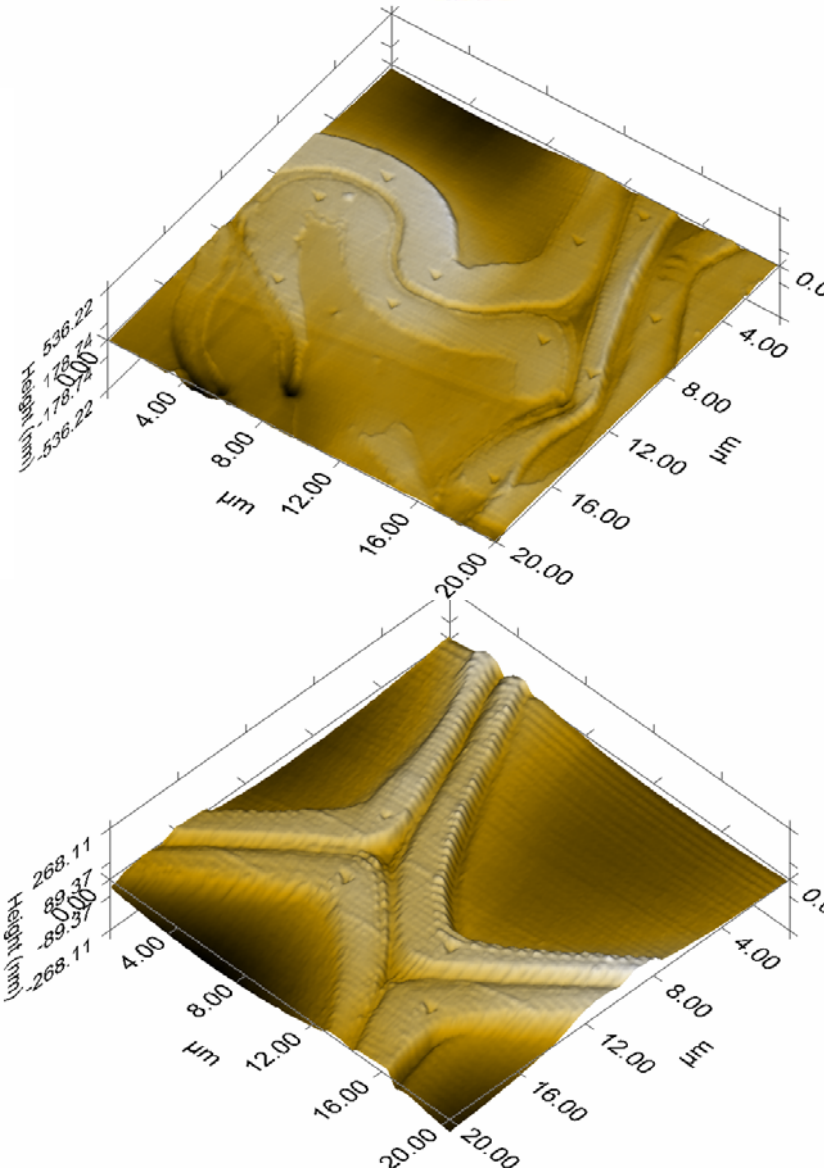


Wood cell walls in the Interphase region





Wood cell walls in the Interphase region

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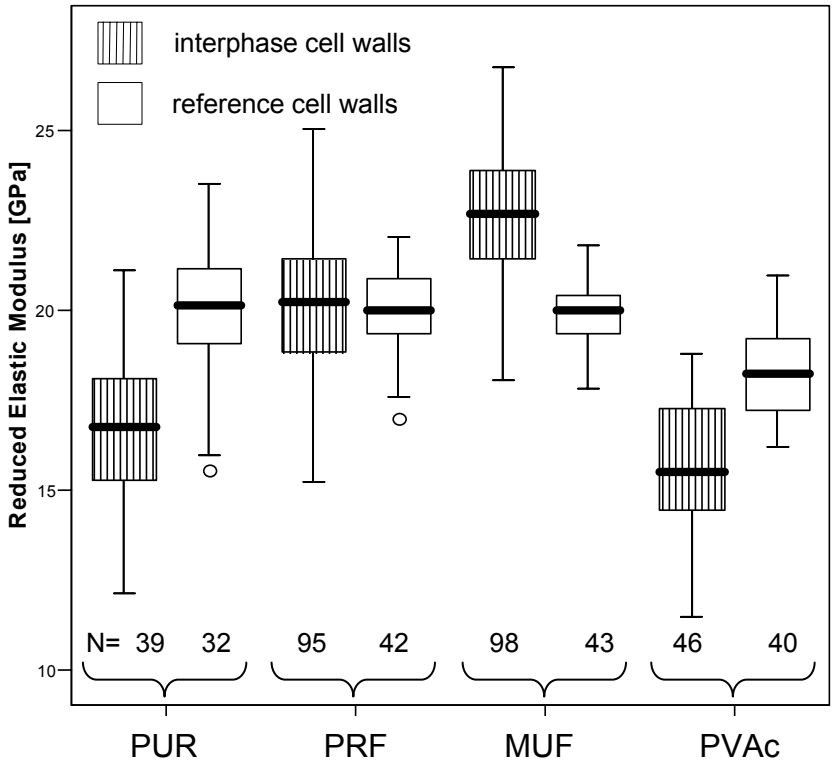
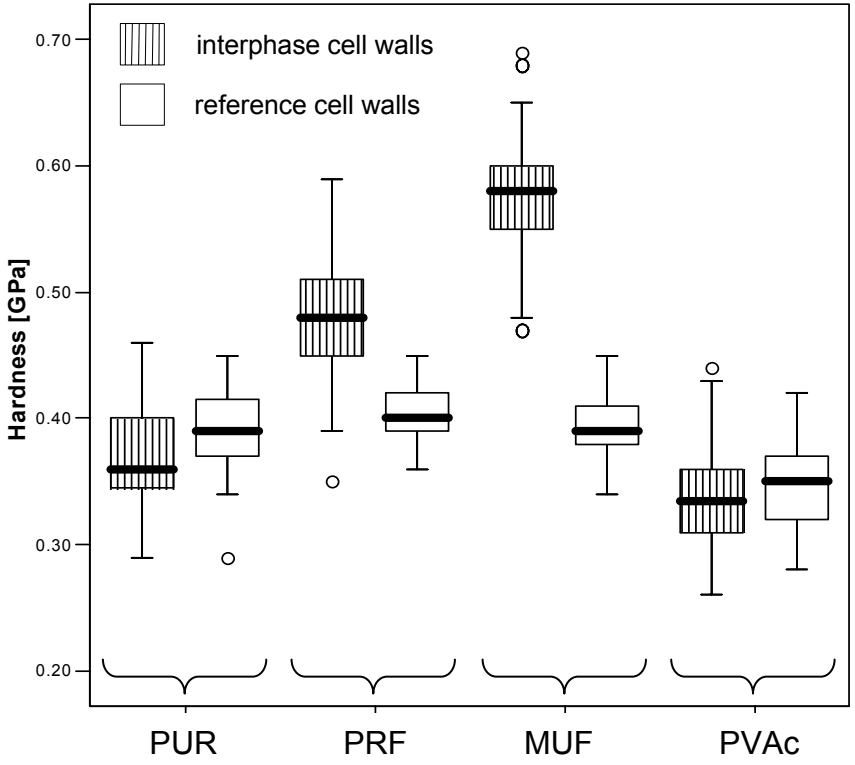
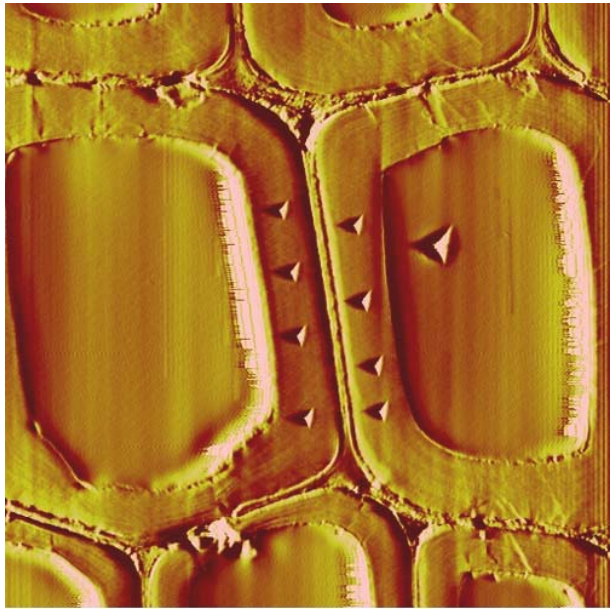


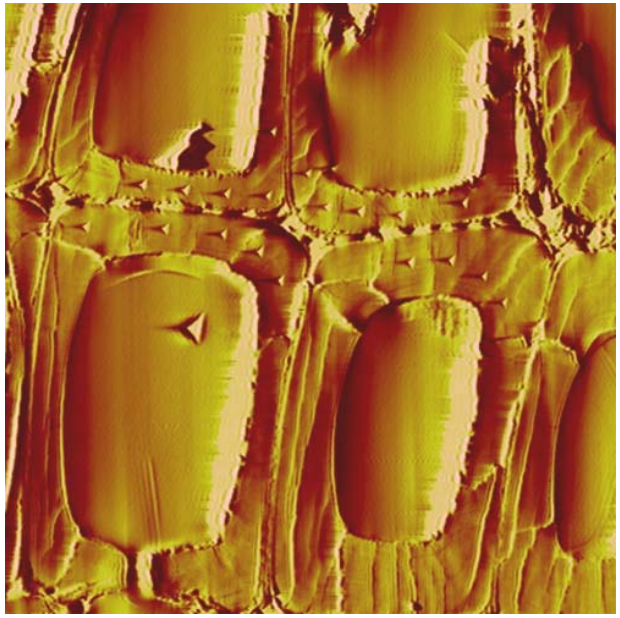


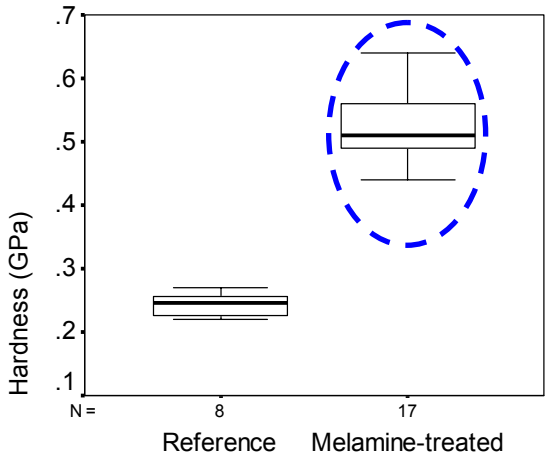
Melamine-modified spruce wood

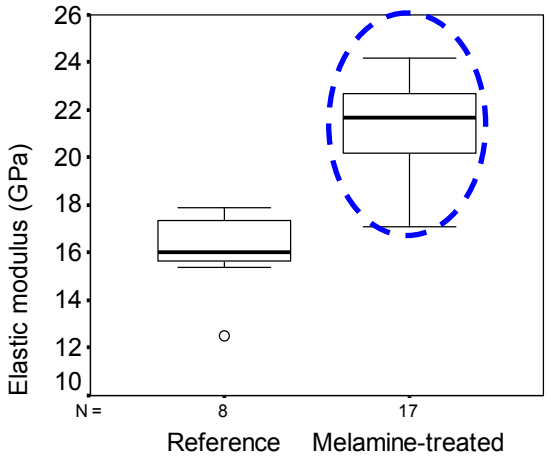


Reference

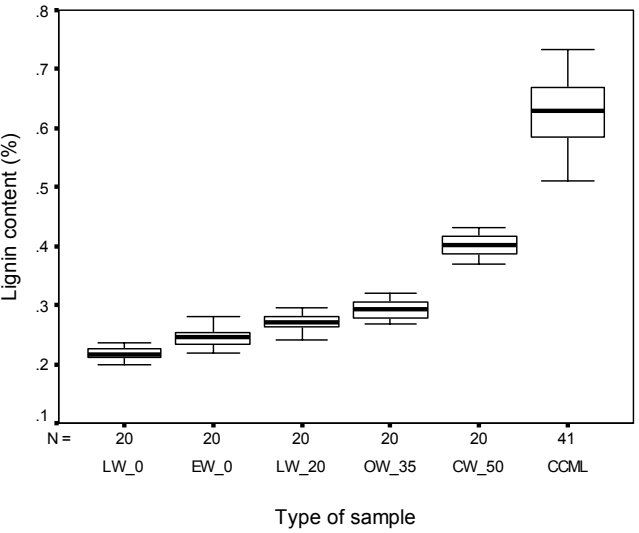
Melamine-modified

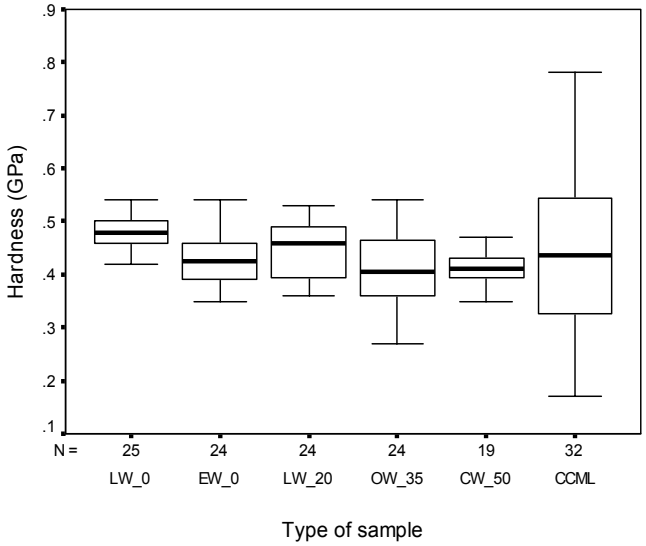


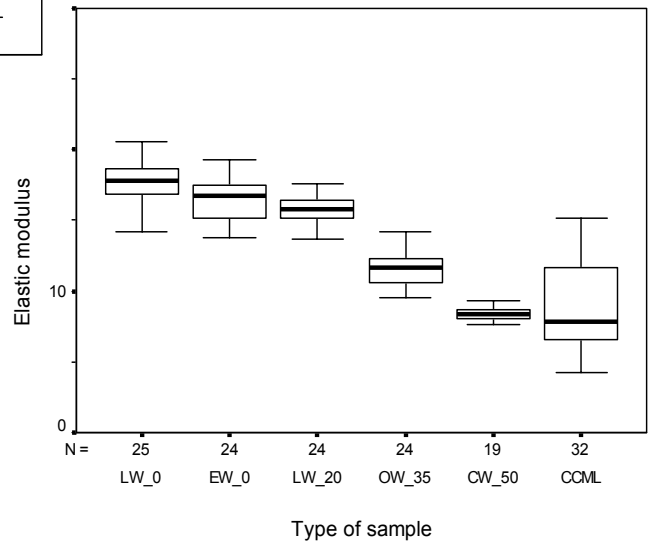




Cell wall micromechanics







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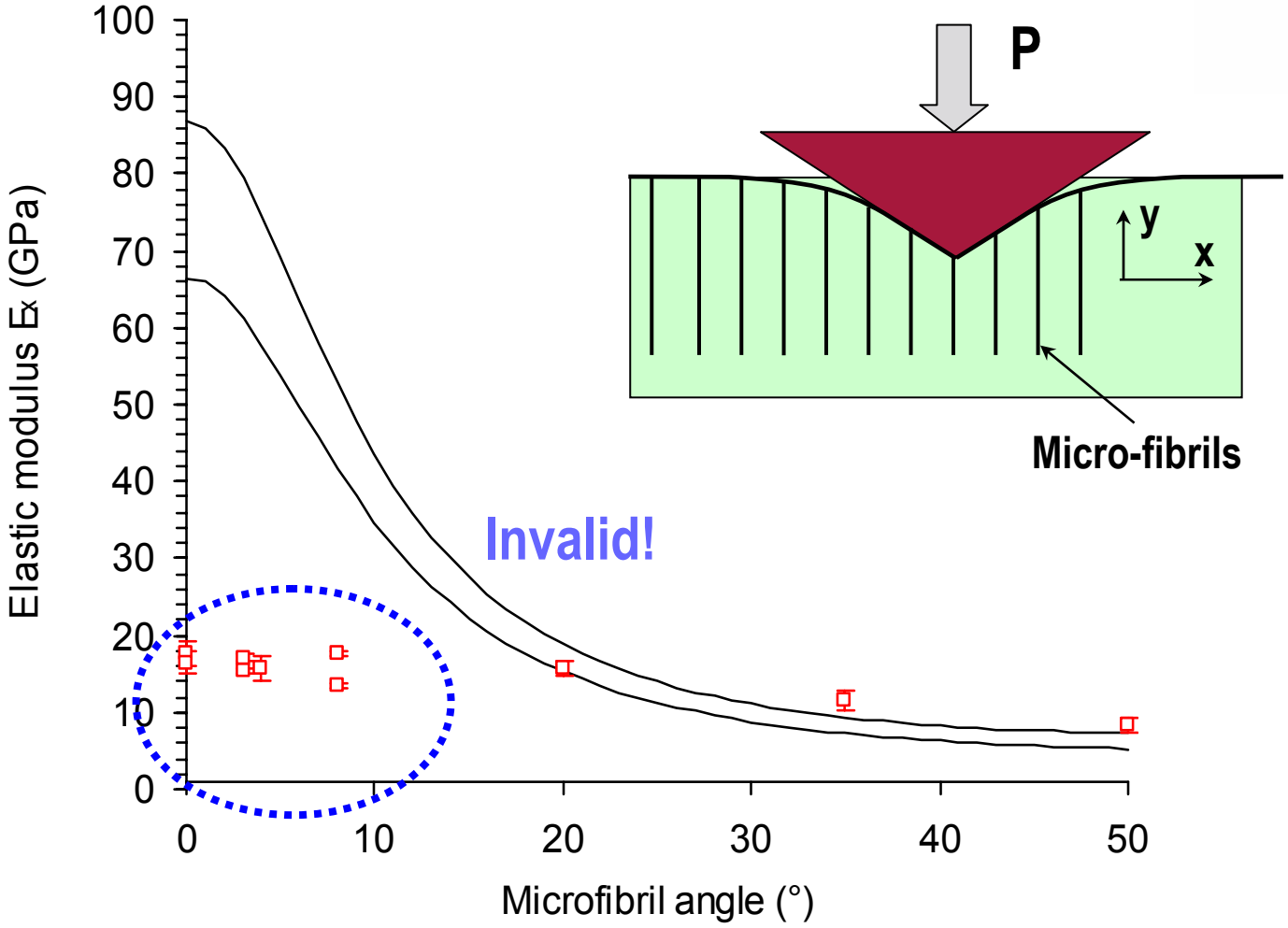
Cell wall micromechanics



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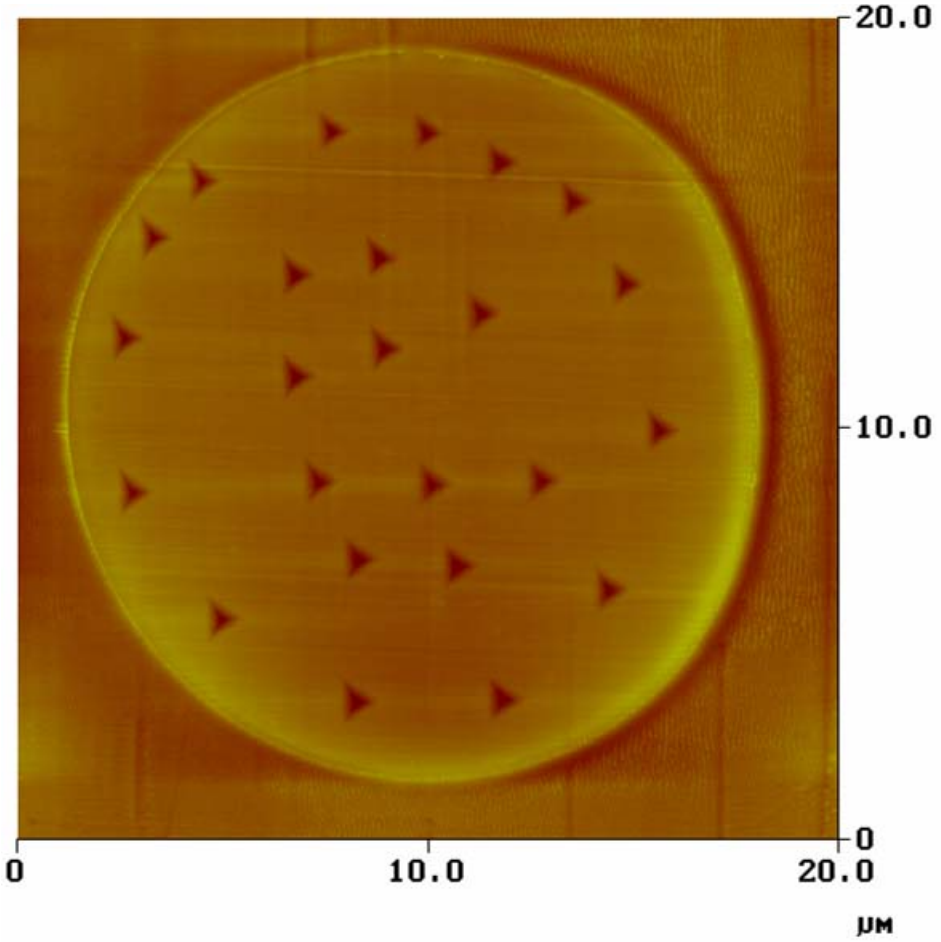
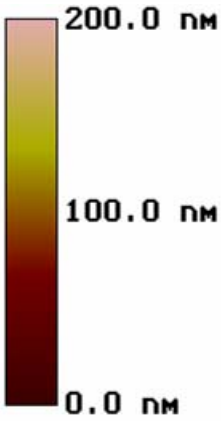
Fibers





Digital Instruments NanoScope
Scan size 20.00 µm
Scan rate 1.001 Hz
Number of samples 512
Image Data Height
Data scale 200.0 nm

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Cell wall micromechanics

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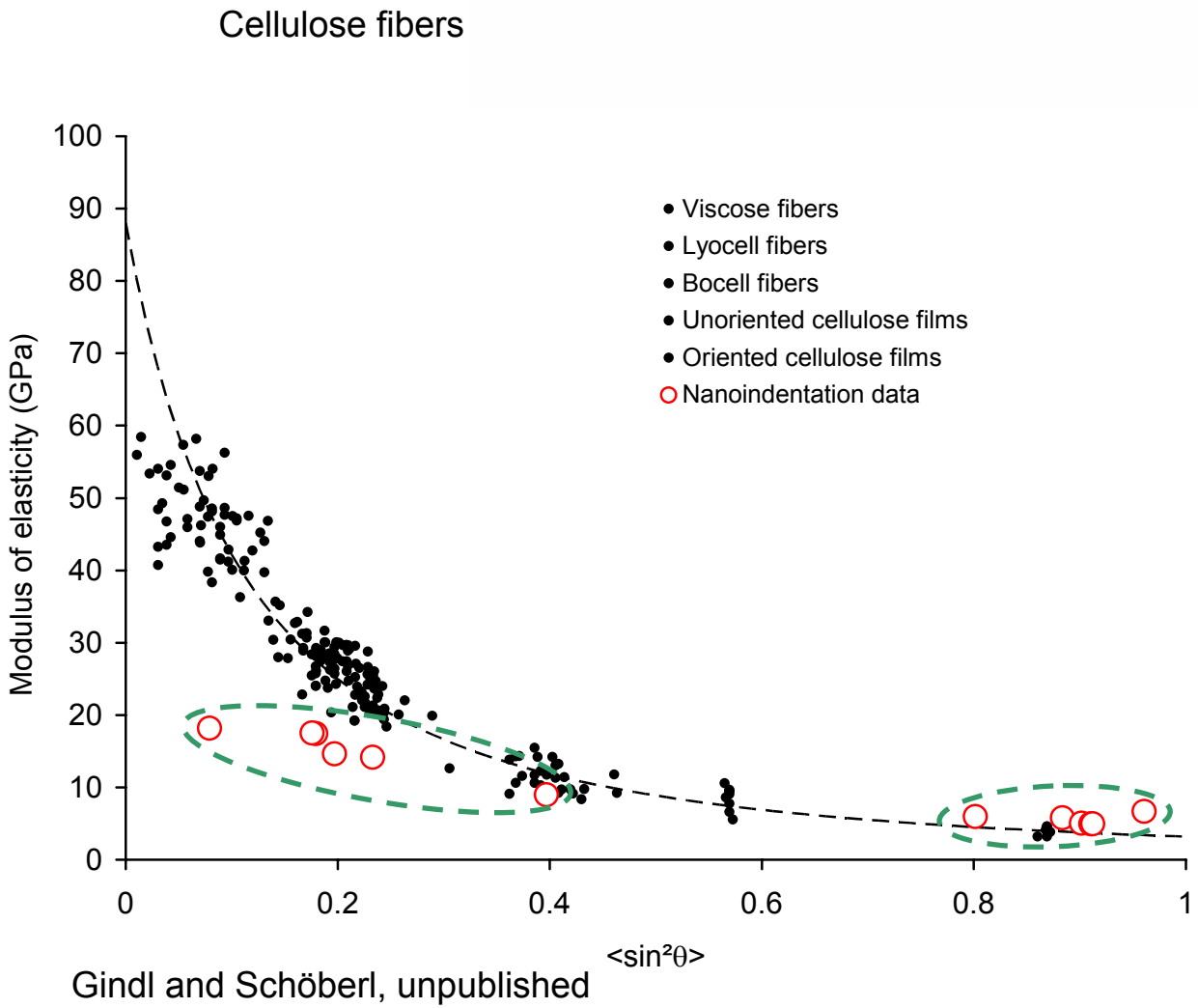

Gindl and Schöberl, unpublished

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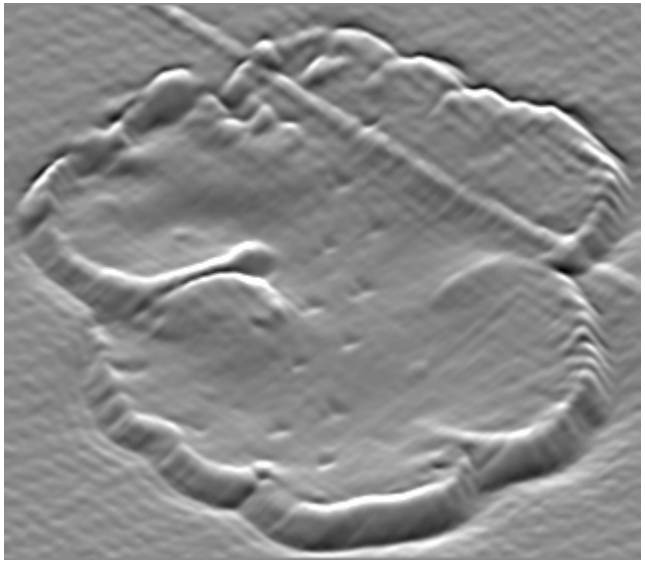

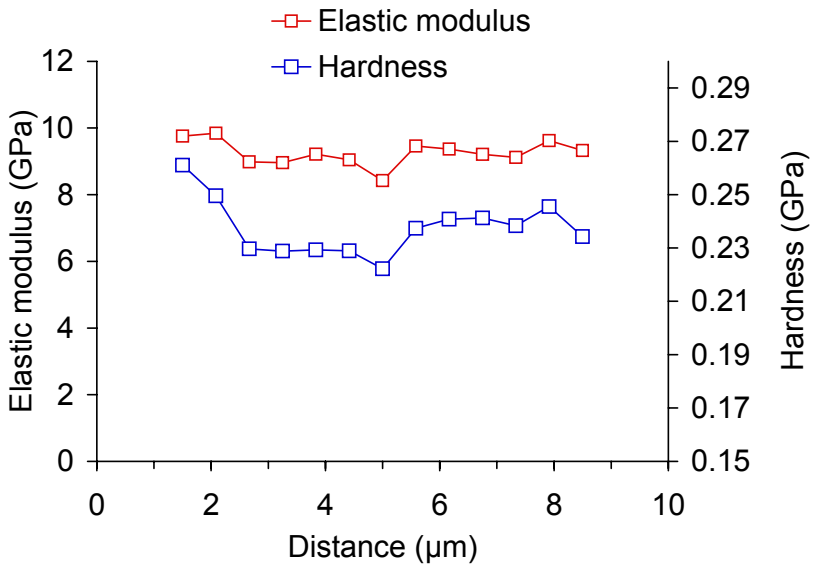

Wood cell walls in the Interphase region
Nanoindentation-Mapping

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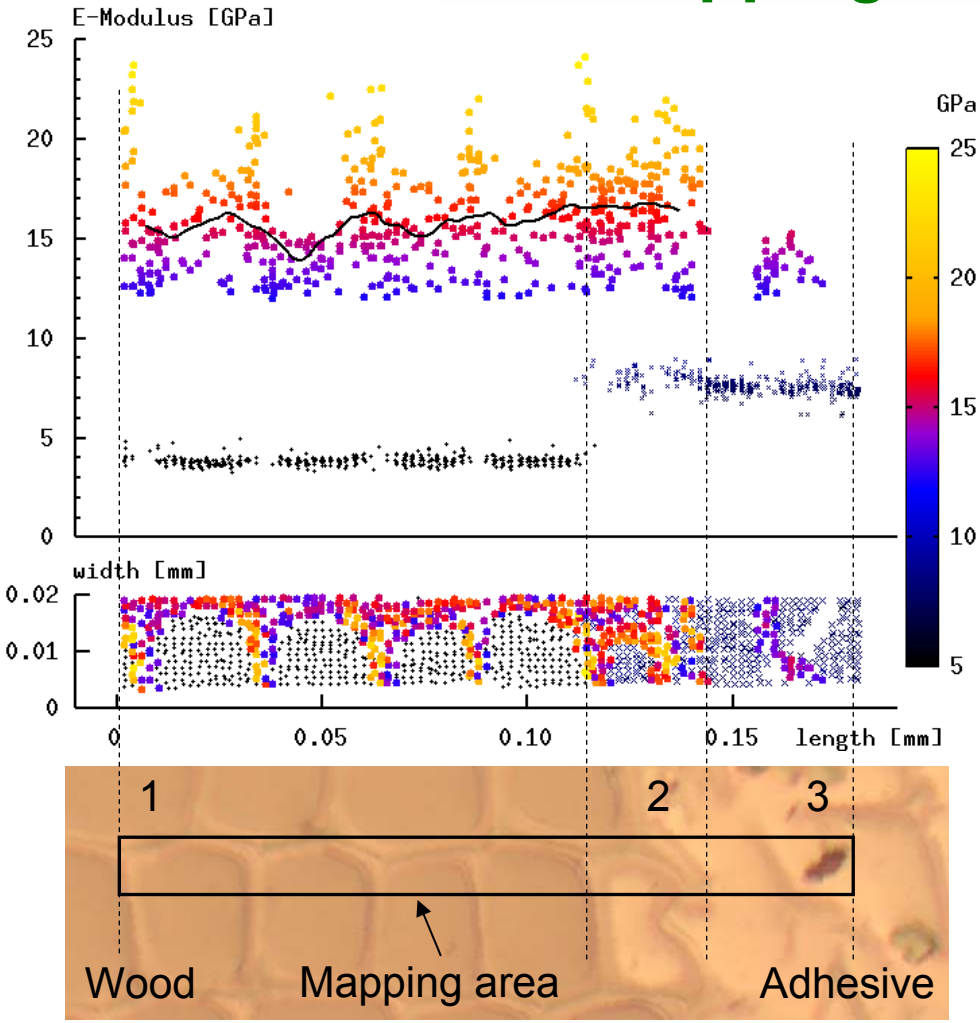
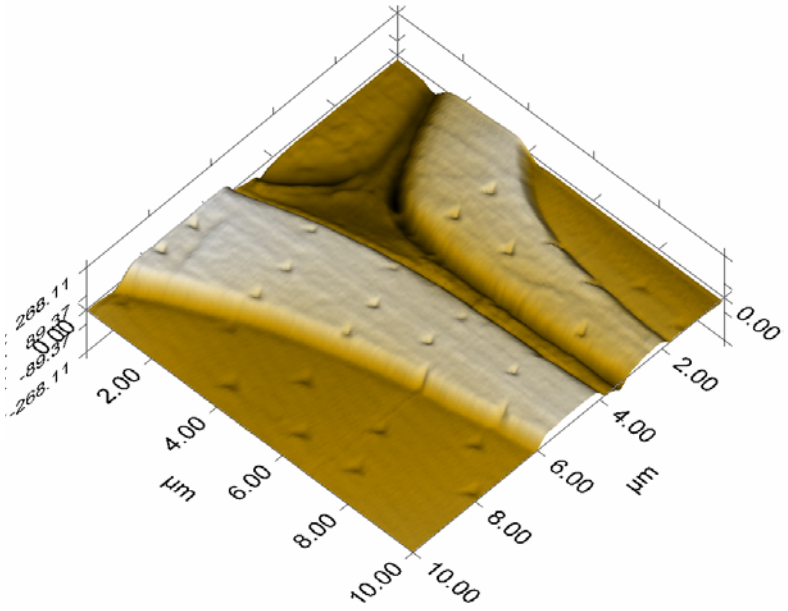
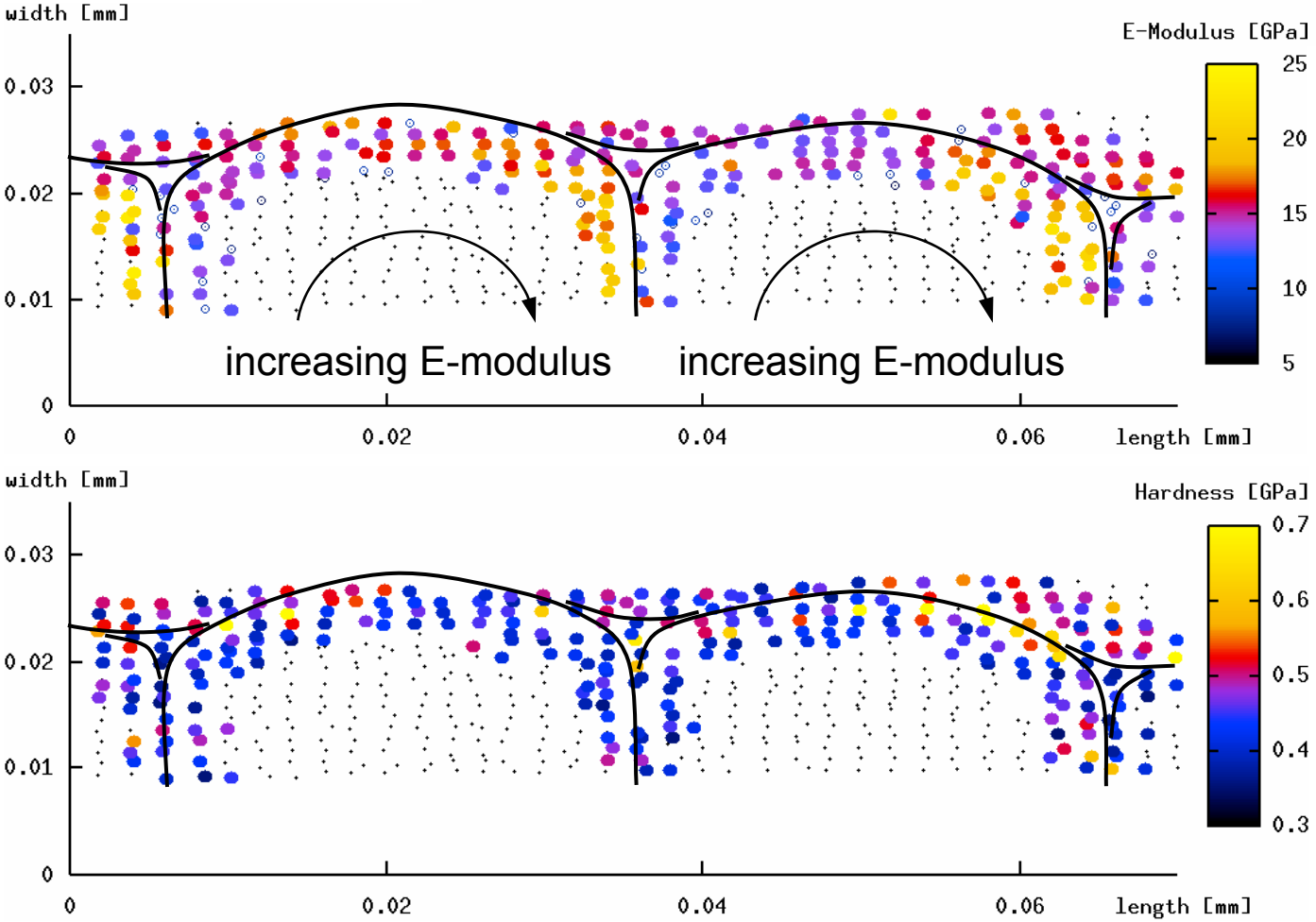




Wood cell walls in the Interphase region
Nanoindentation-Mapping



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Influence of tip geometry and Micro Fibril Angle on measurements

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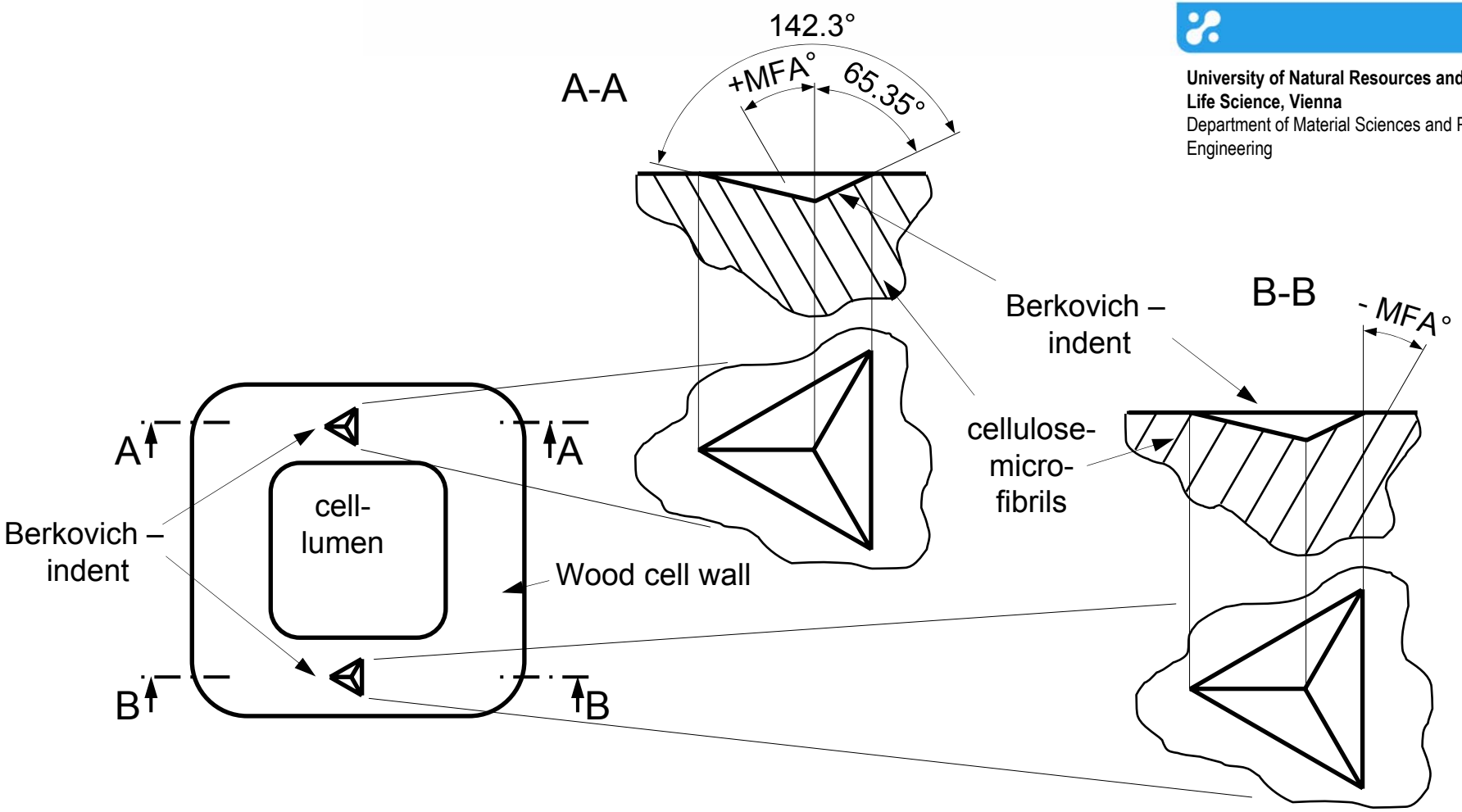
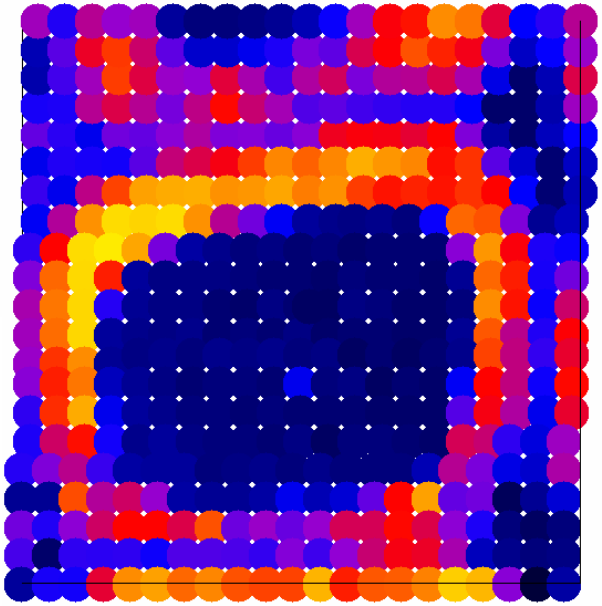
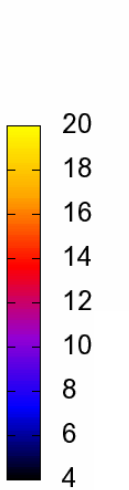


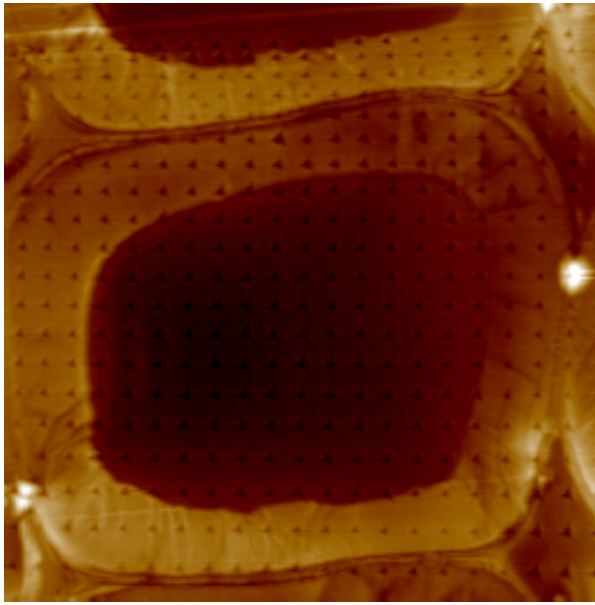
New Tip geometry

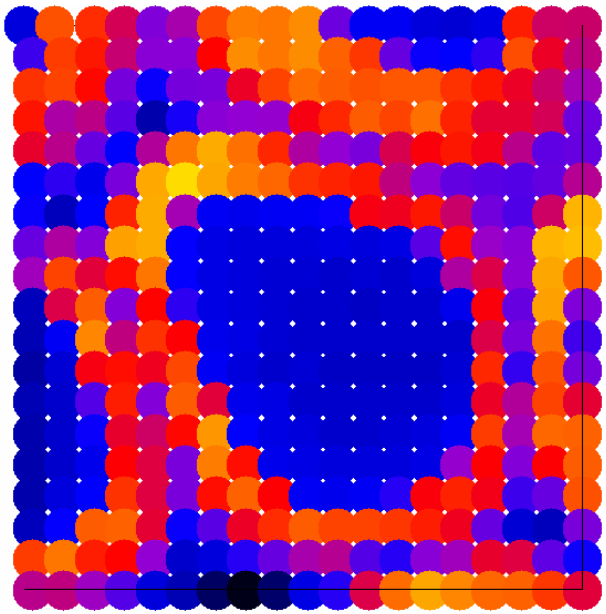
Berkovich 142,3°
100nm tip radius

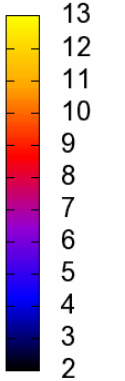


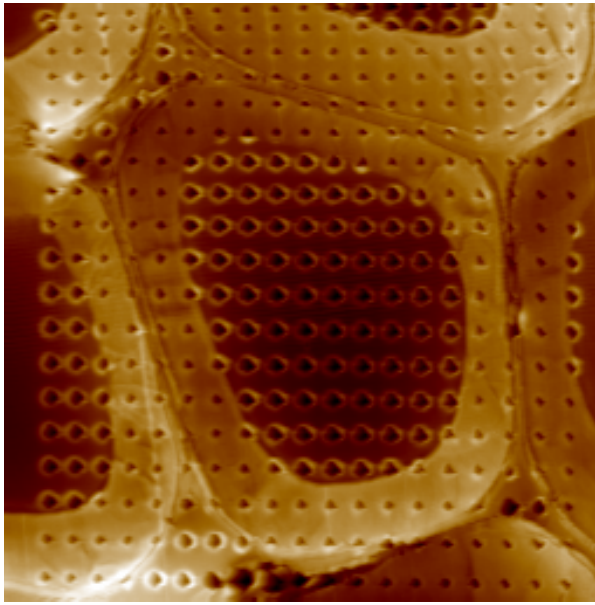


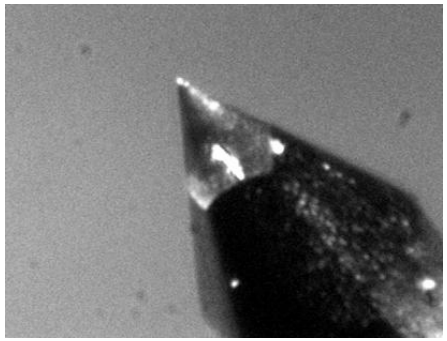
Er [GPa]











Cone 60°, 150nm

Publications related to Nanoindentation

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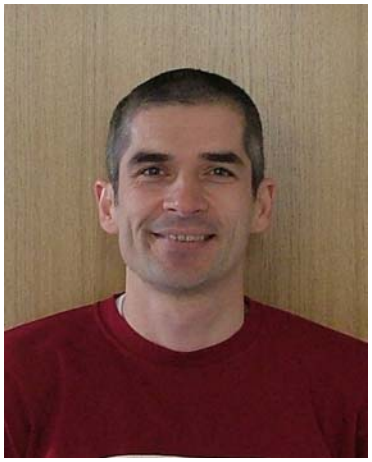
- **Gindl W**, Gupta HS, Grunwald C (2002) Lignification of spruce tracheid secondary cell walls related to longitudinal hardness and modulus of elasticity unsing nano-indentation, Canadian Journal of Botany-Revue Canadienne de Botanique, 80, 10, 1029-1033
- **Gindl W**, Gupta HS (2002) Cell-wall hardness and Young's modulus of melamine-modified spruce wood by nano-indentation, Composites Part A: Applied Science and Manufacturing, 33, 8, 1141-1145
- **Gindl W**, Gupta HS, Schoberl T, Lichtenegger HC, Fratzl P (2004) Mechanical properties of spruce wood cell walls by Nanoindentation, Applied Physics A: Materials Science & Processing, 79, 8, 2069-2073
- **Gindl W**, Schoberl T (2004) The significance of the elastic modulus of wood cell walls obtained from nanoindentation measurements, Composites Part A: Applied Science and Manufacturing, 35, 11, 1345-1349
- **Gindl W**, Schoberl T, Jeronimidis G (2004) The interphase in phenol-formaldehyde and polymeric methylene diphenyl-di-isocyanate glue lines in wood, International Journal of Adhesion and Adhesives, 24, 4, 279-286
- **Konnerth J**, Jäger A, Eberhardsteiner J, Müller U, and **Gindl W** (2006) Elastic properties of adhesive polymers, Part II: Polymer films and bond lines by means of nanoindentation. Journal of Applied Polymer Science, 102, 2, 1234-1239
- **Konnerth J, Gindl W** (2006) The interphase in wood-adhesive bond lines by nanoindentation. Holzforschung, 60, 429-433
- **Gindl W, Konnerth J**, Schoberl T (2006) Nanoindentation of regenerated cellulose fibres. Cellulose, 13, 1, 1-7
- **Gindl W**, Schoberl T, Keckes J (2006) Structure and properties of pulp fibre-reinforced composite with regenerated cellulose matrix, Applied Physics A: Materials Science & Processing, 83, 1, 19-22
- **Konnerth J**, Valla A, **Gindl W** (2007) Nanoindentation-mapping of a wood-adhesive bond. Applied Physics A: Materials Science & Processing, DOI: 10.1007/s00339-007-3976-y



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