Ultrastructure of the plant cell wall - link to biomechanics -

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Wood in forest trees undergoes internal stresses during the whole life. Such stress is a potential of the material to strain or even to crack when processed. However, the living tree takes advantages of the stress: tensile longitudinal stress protects sapwood against excessive outer forces such as wind inducing compressive bending stress.

The tension wood is one of the extreme responses of hardwood trees to keep the stem upright or to adjust branches at certain angle to the stem. At the microscopic level, such reaction is found by the formation of G fibers, where the cellulose microfibrils are aligned nearly parallel to the fiber axes. This appears in the upper part of the branch or inclined stem and exert high tensile strength.

At the tree level, the apparition of a tensile stress in the newly formed wood layers is related to the conjunction of two facts: during its formation, the wood have a spontaneous tendency to shrink longitudinally; but this tendency is impeded because the new wood is strongly glued to the internal older wood, so that a tensile longitudinal stress results. The magnitude of the maturation stress can be estimated at the surface of living trees, by mechanically dissociating a portion of wood from the rest of the tree, and recording the generated strain. The order of magnitude of the measured longitudinal strains is around to ca. 300 microstrains (μm/m) in normal wood and can be up to ca. 3000 microstrains in tension wood.

The present study focuses on the role of cellulose crystal in relation to such growth stress in tension wood. The branches from poplar tension wood were introduced to the beam line BL40XU, and the WAXS patterns were collected by the exposure less than second. After taking the first diagram, the sample was trimmed by sawing to release the longitudinal stress. Then, the second diagram was taken without delay. These lines of experiments demonstrate that, before the stress release, the cellulose was in a state of tension, which is, to our knowledge, the first experi- mental evidence supporting the assumption that tension is induced in cellulose micro- fibrils in the tension wood cell wall [1].

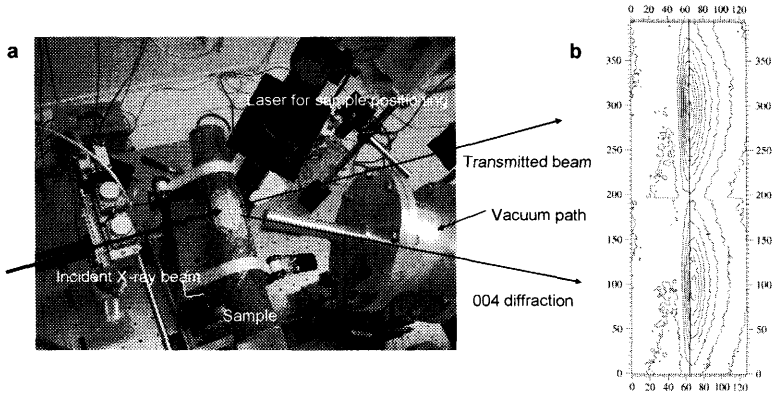

Fig 1 a: Experimental setup at BL40XU, SPring8, Harima, Japan. The log was tightly fixed being tilted ca.15° with respect to the incidence so that the (004) planes satisfy Bragg condition. The vacuum path of 1.5 m was inserted to suppress the background due to the air scattering.
b: The peak position of (004) diffraction shifted toward the higher angle (to the right), indicating that the fiber repeat distance is extended upon the release of the maturation stress.

[1] Clair B, Almeras T, Yamamoto H, Okuyama T, Sugiyama J, 2006, Biophys J, BioFAST: doi:10.1529/ biophysj.105.078485