COMBINED X-RAY SCATTERING AND X-RAY MICROTOMOGRAPHY SET-UP REVEALS NOVEL INFORMATION ON PLANT STRUCTURES

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The complex, hierarchical structure of plant materials is a challenge from an experimental viewpoint. The macroscopic properties of plants are related at the microscale to the distribution of the different cells and their cell wall orientation. They are, however, also related to the nanoscale structure: in particular to the distribution, crystallinity and orientation of the cellulose microfibrils. In order to connect the structures at different length scales, more than one experimental technique is needed. X-ray microtomography (XMT) and wide-angle X-ray scattering (WAXS) yield information at micrometer and nanometer size scales, respectively.

A unique bench-top set-up built at the Department of Physics [1] combines the XMT and WAXS instruments. It allows the three-dimensional information obtained from the XMT to be used for selecting a volume-of-interest from the sample. This technique is called spatially-localized X-ray scattering and it employs a 200-μm diameter pencil-beam for the scattering experiments.

With WAXS, the sample crystallinity, the average cellulose crystallite size, the microfibril angle and the possible presence of crystalline, non-cellulosic material can be assessed. The spatially-localized WAXS connects this uniquely to the cell-level structure. In addition to the volumes-of-interest, the method can be used to obtain a two- or three-dimensional WAXS information mapping by using diffraction-contrast tomography. Due to the high-accessibility compared to synchrotron sources, the bench-top instrument is a very promising tool for studying the structure of plant materials at different, inter-connected length scales.

As a proof-of-concept, the set-up has been recently used to study the orientation in different tissues of Moso bamboo [2]. The parenchyma and fiber tissue did not differ in crystallinity or cellulose crystallite size, but differed significantly in the orientation of the cellulose microfibrils. Novel quantitative models for the microfibril angle distribution in the parenchyma and fiber tissues were obtained. A new application for this set-up is the upcoming project focusing on the wood material used in electric guitars.

[1] J.-P- Suuronen, A. Kallonen, V. Hänninen, M. Blomberg, K. Hämäläinen and R. Serimaa, Journal of Applied Crystallography 47 (2014) 471.
[2] P. Ahvenainen, P. G. Dixon, A. Kallonen, H. Suhonen, L. J. Gibson and K. Svedström. Plant Methods 13:5 (2017)