Grain Raising, Finish Atomization & Moisture Effects on Wood Finishing:

The Role of University R & D

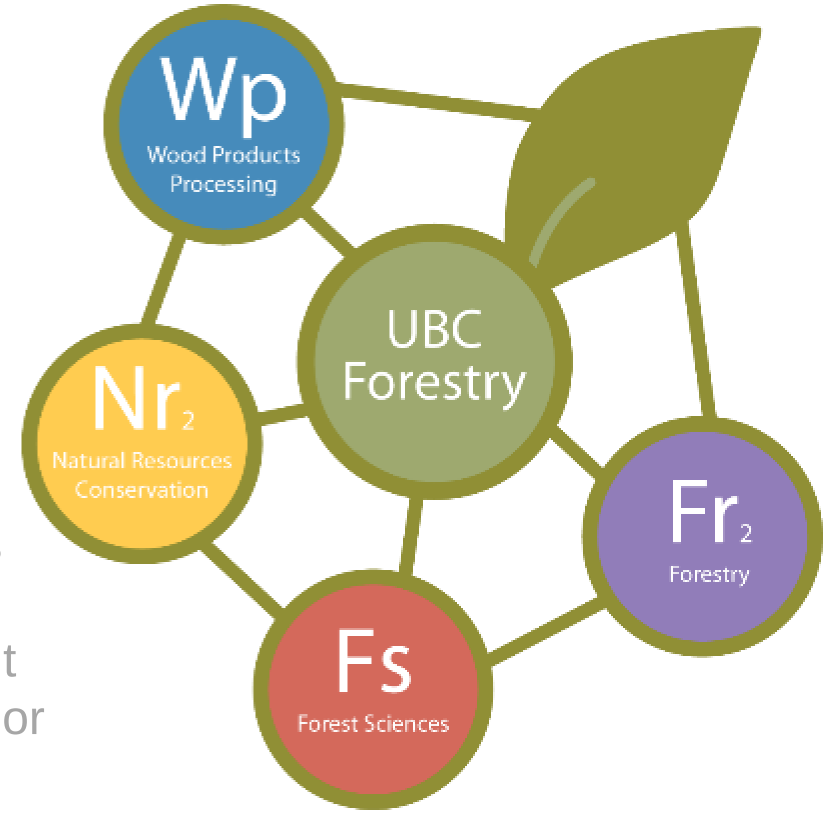
Professor Philip D. Evans

Centre for Advanced Wood Processing University of British Columbia, Vancouver, Canada

UBC Forestry
University of British Columbia

UBC ranked 34th in Global Rankings

BSc Wood Products Processing



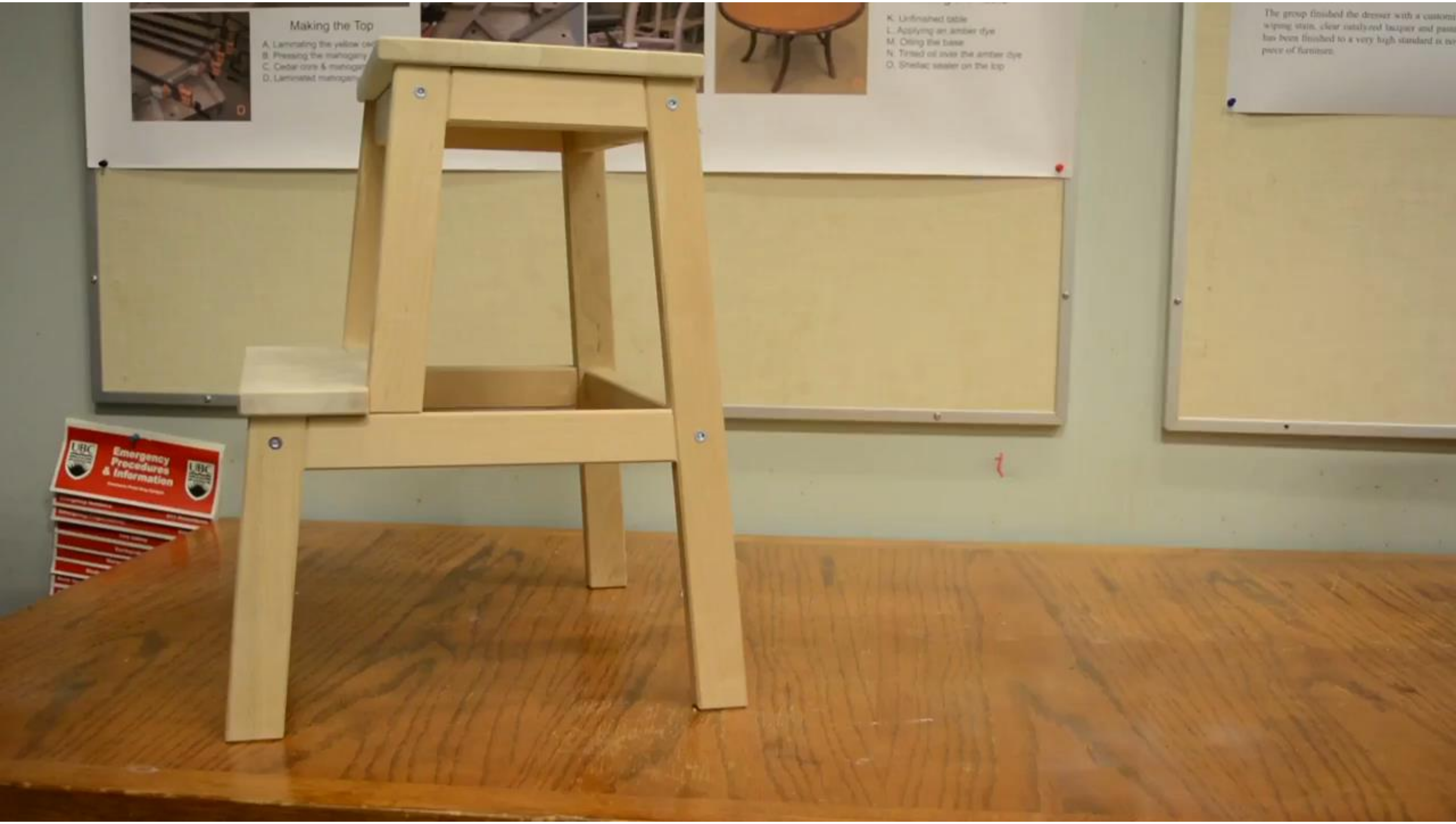
BSc Natural Resources Conservation
Science and Management or Global Perspectives major

BSc Forestry
Forest Resources Management or Forest Operations major

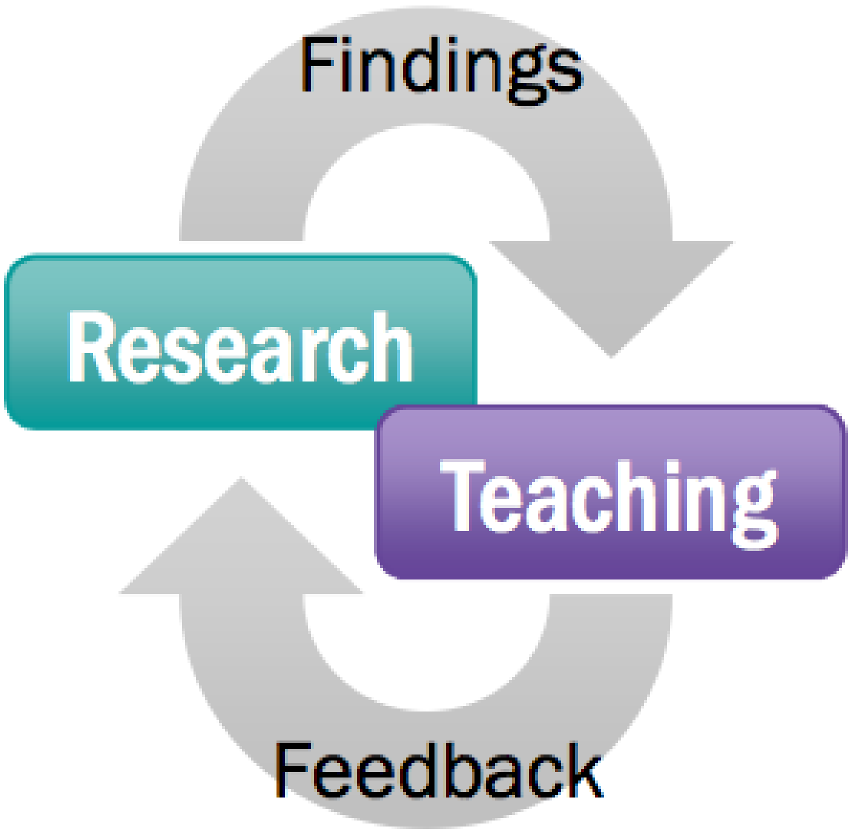
BSc Forest Sciences

Teaching & Wood Finishing





Making the Top
K. Unfinished table
L. Applying an amber dye
M. Oiling the base
N. Tinted oil over the amber dye
O. Shellac sealer on the top
UBC
Emergency Procedures & Information

Research



Wood Surface Science Group

What is Research?

What is Research?

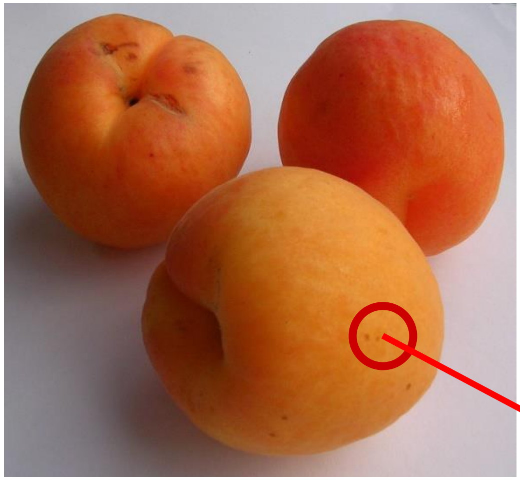
Research is About Discovering (Seeing) New Things

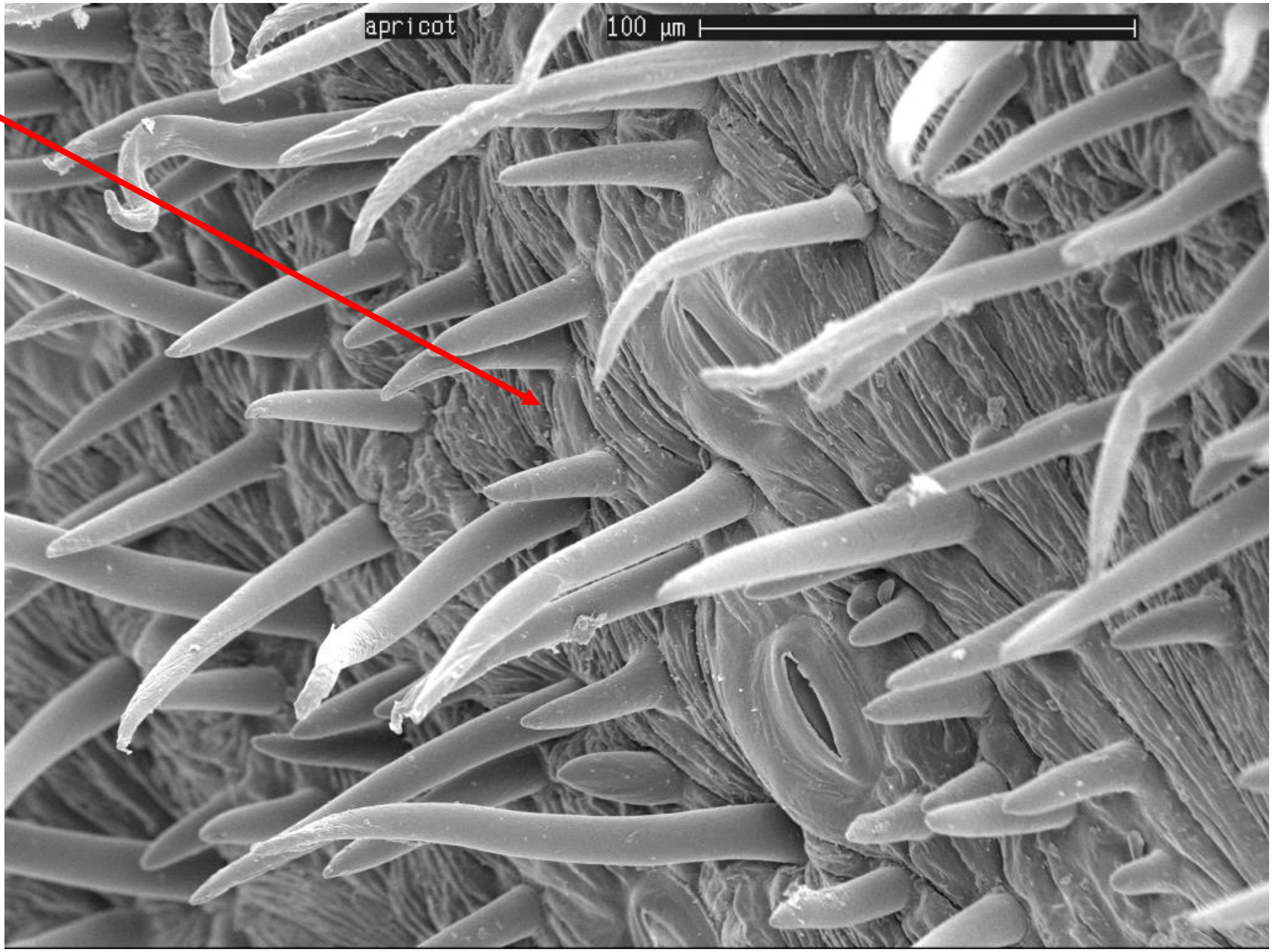
Hitachi FB-2100 (40kV)

Hitachi H-9000UHR (300kV) (LaB6 gun)

Powerful Ways of Seeing!

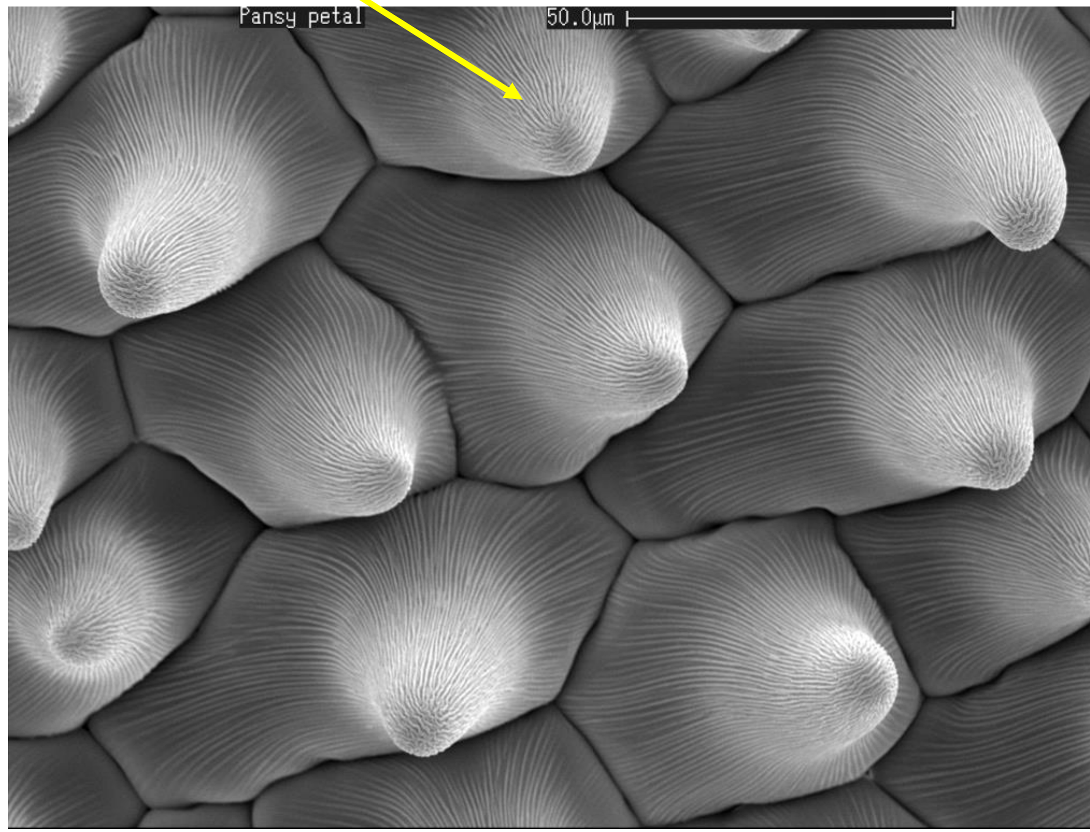
Apricot Skin under the Electron Microscope





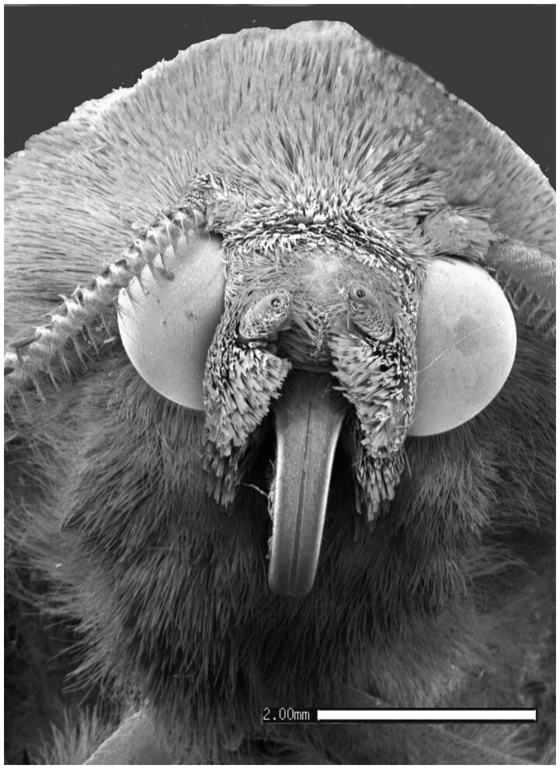
Photos taken by Dr Roger Heady (RIP)

Pansy Petal under the Electron Microscope

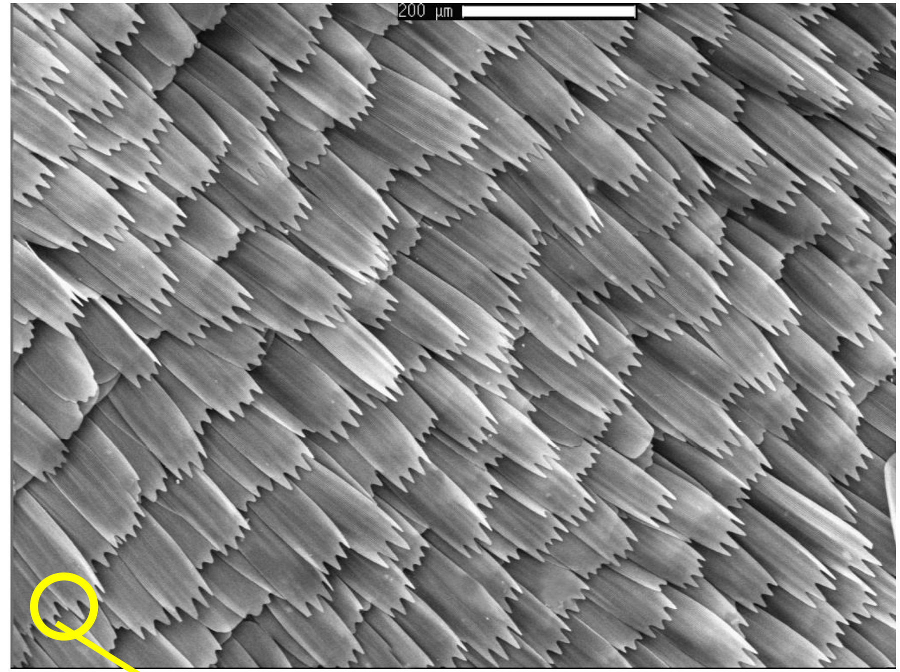


Photos taken by
Dr Roger Heady

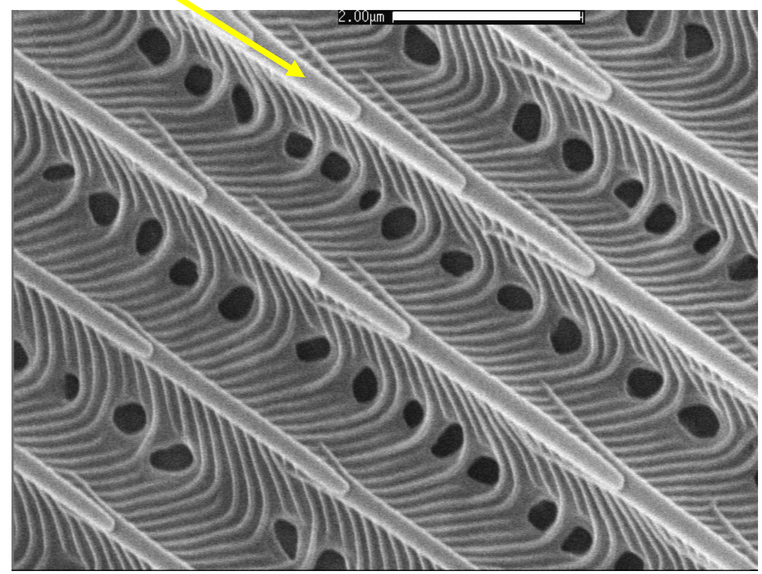
Bogong Moth under the Electron Microscope



Head



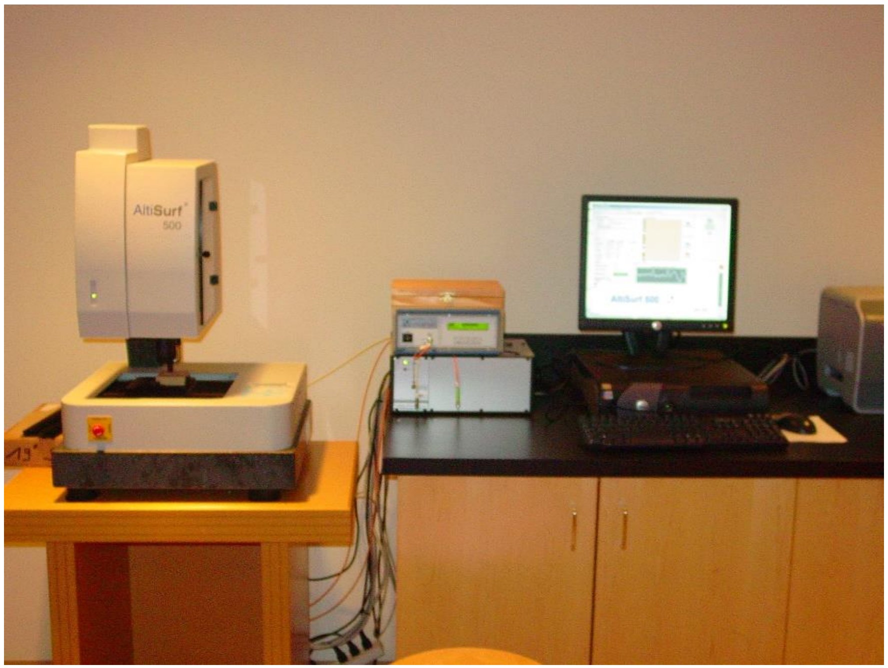
Part of wing showing wing scales

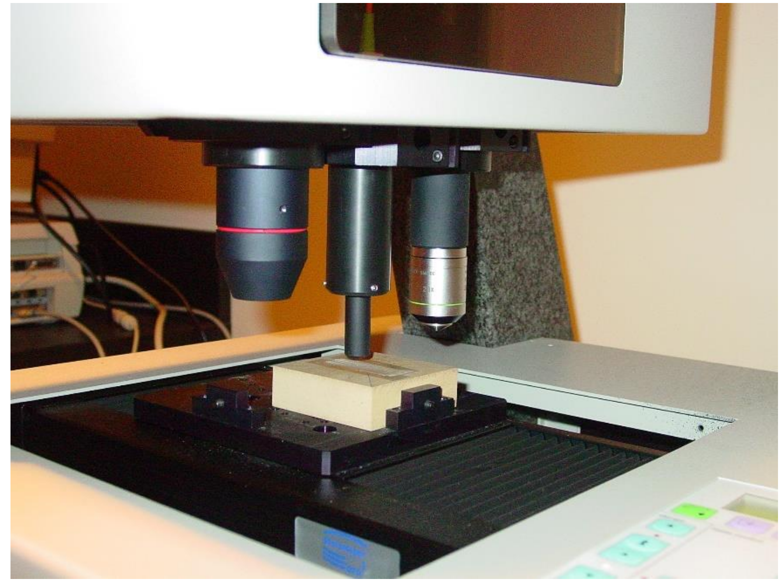


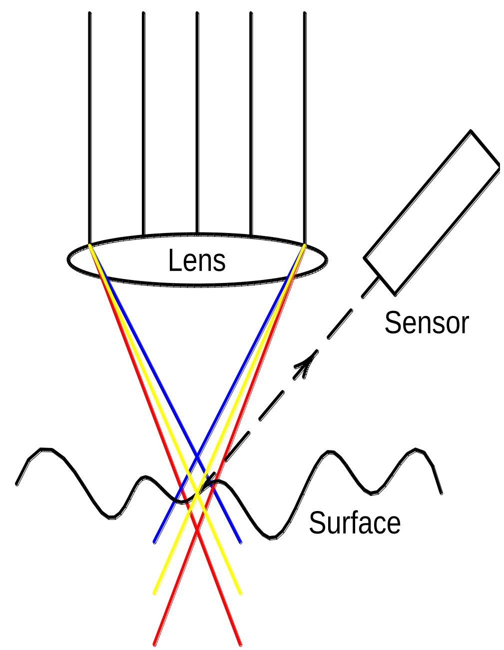
Close-up of wing scales

Photos taken by Dr Roger Heady

Surface profileometry

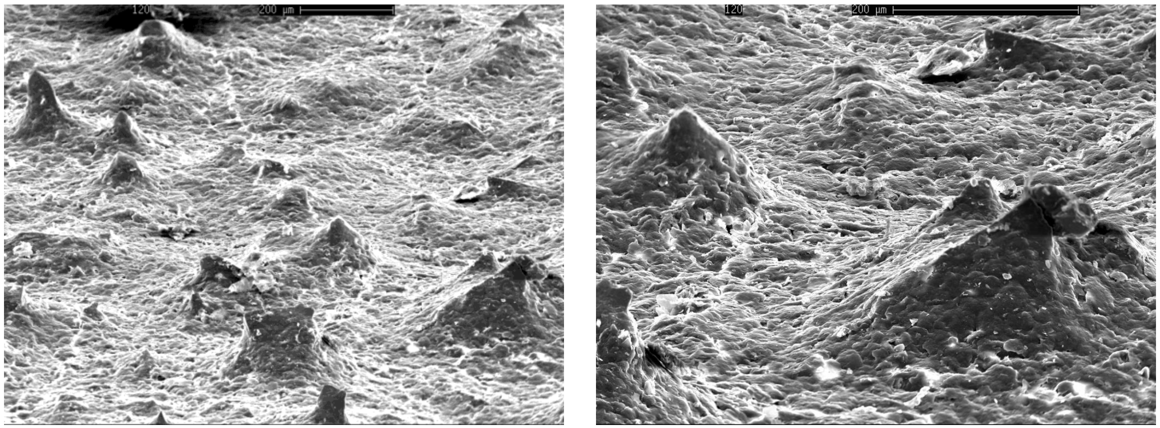




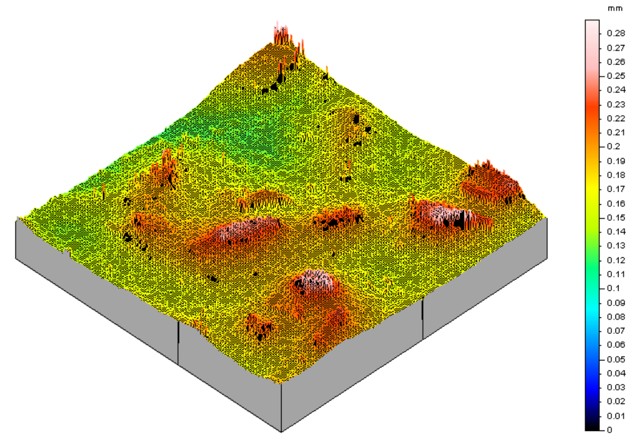


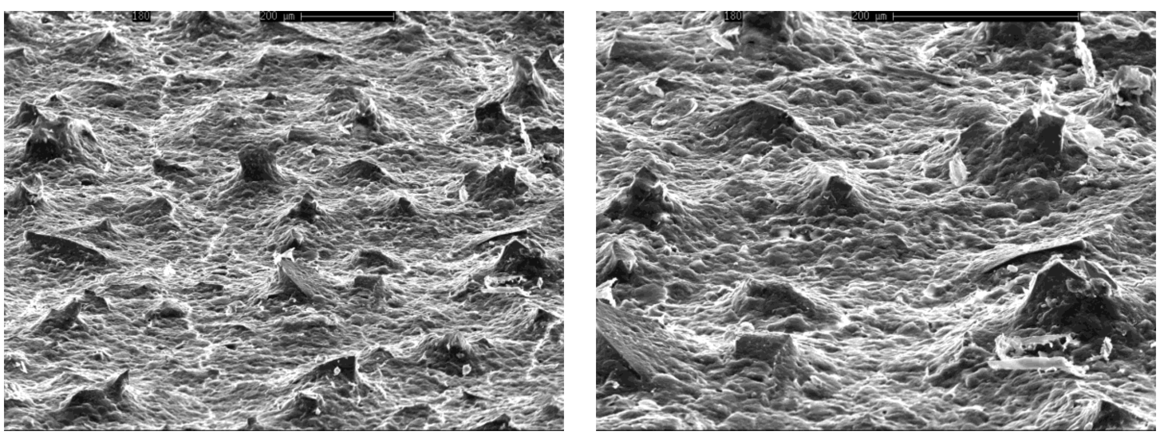
Cotec Altisurf profileometer

Abrasive Paper under SEM & Profilometer

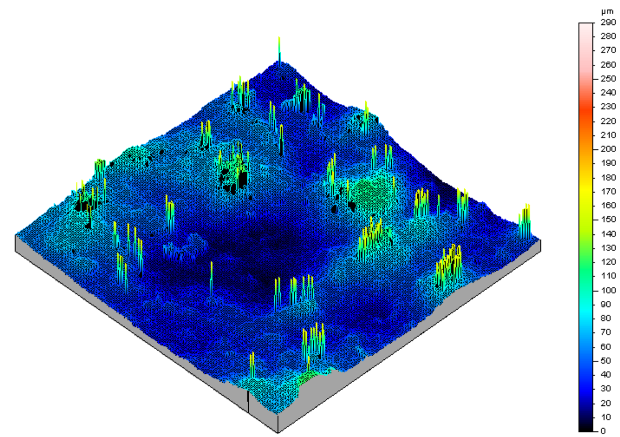


SEM of 120 grit aluminum oxide paper





SEM of 180 grit aluminum oxide paper



What is Grain Raising?

Grain Raising

When water-borne finishes are applied to wood the surface of the wood becomes rougher or develops a 'fuzz'

This effect is known as grain raising

Grain raising can be caused by other finishes, but it is a particular problem with water-borne finishes

According to the Web!

Wood species; More severe with conifers (pine) than hardwoods (maple, cherry)?

Sanding; sanding with high grit size (220 or 280) can eliminate grain raising in some species?

Environment; Grain raising is less severe in warm environments?

Application technology and finish type; grain raising is less severe with certain types of guns and finishes?

Previous Scientific Studies

Koehler, A. (1932). Some observations on raised grain. *Transactions of the American Society of Mechanical Engineers*. 54: 27-30

Marra, G.G. (1943). An analysis of the factors responsible for raised grain on the wood of oak following sanding and staining. *Transactions of the American Society of Mechanical Engineers*. 65: 177-185

Nakamura, G-I, Takachio, H. (1961). An experiment on the roughness and stability of sanded surface. Mokuzai Gakkaishi. 7(2): 41-45.

Arthur Koehler

Summary of Previous Findings

Arthur Koehler 1932:

- Suggested that raised grain consists of individual fibres, groups of fibres or even fibre fragments projecting from the surface after sanding and wetting

George G. Marra 1943:

- Stated that raised grain was due to: (I) Ruptured and collapsed pore walls; (II) Swelling of sanding ridges; (III) Fibre-fibre separations

Nakamura & Takachio 1961:

- Quantified grain raising using roughness measurements obtained using a mechanical (stylus) profileometer

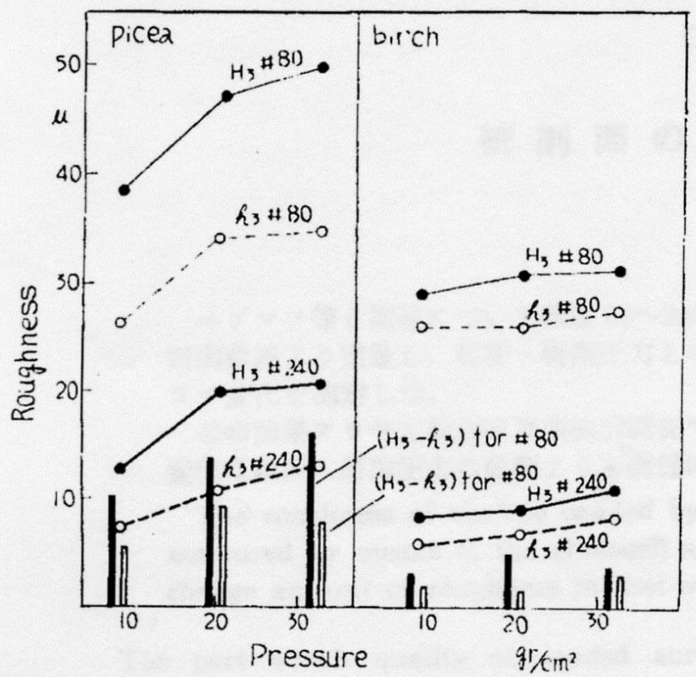
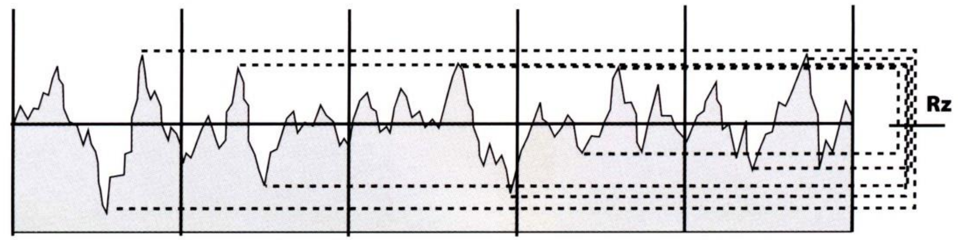


Fig. 7 Relation of roughness to sanding pressure and the value of (H_3-h_3) for 80, 240 mesh.

Results from Nakamura & Takachio 1961

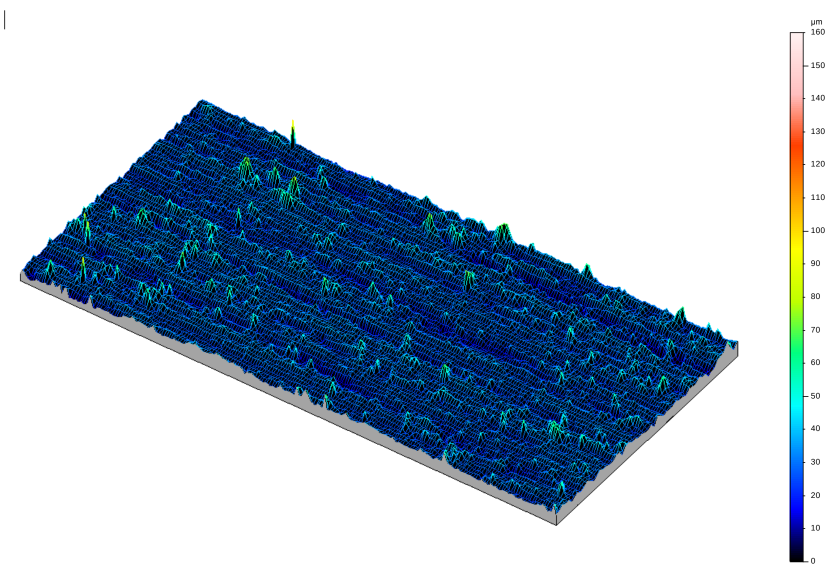
Outputs of non-contact surface profileometry



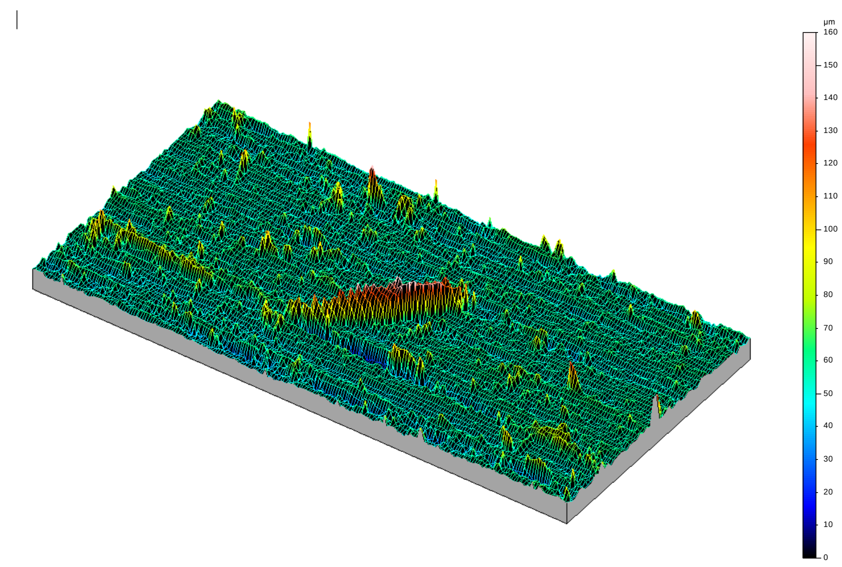
Ra = the average profile height compared to the medium line within the measure length

Rmax = the largest height difference between peaks and dips that are next to each other within a reference length

Rz = average of Rmax within five reference lengths

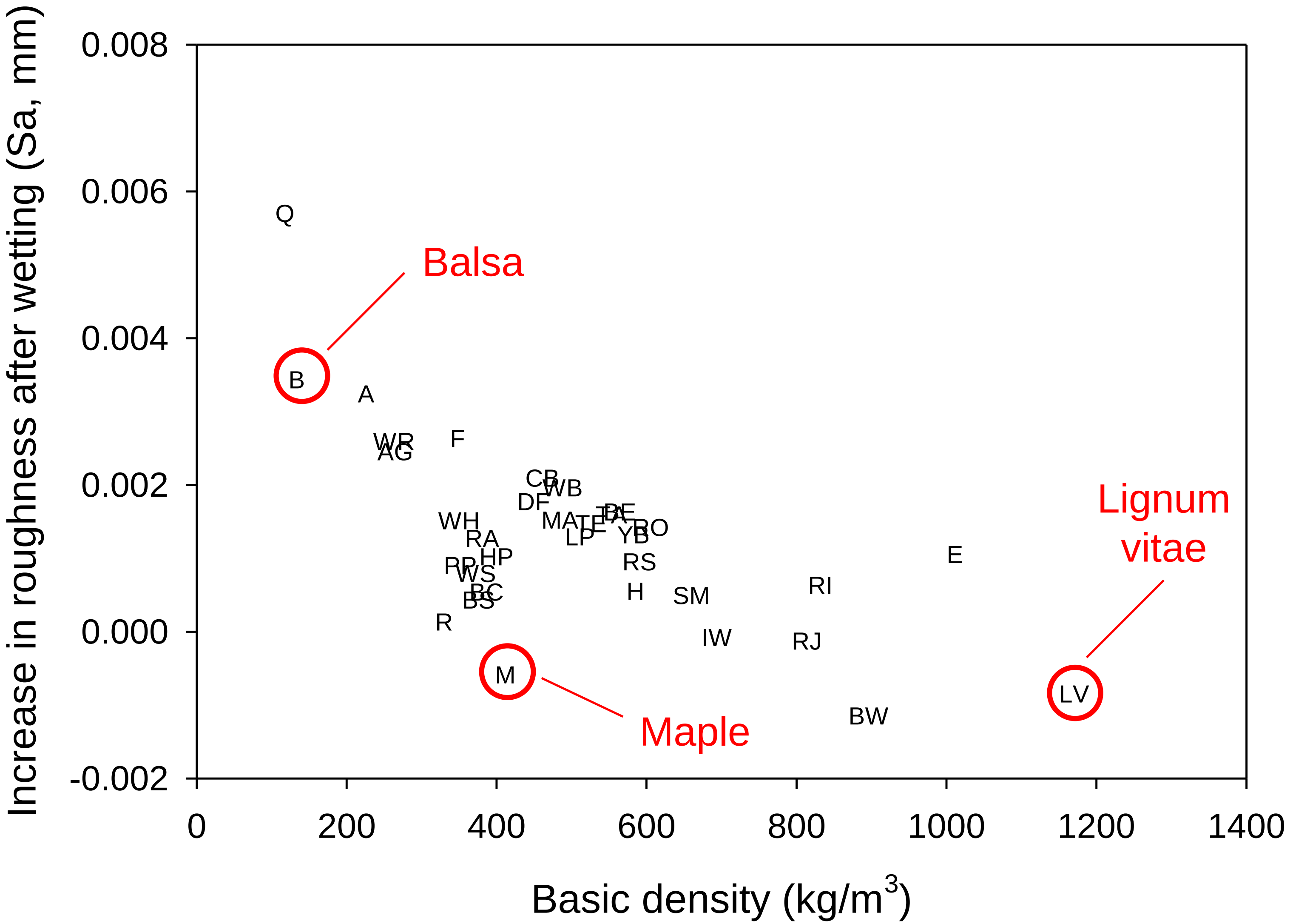


Yellow birch after sanding

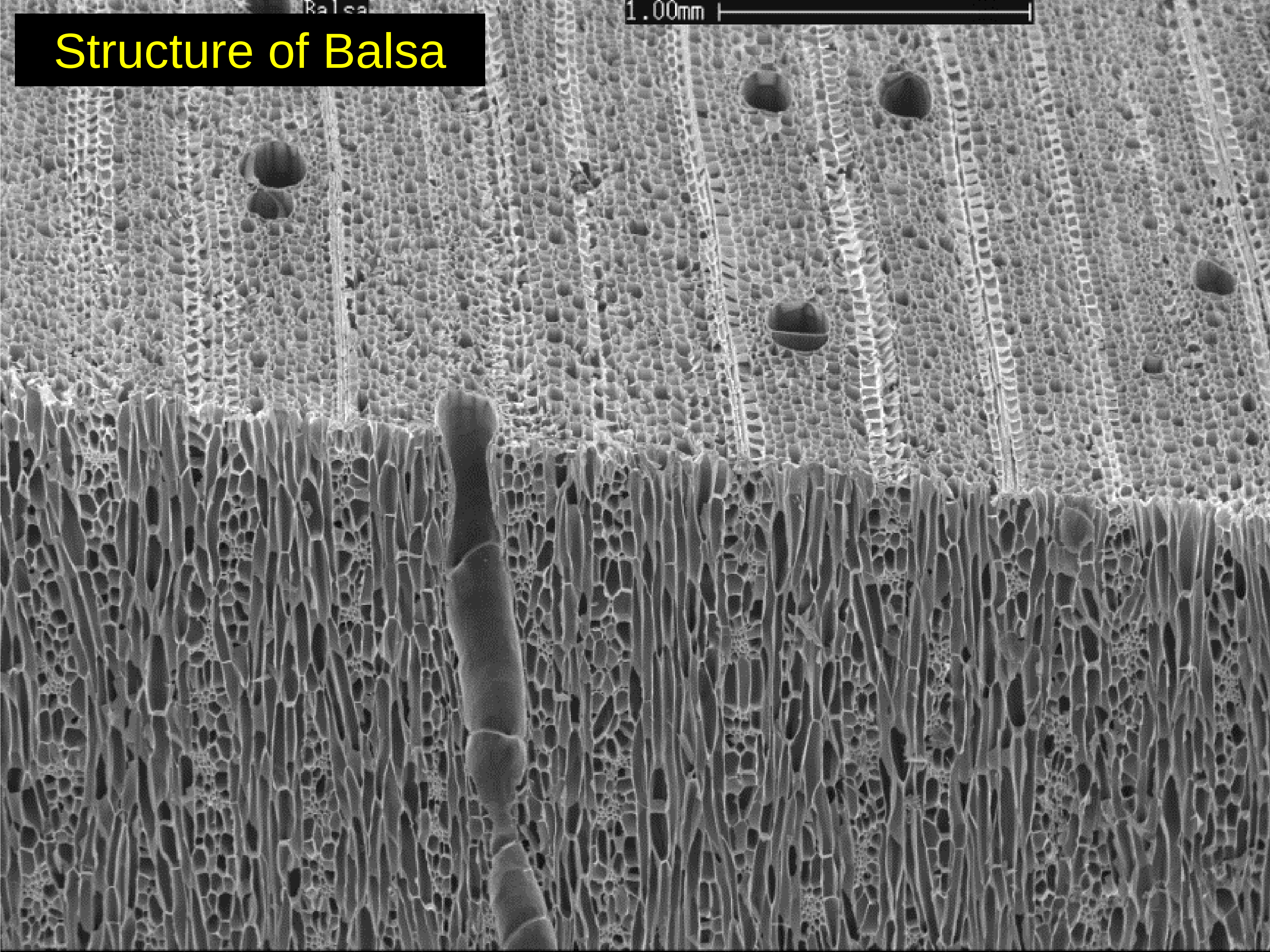


Yellow birch after sanding and wetting

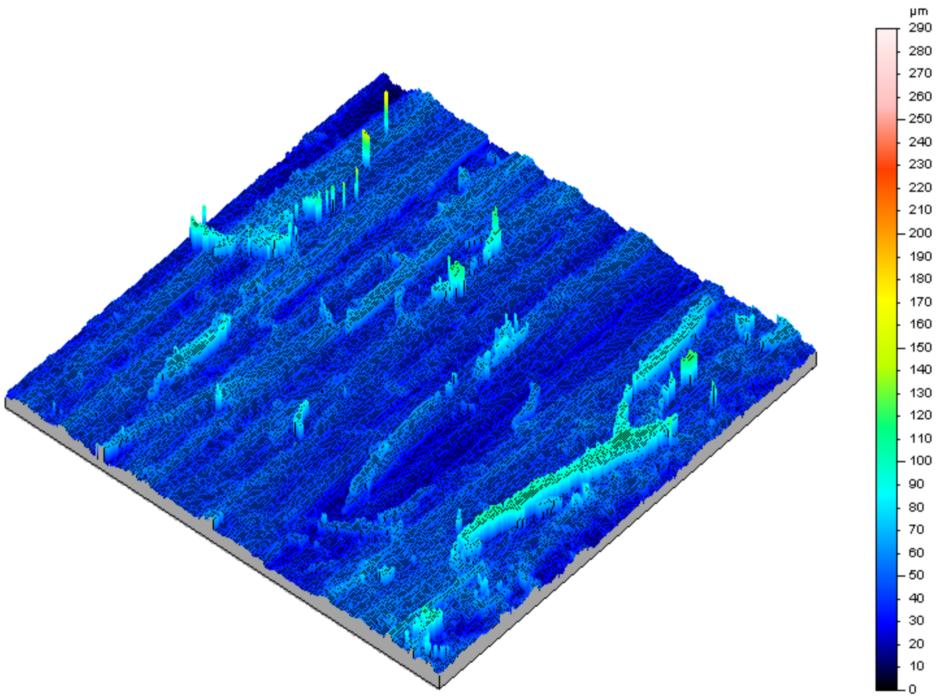
Increase in Roughness of Different Wood Species After Wetting



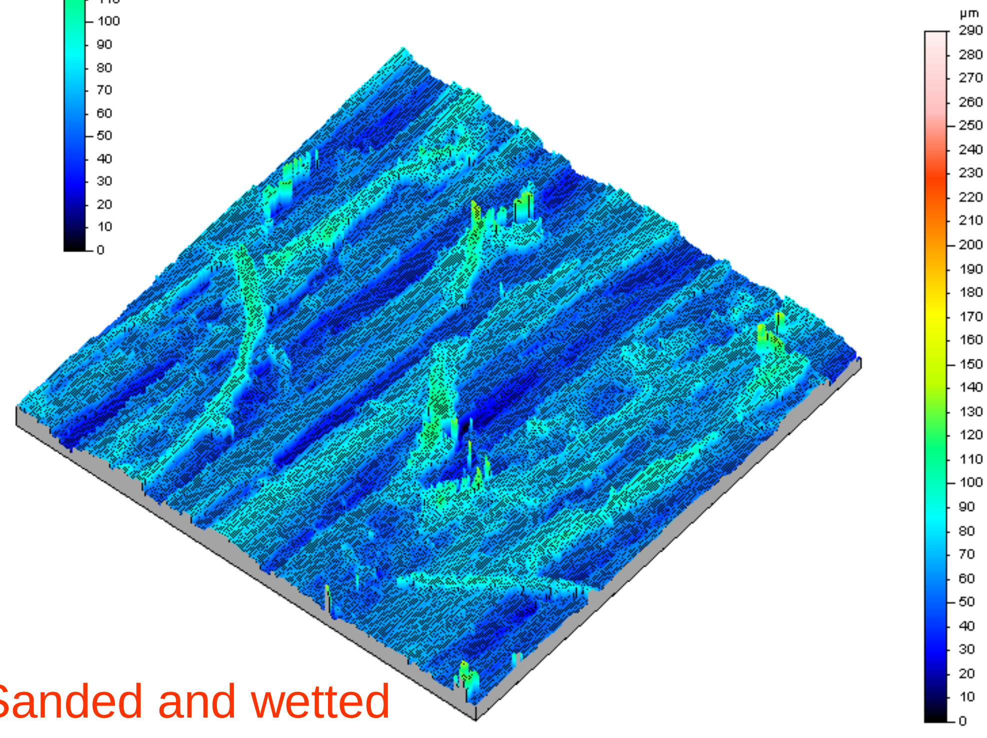
Structure of Balsa



Balsa Profilometry: Sanded Surfaces



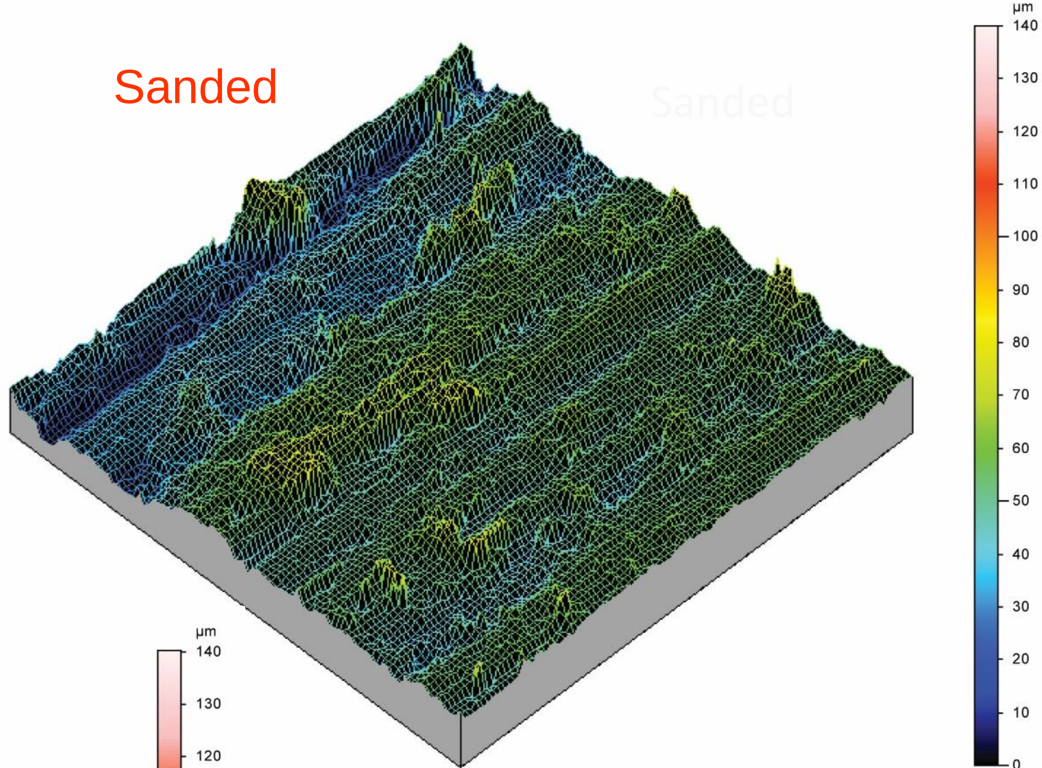
Sanded

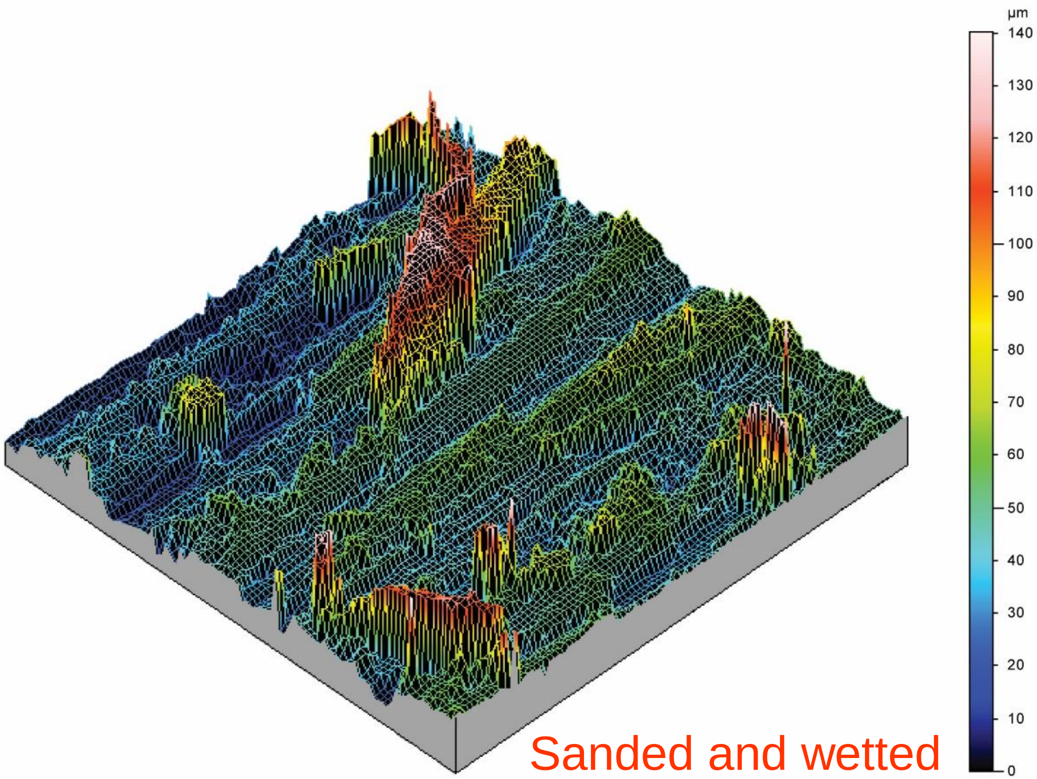


Sanded and wetted

Sanded Balsa

Sanded

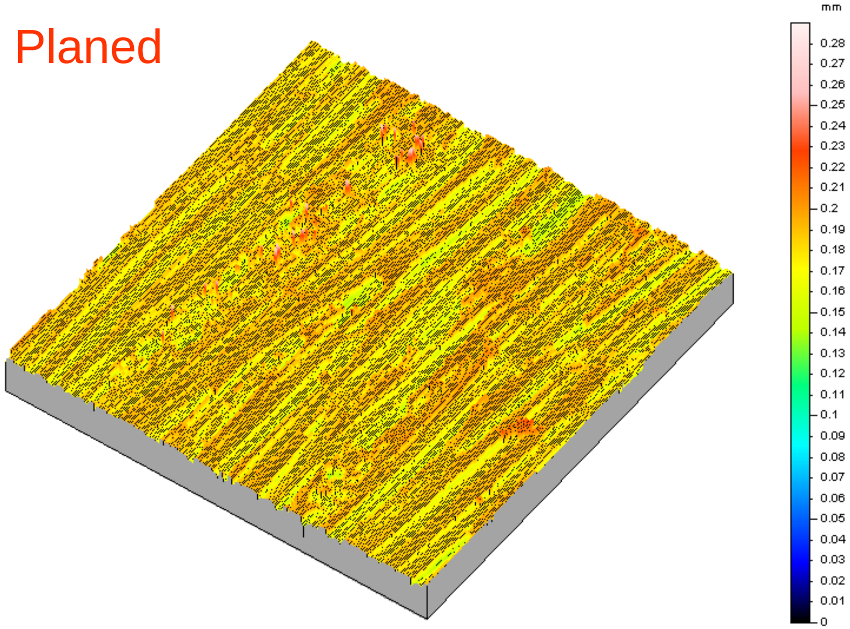


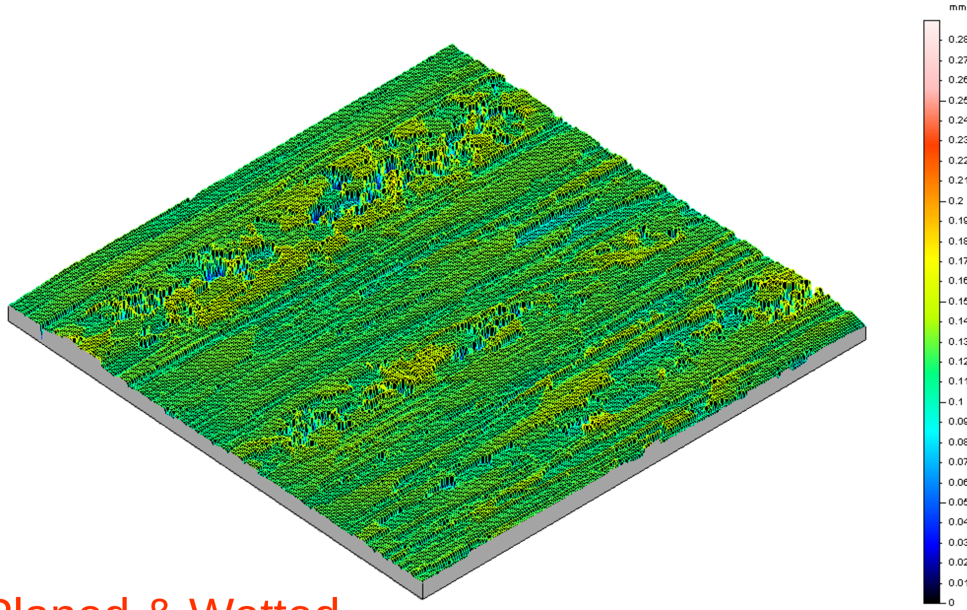


Sanded and wetted

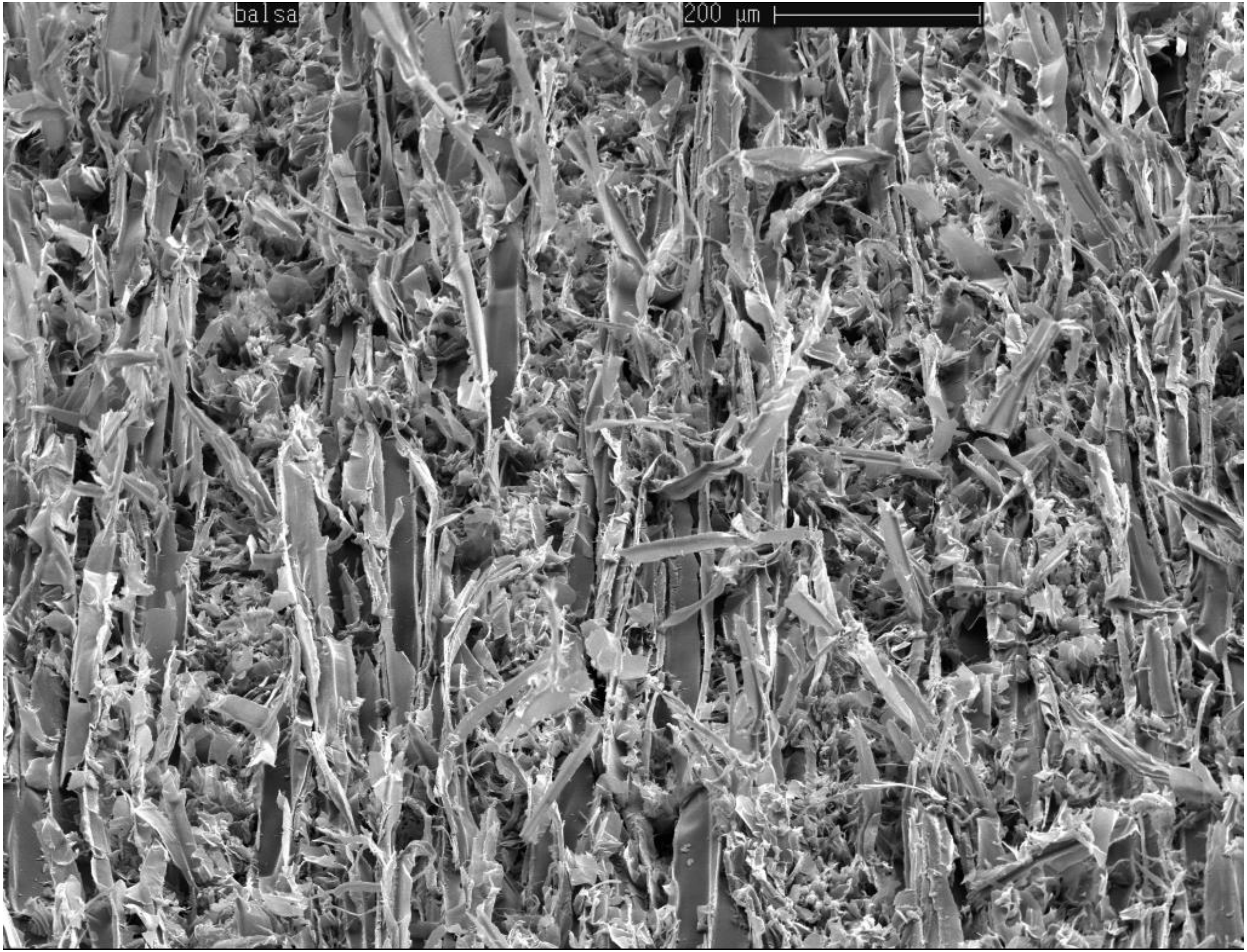
Balsa Profilometry: Planed Surfaces

Planed

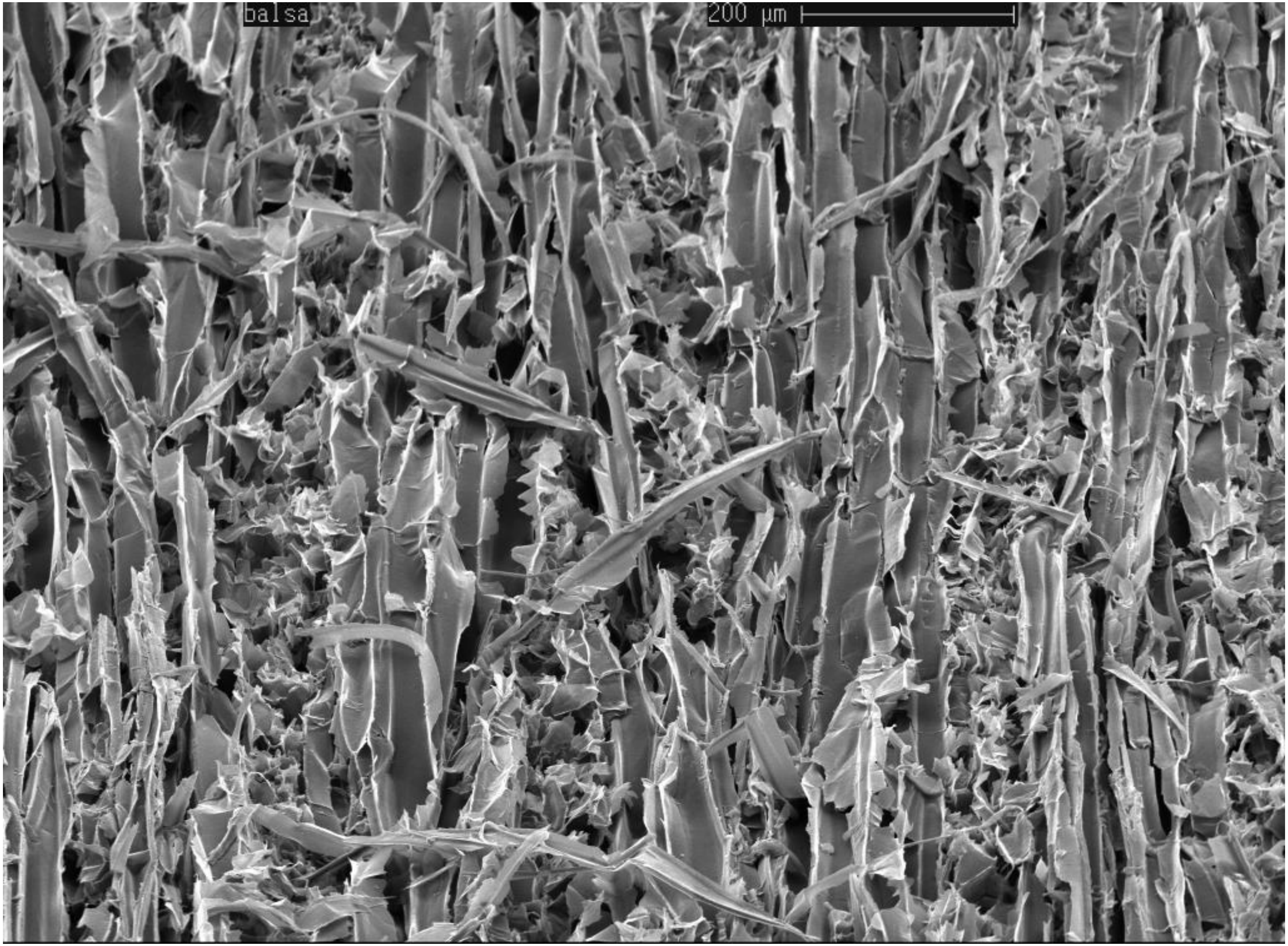




Planed & Wetted

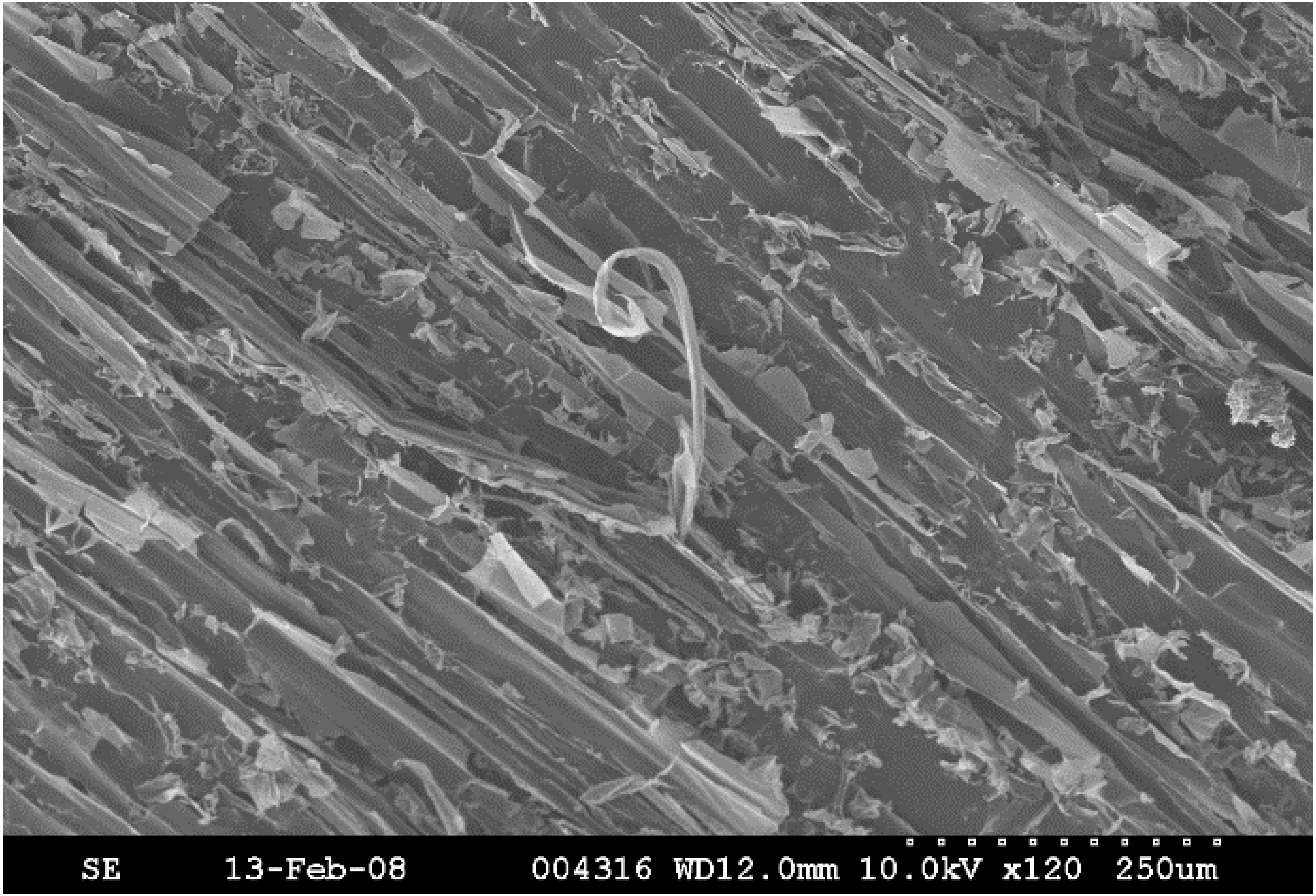


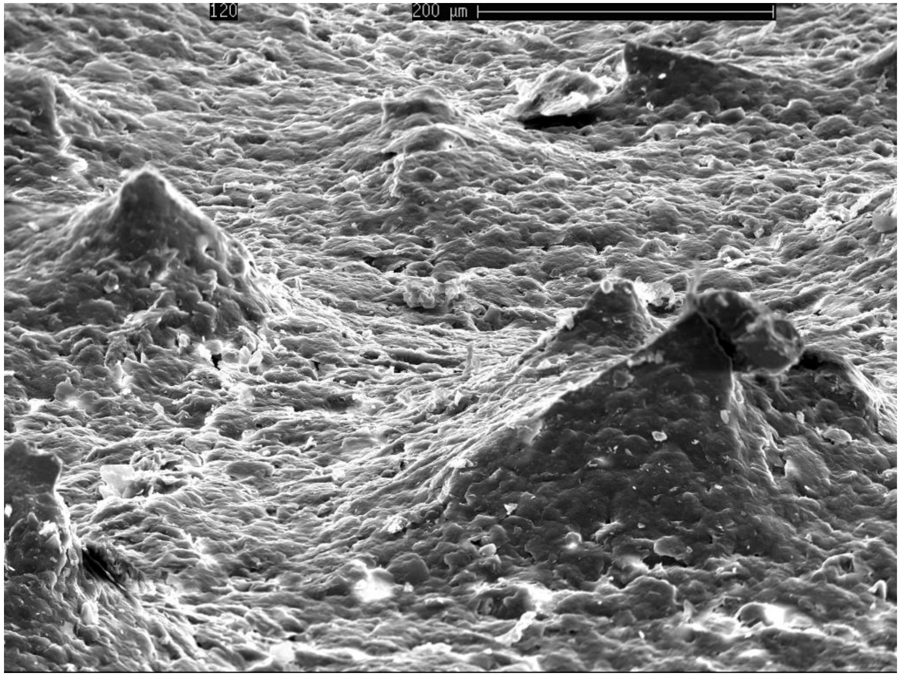
Balsa Sanded & Dry under the Electron Microscope



Balsa Sanded and Wetted under the Electron Microscope

Material Removed from Sanded Balsa by Scotch Tape

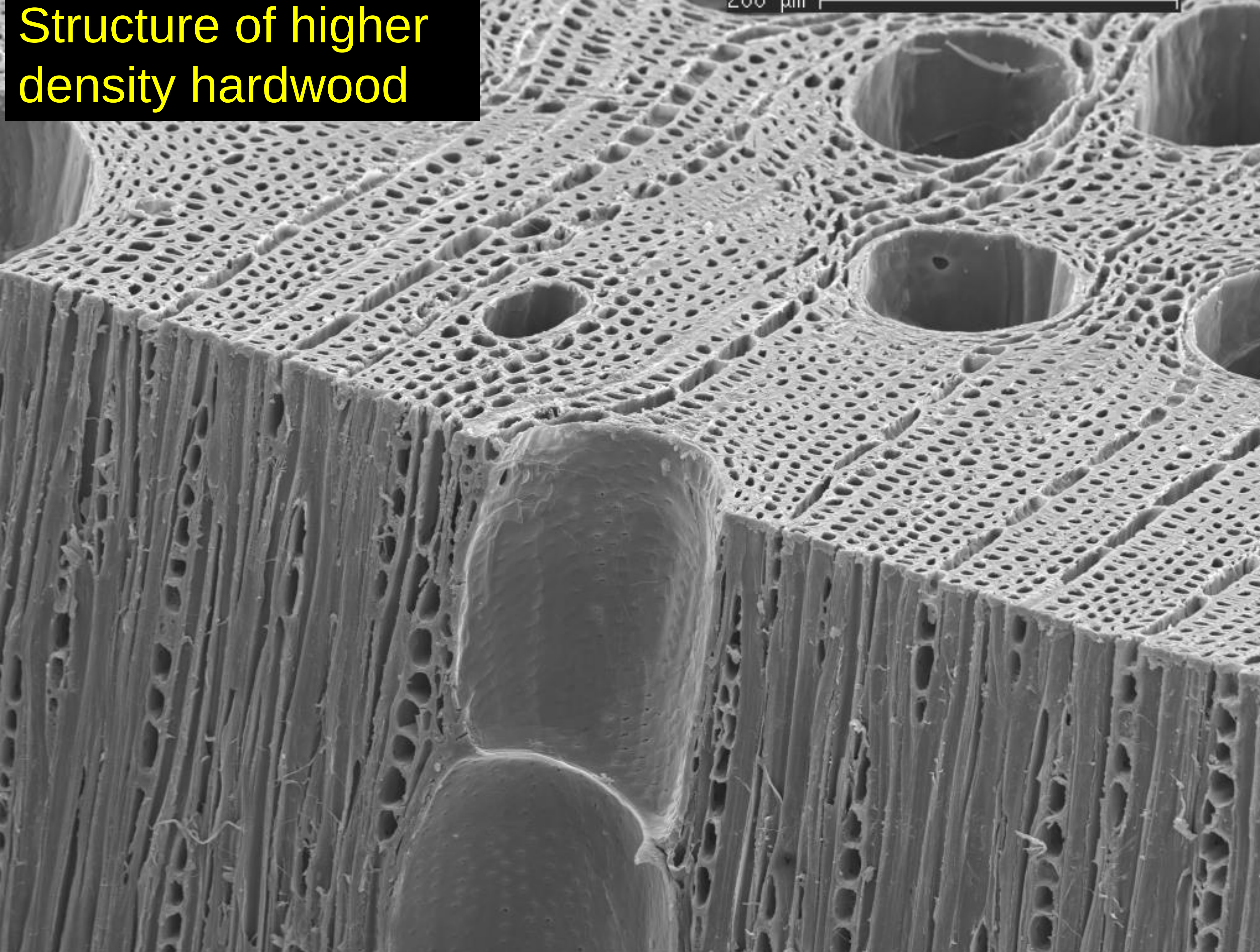




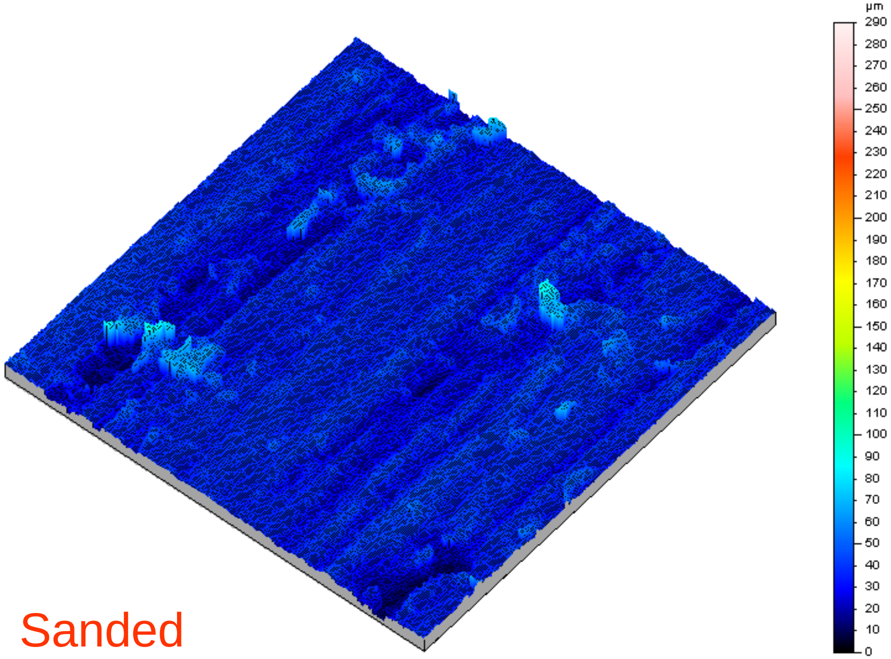
A Simple Model of Damage to Wood During Sanding

Maple

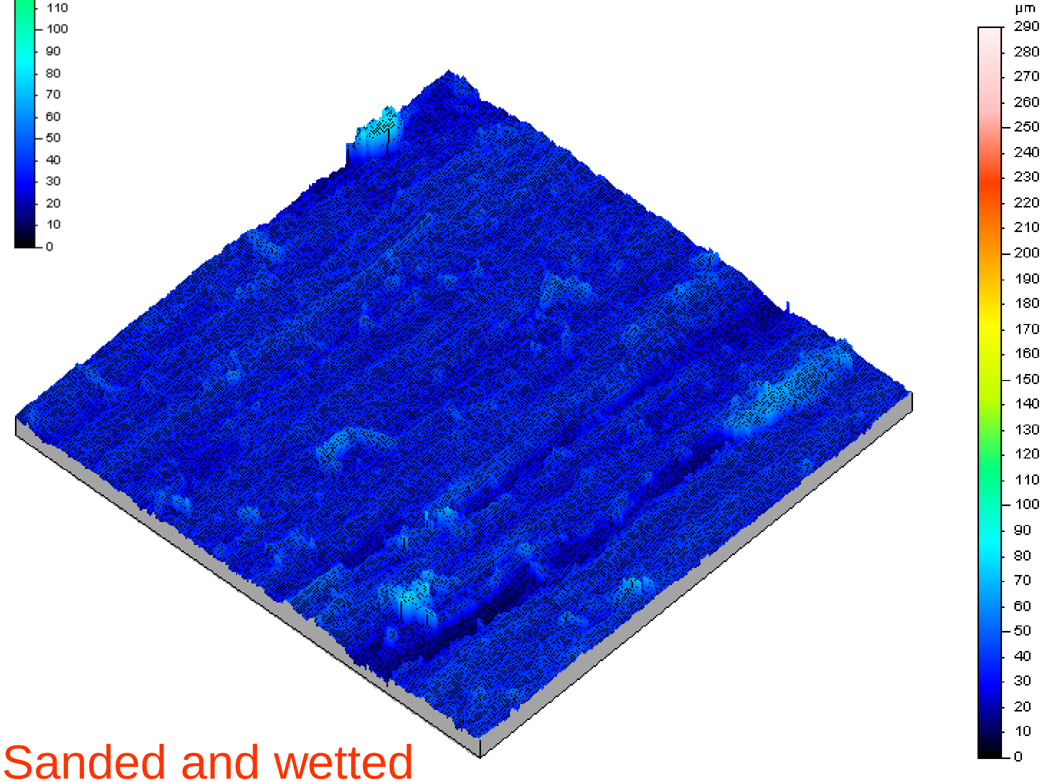
Structure of higher density hardwood



Maple Profilometry: Sanded Surfaces

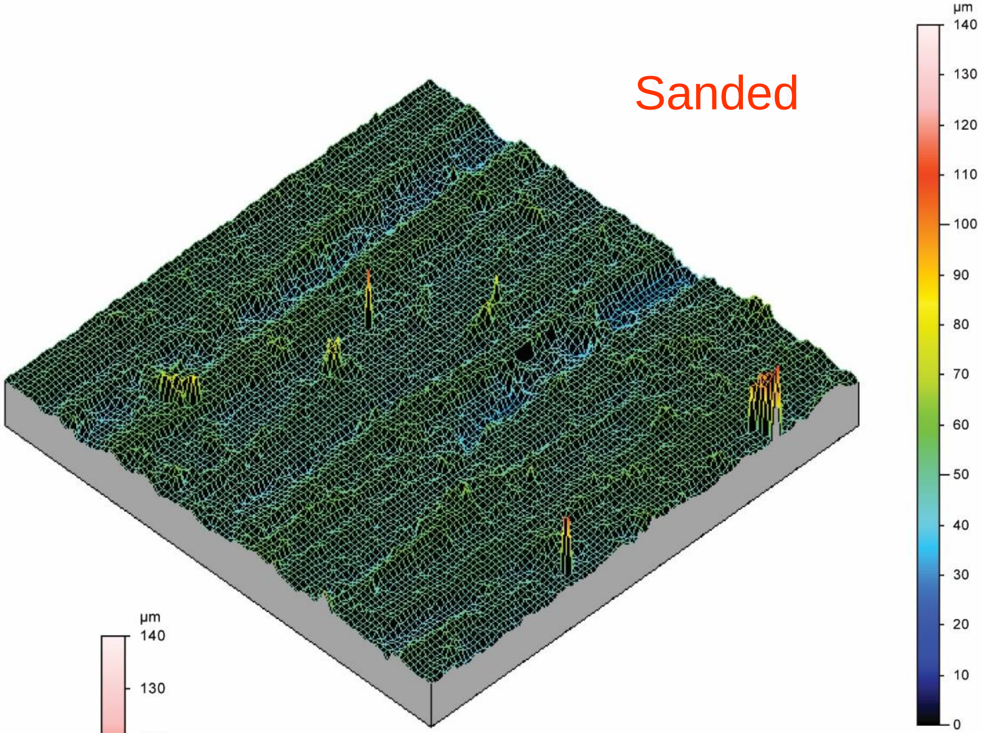


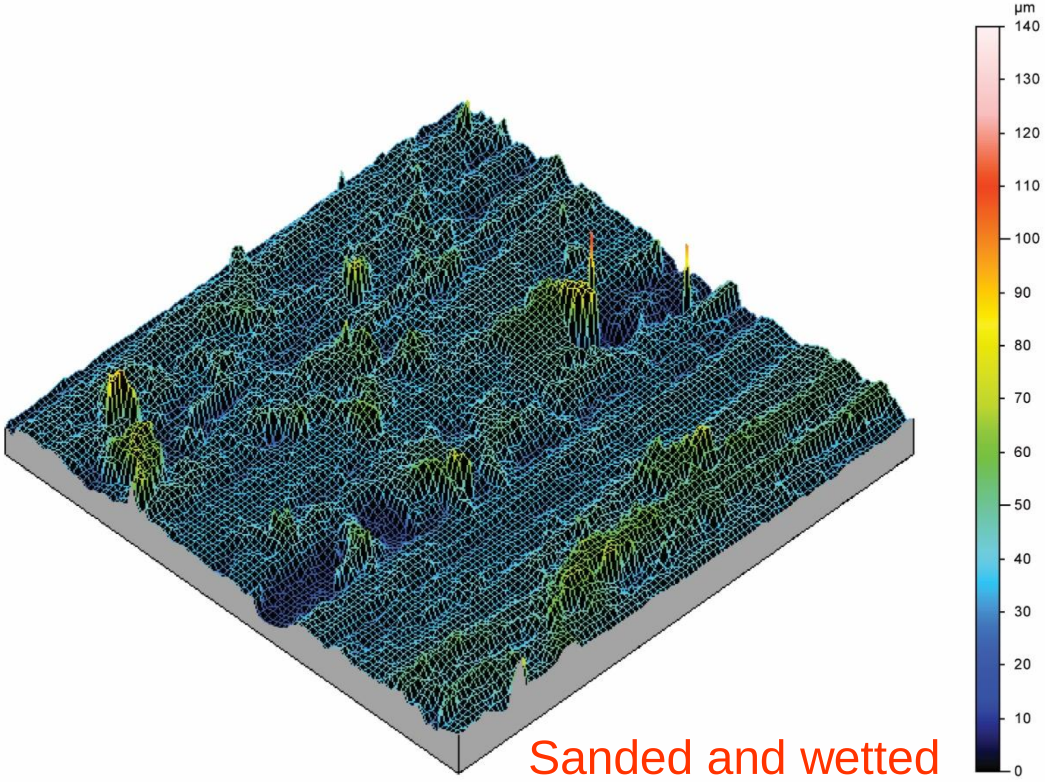
Sanded



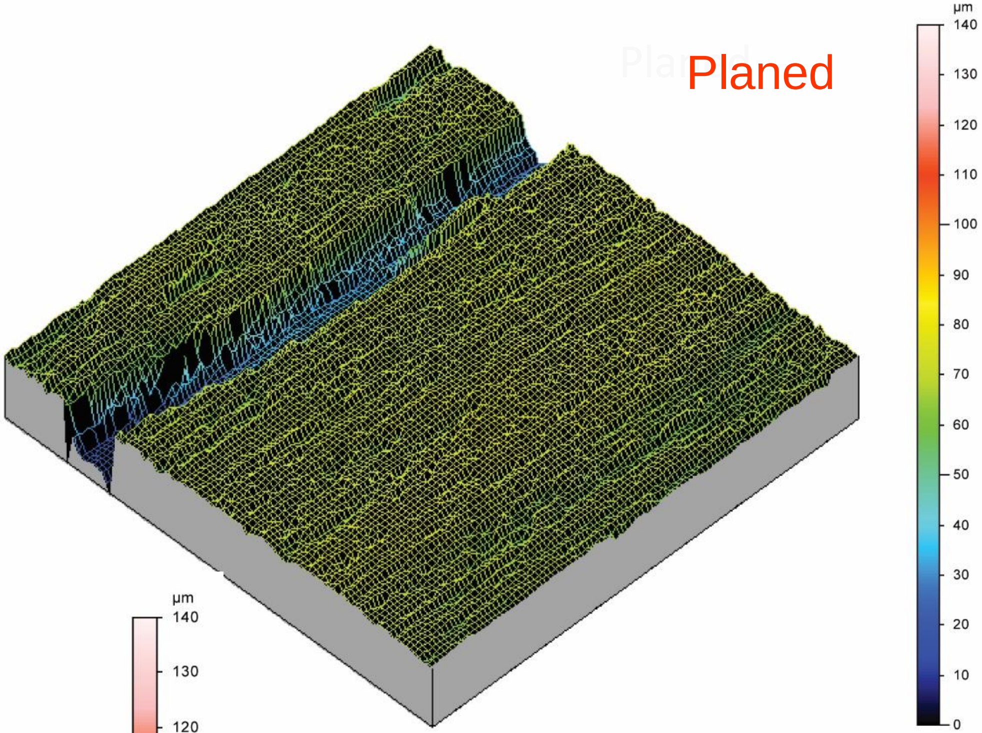
Sanded and wetted

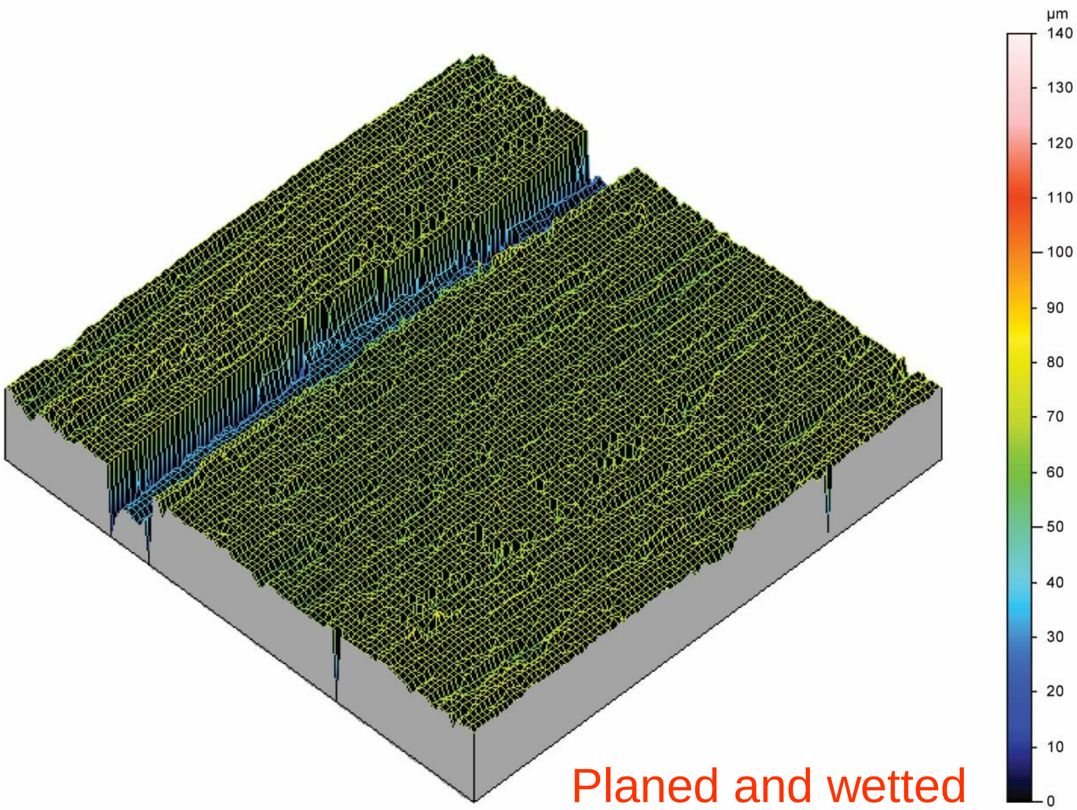
Sanded maple

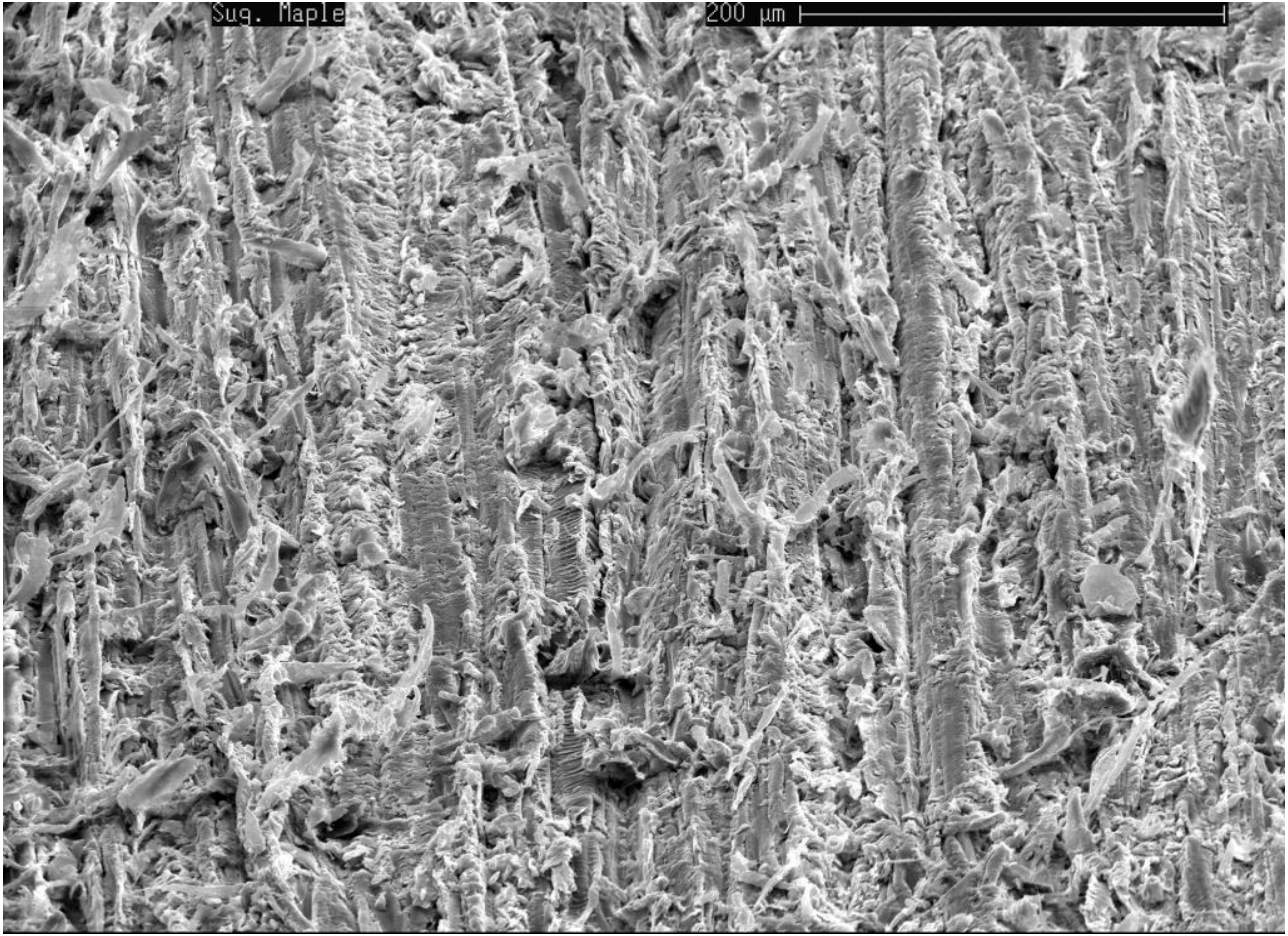




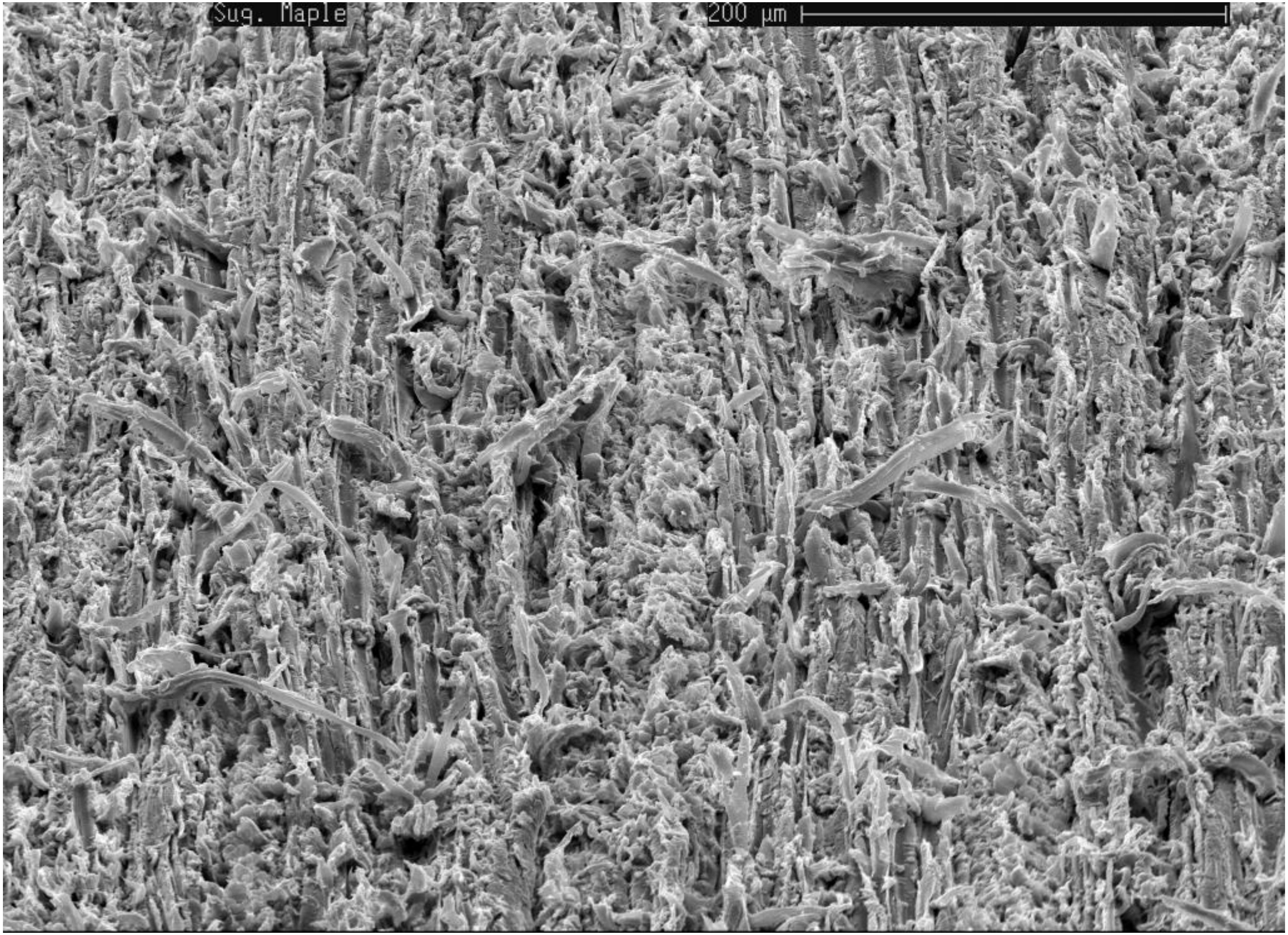
Planed maple





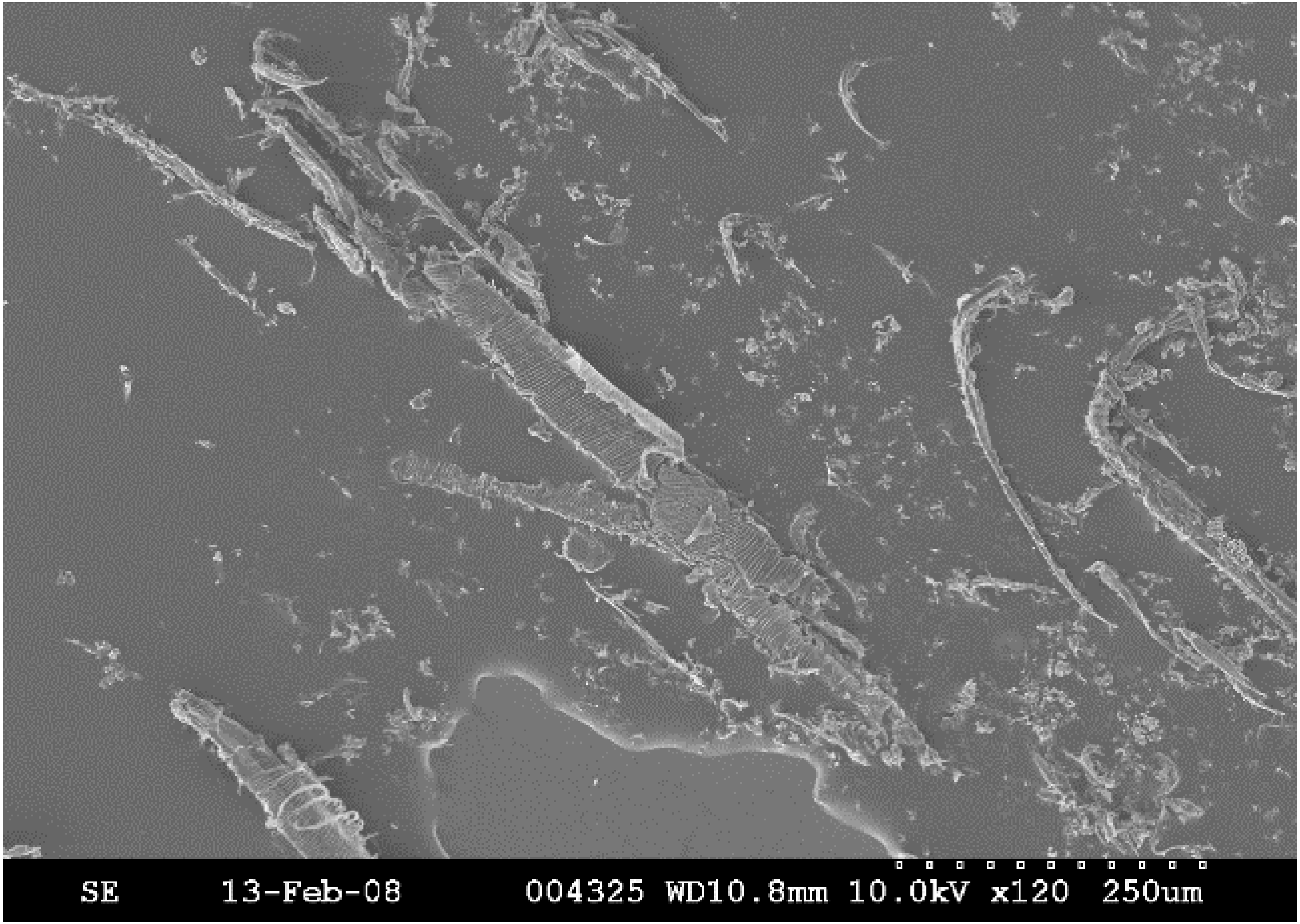


Maple Sanded & Dry under the Electron Microscope

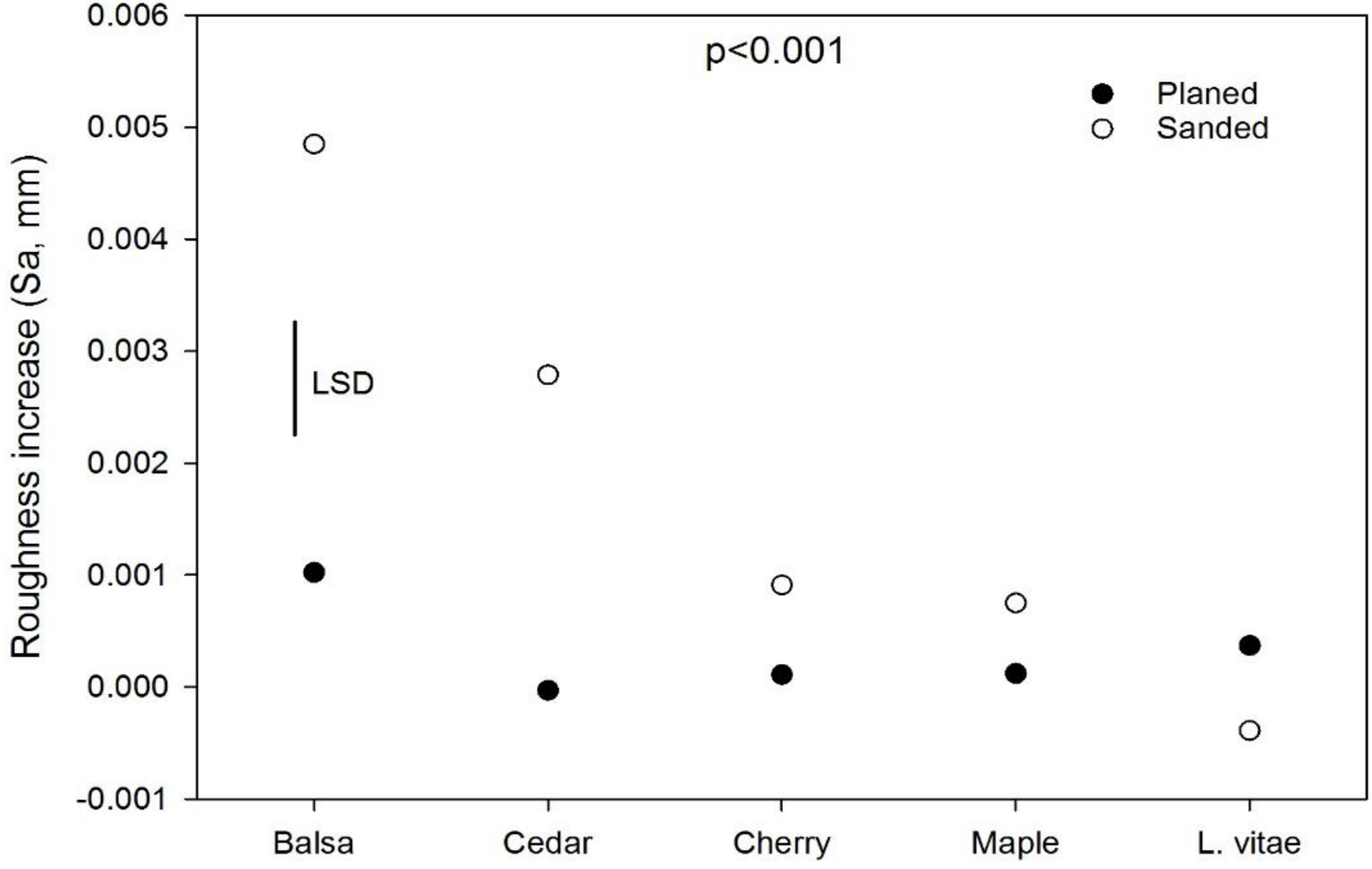


Maple Sanded & Wetted under the Electron Microscope

Material Removed from Sanded Maple by Scotch Tape



Grain Raising: All Species



Summary

Grain raising is more pronounced in lower density species than higher density ones

Sanding creates a surface that is susceptible to developing raised grain when water is applied to it:

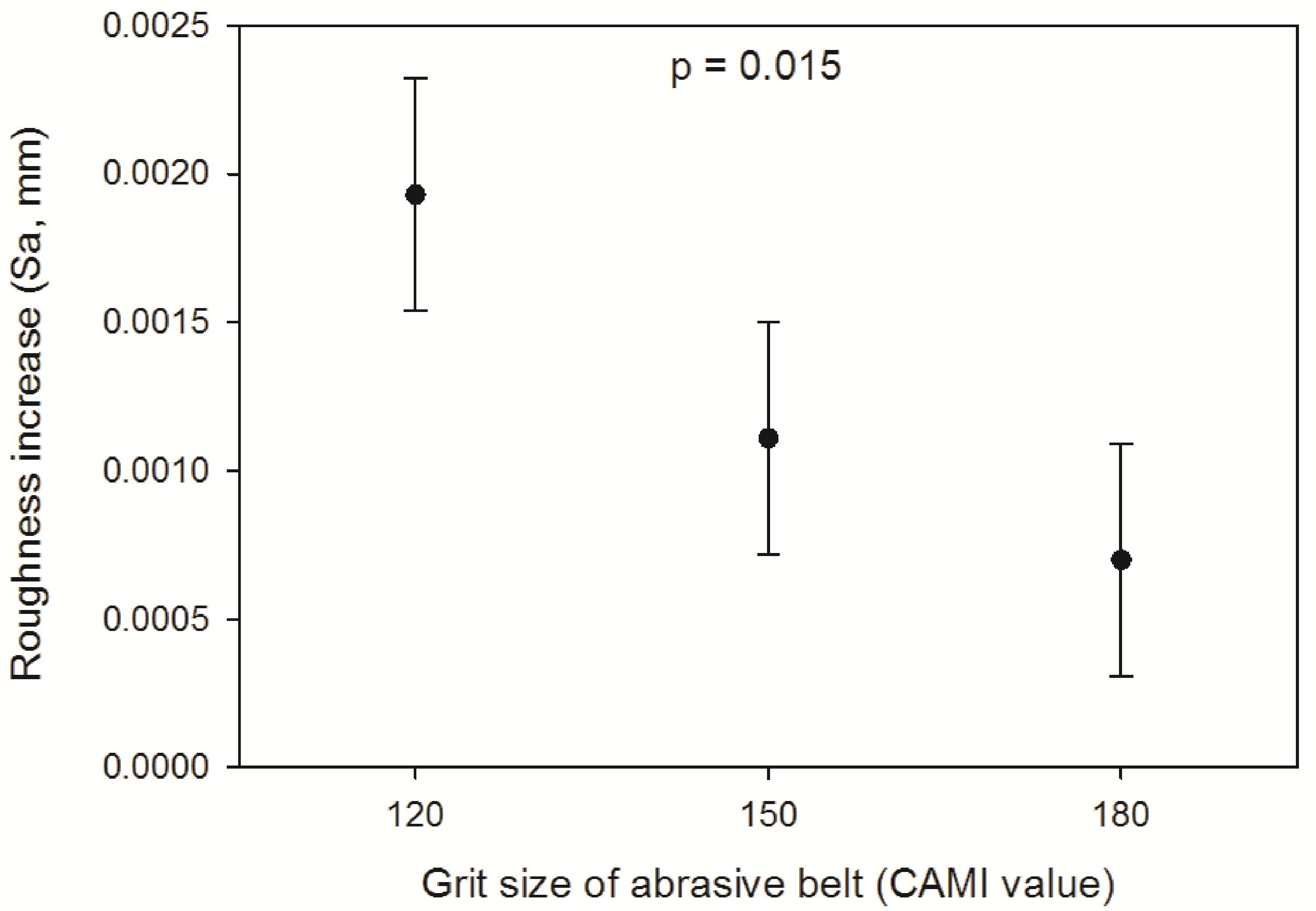
- In lower density wood species and in the thin walled elements of other species the abrasives cut wood cells along their length and leave loosely attached cell wall slivers that rise up after water is applied
- Some parts of fibres and even bundles of fibres can also be partially detached from wood surfaces

Our findings suggest that research to reduce grain raising should focus on changing or optimising the sanding process to reduce the damage that it causes to wood surfaces

Effects of Abrasive Size on Grain Raising

An experiment was conducted to examine the effect of abrasive size (120, 150 and 180 grit aluminium oxide) on grain raising of 12 maple veneer panels following sanding using an industrial wide-belt sander

Grain Raising of Maple Boards Sanded with Abrasives with Different Grit Size



Conclusions: Grain Raising

Sanding can create micro-structural damage to wood surfaces that leads to grain raising

Grain raising is inversely related to wood density and abrasive grit size

Grain raising can be reduced by tailoring sanding parameters to suit wood species being processed

Next Steps: Dissemination of Results

Every University expects Professors to publish their research in a journal that is: (1) peer reviewed; (2) respected

1. **Peer reviewed** means that the paper will be reviewed by two experts in the field to determine the quality of the work and its importance

2. The **respect** given to journals depends on a measure called the impact factor, which is the extent to which other scientist refer to others' work in their own papers

coatings

Article

Microstructure and Mechanism of Grain Raising in Wood

Philip D. Evans [1,2,*], Ian Cullis [1], Joseph Doh Wook Kim [1], Lukie H. Leung [1], Siti Hazneza [1,3] and Roger D. Heady [4]

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2 Centre for Wood Durability and Design Life, University of Sunshine Coast, Sunshine Coast QLD 4558, Australia Bioresource, Paper and Coatings Technology, School of
3 Industrial Technology, Universiti Sains Malaysia, Penang 11800, Malaysia
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http://www.mdpi.com/2079-6412/7/9/135

What is Research?

Q. Why Do I get Complaints about The Quality of our Finish?

Problem Finishing Cabinets in Mid-West with Water-borne Coatings

A finish supplier received complaints from a customer that there were times of the year when a water-borne coating was not meeting expectations in terms of finish quality

Investigating the Problem

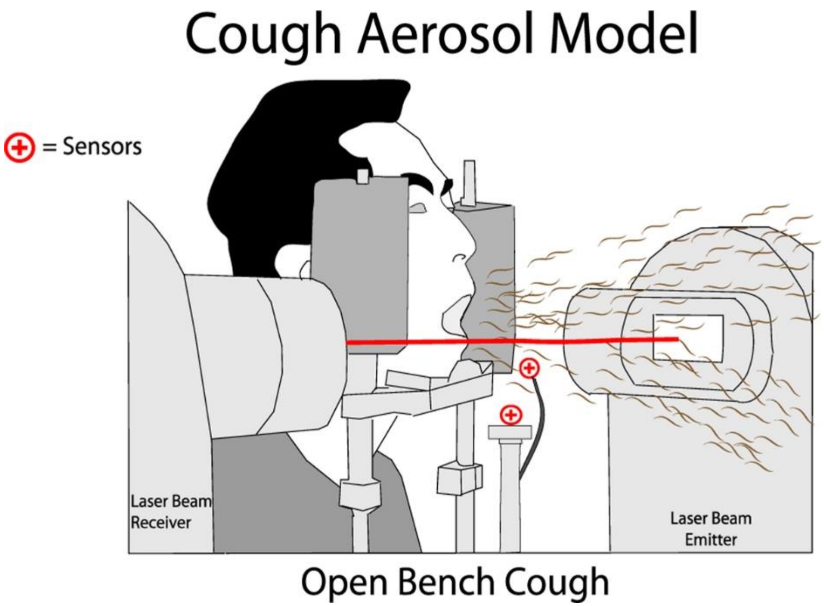
Finish supplier visited our laboratory and research was done to investigate the problem:

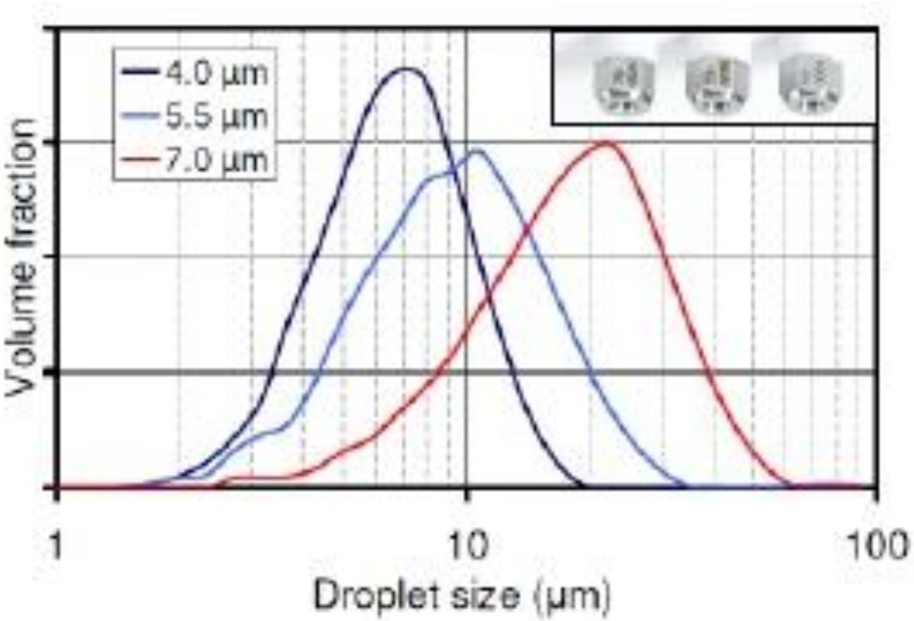
1, Tested the effects of various parameters on the atomization of a water-borne coating

2, Developed a test to relate atomization characteristics to formation of coatings in real time

Measuring Atomization of Coatings

- We used a laser device to measure droplet size in spray gun plumes





Experiment

- Spray system parameters
  - Air assisted airless pump (Airmix® 10c18) and spray gun (Airmix® xcite™)
  - Three tip sizes and associated pump/gun settings
- Various parameters were altered including dilution of finish, finish types (primer v top coat) and temperature of finish

Parameter Details

Tip sizes

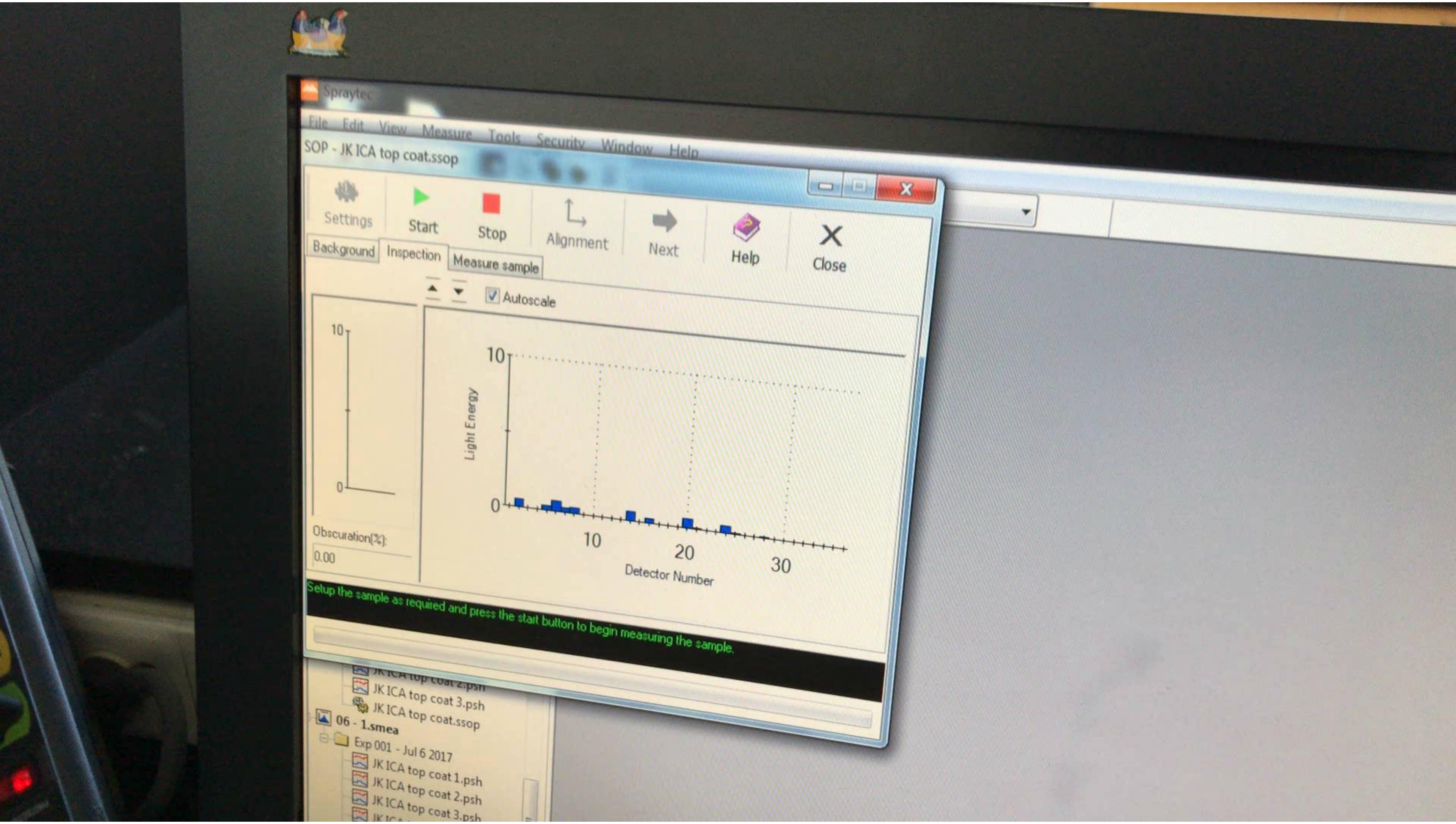
1. 06 (092) - 0.011/inch, 0.23 mm
2. 09 (152) - 0.013/inch, 0.33 mm
3. 12 (152) - 0.015/inch, 0.38 mm

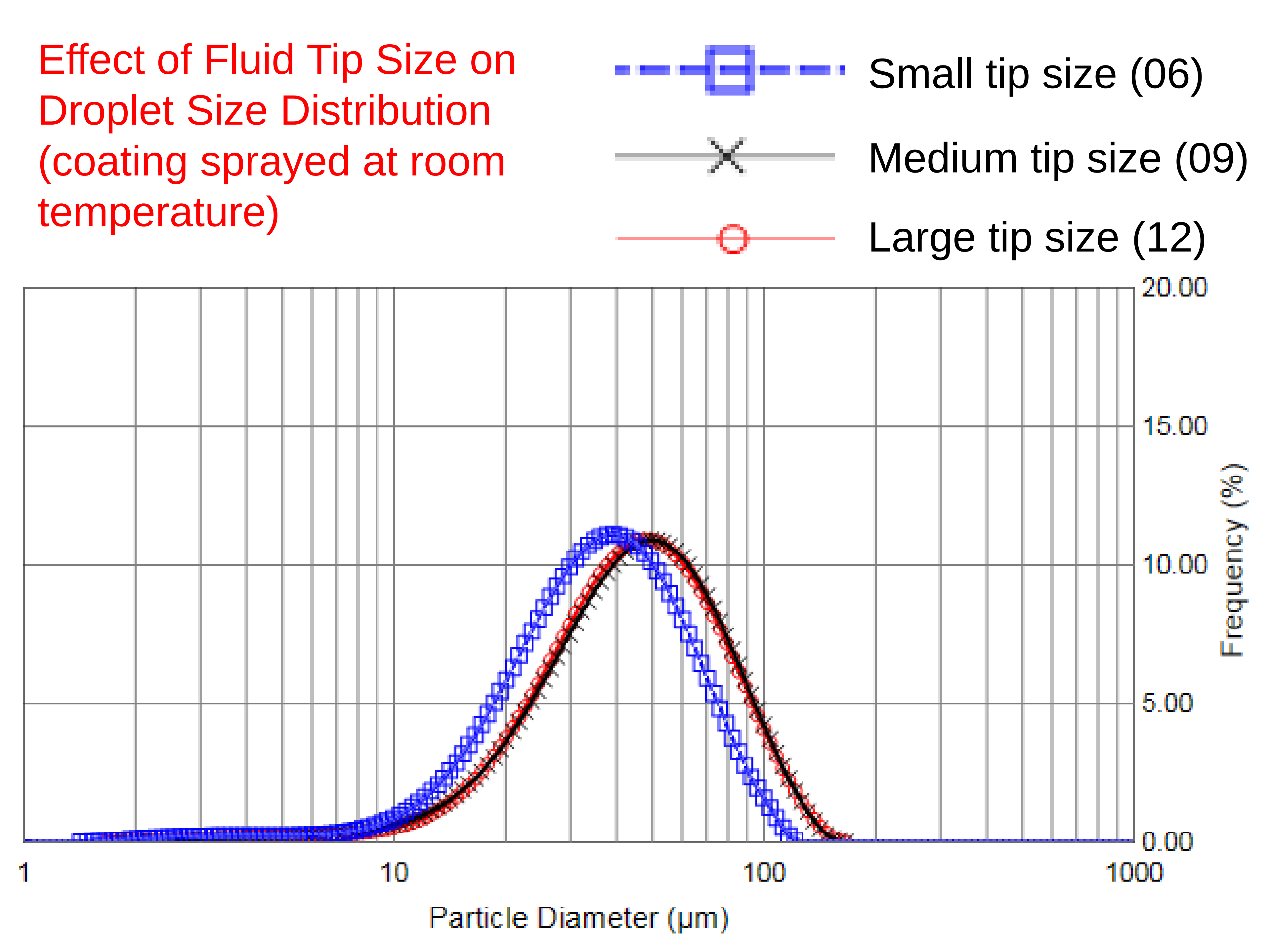
Fluid and air pressures

1. Fluid 4.5; Air 1.8
2. Fluid 3.0; Air 1.4
3. Fluid 2.0; Air 1.4

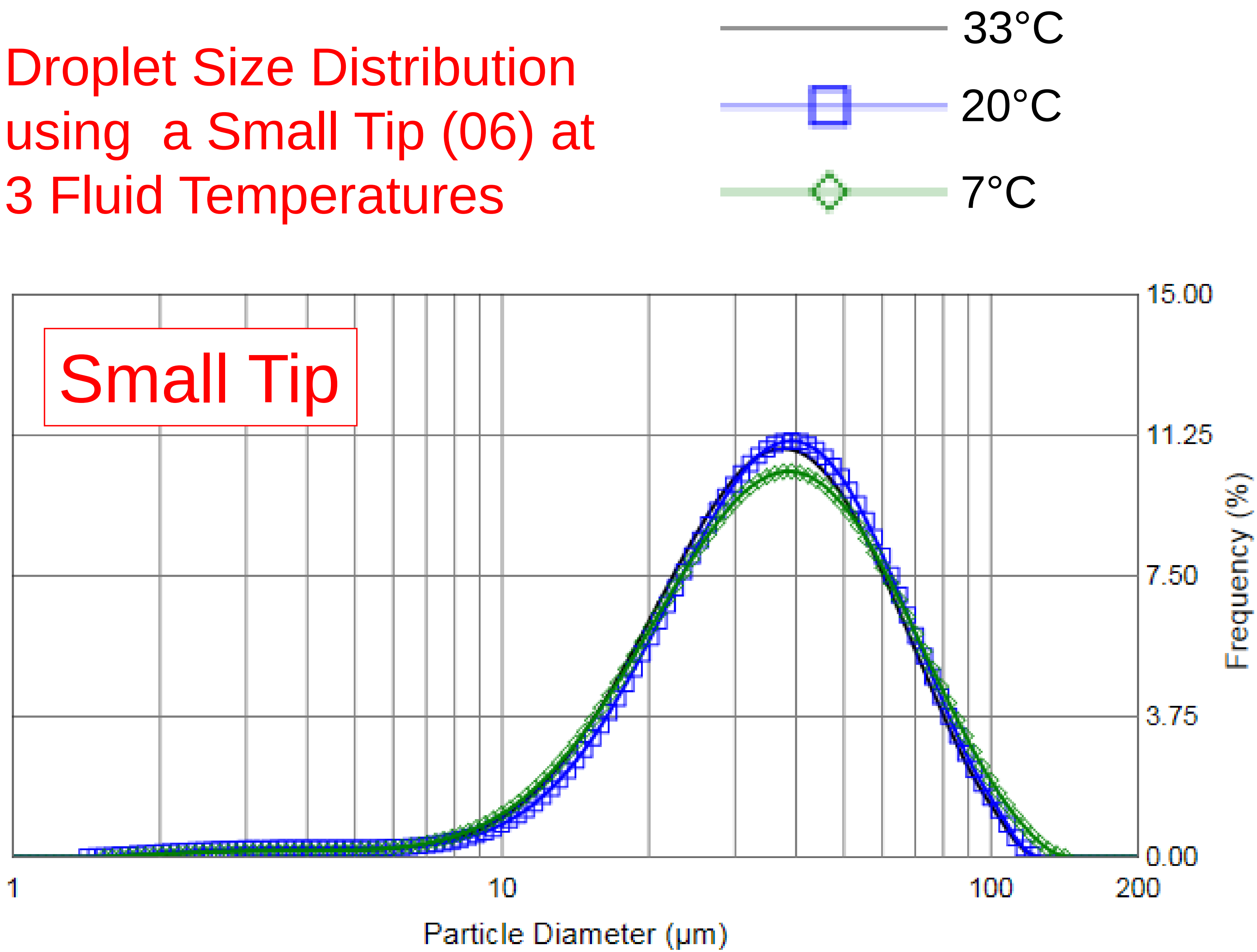
Three fluid temperatures

7°C (45°F)
20°C (68°F)
33°C (91°F)

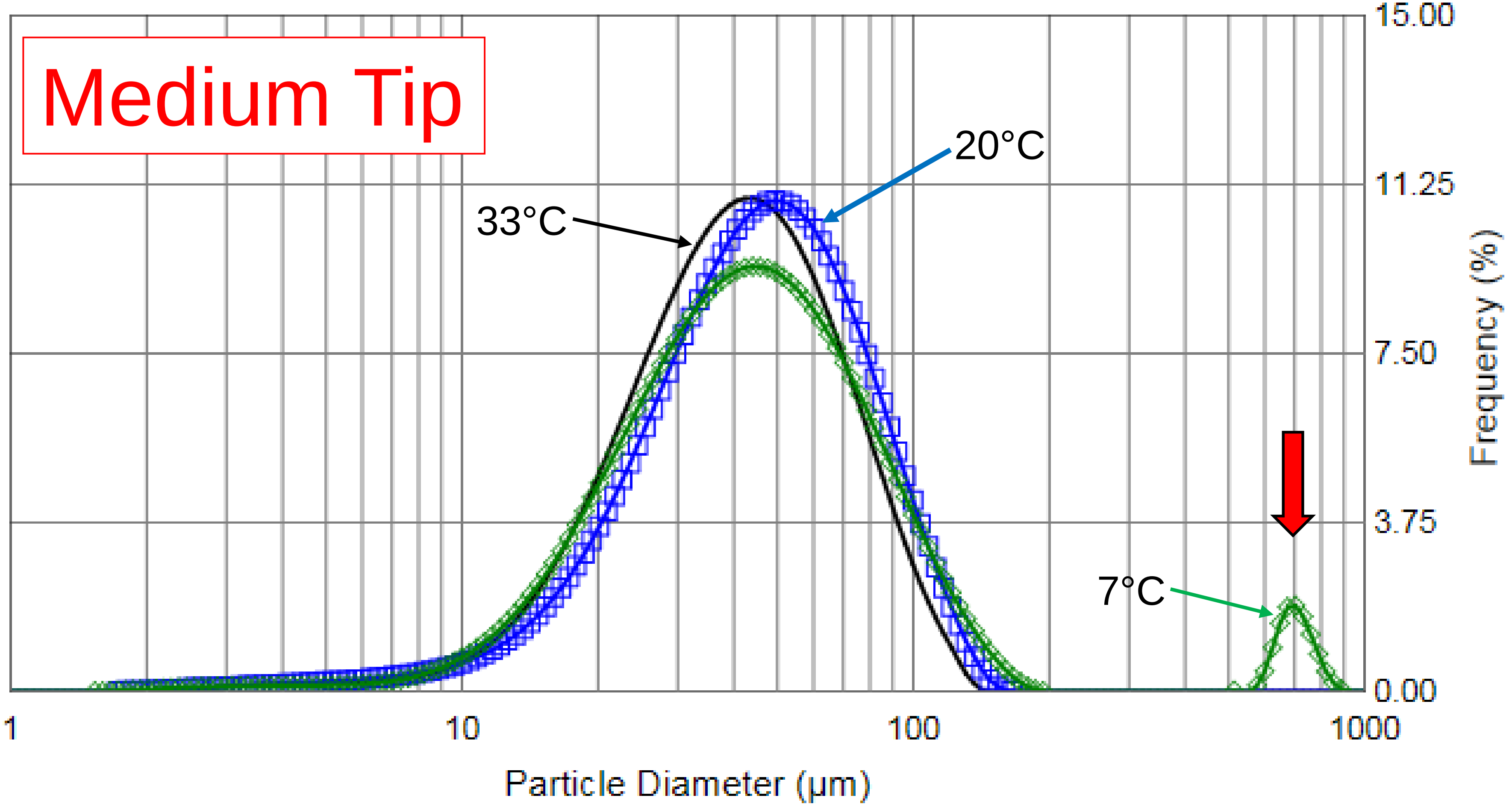

Spraytec
File Edit View Measure Tools Security Window Help
SOP - JK ICA top coat.ssop
Settings
Start
Stop
Alignment
Next
Help
Close
Background
Inspection
Measure sample
Autoscale
10
0
Obscuration(%):
0.00
Light Energy
Detector Number
10
20
30
Setup the sample as required and press the start button to begin measuring the sample.
JK ICA top coat 3.psh
JK ICA top coat.ssop
06 - 1.smea
Exp 001 - Jul 6 2017
JK ICA top coat 1.psh
JK ICA top coat 2.psh
JK ICA top coat 3.psh


Effect of Fluid Tip Size on Droplet Size Distribution (coating sprayed at room temperature)
Small tip size (06)
Medium tip size (09)
Large tip size (12)
20.00
15.00
10.00
5.00
0.00
Frequency (%)
1
10
100
1000
Particle Diameter (µm)

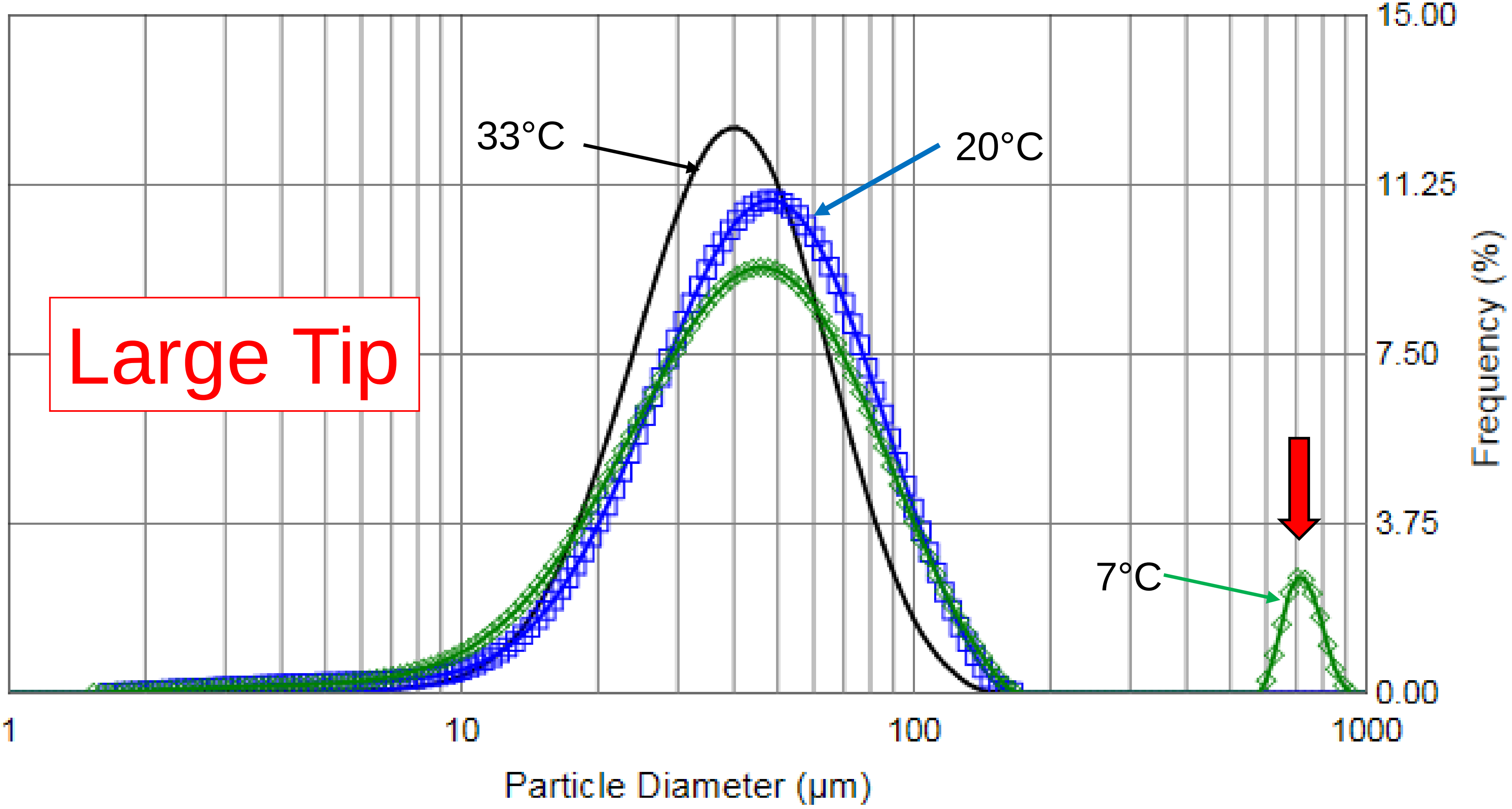
Droplet Size Distribution using a Small Tip (06) at 3 Fluid Temperatures



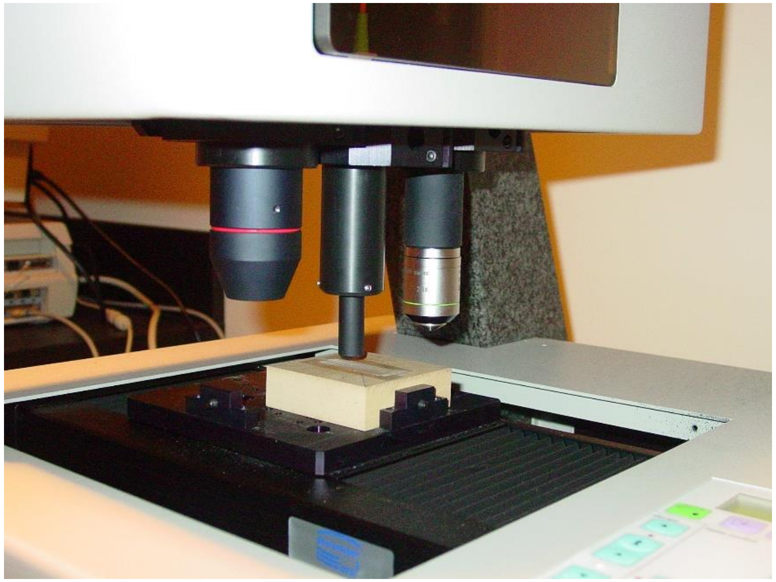
Droplet Size Distribution using Medium Tip (09) at 3 Fluid Temperatures



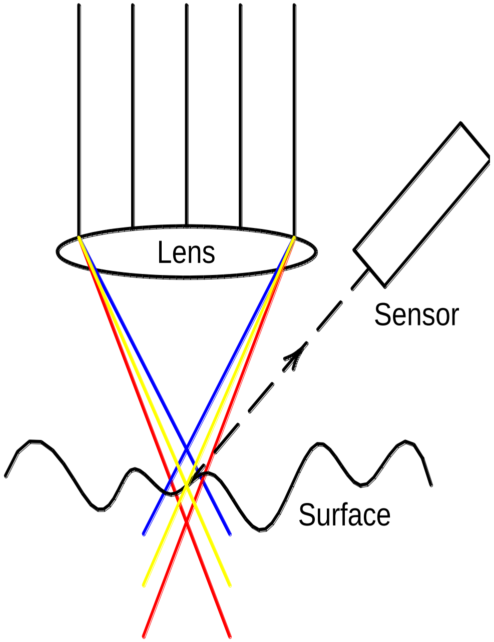
Droplet Size Distribution using Large Tip (12) at 3 Fluid Temperatures



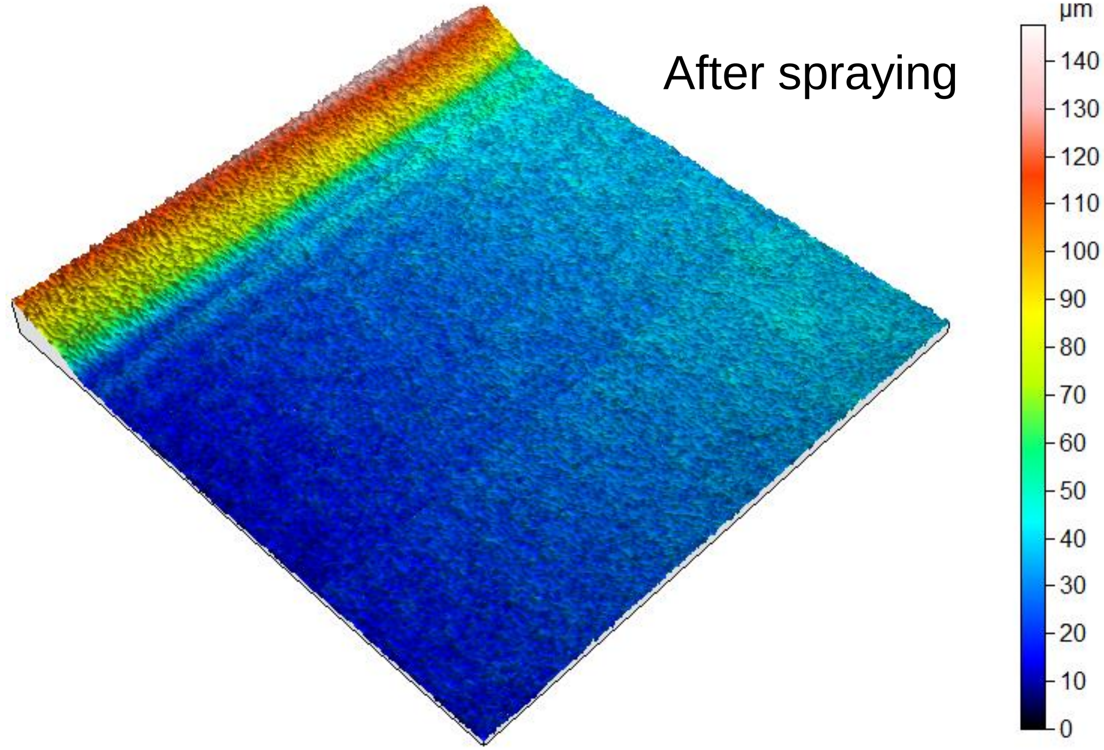
Surface Profileometry



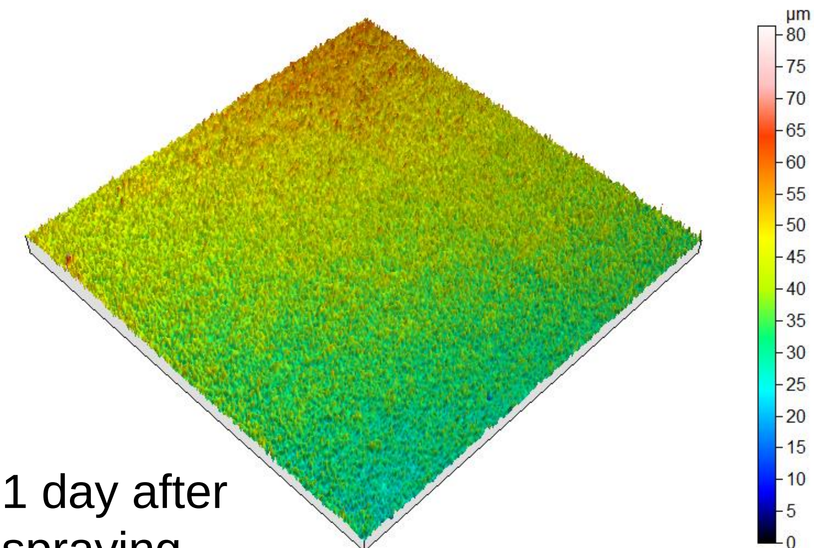
Cotec Altisurf profileometer



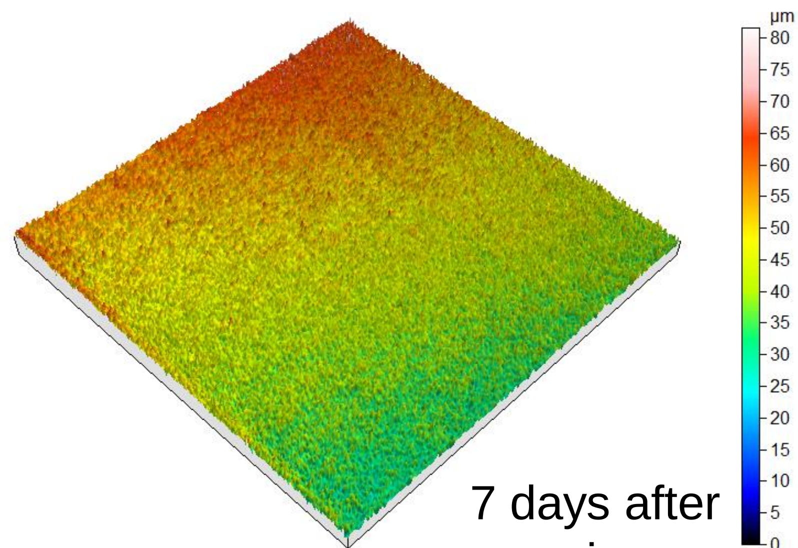
Surface Quality of Coating on Glass Sprayed Using Tip 09



After spraying



1 day after spraying



7 days after spraying

Roughness of Coating on Glass and MDF (sprayed at room temperature)

Spray setup		Roughness (*Ra*) of coating on glass		Roughness (*Ra*) of coating on MDF	
		0 days	7 days	0 days	7 days
(1)	Tip 06-092	1.91 µm	1.72 µm	1.66 µm	1.78 µm
(2)	Tip 09-152	1.65 µm	1.41 µm	1.54 µm	1.74 µm
(3)	Tip 12-152	2.07 µm	1.63 µm	1.65 µm	1.73 µm

(1). 4.5 bar fluid pressure,1.8 bar air pressure
(2). 3.0 bar fluid pressure, 1.4 bar air pressure
(3). 2.0 fluid pressure, 1.4 bar air pressure

Summary

There were differences in droplet size distribution with tip size (droplets were smaller with finer tip, as expected)

At low (fluid) temperatures some of the fluid passing through larger tips was poorly atomized (some large droplets)

The combination of droplet size measuring equipment (Spraytech) in combination with ultra-sensitive surface roughness measuring device (Altisurf) has the ability to produce very valuable information for companies

UBC

Centre for Advanced Wood Processing

Why Can’t I Achieve Colour Consistency with Stained Veneer Panels at Certain Times of the Year?

CANADA'S ECONOMIC ACTION PLAN
PLAN D'ACTION ÉCONOMIQUE DU CANADA

Review of Field

No existing relevant literature

Evidence that dyeing of wool is influenced by its moisture content*

Wool is a moisture sensitive material like wood

*Adamiak UM, Dittrichs J-H, Struckmeier S, Reumann R-D. 2001. Right-first-time production in batch dyeing of wool. Colour Technol 117(6): 313-317

Hypothesis

‘The colour of stained wood veneer panels will be influenced by the moisture content of the veneer panels’

Experimentation

Five types of veneer panels were tested: Alder, Mahogany, Maple, Oak and Pine Panels (8 per species) were conditioned to 3 different moisture contents (6, 12 and 20%)

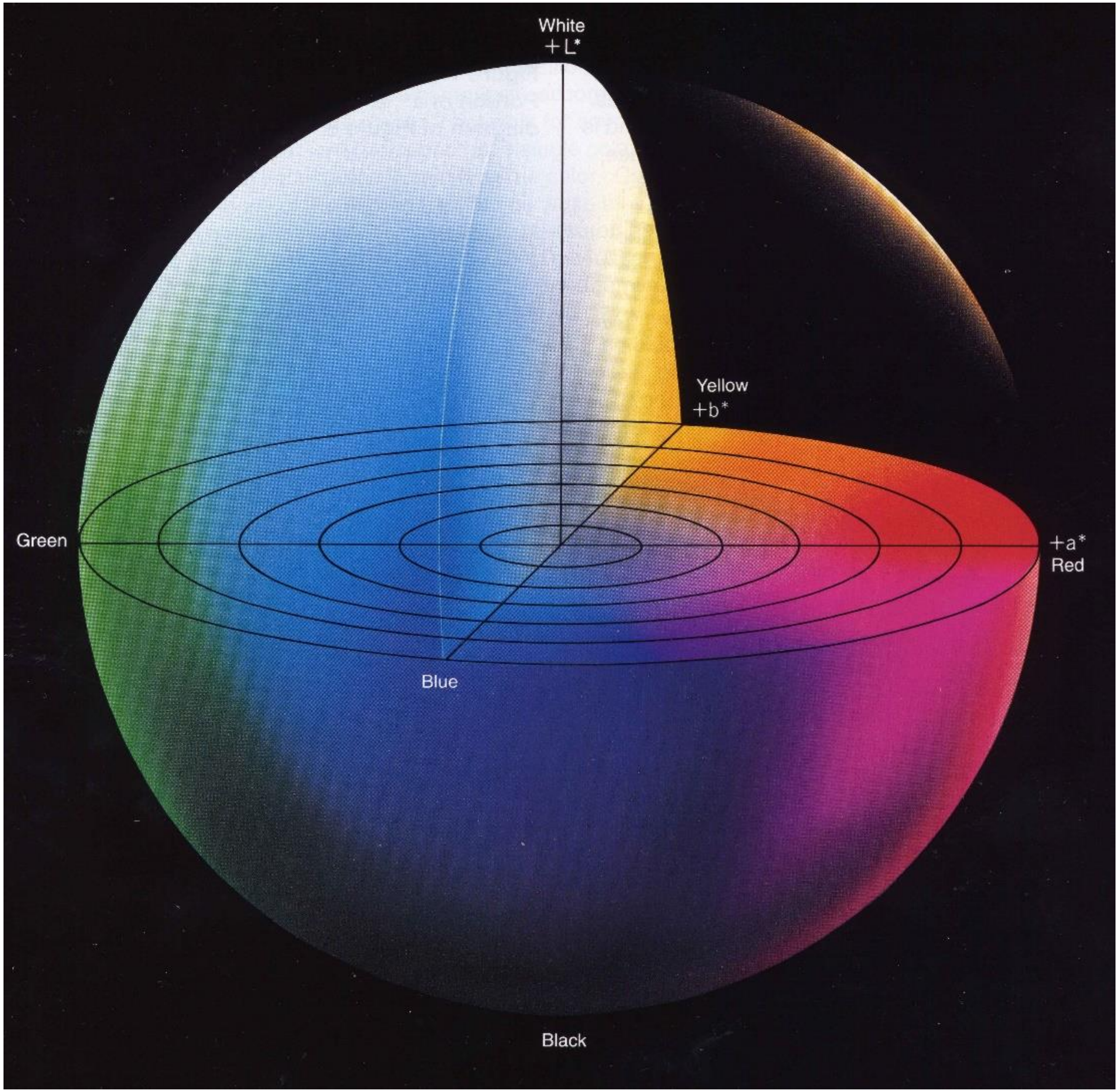
Veneer was stained with a red solvent-borne wiping stain and half of each veneer panel was finished with a clear catalysed lacquer

Colour was measured with a spectrophotometer and expressed using CIE L, a, and b parameters

Conditioning & Colour Measurement

Chamber for controlling temperature and humidity

Spectrophotometer for measuring colour of stained wood



L = Light (white =100) to dark (black = 0)

a = red (+ 60) to green (- 60)

b = yellow (+ 60) to blue (- 60)

CIE Lab colour parameters

Target and Actual Moisture Contents (MC) of Veneer-faced Specimens After Conditioning

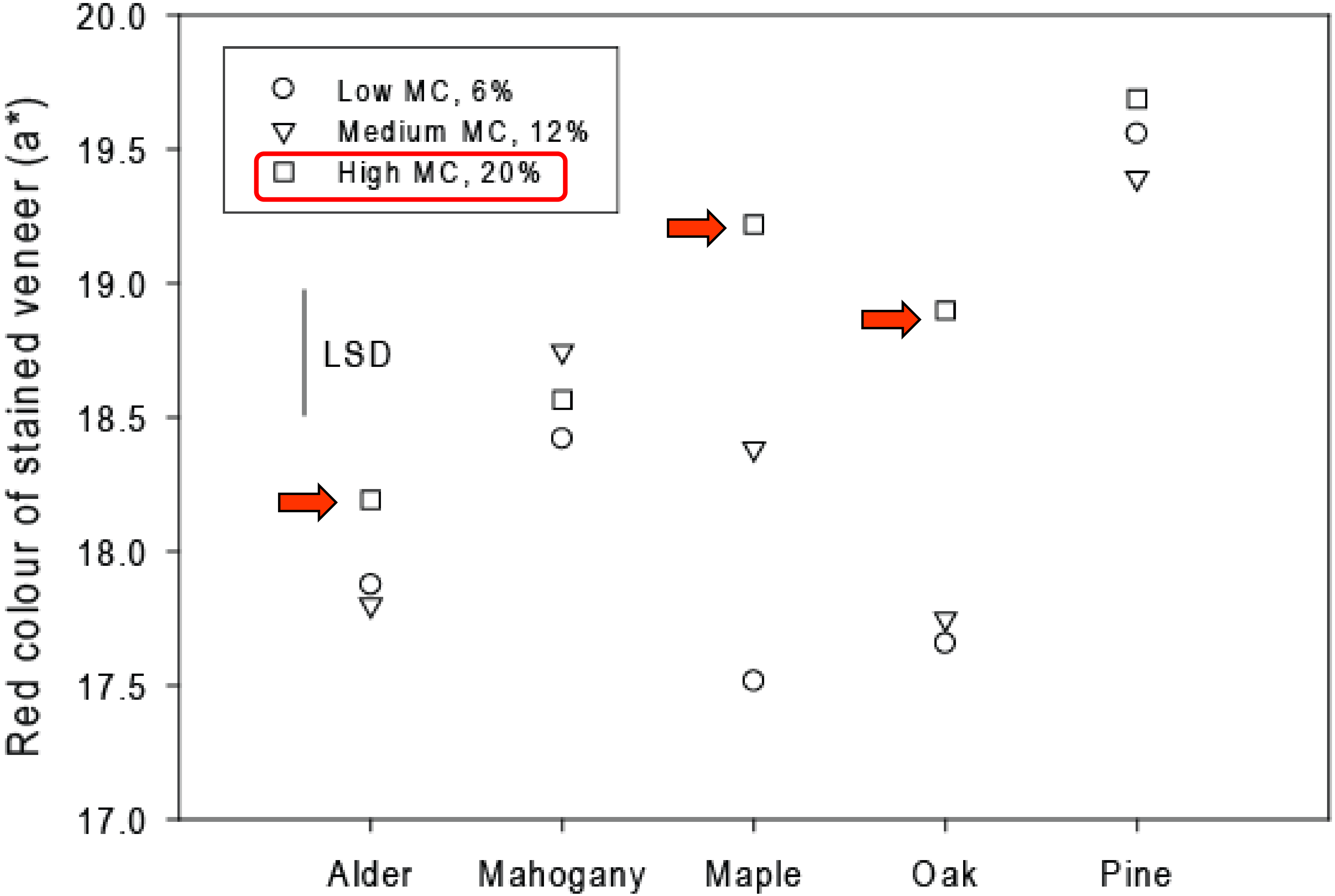
Target MC (%)	Temp. (°C)	R.H. (%)	*Actual Moisture Contents of Conditioned Specimens (%)				
			Alder	Mahogany	Maple	Oak	Pine
20	25	85	18.4	18.5	17.4	18.7	19.2
12	20	65	10.6	8.7	12.0	9.6	12.5
6	25	35	6.6	5.7	6.7	6.4	7.3

*Each figure for the moisture content of conditioned wood specimens is the mean of measurements made on 8 individual specimens

Results

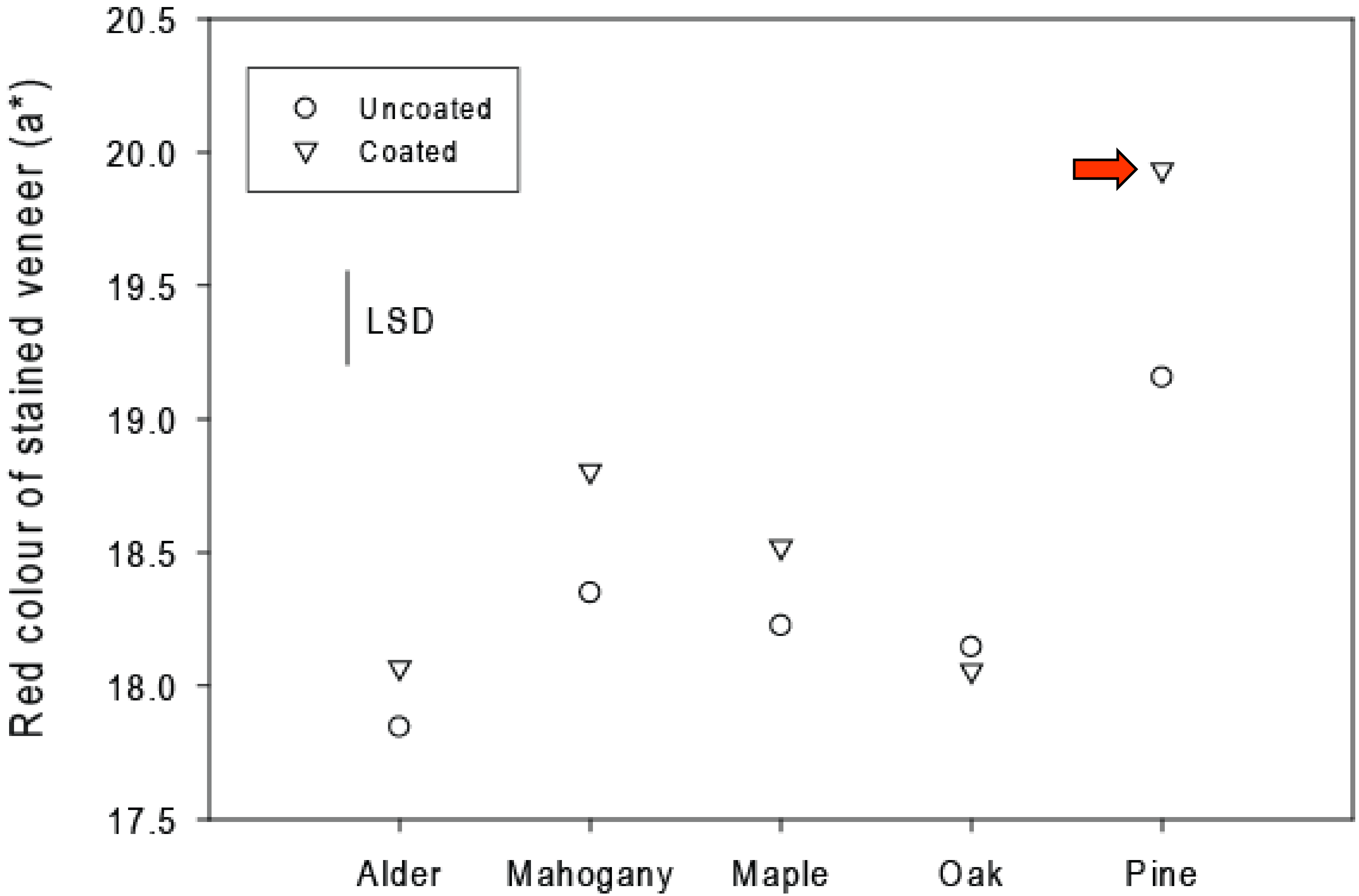
Effect of Moisture Content and Clear-coating on the Colour of Stained Veneer Panels

Red Colour of Stained Panels



Effect of Clear Coating

Effect of Clear Coating on Redness



Summary of Results

Panels conditioned to 20% moisture content were generally redder than panels conditioned to 6 or 12% moisture contents (particularly maple and oak)

Panels conditioned to 20% moisture content were also darker than those conditioned to lower (6 and 12%) moisture contents (particularly mahogany and oak)

Coating samples with a clear lacquer made them redder (pronounced in mahogany and pine) and darker (pronounced in alder, mahogany and pine)

Conclusions & Recommendations

We conclude that large departures from the recommended moisture content for staining (6-8%) can significantly alter the colour of mahogany, maple and oak stained with a solvent-borne wiping stain

Variation in the colour of stained veneer panels can be reduced by minimising variation in their initial moisture content

Surface moisture content of wooden components could be measured before finishing to ensure that their moisture contents fall within certain tolerances

These tolerances will vary between species, because the effect of moisture content on the colour of stained wood varied between species

Publication of Results

Once a paper is published its sometimes difficult for the public to access the findings because the publishers charge a fee to each person who wants to download the paper!

The solution to this problem is for authors to publish their work in open access journal, as we did for our grain raising research

A Note on the Effect of Wood Moisture Content and Clear Coating on the Color of Veneer Panels Stained with Solvent-Borne Stain

Philip D. Evans
Ian Cullis

Abstract

Red alder, mahogany, maple, white oak, and pine veneer panels conditioned to 6, 12, or 20 percent moisture content (MC) were stained with red solvent-borne stain, partially coated with clear lacquer, and air dried. All of the hardwood panels stained at an MC of 20 percent were either significantly redder or darker than panels stained at lower MCs. Clear coating made panels darker and redder (except oak). We conclude that large departures from the recommended MC for staining (6% to 8%) can significantly alter the color of hardwood veneer panels stained with solvent-borne stain.

The staining of wood with solvent-borne stains is an important part of the finishing of furniture, and in 2009 over 2.8 million liters of interior solvent-borne stains were used in the United States (US Census Bureau 2010). Staining can be used to give wood a more attractive even color that mimics the color of more expensive woods (Newell and Holtrop 1961). Once this has been achieved, the color needs to be reproducible within and between stained pieces by carefully controlling the staining process. Reproducing exactly the same color during the staining of wood, however, is difficult in practice. Variation in the color of stained wood can be reduced by applying a sealer before staining to reduce differential absorption of stain or by restaining pieces, which can involve applying stain between coats of lacquer (glazing) or applying a tinted lacquer to the wood (toning). These additional finishing steps allow furniture manufacturers to control wood color, but they also increase the overall complexity and cost of finishing.

Controlling color and minimizing color variation is also important in other industries. The textile industry in particular has carried out research on the factors affecting the dyeing process to better control the color of dyed fabric (Adamiak et al. 2001). One factor that has been shown to have an important effect on the color of dyed textiles is the moisture content (MC) of the yarn. Moisture-sensitive yarns such as wool can show differences in MC of up to 8 percent when atmospheric relative humidity (RH) changes from 40 to 80 percent (Adamiak et al. 2001). Changes in the MC of wool before dyeing can create noticeable differences in the color of dyed yarn that exceed commercially acceptable tolerances (Adamiak et al. 2001). Wood is also a moisture-sensitive material, and its MC can change significantly as a result of fluctuations in atmospheric RH (Millett 1951). Accordingly, we hypothesize that changes in the MC of wood before finishing will alter the color of the stained wood. An increased understanding of factors affecting the staining of wood could lead to better control of the staining process and less variation in the color of stained wood and possibly lower manufacturing costs due to prevention of defects and restaining.

Materials and Methods

Forty veneer panels overlaid with red alder (*Alnus rubra* Bong), mahogany (*Swietenia* sp.), maple (*Acer* sp.), white oak (*Quercus* sp.), or pine (*Pinus* sp.) veneers (eight panels per species) were donated by Pacific Rim Cabinets, Delta, British Columbia, Canada. Panels were sanded with 120, 150, and 180 grit aluminum oxide paper using a wide-belt sander and then cut into three specimens, 10 by 10 cm square (120 specimens in total). Specimens were placed in three different chambers and conditioned to 20 percent (high), 12 percent (medium), or 6 percent (low) MCs (Table

The authors are, respectively, Professor and Research Associate, Centre for Advanced Wood Processing, Univ. of British Columbia, Vancouver, British Columbia, Canada (phil.evans@ubc.ca, icullis@forestry.ubc.ca). This paper was received for publication in October 2009. Article no. 10699.

Forest Prod. J. 60(3):000–000.

Overall Conclusions

Our work on wood finishing has been valued by industry, but the government schemes that supported our work were discontinued. Funding is now directed to other priority areas (tall wood buildings, genetically modified trees, making wood into alcohol, etc). Why?

It's a great pity that there are no avenues for support for work on the very complex challenges of finishing wood. Why?

Thanks & Q's

- I thank Natural Resources Canada (NRCAN) Value-to-Wood Research Scheme, Canadian Foundation for Innovation, BC Knowledge Development Fund for their past financial support of all of this research
- Thanks for your attention. Any Questions?