



Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences



Innovative wood materials

InnovaWood General Assembly 2015, Zagreb

Outline of presentation

- ▶ Presentation of BUAS
- ▶ Utilization of side streams
 - ▶ Extraction of bark, sustainable adhesives for wood products
- ▶ Light weight boards
 - ▶ development of a bio-based ultra-light particleboard
 - ▶ Structural Panel based on beech wood
- ▶ Adhesives for Hardwood

Bern University of Applied Sciences

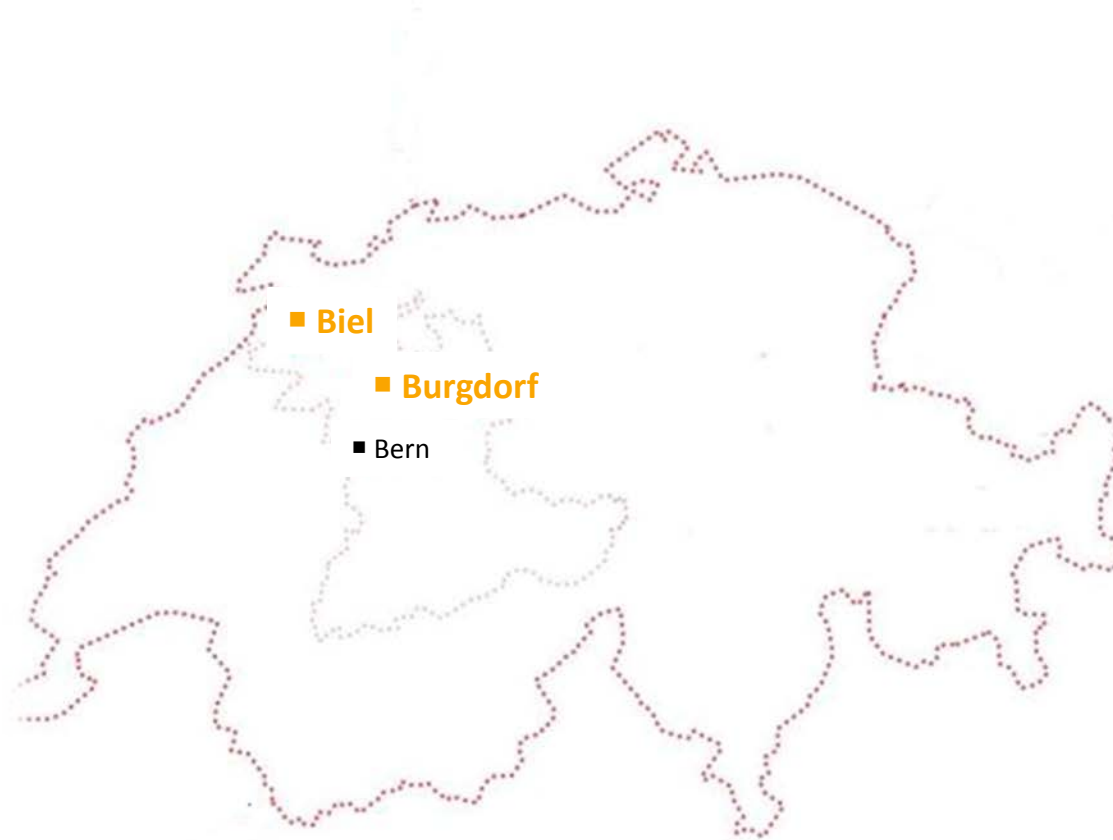
Foundation:	1. October 1997
Funding body:	Canton Bern
Bachelor's degree courses:	29
Master's degree courses:	21
Students:	6775
Staff:	2934

Departements

- ▶ Architecture, Wood and Civil Engineering
- ▶ Bern University of the Arts
- ▶ School of Agricultural, Forest and Food Sciences
- ▶ Engineering and Information Technology
- ▶ Business, Health, Social Work
- ▶ Swiss Federal Institute of Sports Magglingen

Bern University of Applied Sciences

Architecture, Wood and Civil Engineering



Biel campus

- Bachelor of Science in Holztechnik
- Master of Science in Wood Technology
- Continuing education in fields of wood, windows, sustainability, management, etc.
- Higher Technical School of Wood Biel
- Research and Development together with TechnologyPark



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7

Burgdorf campus

- Bachelor of Arts in Architecture
- Master of Arts in Architecture
- Bachelor of Science in Civil Engineering
- Master of Science in Engineering
- Continuing education in fields of construction and architecture, sustainability, management etc.
- Research and Development with Geotechnics laboratory (in cooperation with Bern University)



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8

Department Architecture, Wood and Civil Engineering

Foundation: 2003 Merger to department

Number of students: 800

Number of employees: 400

- ▶ BA in Architecture
- ▶ BSc. in Wood technology
- ▶ BSc. in Civil engineering

- ▶ MA in Architecture (Joint Master of Architecture JMA, cooperation with HES-SO)
- ▶ MSc. in Wood technology (cooperation with Hochschule Rosenheim)
- ▶ MSc. in Engineering MSE (Civil engineering, cooperation with all Swiss Universities of Applied Sciences)

Affiliated school: Higher Technical School of Wood Biel

Institute for Materials and Wood Technology

Institute for Materials and Wood Technology

- ▶ Research activities focus on the development of wood-based materials
- ▶ Research fields : Wood surface treatment and wood modification, Material emission, wood chemistry and adhesive technologies
- ▶ Market: Wood-based panel manufacturers, adhesive manufacturers, furniture industry, wood coating industry

- ▶ **Materials, Furniture and Design**
- ▶ **Wood and Surface Treatments**
- ▶ **Wood and construction adhesives**
- ▶ **Materials and Wood Chemistry**
- ▶ **Material Emissions und Extractives**

Heiko Thömen

Thomas Volkmer

Frédéric Pichelin

Reto Frei

Ingo Mayer

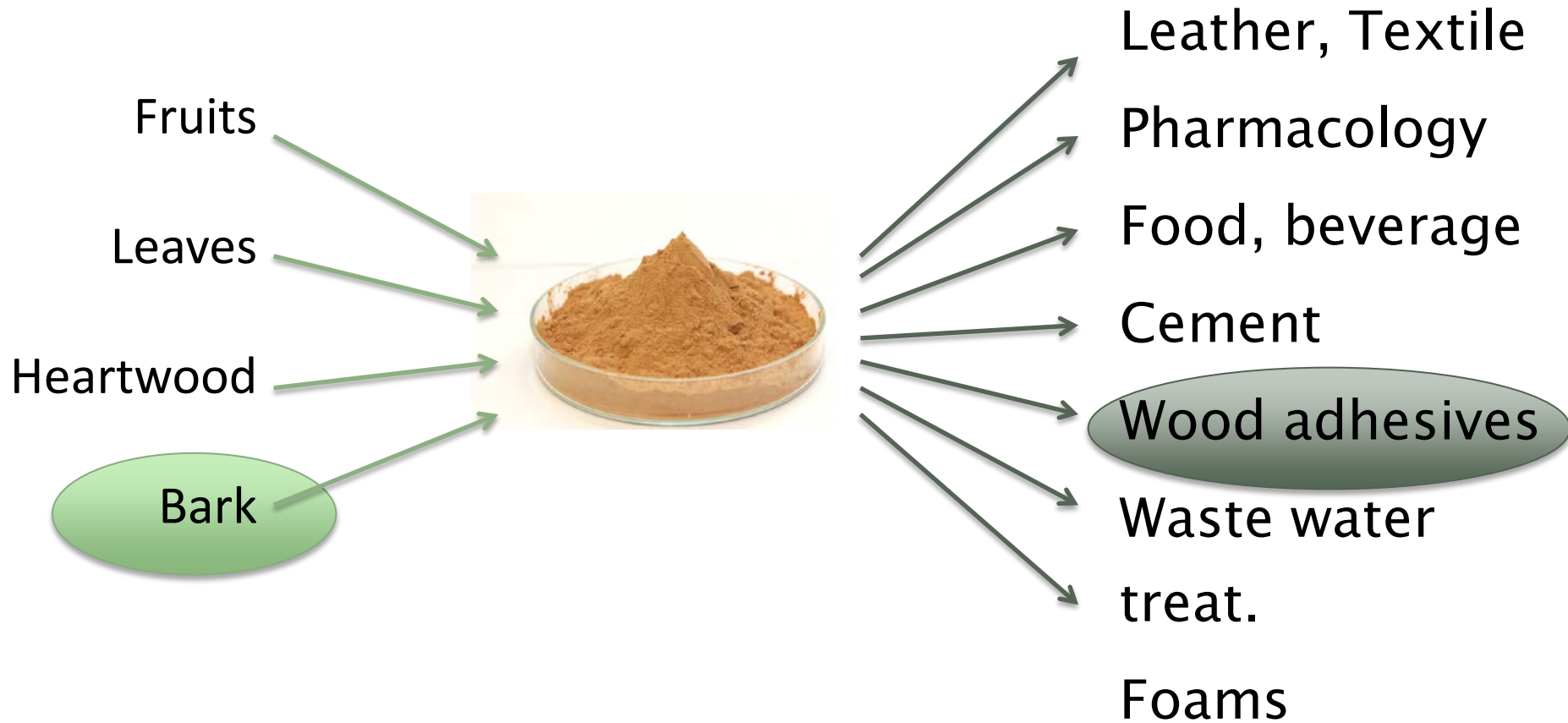


Extraction of Bark



Ressource Holz

Tannin



Tannin extraction from domestic softwood species

Objective:

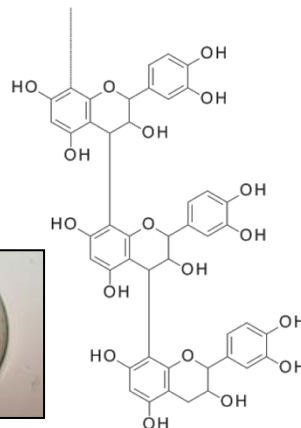
Development of a tailored extraction process for tannins from the bark of domestic softwood species

Application:

- Green adhesives for wood-based materials
- Composite materials from renewable sources

Relevance:

Solution for Switzerland in the field of bark valorization and green adhesives



Project team:



Dr. Frédéric Pichelin
Dr. Ingo Mayer
M.Sc. Sauro Bianchi



Dr. Ivana Kroslakova

UNIVERSITÄT
LIECHTENSTEIN

Dr. Hans Vettiger

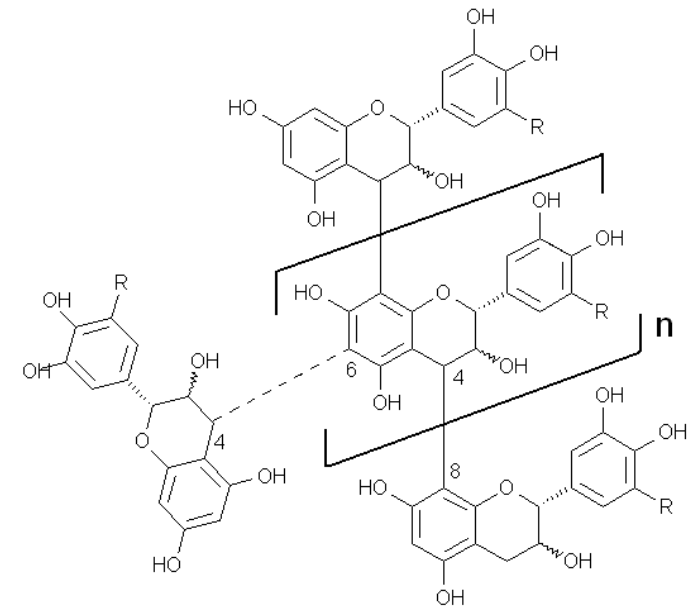
Running:

September 2012
to August 2015

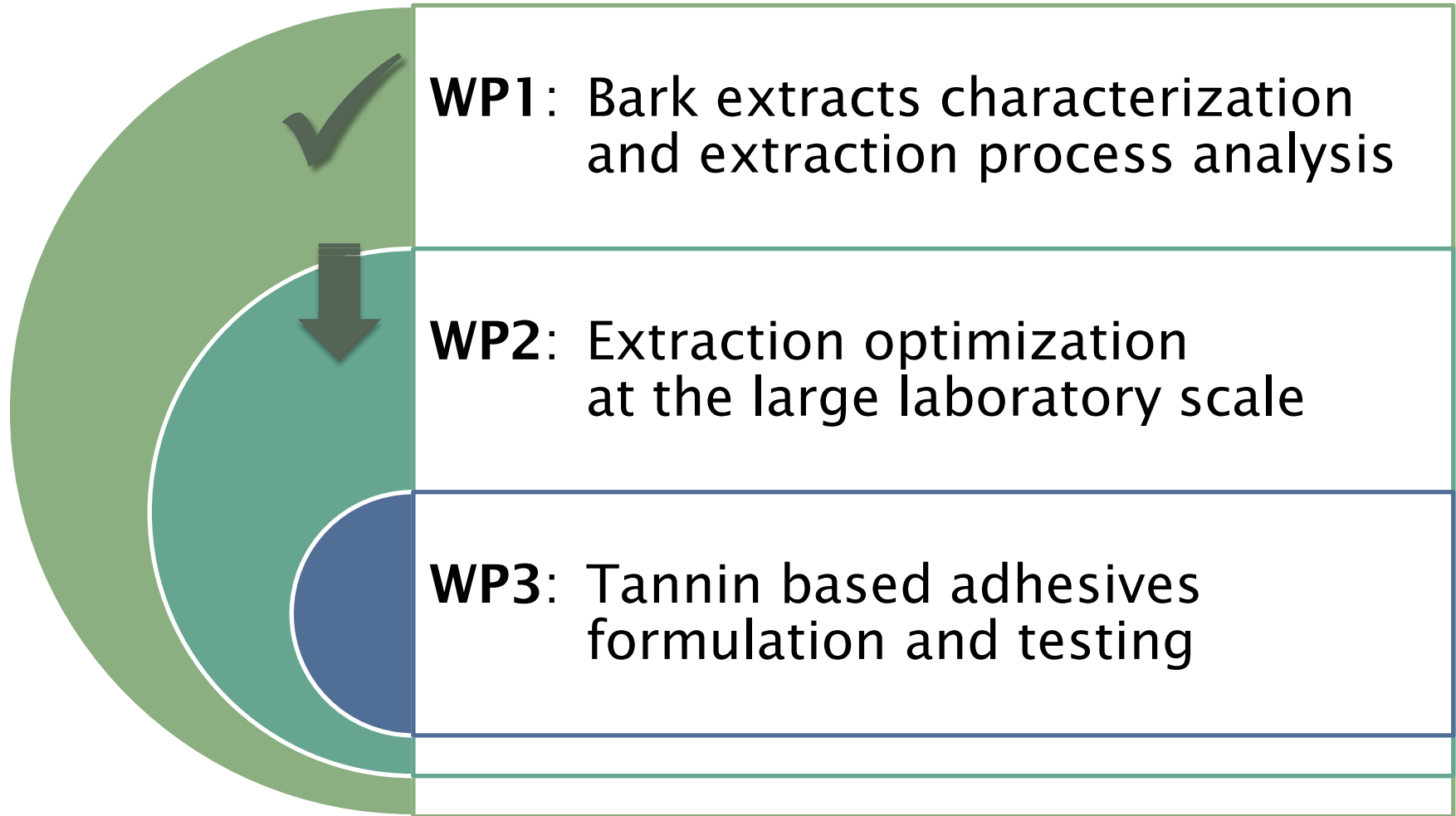
Extraction

❑ Selected species:

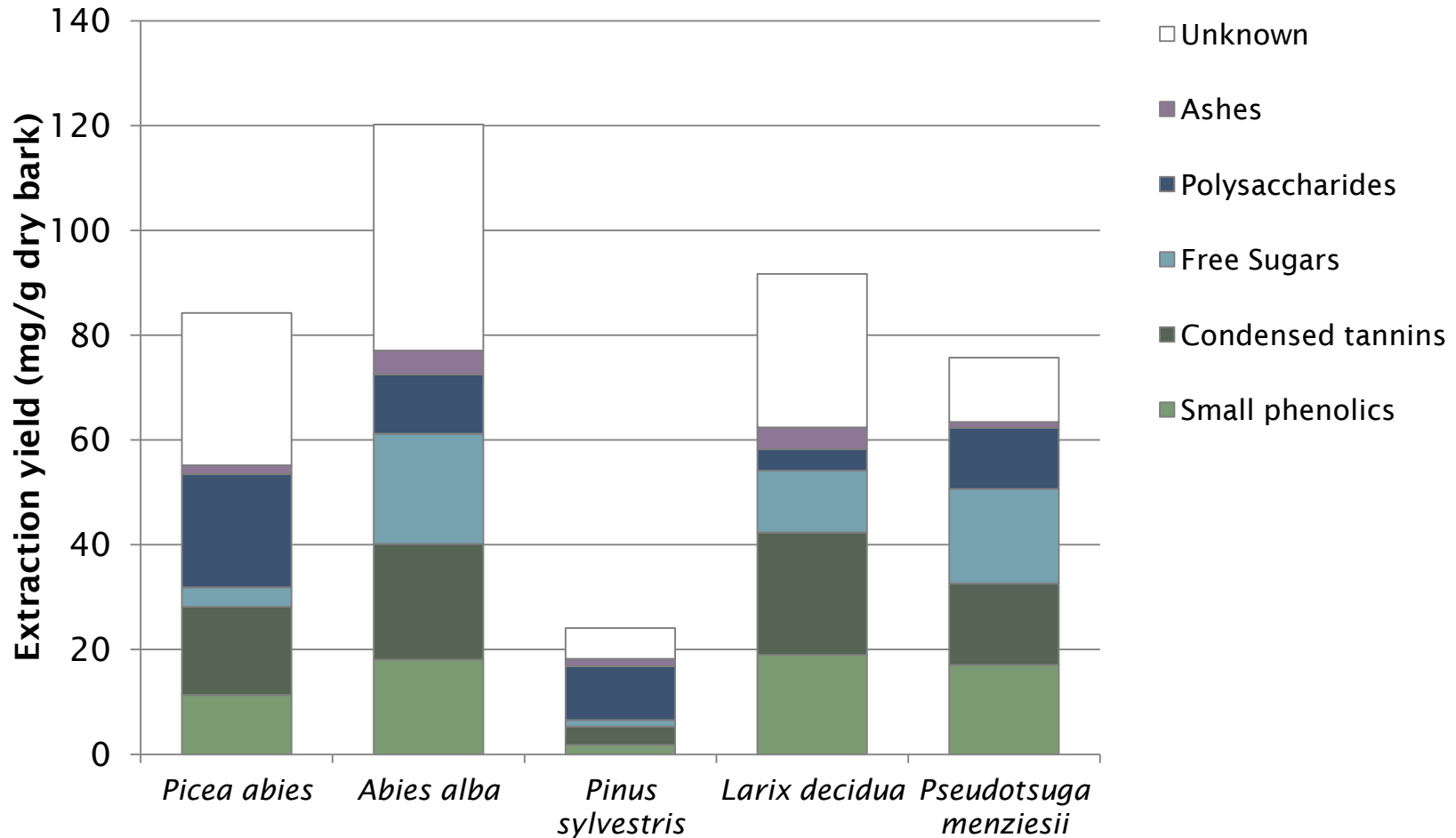
- *Picea abies* (Norway spruce)
- *Abies alba* (Silver fir)
- *Pinus sylvestris* (Scots pine)
- *Larix decidua* (European larch)
- *Pseudotsuga menziesii* (Douglas fir)



Project overview

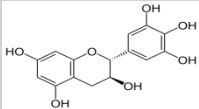
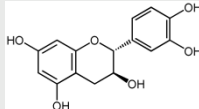
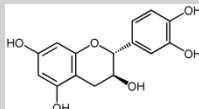
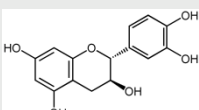
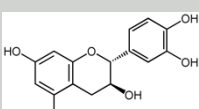


Bark extracts compositions



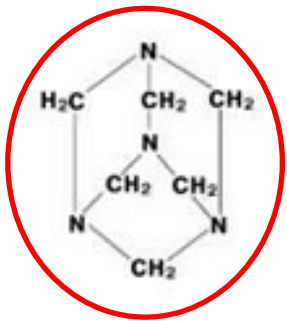
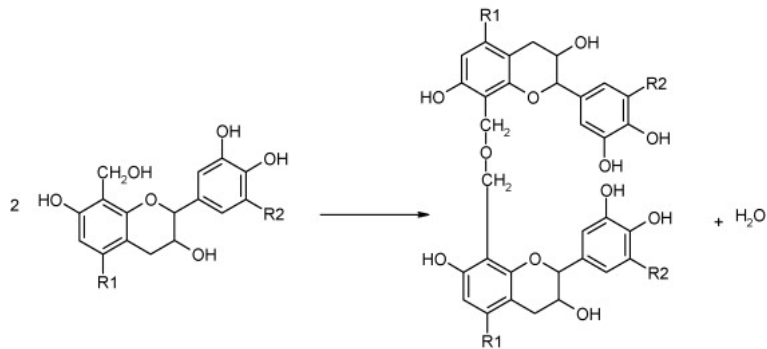
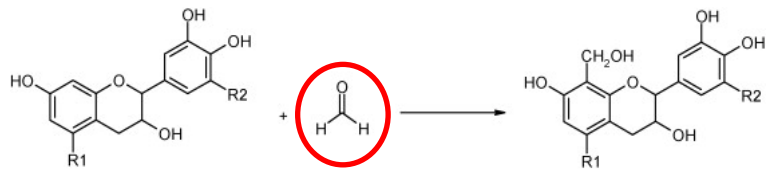
S. Bianchi, A. Glöss, I. Krosiakova, I. Mayer, F. Pichelin Analysis of the structure of condensed tannins in water extracts from bark tissues of Norway spruce and Silver fir using MALDI-TOF mass spectrometry, *Industrial Crops & Products* 61 (2014) 430-437

Bark tannin molecular structure

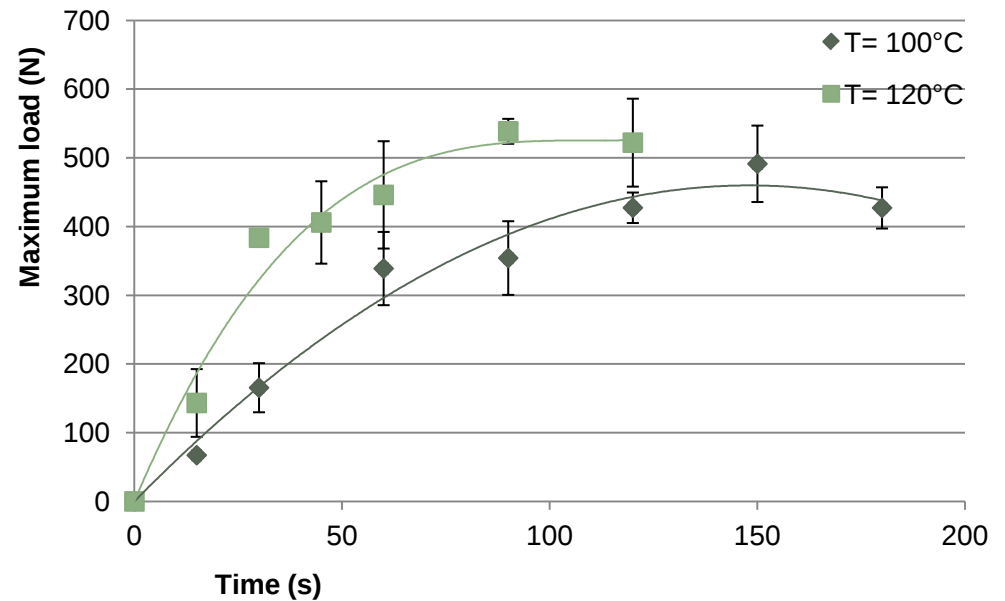
Species	Main structure	Other monomers	mean polymeriz. degree
<i>Abies alba</i>	Prodelphinidins 	Flavan-3-ol gallates	3.0
<i>Larix decidua</i>	Procyanidins 	Stilbene glucosides	3.5
<i>Picea abies</i>	Procyanidins 	Stilbene glucosides	4.5
<i>Pseudotsuga menziesii</i>	Procyanidins 	Flavan-3-ol glucosides	3.7
<i>Pinus sylvestris</i>	Procyanidins 	Flavan-3-ol glucosides	4.4

S. Bianchi, A. Glöss, I. Krosiakova, I. Mayer, F. Pichelin Analysis of the structure of condensed tannins in water extracts from bark tissues of Norway spruce and Silver fir using MALDI-TOF mass spectrometry Industrial Crops & Products 61 (2014) 430-437

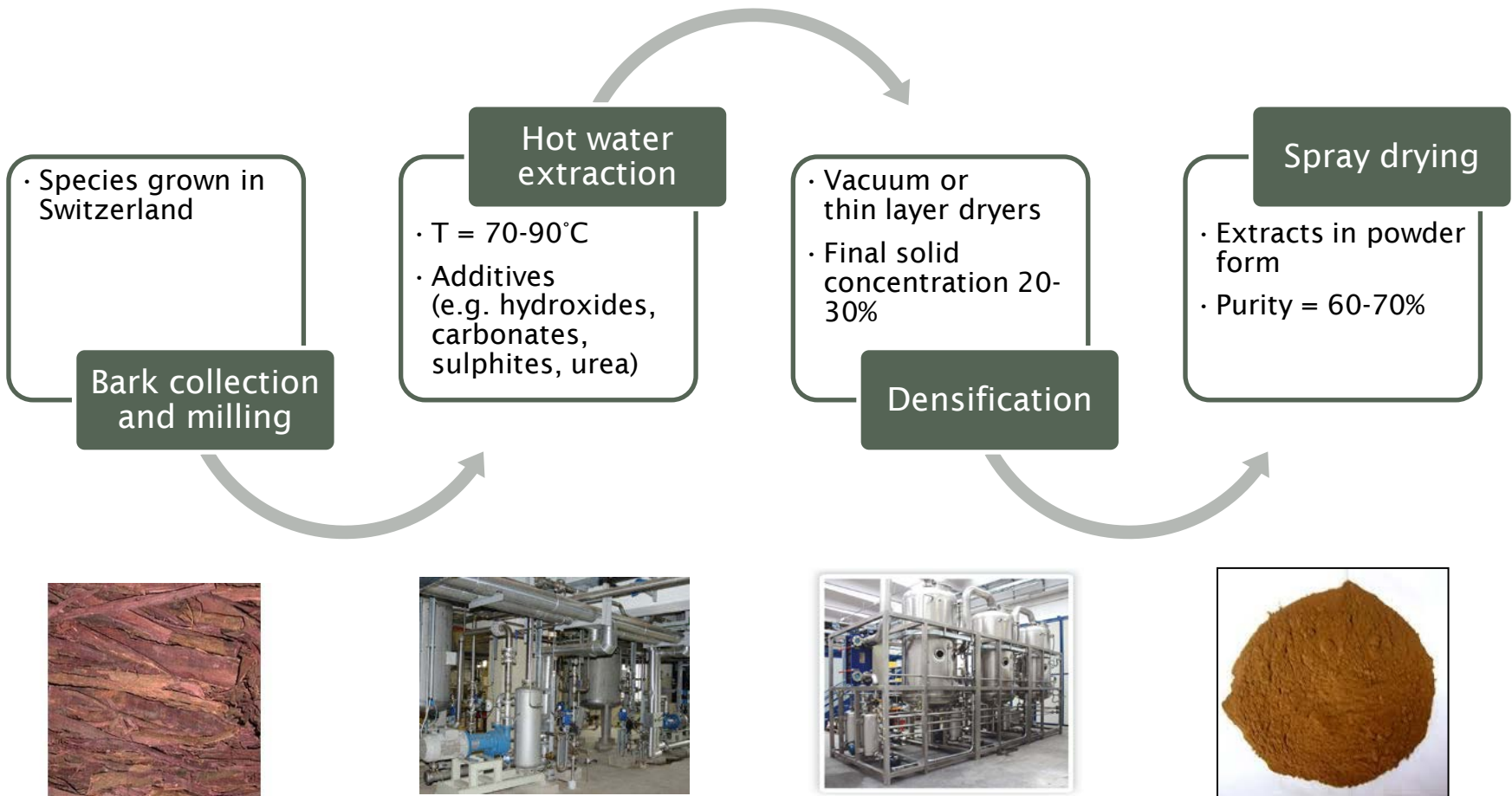
Adhesive formulation



Pinus radiata



Industrialization



Development of a bio based ultra-light particleboard



New generation of ultra-light particleboard

- ▶ Average density below 350 kg/m³
- ▶ Economically competitive with conventional wood-based panels
- ▶ Bio-based and biodegradable



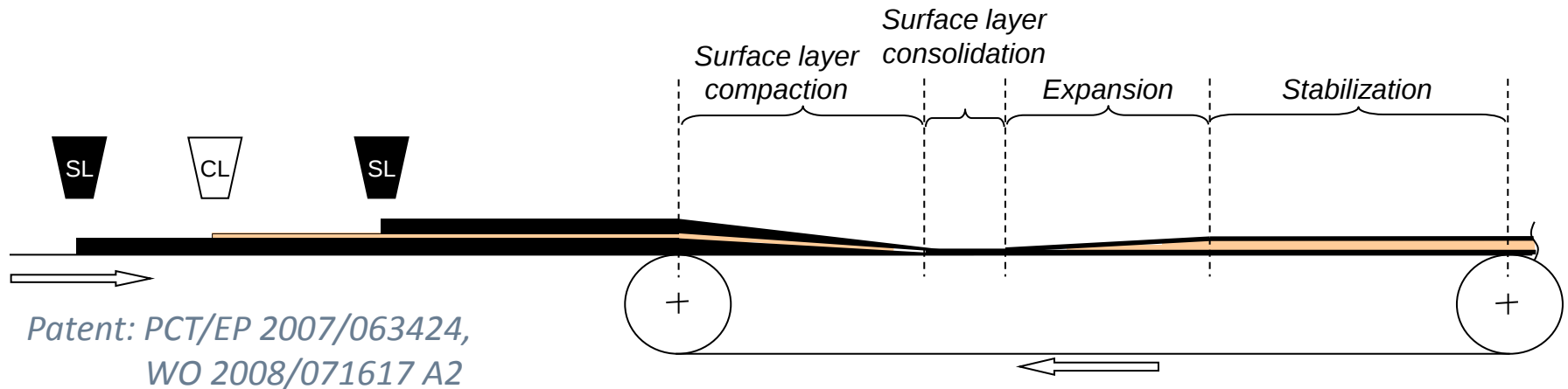


Applications of ultra-light particleboard

- ▶ Furniture
- ▶ Interior paneling
- ▶ Packaging



New: One-step process



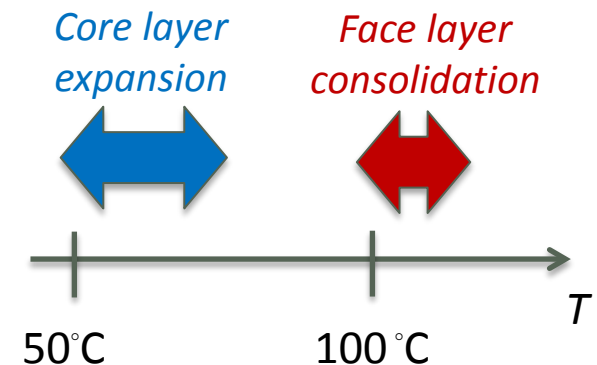
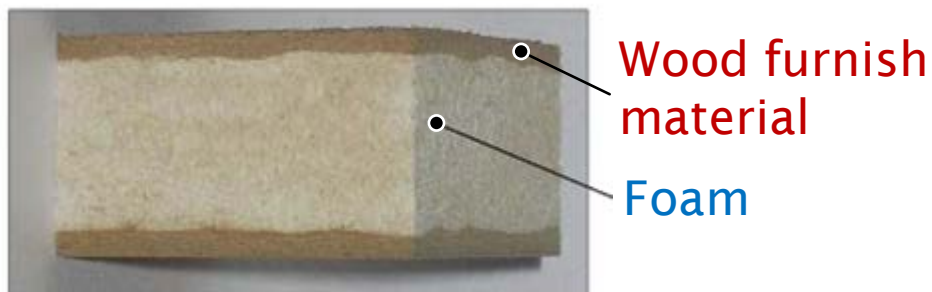
Board production in the wood-based panel lab



Objectives of project

... within the Swiss National Research Programme «Ressource Wood»

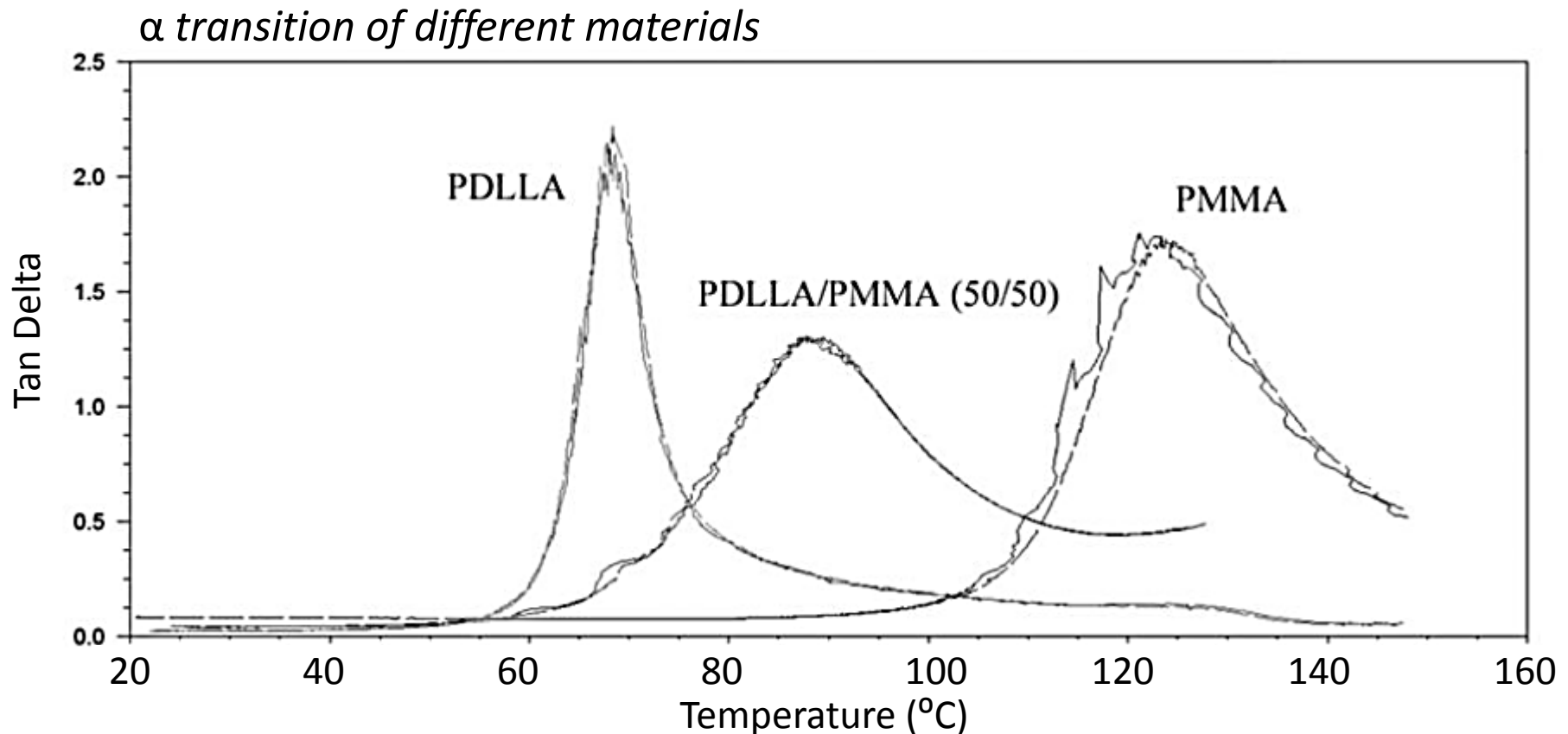
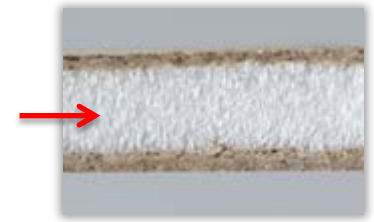
- ▶ Development of a bio-based foam
- ▶ Expansion of processing window for face layers
- ▶ Adaptation of board manufacturing technology
- ▶ Assessment of the environmental impact



Foam development

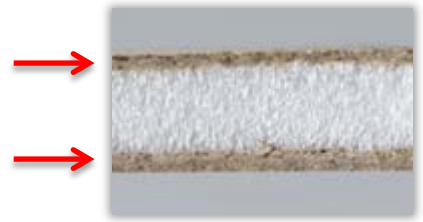
Material selection

- ▶ PLA/PMMA blend: Amorphous and semicrystalline grades of PLA could be tailored by blending with amorphous PMMA ($T_g \sim 120^\circ\text{C}$)



Low temperature adhesives

Literature review



1. Urea-formaldehyde with ammonium peroxodisulfate (80°C)
R. Marutzky, L. Ranta; 1979
2. Tannin-hexamine binder (70°C)
M.Theis, B.Grohe; 2002
3. PMDI – Huntsman (75°C - 85°C)
PR company report; 2010
4. Urea-formaldehyde with melamine salts (60°C - 65°C)
C. Kamoun, A. Pizzi; 1998

Reference:

5. Urea-formaldehyde with ammonium sulfate

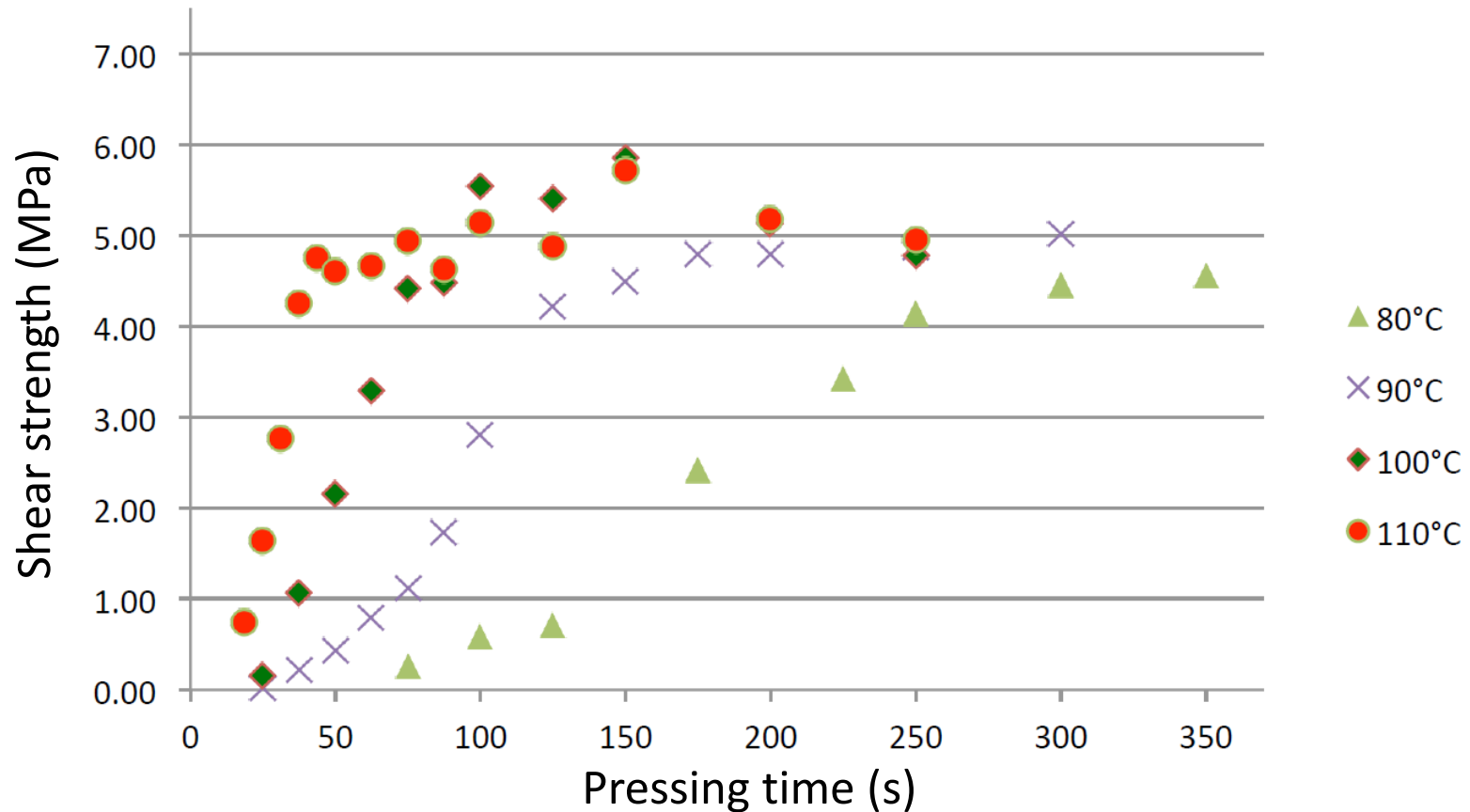
Low temperature adhesives

ABES tests



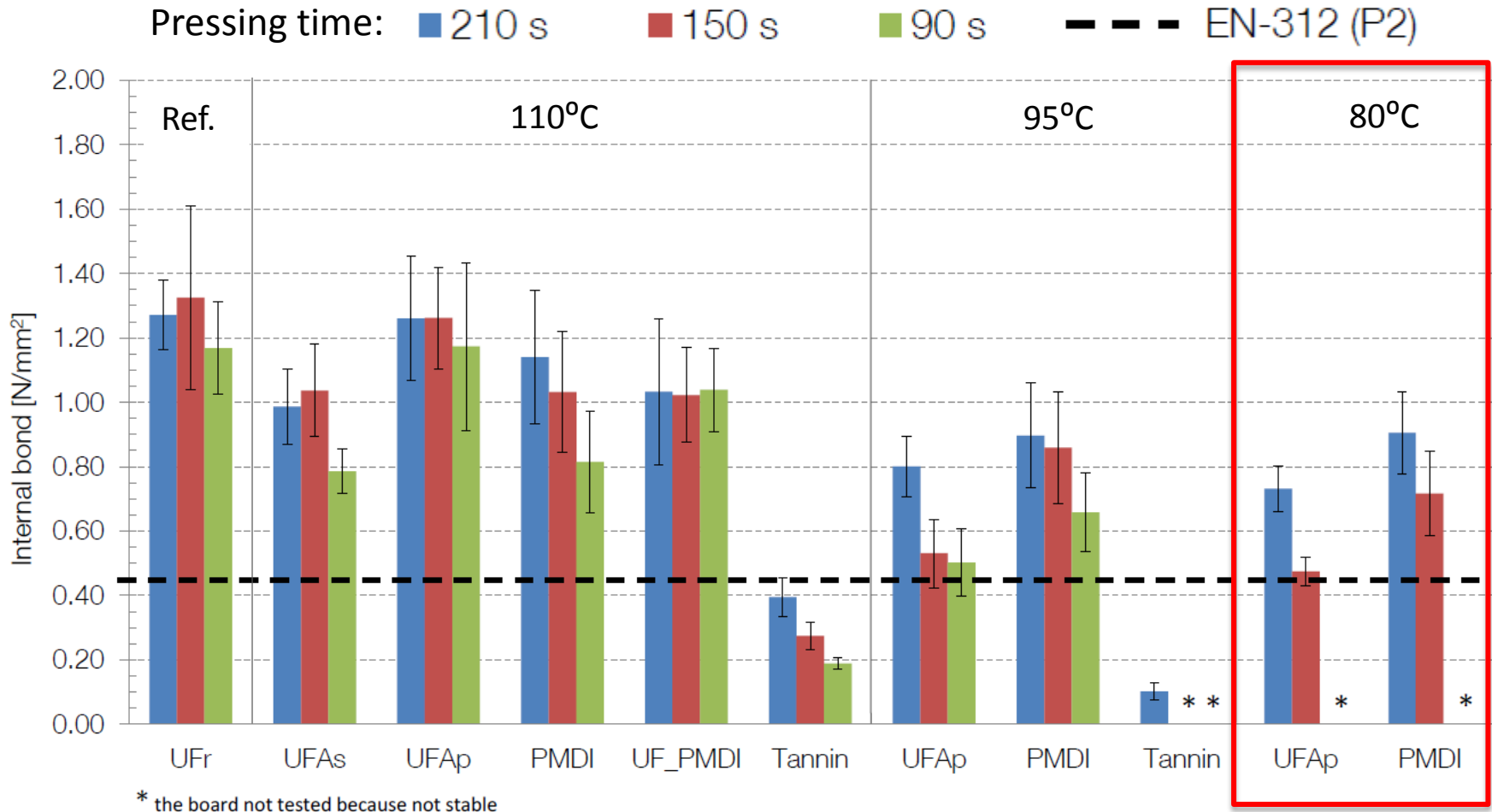
Typical ABES results

Here: UF adhesive with ammonium sulfate $(\text{NH}_4)_2\text{SO}_4/40\%$



Low temperature adhesives

Results of IB tests (EN 319)



UFAP = Urea formaldehyde / ammonium persulfate

PMDI = Polymeric methane diphenyl diisocyanate

Summary and conclusions

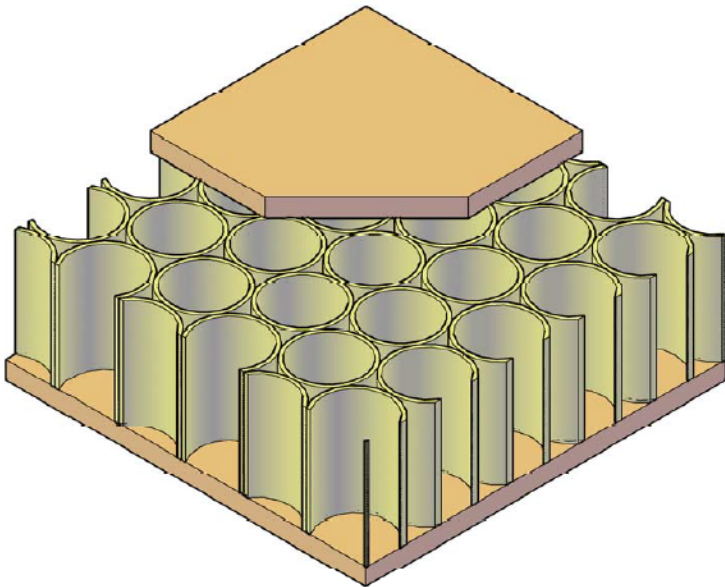
- ▶ Successfully demonstrated: Possibility of producing foam-core particleboard in a one-step process using a (partially) **bio-based foam** and **CO₂** as a blowing agent.
- ▶ Use of **PMMA** as an additive has provided an original, cost-effective and pragmatic solution to the shortcomings of pure amorphous PLA.
- ▶ For **surface layers**: Systems designed to cure at T well below 100°C are generally scarce on the market.
- ▶ From an **LCA** perspective there is a strong incentive to search for non-petroleum-based alternatives.
- ▶ Project phase II: Reinforcement of the PLA foam core with wood fibres and cellulose nanofibers
- ▶ New project partner: EMPA (Tanja Zimmermann)

Development of a structural panel based on beech wood

Motivation

- Increased utilization of Beech wood for construction
 - Availability of Beech wood (also in future)
 - High strength
 - Challenge bonding of surfaces
- Efficient utilization of the material
- Sustainable construction
- Development of a light-weight building board based on beech wood
- Use as wall panel and/or floor element
- Mechanical Properties independent of loading direction
- Easy composition and production technology

Basic Idea



- Steel 7850 kg/m³
- Reinforced concrete 2500 kg/m³
- Light weight concrete 800 – 2000 kg/m³
- Brick 1000 – 1800 kg/m³
- Beech ~ 660 kg/m³
- Spruce ~ 420 kg/m³
- Honeycomb 150 – 450 kg/m³
- Beech ultralight < 100 kg/m³

Board construction

- Prototype is produced on lab scale
- Rolls can be produced with designed equipment
- The equipment is flexible according to material and diameter of the rolls
- Short term load bearing capacity
 - Two layer rolls meet the requirement
 - Fiber board can be used as surface layer
- Long term load bearing capacity
 - Increased humidity leads to uncontrolled deformation
 - Change to a melamin based adhesive system
 - Plywood as surface layer

Perspectives

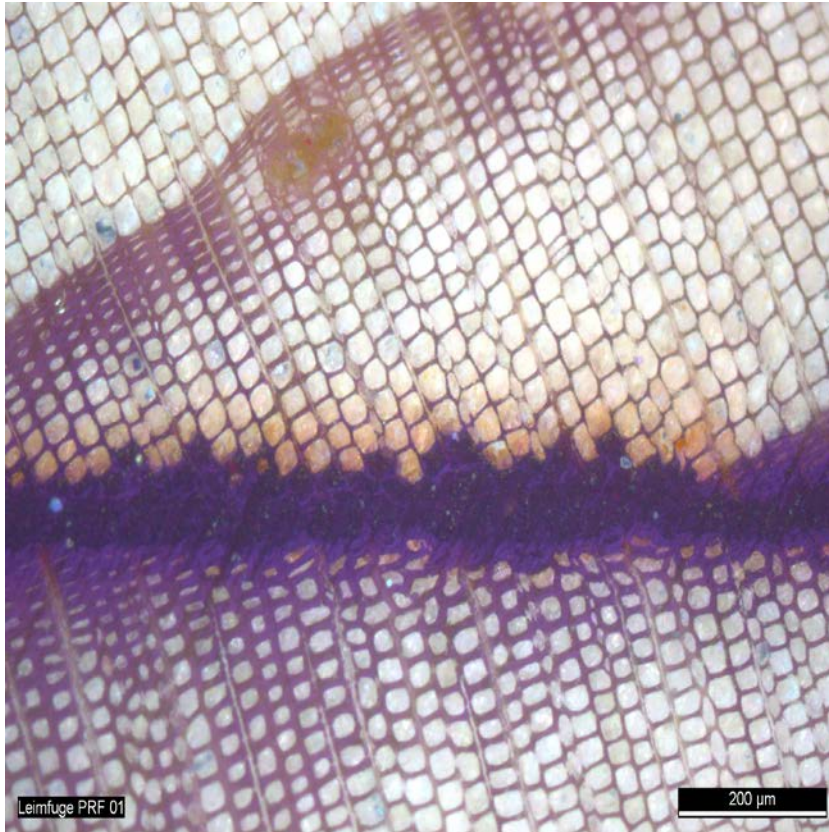
- **Some challenges for the utilization as load bearing boards**
- Long term load bearing capacity
- Vibration behavior
- Climate influence (humidity)
- Fixation of additional sheets
- Constructive Details

Investigation of Bond Quality of Hardwoods with Micro Structured Surfaces

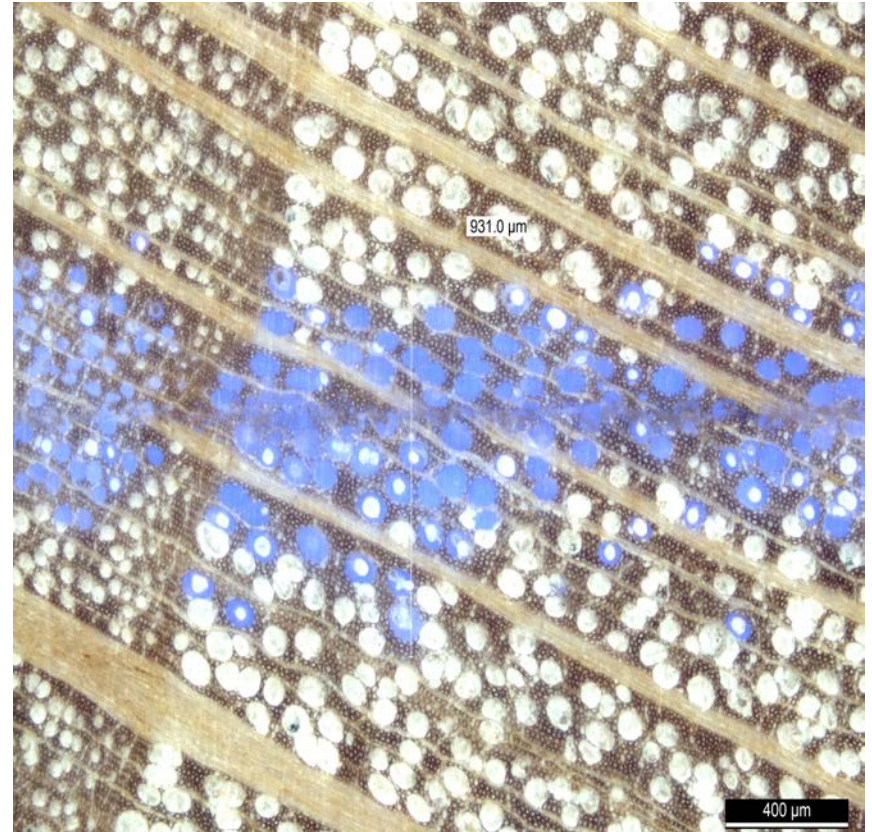
Motivation

- ▶ Bond quality of hardwoods is an unsolved obstacle for structural uses
- ▶ Spruce (*Picea Abies*) is a limited resource
- ▶ Hardwoods have superior mechanical properties
e.g. Beech (*Fagus Sylvatica*) and Ash (*Fraxinus Excelsior*)
- ▶ Hardwoods are rarely used for structural purposes
- ▶ Micro structured surfaces have shown positive influence on the durability of varnishes
- ▶ The timber industry is demanding a efficient solution to bond hardwoods

Introduction



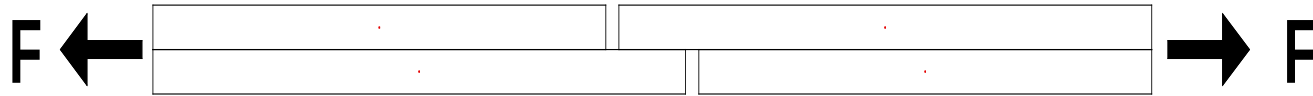
Homogenous adhesive line in spruce, the penetration depth is limited to the first cell rows.



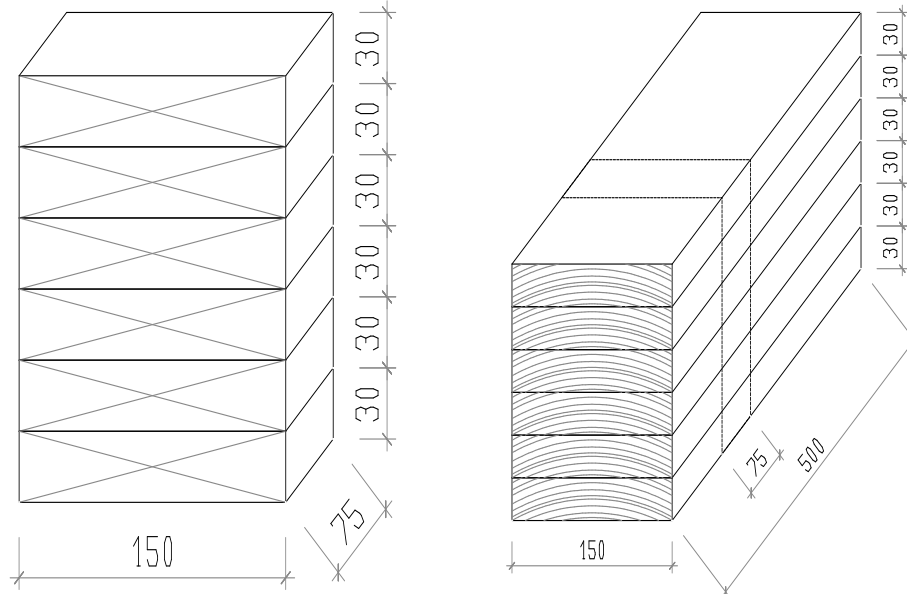
Heterogeneous adhesive line in beech, the penetration depth differs a lot and a specific glue line cannot be identified.

Standards

- ▶ Tension-shear tests along EN 302-1



- ▶ Delaminating test along EN 302-2



Delaminating Tests EN 302-2

High Temperature Process

- ▶ ***Adhesive type I***
- ▶ Water impregnation
 - ▶ Vacuum -0.75 kPa
 - ▶ Pressure +5 kPa
 - ▶ 2 Cycles
- ▶ ***Drying***
 - ▶ ***Temperature 65° C***
 - ▶ ***Humidity 12.5%***
 - ▶ ***Duration ~20h***
- ▶ ***3 complete cycles***

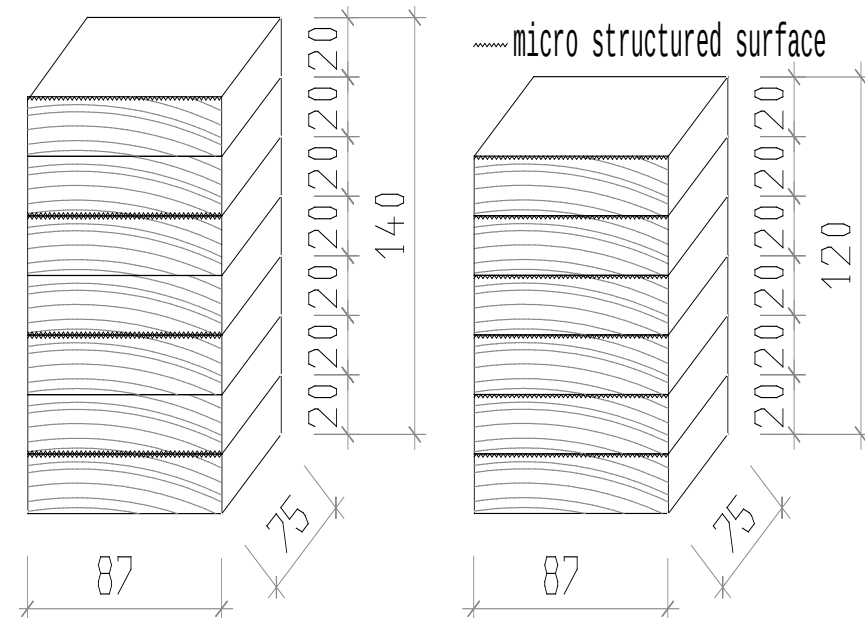
Low Temperature Process

- ▶ ***Adhesive type II***
- ▶ Water impregnation
 - ▶ Vacuum -0.75 kPa
 - ▶ Pressure +5 kPa
 - ▶ 2 Cycles
- ▶ ***Drying***
 - ▶ ***Temperature 27.5° C***
 - ▶ ***Humidity 30%***
 - ▶ ***Duration ~90h***
- ▶ ***2 complete cycles***

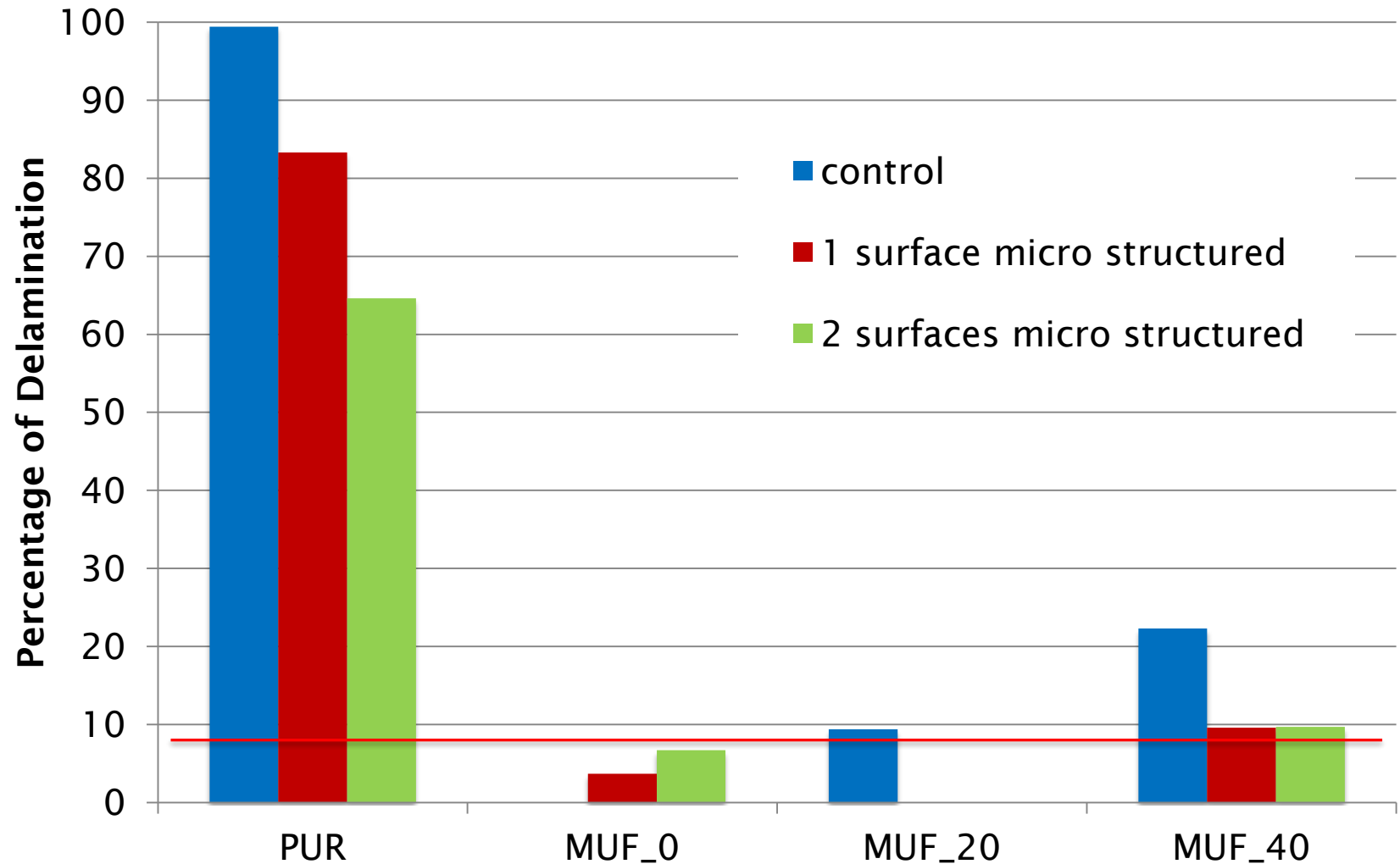
Delaminating Tests

- ▶ Adhesives:
 - ▶ PUR (no primer used)
 - ▶ MUF no closed waiting time
 - ▶ MUF 20 min closed waiting time
 - ▶ MUF 40 min closed waiting time
- ▶ Surface:
 - ▶ Micro structured (both sides)
 - ▶ Micro structured (one side)
 - ▶ Standard planed (both sides)
- ▶ Species
 - ▶ Beech (*Fagus Sylvatica*)

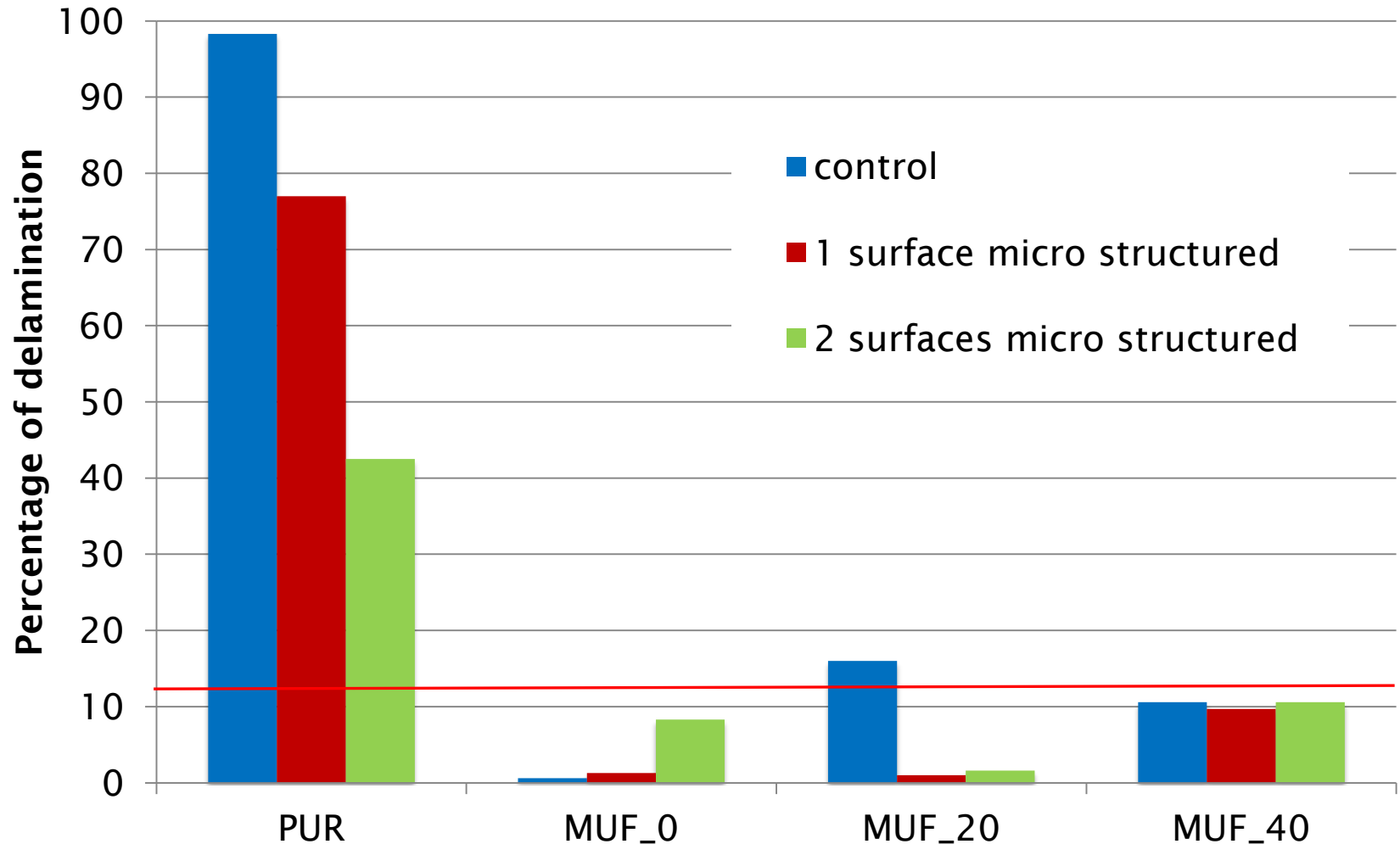
- ▶ High temperature Process
- ▶ Low temperature Process



Delaminating Test High Temperature Process



Delaminating Test Low Temperature Process



Conclusions

- ▶ The micro structured surface has clear a positive influence on the bond quality of beech using MUF or PUR
 - ▶ One micro structured surface showed the best performance
 - ▶ For MUF the closed waiting time may be avoided
 - ▶ For PUR micro structured surfaces allow not to avoid a primer
- ▶ The micro structured surface has a positive influence on the failure locus in the tension-shear tests.
- ▶ A statistical significant amount has to be tested to confirm the results
- ▶ The exact process parameters have to be determined



Thank you for your attention!

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