Bio-Based Porous Carbon Pre-Forms for the Manufacture of High-Performance Composites (BioC4HiTech)

Andreas Haider, Fürst Christian

Introduction – key data

Foundation 2000

- Wood K plus was set up to become the leading Austrian research organisation in the areas **wood materials and wood chemistry**
- as a **non profit organisation**, structured as GmbH (ltd. Company)

Public Owners:

- Upper Austrian Research GmbH – UAR 48 %
- State of Carinthia – BABEG 26 %
- University of Natural Resources and Life Sciences, BOKU 13 %
- Johannes Kepler University, JKU 13 %

Sites:

- Linz (OÖ), St. Veit (Ktn.), Tulln (NÖ)

Personnel:

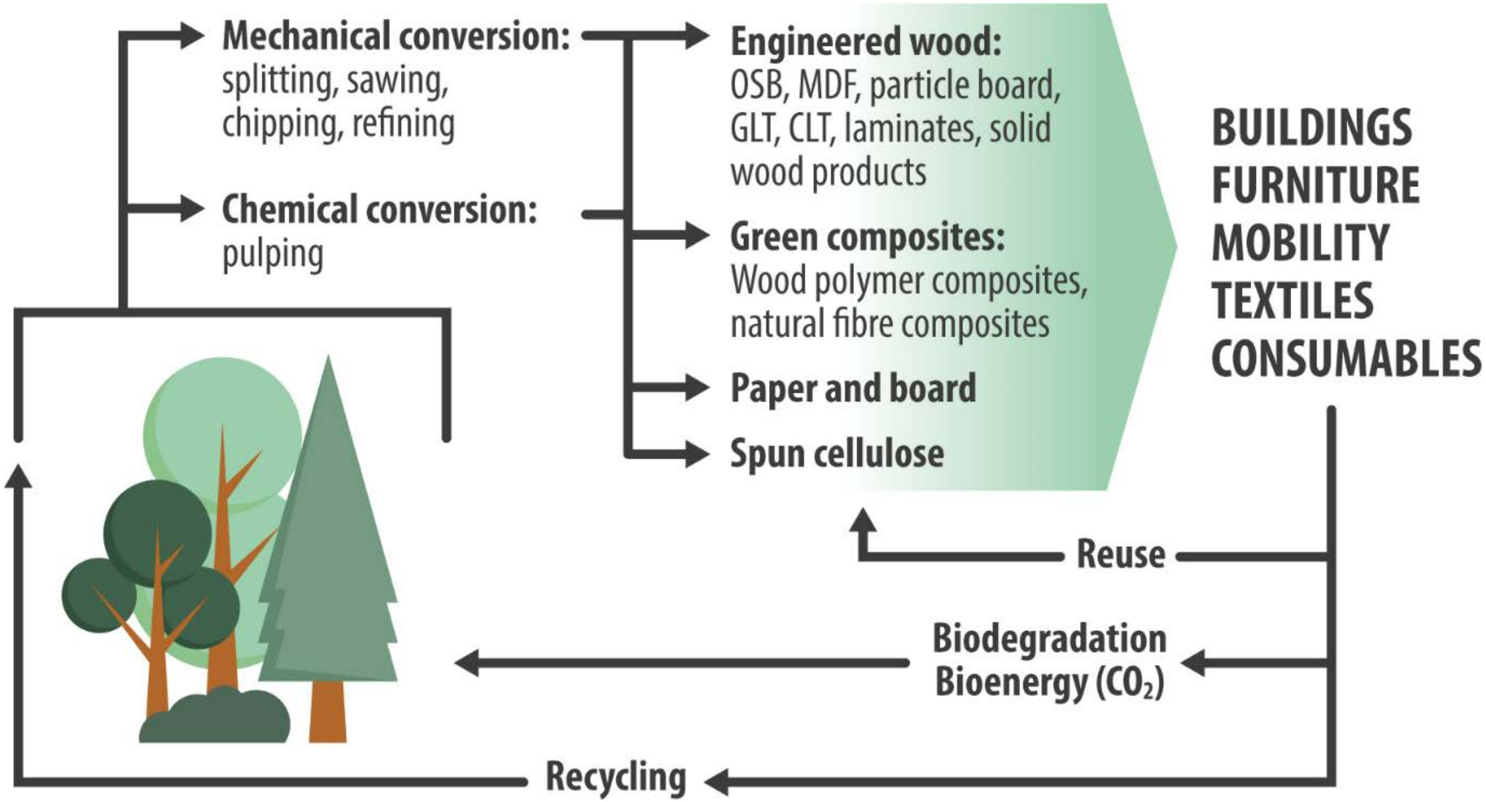
- ca. 125 employees Wood K plus / about 50 % women (!)
- >150 researchers of partner organisations participate in projects of Wood K plus

Linz

St. Veit an der Glan

Tulln

K1 Center 2030: research programme
WOOD - Transition to a sustainable bioeconomy

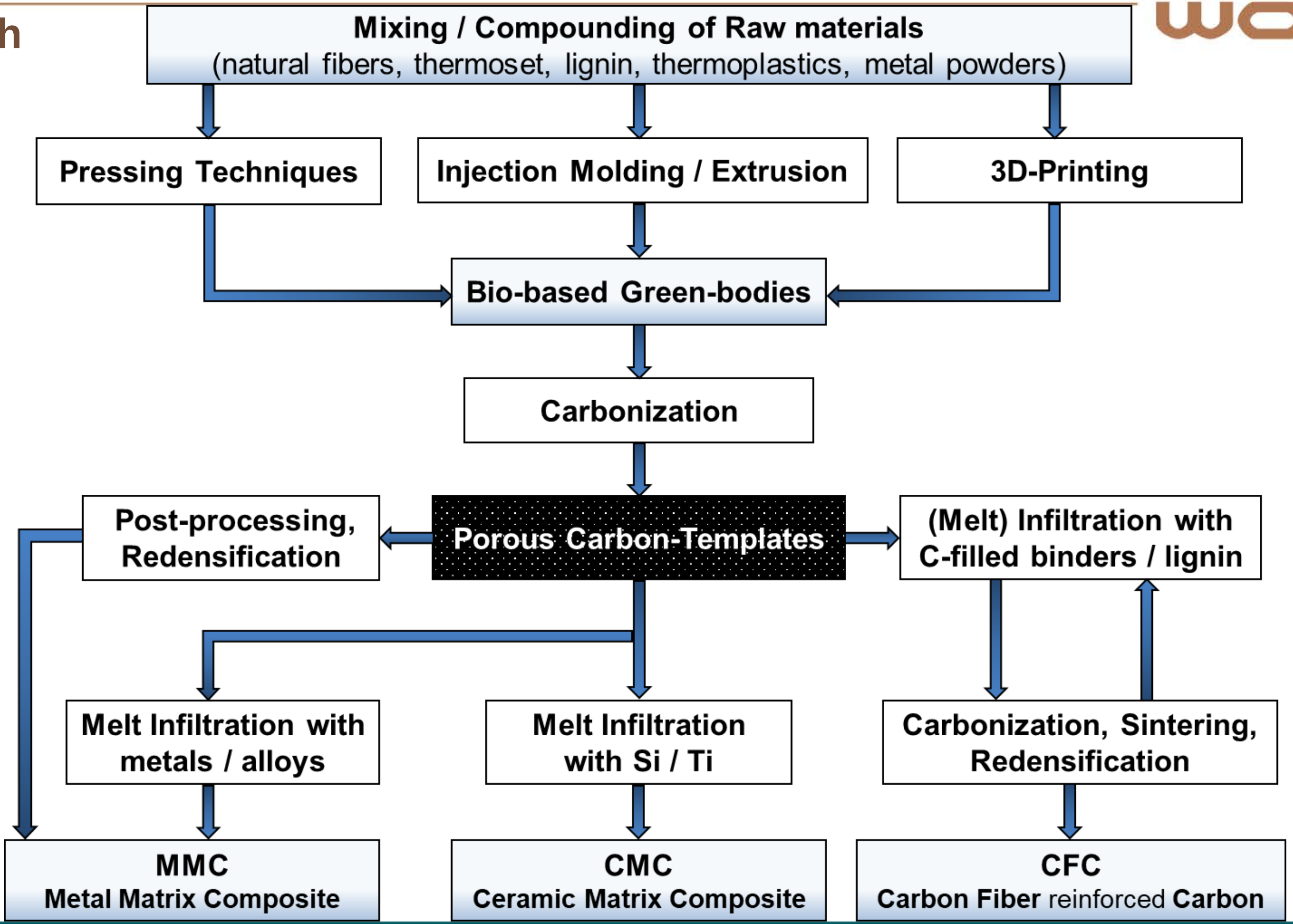


Approach

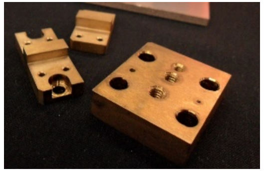
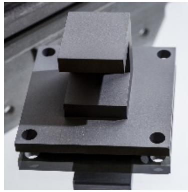
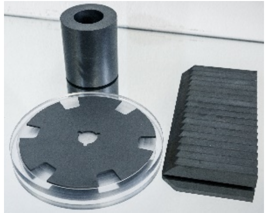
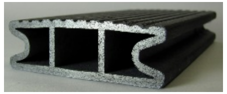
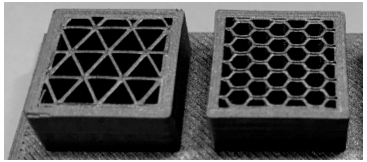
Development of **bio-based precursors** for **porous carbon pre-forms for** the manufacture of **MMCs, CMCs and CFCs**.

- **Preparation of green-bodies** from novel thermoset-based natural fiber composites (NFCs) using **injection molding, 3D-printing, extrusion** and **pressing techniques.**
- Transformation of the NFC green-bodies into **porous carbon pre-forms by** a subsequent **carbonization** step.
- **Melt infiltration** of the porous carbon pre-forms **with metals, semi-metals and carbon-rich bio-based binders** to form MMCs, CMCs and CFCs.
- Evaluation of the material specifications of the MMCs, CMCs and CFCs.
- **Benchmark** the **properties** of the experimental models with comparable PAN-CF respectively fossil based MMCs, CMCs and CFCs.

Approach and Methods



Specifications, Applications

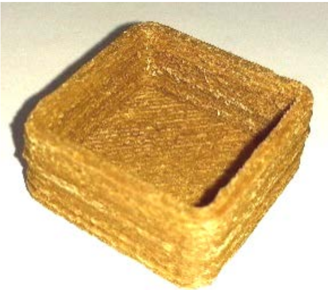
	Material Specifications	Possible Appilcations	
MMCs	▪ High heat conductivity ▪ Low thermal dilatation	▪ Cooling elements ▪ Brackets ▪ Tribolic, self greasing materials	  
CMCs (SiC/C)	▪ High resistance to thermal shock ▪ Low thermal dilatation ▪ Enhanced toughness ▪ Temperature stability	▪ Brake disks ▪ Friction bearing ▪ Ballstic elements ▪ Heat exchanger ▪ Furnace elements	  
CFCs	▪ Low thermal dilatation ▪ Pressure resistant ▪ High bending strength	▪ Furnace structure elements ▪ Collimators ▪ Furnace insulation ▪ Heater elements ▪ Thermal Isolation, spreader	 

Photos: RHP Technologies, Wood K plus

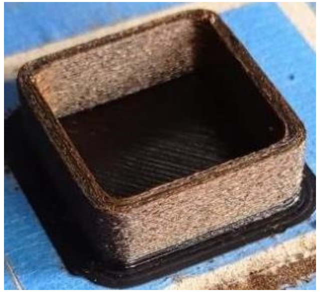
Results and Discussion

Preparation of Green-Bodies and Corresponding Porous Carbons

3D-Printing (feedstock printer) **Injection Molding**

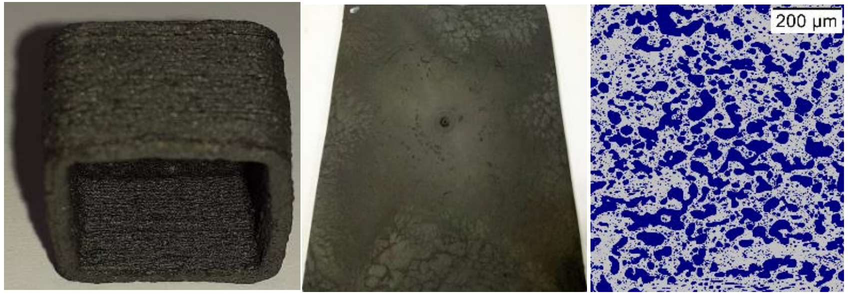


Wood fiber based



Lignin based

Wood fiber based



Corresponding porous carbon templates and micrograph

- 3D-printing and injection molding: around 30 wt% natural fiber content is the upper limit → **injection pressure and flowing properties are limiting**.
- 3D-printing: **zero pressure** / injection molding: **up to 2000 bar**.
- **Carbonization** of green-bodies with 30 wt% natural fiber content leads to porous carbon templates with densities between 0.60-0.75 g cm^{-3}.

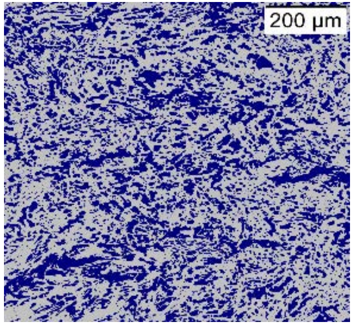
Results and Discussion

Preparation of Green-Bodies and Corresponding Porous Carbons

Press

Profile Extrusion

Both wood fiber based with corresponding porous carbon templates



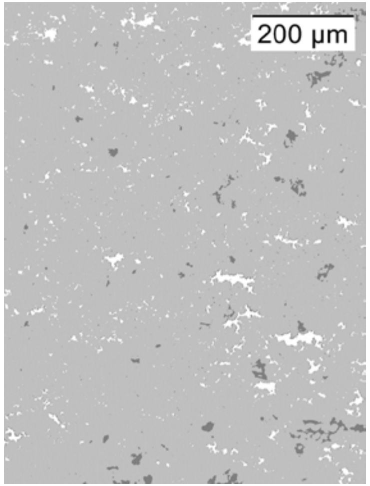
Carbon micrograph

- Compounds with a natural fiber content **> 40 wt%** → by pressing and extrusion only.
- Press: **10-30 bar** / profile extrusion: **100-200 bar**.
- With fiber contents of **50 wt%** in the green-bodies densities of the porous carbon templates reach 0.85-0.95 g cm^{-3}.

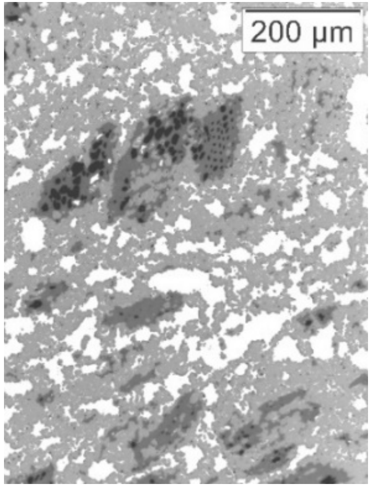
Results and Discussion

Preparation of CMCs by Si-infiltration of Porous Carbons

C/Si/SiC-ceramic profile



C/Si/SiC with high SiC-content



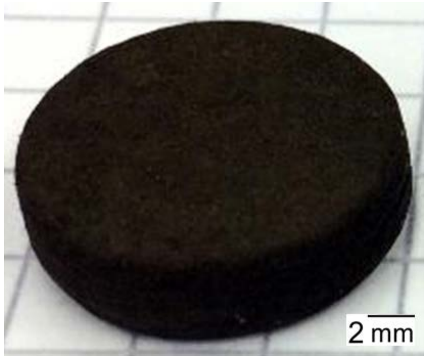
C/Si/SiC with high Si-content

micrographs (SiC: light grey, C: dark grey, Si: white)

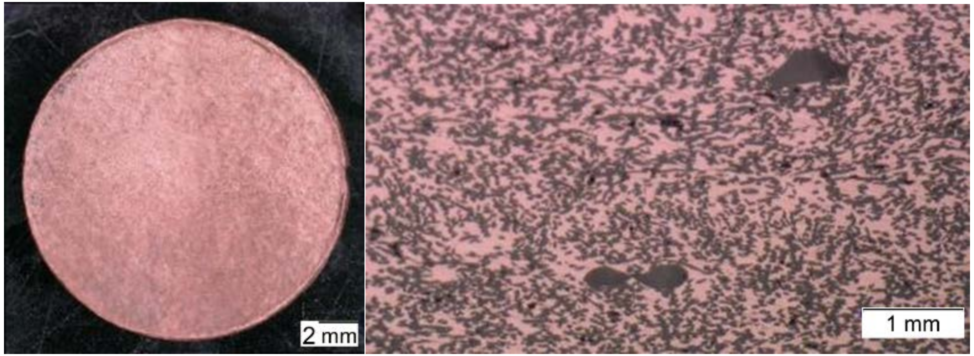
- **Liquid silicon infiltration** at 1600 °C, vacuum.
- Density of the porous carbons determines the grade of the **C/Si/SiC-ceramics**.
- Green bodies with **30 wt% natural fibers → high Si content** in ceramic.
- Green bodies with **50 wt% natural fibers → high SiC content** in ceramic.

Results and Discussion

Preparation of Cu/C-MMCs by Pressing Techniques



Mixed fibers and copper powder pressed at 100 MPa and carbonized



Cu/C-MMC: redensified at 1000°C, 50 MPa (Ar+H_2) and micrograph (Cu: reddish).

- 50/50 wt% mixtures of **copper powder and Tencel© fibers** were pressed with 100 MPa to pellets and carbonized at 900 °C (inert atmosphere).
- Redensification and heat treatment at 1000 °C and 50 MPa under a reducing atmosphere.
- The micrograph of the resulting Cu/C-MMC shows an **overall homogeneous distribution** of the carbon in the copper matrix. Some aggregates are visible.

Summary and Outlook

- Novel thermoset-based NFC **green-bodies** have been prepared by injection moulding, 3D-printing, extrusion and pressing techniques.
- A carbonization of these NFC green-bodies leads to **porous carbon pre-forms**.
- Further processing to **CMC**s by liquid silicon infiltration leads to **C/Si/SiC-ceramics**. The fiber content in the green-bodies determines in a great extent the grade of the final CMCs.
- **MMC**s have been prepared by pressing techniques and heat treatment from **copper** and **natural fibers**. The fiber structure of viscose derived Cu/C-MMCs is superior to the particle structure of wood and leads to competitive heat conductivities compared to PAN-CF MMC analogues.
- The focus in the **following work** lies in developing MMCs by infiltration with metal melts and CFCs by infiltration with carbon-rich bio-based binders into porous carbon pre-forms.

This work was conducted within the **project BioC4HiTech** funded through the program

Production of the Future by the **Austrian Research Promotion Agency (FFG)**.

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

FFG
Forschung wirkt.

Contact:

Dr. Andreas Haider
Business Development

Kompetenzzentrum Holz GmbH
Altenberger Straße 69, 4040 Linz, Austria

Phone: +43 (0)732 2468 6771
Cell: +43 (0)676 897 44 535
E-Mail: a.haider@wood-kplus.at

Homepage: www.wood-kplus.at
YouTube: https://www.youtube.com/channel/UCiTTkVVmNwOXMpvbXr3jPqQ
LinkedIn: https://www.linkedin.com/company/kompetenzzentrum-holz-gmbh