Characterization of the microstructure of wood-based ceramics using synchrotron radiation-based x-ray microtomography (SRµCT)

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Wood is a natural tissue complex consisting of various cell types like tracheids, fibres, vessels and parenchyma cells. It is mainly composed of cell walls with cellulose, hemicellulose and lignin as the major biopolymeric constituents. Due to this unique hierarchical architecture of the cellular microstructure wood exhibits a remarkable combination of high strength, stiffness and toughness at low density. Recent activities are directed to the question how to transform the hierarchical cellular structure of wood into inorganic materials like ceramics with specific functional properties. SiC-based ceramics exhibit excellent properties like strong mechanical strength at high temperature as well as corrosion resistance. Therefore, such materials are currently intensively studied for a broad variety of uses ranging from dense materials for frictional and structural application, to materials with a defined porosity for high-temperature filter or catalyst support structures. With regard to SiC-ceramics derived from wood it was shown that the cellular structure can be transformed into biocarbon templates and SiSiC-ceramics. However, the anisotropic mechanical behavior of wood is still maintained. Furthermore, optimized wood-based composites were developed and transformed into SiSiC-ceramics, showing high isotropy and easily reproducible characteristics (Hofenauer et al. 2003, 2006). Following carbonization at 800-1800°C in inert atmosphere (Treusch et al. 2004, Zollfrank and Fromm 2009) the carbon template was converted to SiSiC by a liquid infiltration process at 1600°C.

In order to gain insights into the mechanisms which govern the infiltration and reaction processes as well as structure development during Si-infiltration on the micrometer scale we investigated the structure of biomorphous SiSiC-ceramics derived from pinewood and bamboo, as well as of SiC-ceramics of a fiber board. The measurements were performed at the GKSS materials science beamline HARWI-II at DESY in Hamburg, Germany, using photon energy of 23-60 keV, dependent on sample size.

The analysis of the SiC ceramic of the medium fiber board revealed the high porosity of this material, which is distinguishing for this kind of material and also consistent after transformation into a ceramic (Fig. 1A). The high porosity is typical for the Si-gas-infiltration technique applied for this sample. Figure 1B represents a cross section of a SiSiC ceramic of bamboo produced by liquid Si infiltration, showing the darker vascular bundles embedded in parenchymatic ground tissue, consisting of SiSiC. The dark bundle sheath indicates pure carbon, which was not transformed into SiSiC. The longitudional section of the sample (Fig. 1C) shows small and evenly distributed bright patches, which indicate elemental silicon embedded in a grey pictured matrix, which indicates the SiC body; the dark patches again represent pure carbon which has not been transformed due to narrow cellular lumina of the original plant tissue (sclerenchymatous sheath of vascular bundles). Furthermore, the SiSiC ceramic of solid pinewood makes the typical tree ring structure visible and shows a very low porosity typical for the liquid Si-infiltration technique (Fig. 1D).

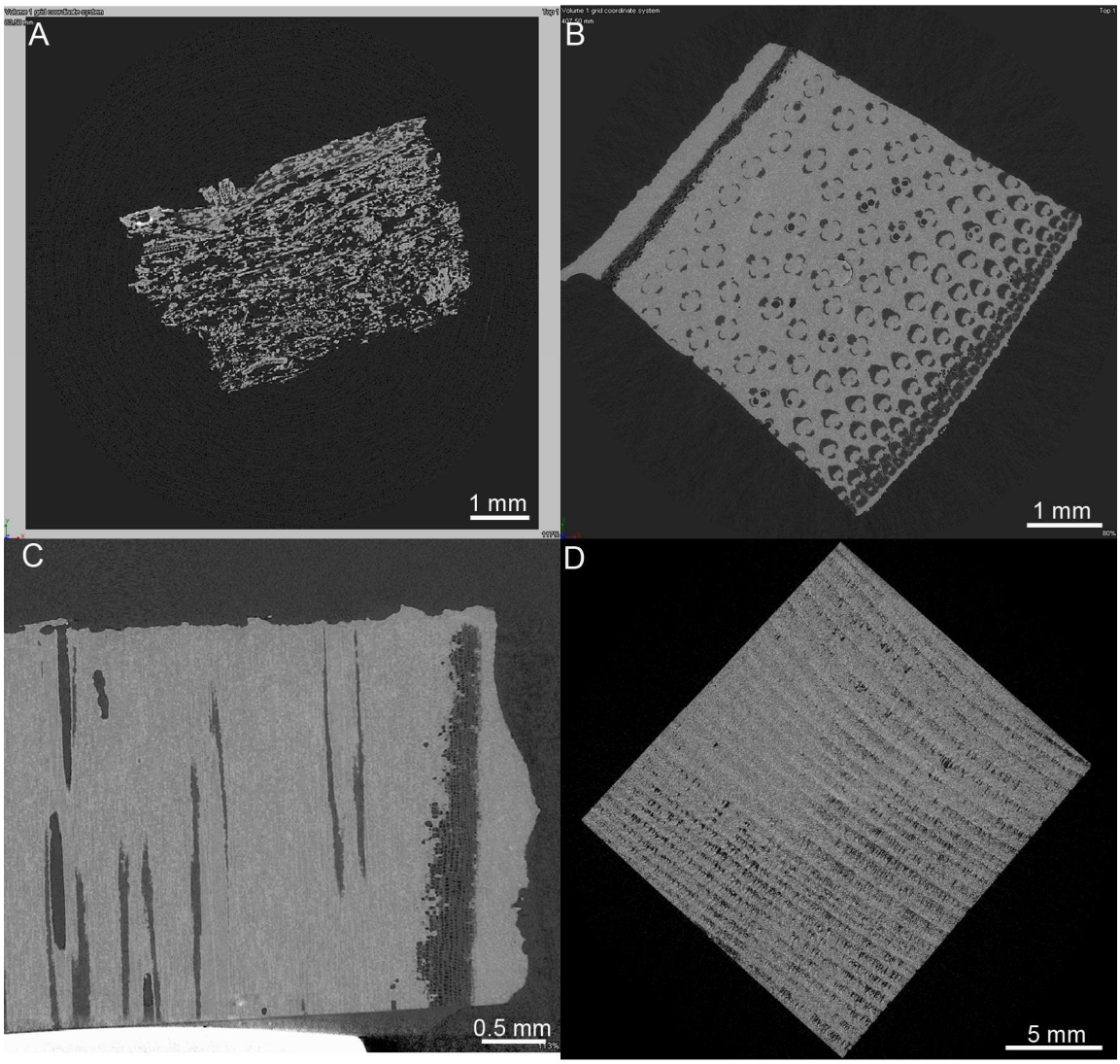

Figure 1: Wood-based ceramics analyzed with µ-CT under different photon energy levels. A: SiC ceramic of a medium fiber board (cross section, E = 23 keV), B and C: SiSiC ceramic of bamboo (B: cross section, C: longitudinal section, E= 31 keV), D: SiSiC ceramic of solid pinewood (cross section, E= 60 keV).

References

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