Polypropylene with wood fiber reinforcement –

Computed tomography analysis of fiber-matrix interaction

3DMC | 2022 | Automation | Digitization | Data Science

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Frederik Obermeier
Roberto Lackner
Prof. Peter Karlinger

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- Introduction and motivation
- Basics and state of the art
- Material and methods
- Results and discussion
- Summary and outlook

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- **Introduction and motivation**
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Introduction - Why wood fibers?

[1]

- Lightweight design [2]
- Use of renewable raw materials and good life cycle assessment [2]
- Local availability and lower raw material risks [3, 4]
- Fiber reinforcment, good mechanical performance for technical apllications [5,6]

Fiber reinforcment?

Fiber volume ratio?

Fiber-matrix interface?

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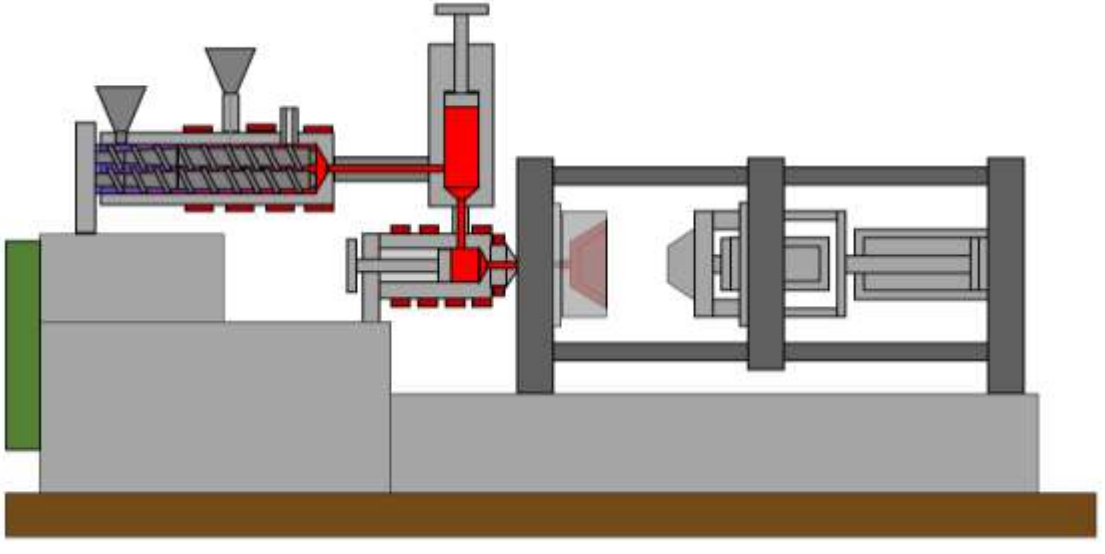
Basics – Injection molding and direct-compounding

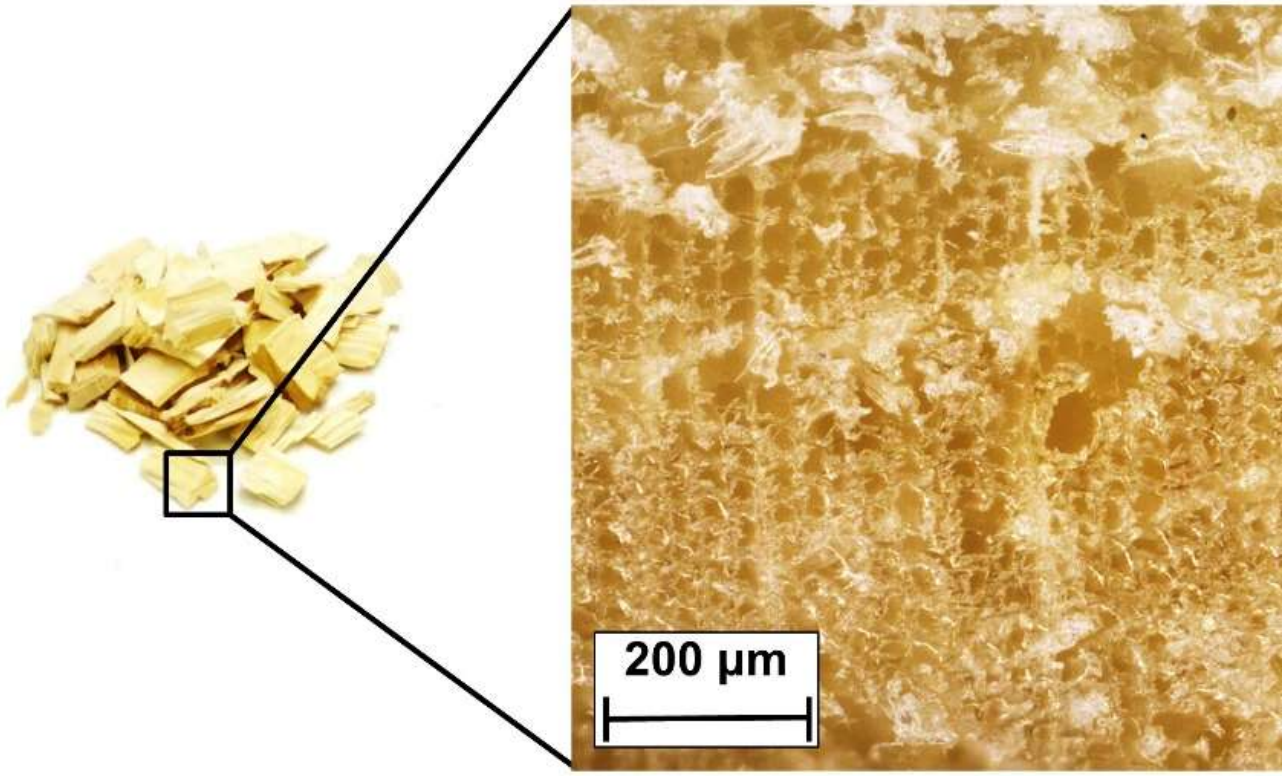
Refiner

Wood fibers

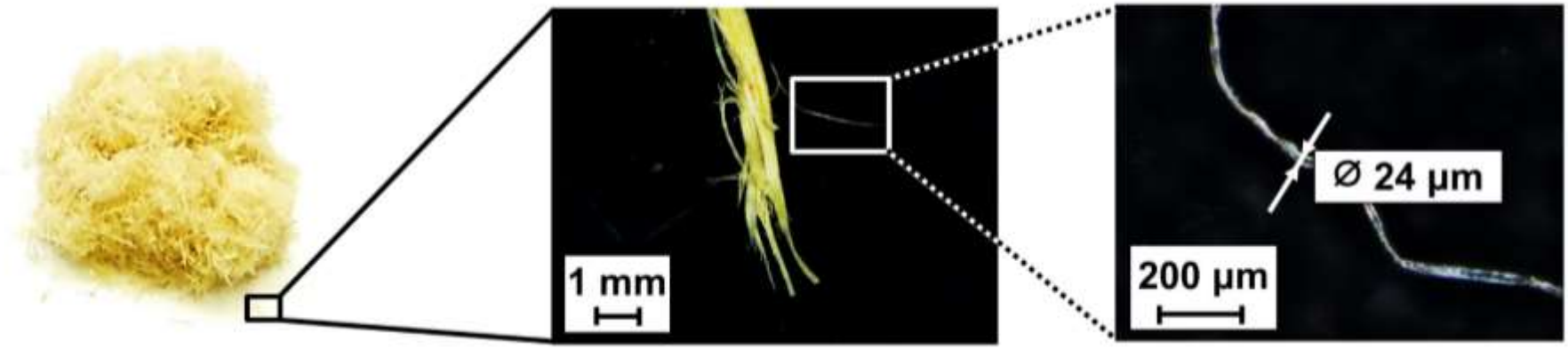
Direct-Compounding

Test specimen

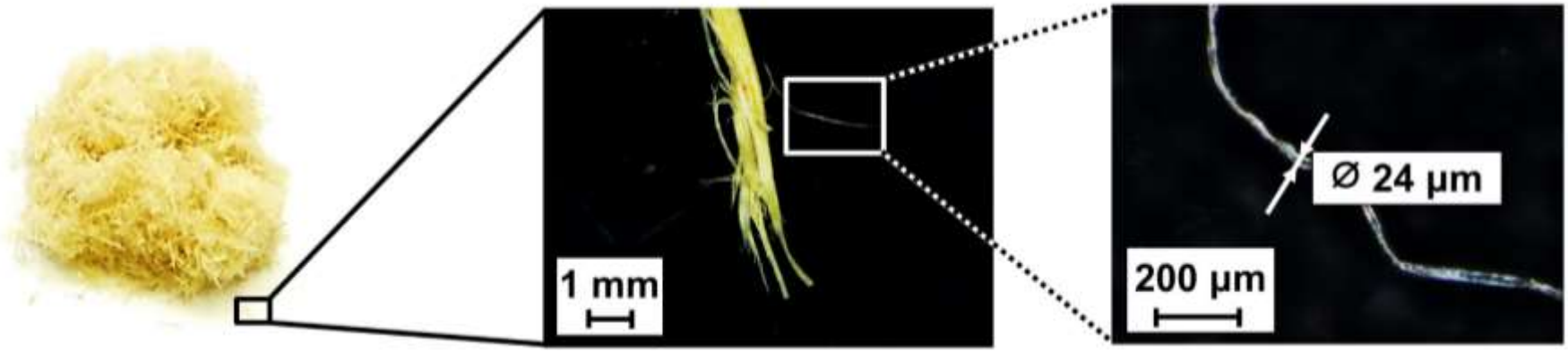




Overview image of some wood chips from spruce (left), microtome section and reflected light microscopy of a wood chip (right)



Overview image of some thermo-mechanically produced fibers from spruce (left); microscopy of a fiber bundle (center) and microscopy of a single fiber (right)



Overview image of some thermo-mechanically produced fibers from spruce (left); microscopy of a fiber bundle (center) and microscopy of a single fiber (right)

Fiber	**Density** [g/cm³]	**Tensile strength** [MPa]	**Tensile modulus** [GPa]
Softwood (e.g., spruce)	1,5	1000	40
Flax	1,5	350-1000	28
Sisal	1,5	500-600	10 - 22
E-glass	2,5	2000 - 3500	70

Mechanical properties of softwood compared to other reinforcing fibers [4]

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Material and Methods – Direct-Compounding

Refiner

Wood fibers

Direct-Compounding

Test specimen

Fiber
Wood logs from Rosenheim area

Matrix	**Coupling Agent**
PP Homopolymer (HJ 120 UB, Borealis)	PP-MAH Copolymer (SCONA TPPP 8112 GA)

Material and Methods – Direct-Compounding

Refiner

Wood fibers

Direct-Compounding

Test specimen

Laboratory refiner
(type 12 1CP, Andritz)

Injection-Molding-Compounder
(type KM 300 CX IMC, KraussMaffei)

Material and Methods – Computed tomography

Refiner

Wood fibers

Direct-Compounding

Test specimen

Computed tomography scanner
(TomoScope XS Plus, Werth Messtechnik)

- Transmission tube
- Monoblock x-ray tube design
- 160 kV maximum tube voltage

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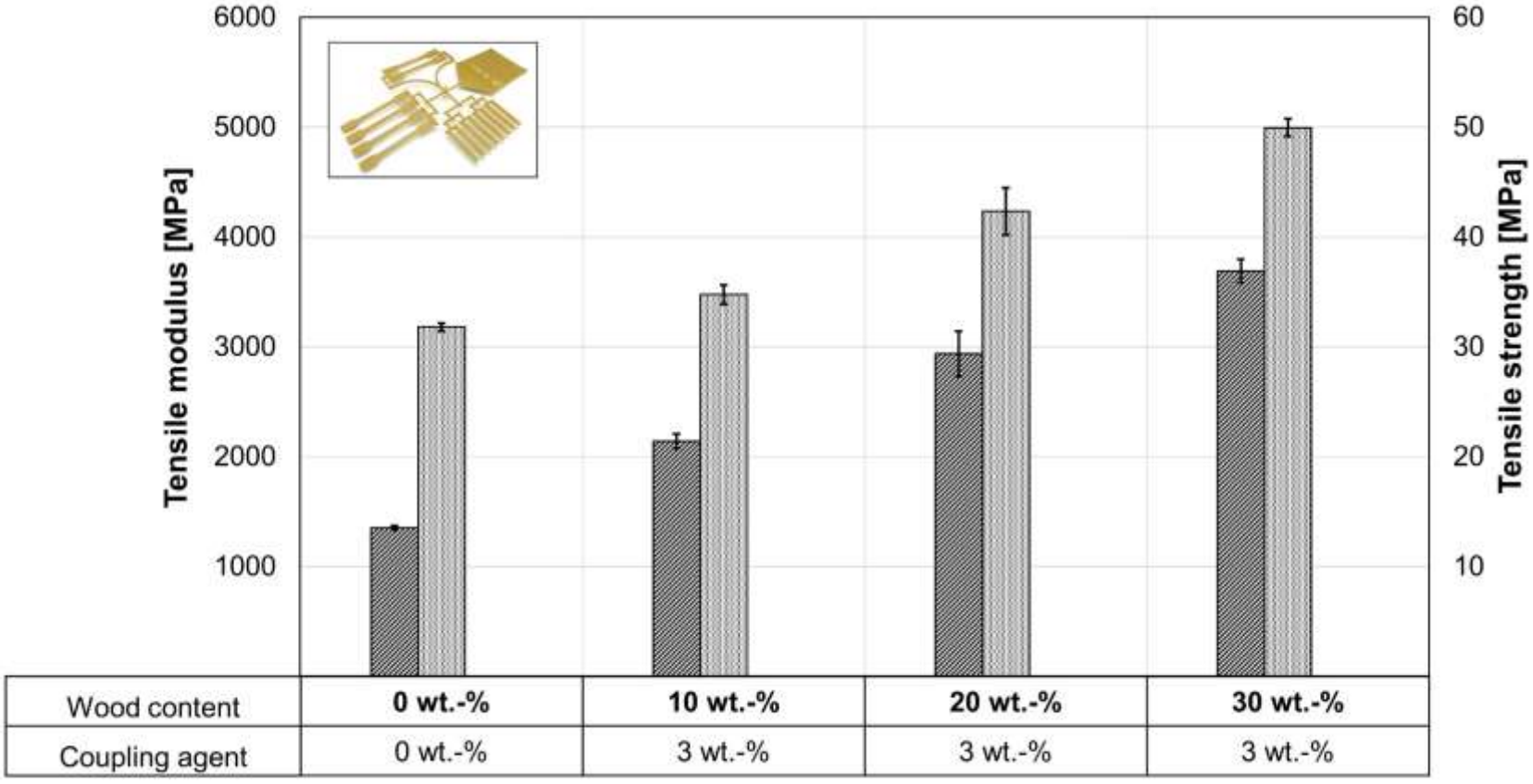
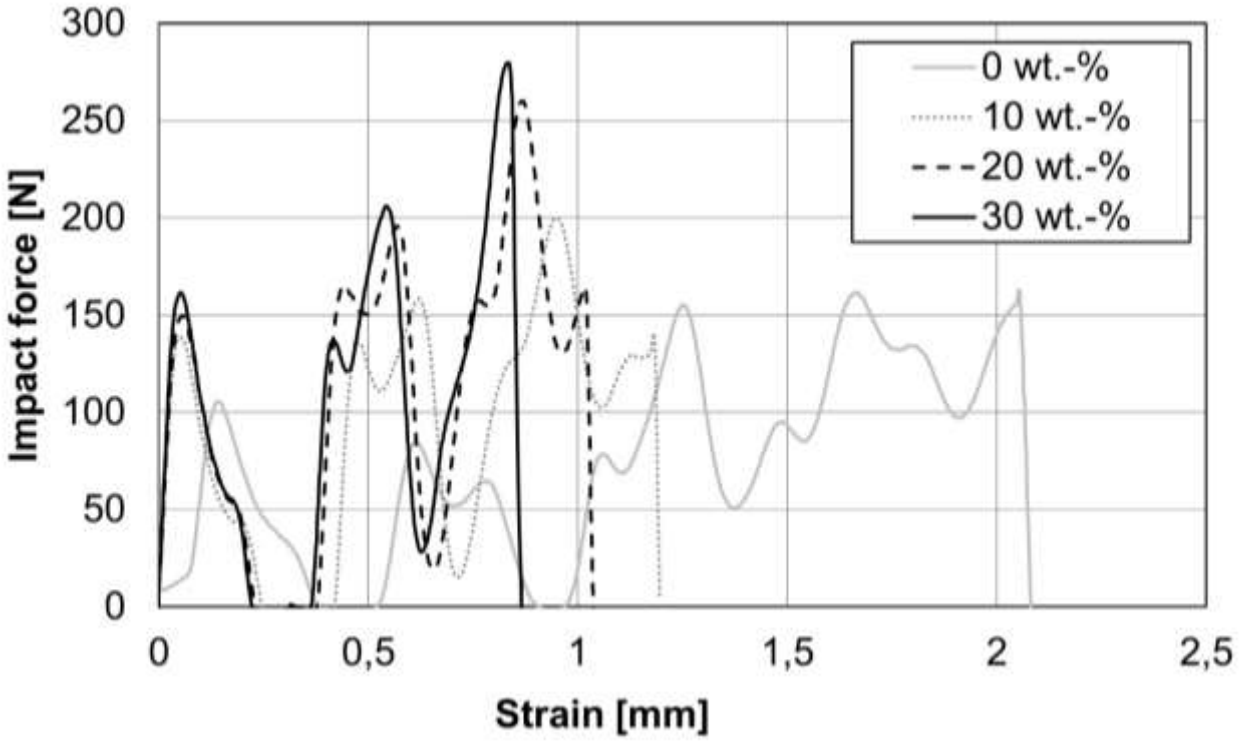


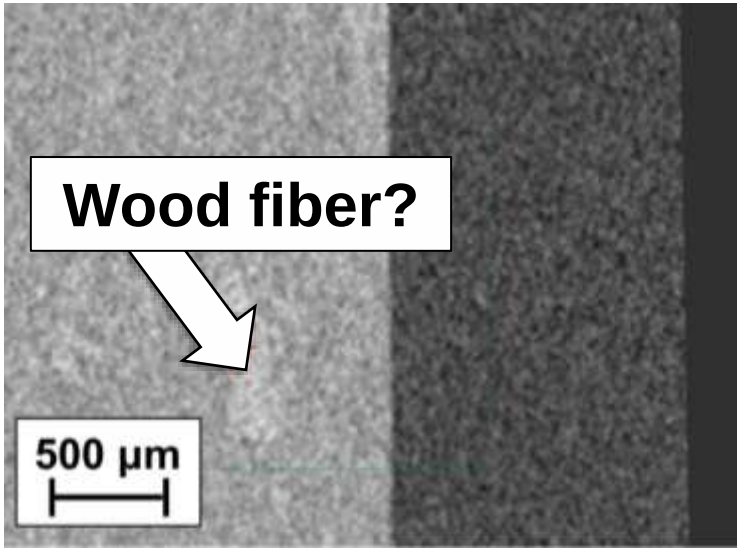
Tensile test according to ISO 527-2/1A of PP with coupling agent and different wood content; tensile testing device type Z020 from Zwick/Roell

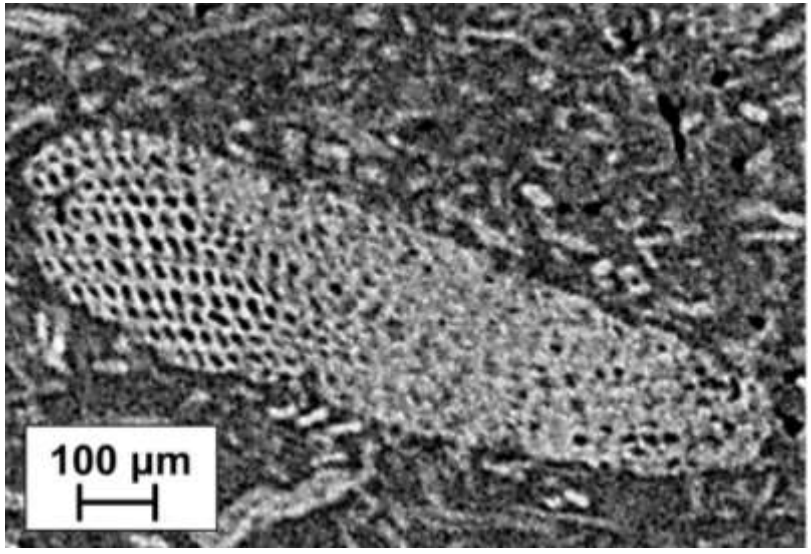


Impact strength test ISO 179/1eB (edgewise, notch type B) of PP with coupling agent and different wood content; exemplary curve progression; pendulum impact tester type HIT50P from Zwick/Roell

First measurements:
- Low resolution
- Low density difference

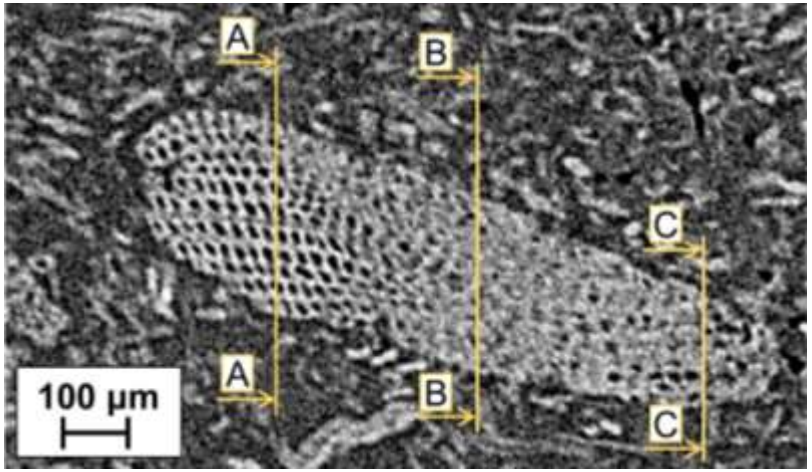
Optimized parameters:
- High resolution
- Reduction of measurement time to 1/3



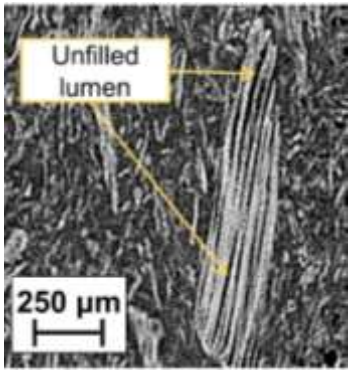


Computed tomography of specimen with 30 wt.-% wood fibers; 120 kV, 280 µA, low resolution (left); 140 kv, 400 µA, high resolution (right)

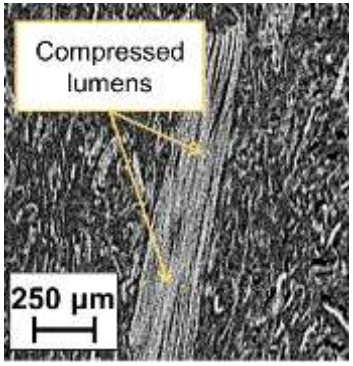
Results and discussion – Computed tomography



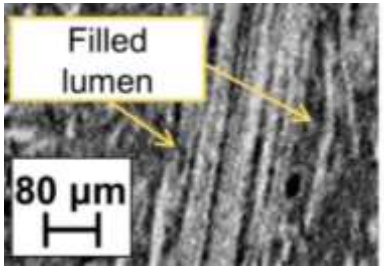
A-A



B-B

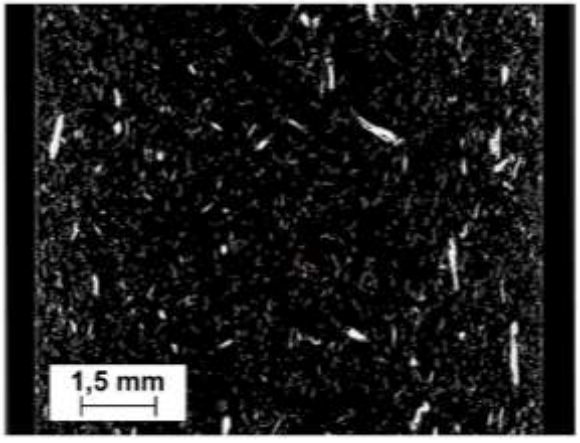


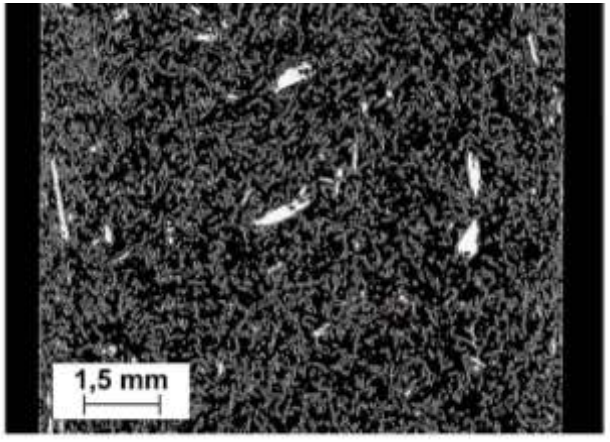
C-C

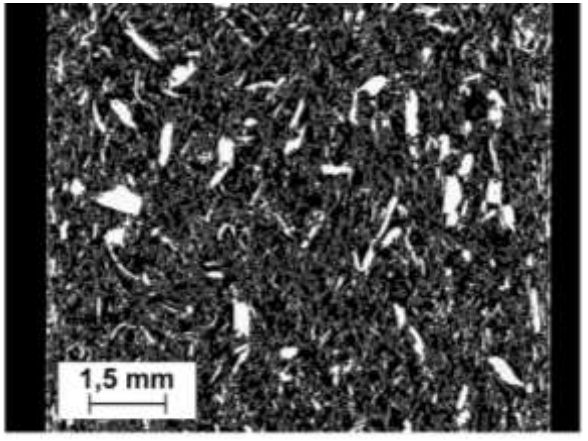


Computed tomography of specimen with 30 wt.-% wood fibers; sectional view A-A, B-B and C-C of a wood fiber bundle

Results and discussion – Computed tomography



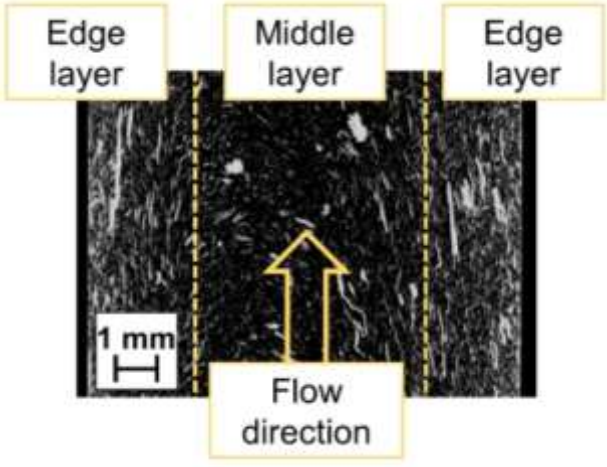


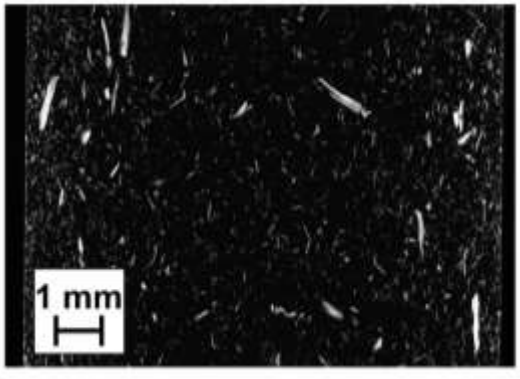


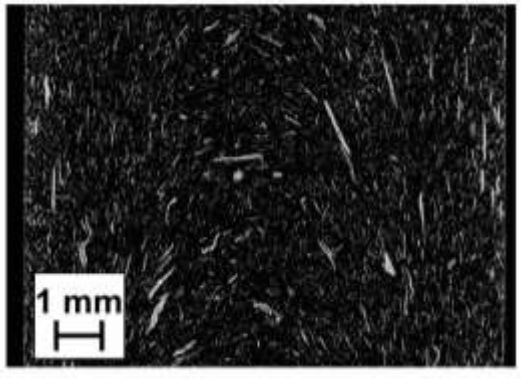
Ψ wood content [wt.-%]	**10**	**20**	**30**
φ wood content [vol.-%]	10 ± 1	23 ± 1	36 ± 4

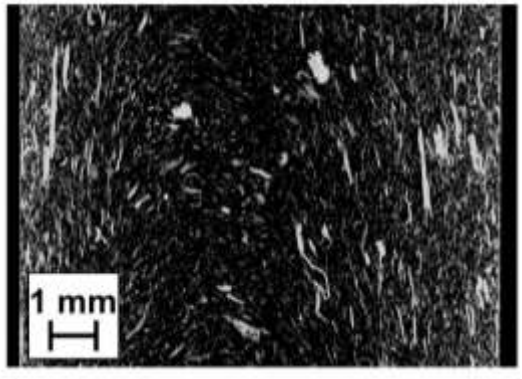
Computed tomography of specimen with 10, 20 and 30 wt.-% wood fibers; analysis of fiber volume content

Results and discussion – Computed tomography









Computed tomography of specimen with 10, 20 and 30 wt.-% wood fibers; analysis of fiber orientation in edge and middle layer

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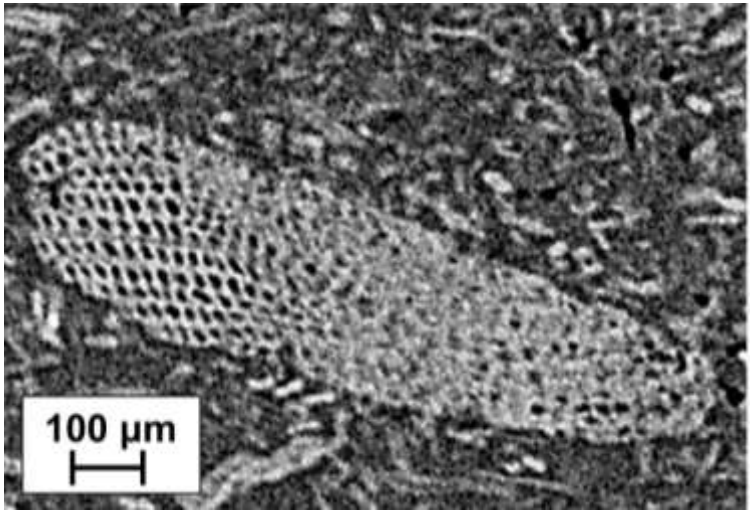
Summary and outlook

Summary

- Fiber reinforcement of polypropylene by wood fibers possible (spruce) in direct compounding processes
- Basic effects (fiber volume content, fiber orientation and fiber-matrix interphase) can be analyzed by CT measurements, thus providing a fundamental understanding of the mechanisms



Outlook

- Increase understanding regarding fiber degradation, fiber lengths and l/d ratio
- Different Polymers (e.g., Biopolymers, Bio-PP, PLA etc.)

Thank you for your attention

Frederik Obermeier (M.Sc.)
Research Associate R&D Plastics Engineering

frederik.obermeier@th-rosenheim.de
+49 (0) 8031 805-2266

Technische Hochschule Rosenheim
Hochschulstraße 1
83024 Rosenheim
www.th-rosenheim.de

Literature

[1] Haider, A.: The market for injection moulded and extruded WPC products; Plastics; 2013 (available online: https://www.plastics.gl/consumer/the-right-mix/)

[2] Carus, M.; Partanaen, A.: Biocomposites, find the real alternative to plastic – An examination of biocomposites in the market; Reinforced Plastics; Volume 63; 2019; pp. 317-321

[3] Bledzki, A.K.; Sperber, V.E.; Faruk, O.: Natural and wood fibre reinforcement in polymers; Rapra Review Reports; 2002

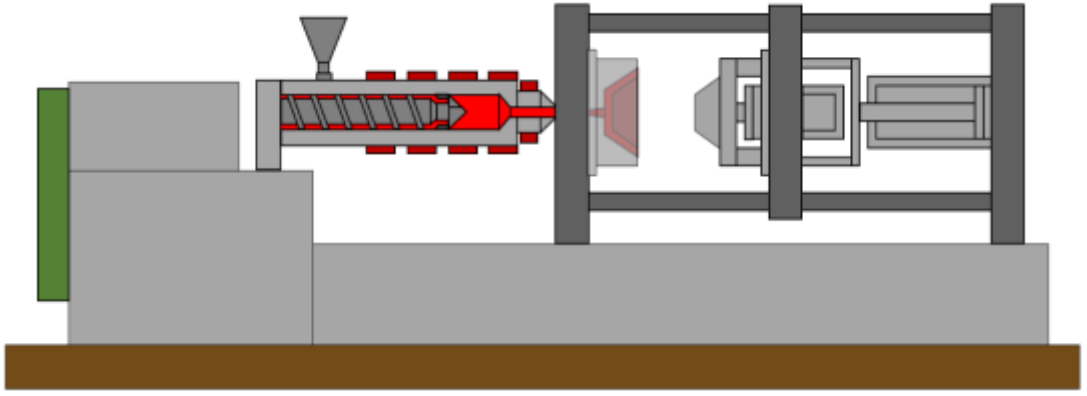
[4] Rinberg, R.: Technologieentwicklung zur Herstellung von naturfaserverstärkten Bauteilen in Leichtbauweise unter Einsatz von Ganzpflanzenrohstoffen; Dissertation; TU Chemnitz; 2011

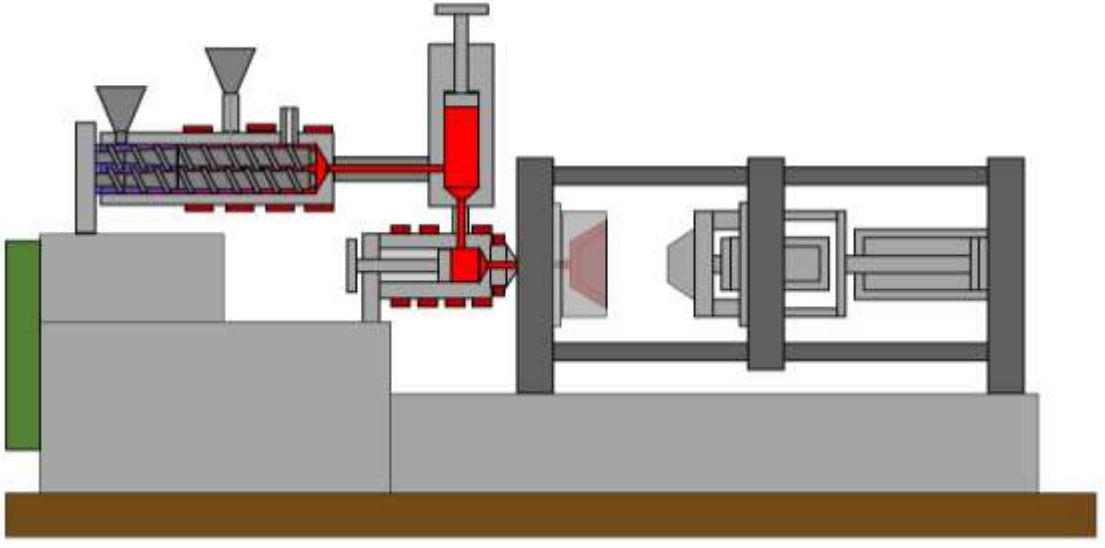
[5] Obermeier, F.; Schumacher, M.; Barth, S.; Karlinger, P.; Michanickl, A.; Schemme, M.; Altstädt, V.: Verstärkung von Polypropylen mit Holzfasern durch Direkt-Compoundierung; Zeitschrift Kunststofftechnik / Journal of Plastics Technology; Volume 17; 2021; S. 87-111

[6] Obermeier, F.; Karlinger, P.; Schemme, M.; Altstädt, V.: Thermoplastic Hybrid Composites with Wood Fibers: Bond Strength of Back-Injected Structures. Materials, Advanced Materials Characterization; Volume 15; 2022

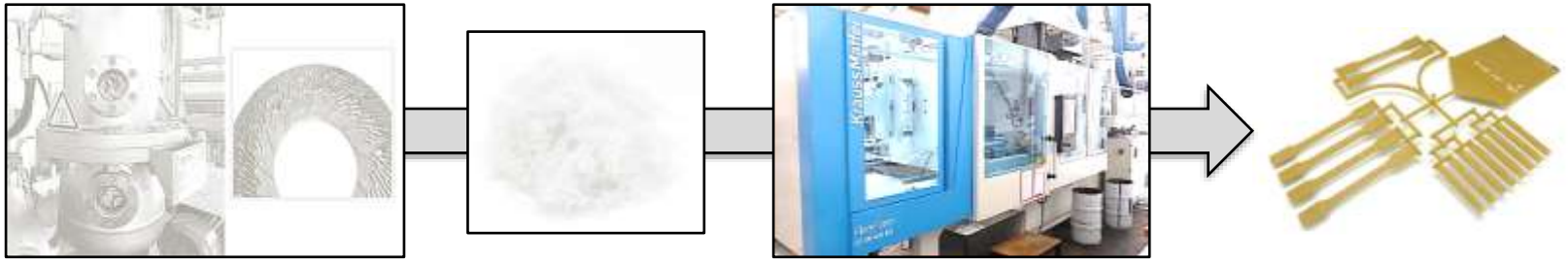
[7] Wiedl, S.; Karlinger, P.; Schemme, M.; List, M.; Ruckdäschel, H. Comparison of Melting Processes for WPC and the Resulting Differences in Thermal Damage, Emissions and Mechanics. Materials, Advanced Materials Characterization; Volume 15; 2022

Basics – Injection molding and direct-compounding

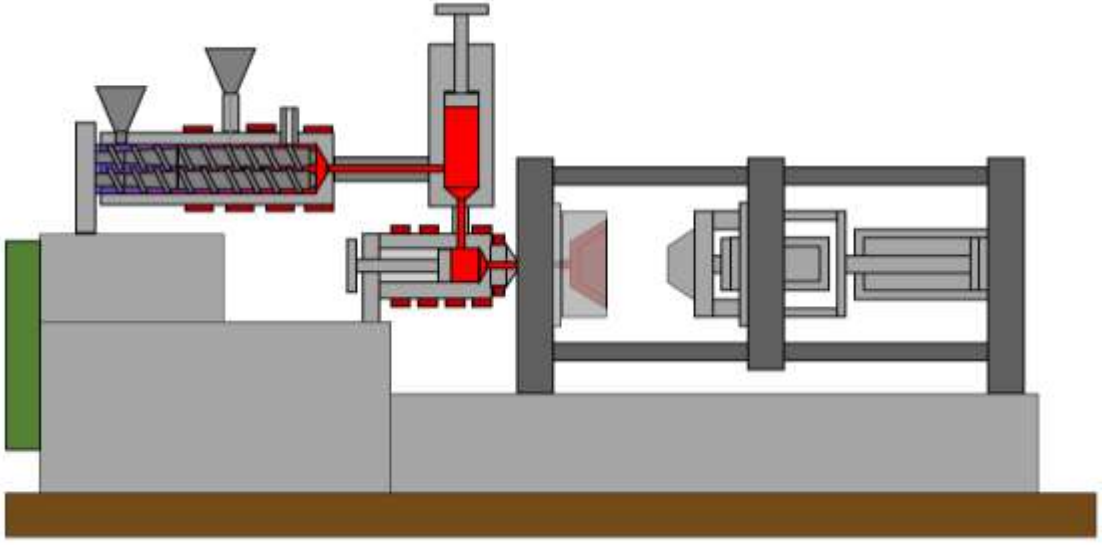


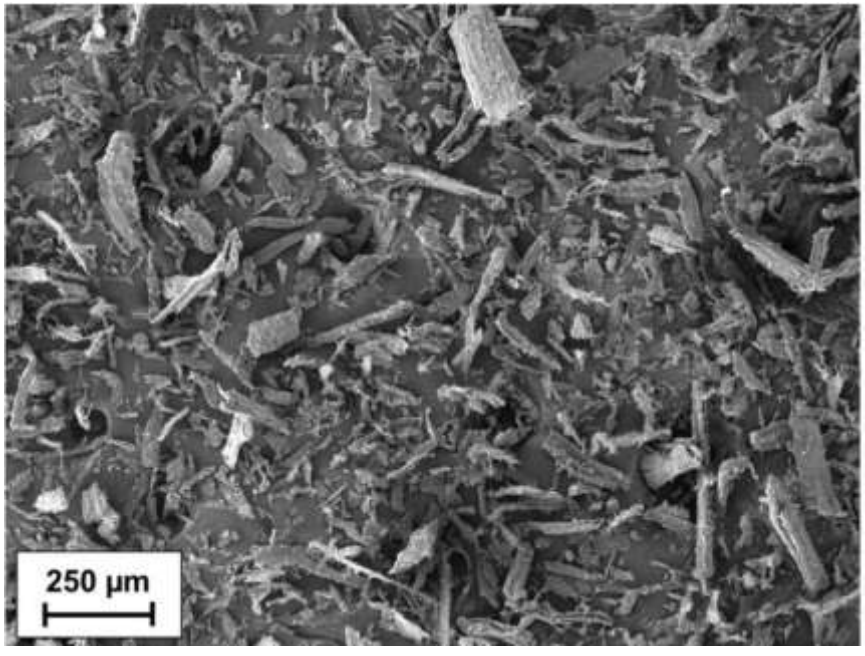


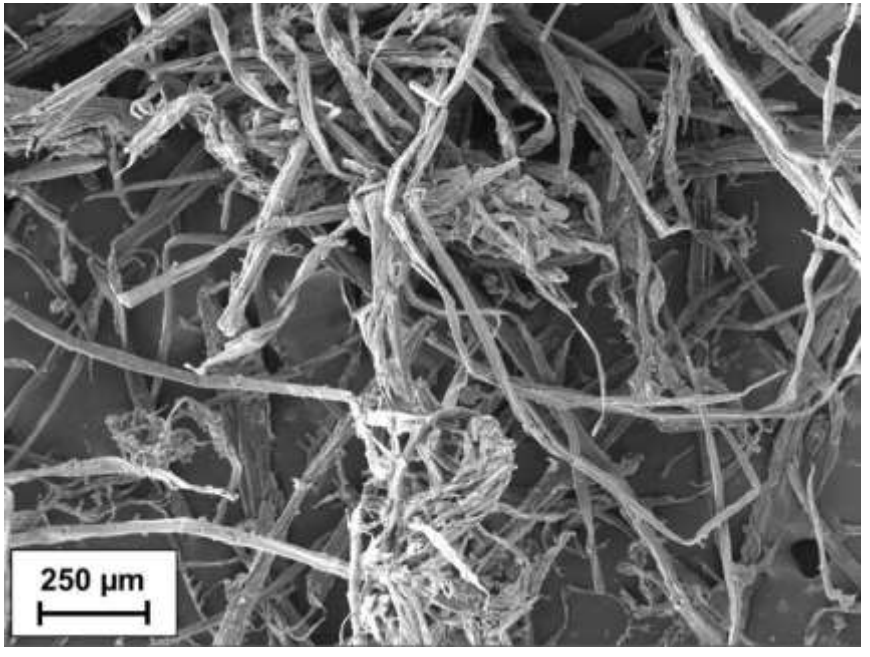
Basics – Injection molding and direct-compounding



Refiner | Wood fibers | **Direct-Compounding** | **Test specimen**

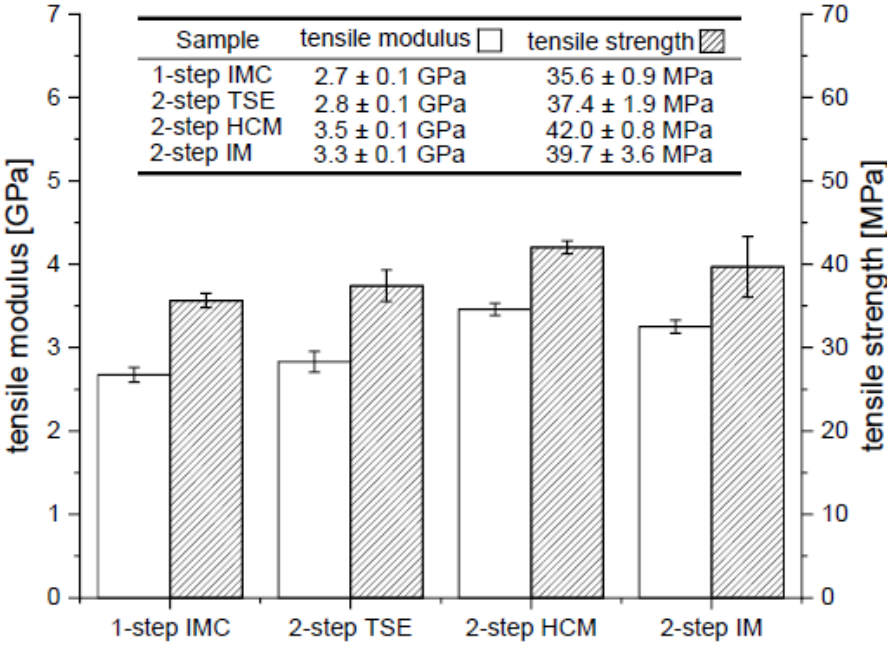


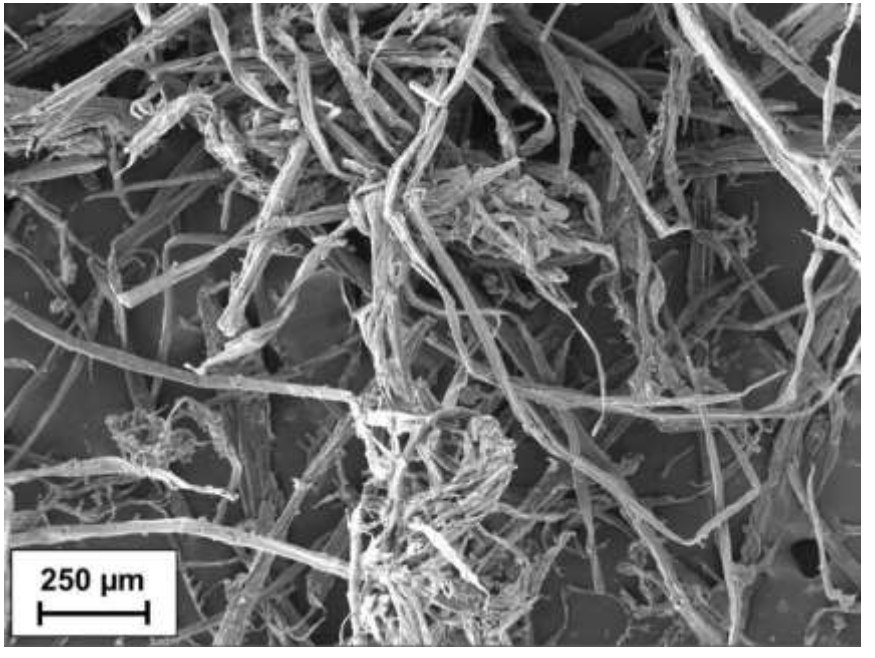




SEM images of wood flour (left) and wood fibers (right) [7]

State of the art – Direct-Compounding





Mechanical values of different compounds with spruce fibers (left) and wood fibers used (right); polyproyplene with coupling agent as matrix [7]

Material and Methods – Direct-Compounding

Refiner

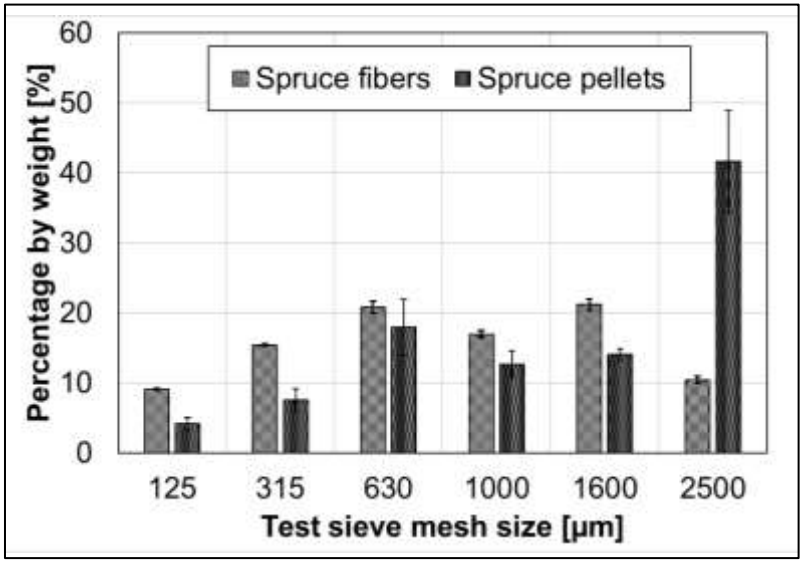
Wood fibers

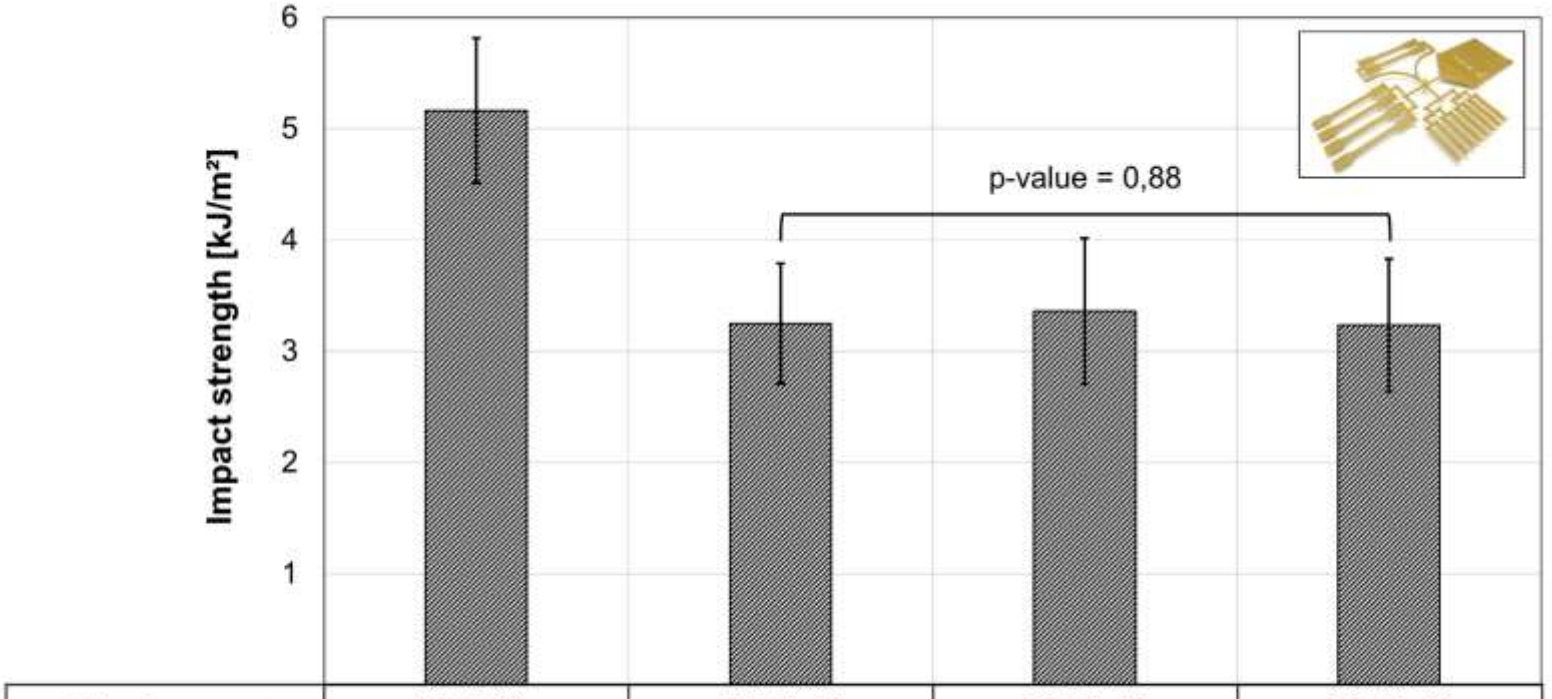
Direct-Compounding

Test specimen

Fiber
Wood logs from Rosenheim area

Matrix	Coupling Agent
PP Homopolymer (HJ 120 UB, Borealis)	PP-MAH Copolymer (SCONA TPPP 8112 GA)

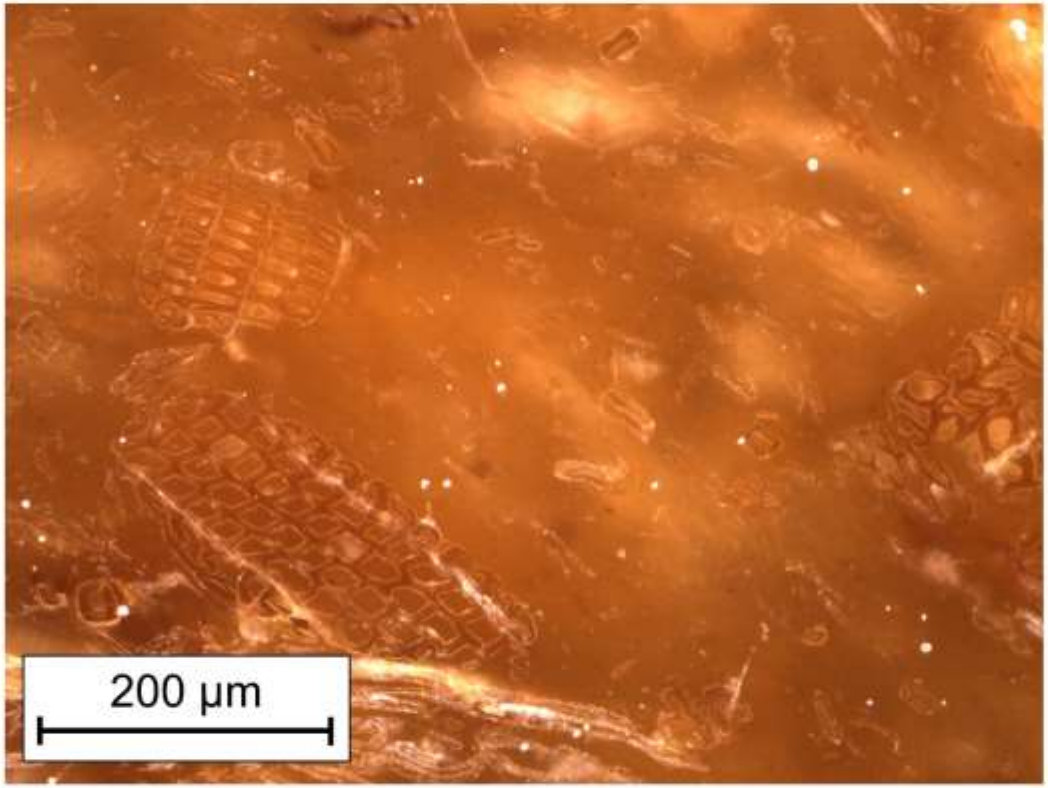




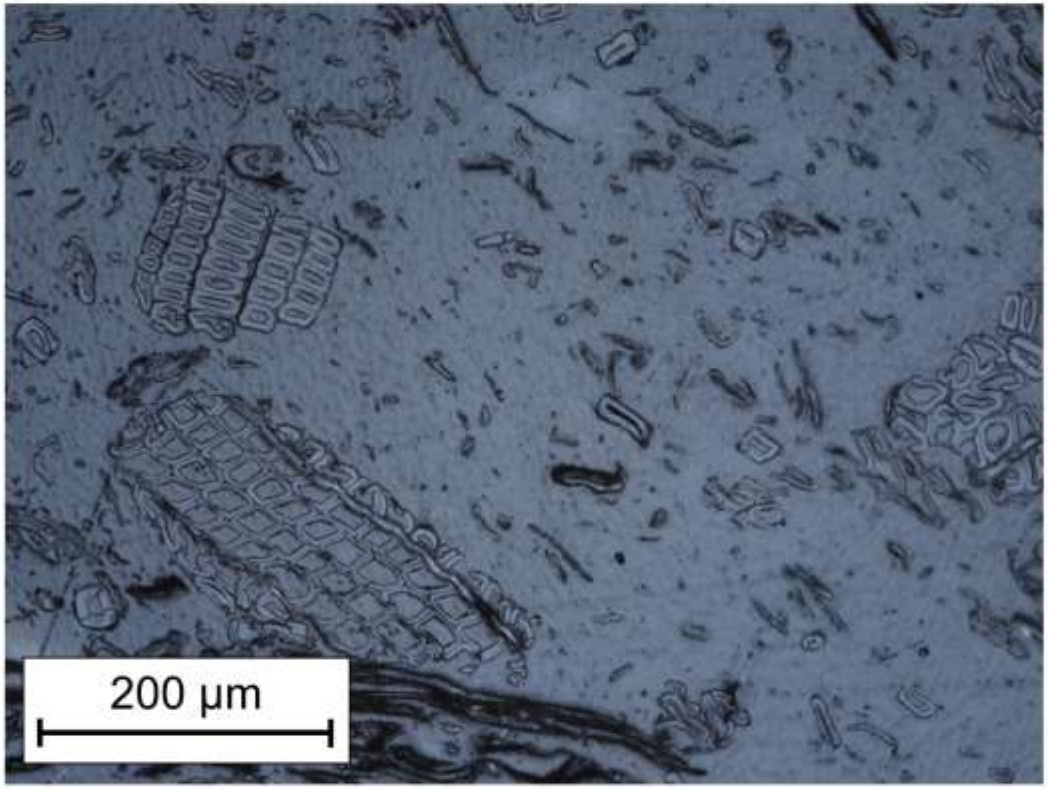
Wood content	0 wt.-%	10 wt.-%	20 wt.-%	30 wt.-%
Coupling agent	0 wt.-%	3 wt.-%	3 wt.-%	3 wt.-%

Impact strength test ISO 179/1eB (edgewise, notch type B) of PP with coupling agent and different wood content; n = 10 ± SD; p-value by single factor analysis of variance at α = 0.05, pendulum impact tester type HIT50P from Zwick/Roell

Results and discussion – Microscopy



Results and discussion – Microscopy



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