Finite Element Modeling of the Cyclic Wetting Mechanism in the Active Part of Wheat Awns

Abstract

Many plant tissues and organs are capable of moving due to changes in the humidity of the environment, such as the opening of the seed capsule of the ice plant and the opening of the pine cone. These are fascinating examples for the materials engineer, as these tissues are non-living and move solely through the differential swelling of anisotropic tissues and in principle may serve as examples for the bio-inspired design of artificial actuators. In this paper, we model the microstructure of the wild wheat awn (Triticum turgidum ssp. dicoccoides) by finite elements, especially focusing on the specific microscopic features of the active part of the awn. Based on earlier experimental findings, cell walls are modeled as multilayered cylindrical tubes with alternating cellulose fiber orientation in successive layers. It is shown that swelling upon hydration of this system leads to the formation of gaps between the layers, which could act as valves, thus enabling the entry of water into the cell wall. This supports the hypothesis that this plywood-like arrangement of cellulose fibrils enhances the effect of ambient humidity by accelerated water or vapor diffusion along the gaps. The finite element model shows that a certain distribution of axially and tangentially oriented fibers is necessary to generate sufficient tensile stresses within the cell wall to open nanometer-sized gaps between cell wall layers.

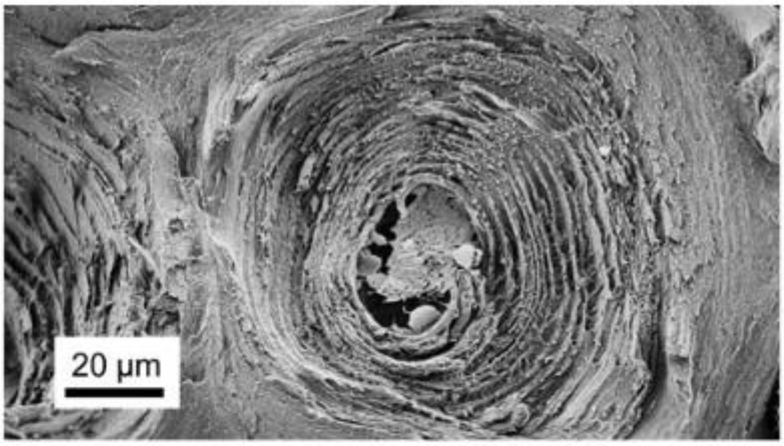

Fig. 2 Environmental scanning electron micrograph of a cell in the active part of the wheat awn showing the alternating layered structure