Applications and Opportunities with European Wood Modification

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Own research background

  - Heat treatment technology (PLATO)
  - Acetylation technology (Accoya)

- 2000 – today: University Göttingen
  - Belmadur
  - Silicones/ Silanes
  - Furfurylation (Kebony)
  - Waxes/ oils
  - Melamines/ phenols
Wood modification

- Why?
- How (principles)
- Processes and material
- Products and markets
- Challenges
Wood: material of the future

- Ecological
- Sustainable
- Renewable
- Esthetical
- Traditional and modern
Wood: material of the future

- Energy efficient
- End-of-life: energy
Wood: material of the future?

Weak points:

• Moisture sensitive
• UV-stability
• Dimensional movements
• Resistance against fungi
• Soft surface
Wood: material of the future?

Maintenance problems due to dimensional instability and UV instability!
Solutions/ Alternatives?

- Use wood with high natural quality (as many tropical hardwoods)
  - Availability (mid term, long term)
  - Sustainability

- Use of wood preservatives
  - Toxicity issues
  - New biocides with low impact
  - Only durability item solved

- Use of new technologies for wood treatment
  - Wood modification!
What is „wood modification“?
What is wood modification?
Wood modification technology

- Heat treatment
- Acetylation (Accoya)
- DMDHEU (Belmadur)
- Furfurylation (Kebony)
- Silicone/Silane
- Oil / Wax/ Parafins

On the market production capacity

- Melamine resin

Production capacity built

- Chitosan/
- Extractives etc.
Challenges: “from idea to commercial applications”
(PhD defense Stig Lande 2008/ ECWM 2009 Militz, Lande)

Technology development

- Raw materials
- Chemical reactions
- Process parameters

Product development

- Material interactions
- Quality control
- Market requirements

Business development

- Market
- Economy
- Intellectual property
Thermo treatment (TMT, Thermowood)

- no chemicals
- temperature 180° C to 220° C
- many wood species used
- difference between producers: technology used

ThermoWood® process

Photos: Plato process
Status quo of production (2010): EUWID
(Europäischer Wirtschaftsdienst)

- Production in **Finland**, Germany, France, Croatia, Austria, Switzerland, Netherlands, Turkey, Sweden, Estonia

- Total capacity approx. 200,000 m³/ year
- Finland approx. 100,000 m³/ year

- Largest plants: 30,000 m³/ year
- Smallest plants: 1,000 m³/ year

- New plants planned/ under construction
Use class 3 (EN 335)
(Photos by Thermowood Association, Finland)
Use class 3 (EN 335)
(Photos by Mitteramskogler/ Austria)
Use class 1-2 (EN 335)
(Photos by Mitteramskogler/ Austria)
Use class 1-2 (EN 335)
(Photos by Mitteramskogler/ Austria)
Modification technology based on liquids

• Belmadur® Technology
  – (DMDHEU)

• Kebony® Technology
  – (Furfurylation)

• Accoya® Titanwood
  – (Acetylation)

• Silanes/ Silicones
Modification based on liquids

- liquid, catalyst
- vacuum-pressure impregnation
- drying and reaction
- drying temp: above 100 °C
Materials and methods

- NMM-BS impregnation of beech
- High temperature curing
**Belmadur® Technology**

Originally:
- textile modification
- (Easy Care Cotton)

DMDHEU
(1,3-dimethylol-4,5-dihydroxyethylene urea)

![Chemical Structure](image-url)
Cross-linking cellulose molecules

Foto: BASF
Process development of the recent years

- Solid wood
- Veneers
- Wood composites
  - Particles
  - Fibres
- WPC
Main focus last years: upscaling processes
Belmadur® Technology

Wood → Treatment → Curing → Belmadur® Wood

Belmadur® Solution

Room temperature

Temperature > 100° C

® = patent and registered trademark of BASF
Superheated steam process

Graph showing process time in hours (Prozesszeit [h]) against various parameters including:
- Solltemp Luft [°C] (Solltemp Luft [°C])
- Temperatur Luft [°C]
- Temperatur Holz [°C]
- Sollfeuchte Luft [%]
- Feuchte Luft [%]
- Feuchte Holz [%]
# Development of construction

<table>
<thead>
<tr>
<th>massive wood</th>
<th>wooden lamella</th>
<th>sandwich</th>
<th>functional layer</th>
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<tbody>
<tr>
<td>frames made from solid</td>
<td>all lamella consist of same wood</td>
<td>Lamella consist of different wood</td>
<td>Choice of material regards the function</td>
</tr>
<tr>
<td>wood blocks</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

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## Diagrams

- [Diagram of massive wood frames](#)
- [Diagram of wooden lamella](#)
- [Diagram of sandwich](#)
- [Diagram of functional layer](#)
New product...new process...

BECKER belmadur®
DMDHEU particle boards
Treatment of particles in „reactor“

- closed system
- vacuum ~30 mbar (org. solvents possible [DMSO])
- temp. until 350 °C
- volume 140 l
- treatment of approx. 10 kg particles and 6 kg fibres
Kebony® Technology

Basic materials

- Hydration from Furfural
- Furfural by distillation from waste of bagasse, corn, rice, peanut..
Autoclave: 13 m length, 3.25 m diameter (0.1 - 13 bar)
Kebony® products

www.kebony.com
Kebony® Products
Kebony® products
Accoya® Titanwood

Process:
- impregnation with acetic anhydride
- reaction at elevated temperatures
- post treatment (acetic acid)

Photos: SHR (NL)
Production plant, Arnhem, NL
Bridge in Sneek (NL)
Lorry bridge (60t lorries, 40 m length)
silicon based compounds

Hydrophilic and potentially reactive

Protection of masonry

Clothes (dyeing agents fixation)

Coupling agents (electrical circuit)

Hydrophobic

Hydrophobation of glass
“water shade effects”
Introduction

Silane

Halosilane

Silicic acid

Silicone

A = CH₃

R = (CH₂)₃-NH₂

m = 7 - 10

n = 300 - 400
types of silanes

\[ Y = \text{“Organo-functional groups”} \]
\[ OX = \text{“Silicone-functional group OCH}_3, \text{ OC}_2\text{H}_5 \text{ etc.} \]

\[ \text{Tetraalkoxy} \rightarrow \text{SiO}_2 \]
\[ \text{TEOS} \rightarrow \text{SiO}_2 \]

\[ \text{Methyltriethoxy} \rightarrow \text{Me-SiO}_{3/2} \]
\[ \text{MTES} \rightarrow \text{Me-SiO}_{3/2} \]
Material properties
TMT: new material, new properties

- Consistent colour through the piece
- Reduced equilibrium moisture content
- Improved durability against decay
- Reduced Thermal conductivity
- Resin removed
- Reduced splitting strength
- Improved stability
- Slightly reduced bending strength
Water uptake

(Tingaut et al., 2005)
Capillary water uptake

- Water absorption coefficient shows the water uptake in relation to time \([\text{kg/m}^2/\sqrt{\text{h}}]\)

- Reduced water uptake after modification

Water absorption coefficient \([\text{kg/m}^2/\sqrt{\text{h}}]\) in tangential (left) and longitudinal direction (right)
Material evaluation

Modified hardwood at natural weathering test according to EN 927-3
Surface appearance

Beech control

30% NMM modified beech
Surface appearance

30% NMM-BS yellow modified beech

30% NMM-BS brown modified beech
Outside weathering - results

- significant lower m.c. than untreated material
- uncoated furfurylated is lower than untreated/ coated

Moisture content [%] of SYP samples over a period of 21 month
Sorption properties
(Tjeerdsma, Boonstra 1990’s)

Scotch pine

- Heat-treated adsorption
- Heat-treated desorption
- Non-treated adsorption
- Non-treated desorption

Non-treated

Heat-treated

Equilibrium Moisture Content (%) vs. Relative Humidity (%)
Swelling and shrinking of wood species

Relative swelling of wood species from 0% moisture content to fibre saturation point

- **teak**
- **pine heartwood**
- **pine sapwood**
- **oak**
- **beech**

Graph showing relative swelling in % for radial and tangential directions.
Brinell hardness (parket flooring)

- **Pinus sylvestris**
- **Tectona grandis**
- **Fagus sylvatica**

Hardness (N/mm²):

- Untreated
- 10%
- 30%
- 50%
- 80%

Concentration of DMDHEU:

- Pine

Graph showing the hardness of different concentrations of DMDHEU for each species.
Strength testing: MOR bending mode
(Bollmus 2010)

control

Methylol treatment
MOE in bending mode (DMDHEU)

(Bollmus 2010)
Impact bending strength
(Bollmus 2010)
Biological testing of new materials

- Biocidal action?
- Solely lab testing?
- Performance testing in field?
- Product testing?
Degradation of beech wood after 32 weeks in soil contact (ENV 807)

- interlaced treatment "A"
- interlaced treatment "B"
- interlaced treatment "C"

Classes:
- class V
- class IV
- class III
- class II
- class I

Graph showing weight gain after reaction vs. mass loss.
Main material properties gained with NMM

- Durability improvement

Pine modified with 10% NMM after 16 weeks EN 113; DBU-Report, Az: 26869 (2009)
**Fungal resistance as function of process conditions**

*(Tjeerdsma, Militz 2002)*

**Pinus silvestris**

- Soil block test
- Weight loss after 54 weeks
Termite resistance: test fields Australia, Portugal, lab tests Spain
General results: Coptotermes/Mastotermes

• Heavy attack in both fields (adequate feeding pressure)
• Pinus sylvestris controls
  • Sapwood 100 % attacked
  • Heartwood well protected
Results *Coptotermes acinaciformis*

![Bar chart showing mass loss of different specimens](chart)

- **Scots pine Feeder**: DMDHEU 1.3 M
- **Scots pine**: DMDHEU 2.1 M
- **Scots pine**: DMDHEU 1.3 M
- **Slash pine**: DMDHEU 2.1 M
- **Slash pine**: DMDHEU 1.3 M
- **Beech**: DMDHEU 1.3 M
- **Beech**: DMDHEU 2.1 M

Mass loss [%]
Challenge: wood species

• Selection of right wood species
  – What are criteria?
  – macroscopical versus microscopical distribution of chemical
Obvious effect for impregnation technology
Wood – Treatability / Permeability

No obvious effect for thermowood
Durability of heat treated Pine and Spruce

(PLATO process, Boonstra 2008)

- Mass loss of treated and untreated Spruce/ Pine
- Incubation with *C. puteana* and *C. versicolor*
- Test standard: CEN /TS 15083-1
Basis materials for wood modification

- Easy „treatable“

- Large quantities
  - Pines
  - Poplars
  - Beech?
  - Eucalypts?
  - Ash? Alder?

- Other fast growing wood species!
• Cleavage test
  - 85-100% failure mode in furfurylated material
  - For fulfillment of the standard, ≥ 90% of wood failure is required
  - All wood species met the requirements of the standard

Failure mode [%] in wood after cleavage with a planer blade
Challenge:
processing, costs and markets
Other factors of concern to clients...

- Environmental concerns
  - Emissions to air
  - Emissions to water
  - Human tox
  - Eco tox
  - Working environment

- Machinability and further processing
  - Tools
  - Material homogenity
  - Glueability/ paintability
  - End product performance

- Disposal/ recycling
  - Reuse of fibres?
  - Energy – burning?
  - Land fill

Furniture, Thermowood
Potential markets for modified wood

**Outdoor**
- Decking
- Roofing
- Utility poles
- Rail ties
- Fences
- Garden furniture
- Bridges
- Marine applications
- And more…

**Indoor**
- Flooring
- Windows
- Doors
- Furniture
- Mouldings
- And more…

Floor, Kebony
Bridge, Accoya
Decking, Belmadur
Chair, Belmadur

Decking, Accoya
Roofing, Kebony
Challenge: markets

- Biocide treated wood
  - Costs!!
  - Special products

- Markets of tropical hardwoods
  - use classes 1-5
  - „high quality“

- Special products with diverse functions
ECWM European Conferences on Wood Modification

- ECWM 6: Sept. 2012 in Ljubljana, Slovenia
- ECWM 2014: Lisbon/ Portugal
- ECWM 2016: Helsinki/ Finland

(Proceedings ECWM 1-6: contact me!)
Thank you for your attention!

10 % NMM, 20 x magnification, ash