Measuring Moisture-Induced Deformation in the Cellulose Crystalline Structure of Wood Cell Walls with Wide-Angle X-Ray Diffraction

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Moisture content in hygroscopic materials such as wood and other forest products can affect their properties, structure and ultimately, performance. Moisture-induced swelling stresses can lead to structural changes across several length scales, including even the deformation of the cellulose crystals. However, the mechanisms behind this swelling are not fully understood.

Here, we used x-ray diffraction with humidity control as a tool to quantify changes in the cellulose crystalline structure within wood cell walls. Wide-angle x-ray scattering experiments were conducted using a Cu-Kα source, and a custom-built chamber that allowed us to control the humidity inside the enclosure using aqueous salt solutions. To minimize variability, we studied earlywood and latewood specimens of various thicknesses obtained from the same growth ring. All samples were placed inside the humidity chamber, in order, to equilibrate them at four different humidity conditions, namely, 0%, 30%, 75% and 95%. Scattering patterns were measured once the samples had equilibrated for over 24 hours at each condition.

The effect of cell wall density and the number of neighboring cells on the measured diffraction patterns will be highlighted, particularly, in terms of our ability to measure the cellulose microfibril angle and the cellulose crystal lattice spacings. It is expected that our findings will allow us to better understand the mechanisms behind the moisture-induced swelling stresses that are observed in unmodified wood, and eventually chemically modified wood.