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Mechanical characterization of the wood cell wall by RC-AFM and UFM: sample preparation and comparison of data

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ABSTRACT

The cell wall of wood fibres is composed of layers that have a specific structure and play different roles in the mechanical properties of wood at the macroscopic scale (e.g., tree rings). The variability of the cells distribution, thickness or properties leads to difficulties in the interpretation of complex wood behaviour at the macroscopic scale (mechanosorption, growth stress generation, etc.). The measurement of the mechanical behaviour of each layer, and/or layer components, must help us to overcome some of these difficulties and achieve a better understanding about the origin of wood properties.

A variety of different Atomic Force Microscopy methods are currently being developed for the understanding and quantitative evaluation of material properties. This work was done within the framework of two STSMs from COST action FP0802, developed in Montpellier and Almadén. The aim was to compare the potential and the differences of two AFM techniques, namely Resonant Contact Atomic Force Microscopy (RC-AFM) [1] and Ultrasonic Force Microscopy (UFM) [2], for inspection of wood cell wall elastic properties. Experiments were performed on exactly the same cell wall of poplar normal wood, and also on chestnut tension wood and paulownia normal wood samples. The first technique, RC-AFM, allows us to obtain a semi-quantitative map of elastic contact modulus on wood cell wall [3]. The second one, UFM, has a very high spatial resolution, sufficient to image the difference of elastic contact modulus between microfibrils bundles and surrounding matrix.

The sample topography of a whole cell of poplar, measured by AFM, is shown in Fig. 1a. We can observe the effect of cutting irregularities on the sample topography [3]. Fig. 1b gives the results obtained in UFM (signal amplitude given by the lock-in amplifier) and Fig. 1c those obtained in RC-AFM (contact modulus). We can see that the data are qualitatively very similar. The highest contact modulus in Fig. 1c is well correlated to the highest UFM amplitude in Fig. 1b. Moreover, on both cases, the compound middle lamella appears a little bit stiffer than the embedding resin but softer than the S₂-layer (as expected), and the topography has a small effect in both measurements.

High-resolution images, not shown in this abstract, allow us to resolve almost ellipsoidal structures of main average sizes from around 50 to 100 nm. They seem to be composed by smaller parts with a diameter around 20 nm, close to what is usually taken to be the size of the microfibrils bundles in softwood and hardwood. So the biggest features observed here could be bundle of microfibrils bundle. However, these structures are, in average, aligned along the cutting direction. This alignment could not be only attributed to the real ultrastructure arrangement in the wall. In the presentation, we

will discuss this data and considered the effects of the sample and surface preparation. According to our results, both techniques give similar results at the cell scale demonstrating that RC-AFM and UFM are complementary techniques.

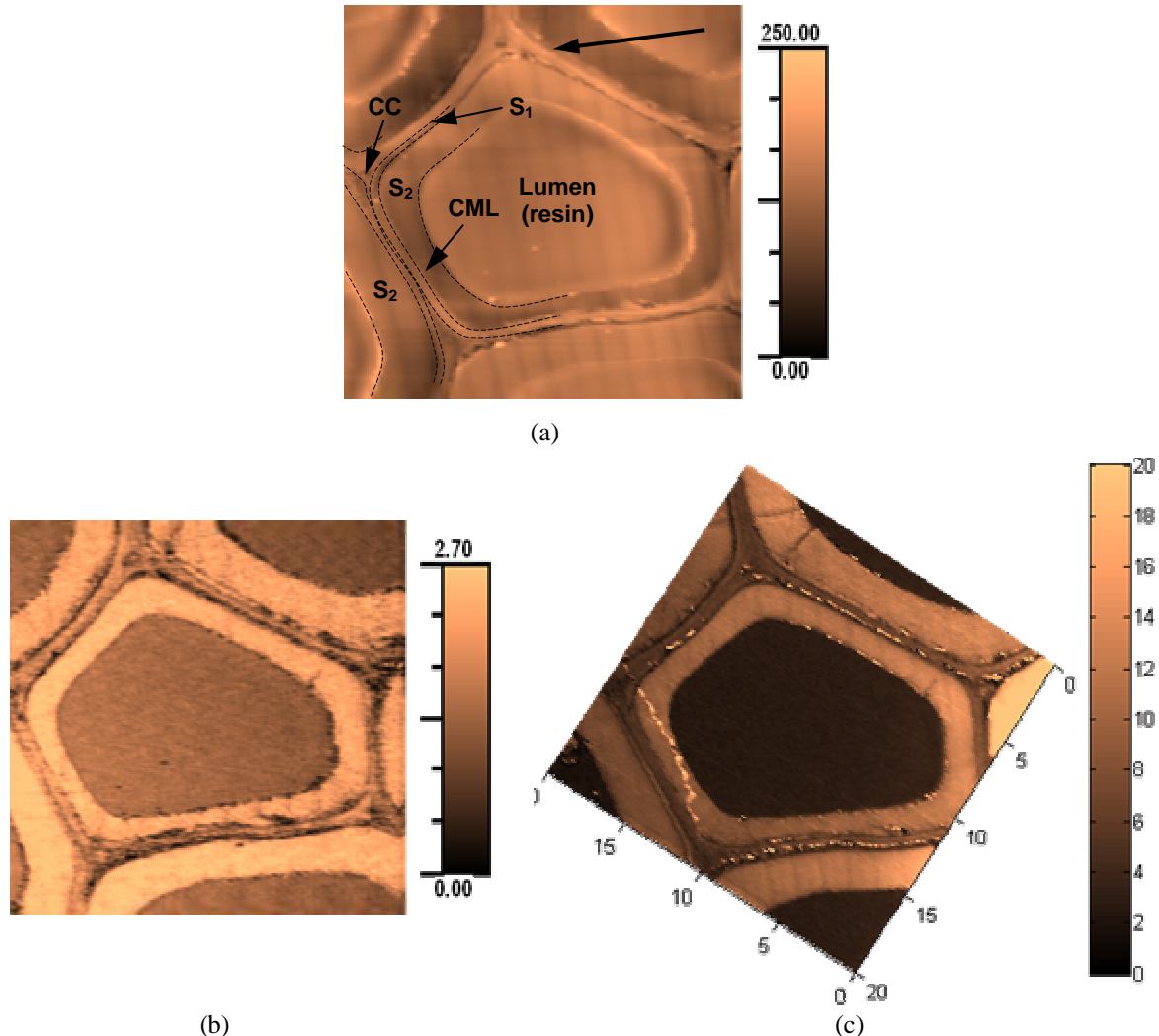


Figure 1: a) AFM topography (nm) of the sample surface in contact mode (20×20 μm): Embedding resin inside the lumen, CC-cell corner, CML-compound middle lamella, S₁ and S₂-layers of the secondary wall. The arrow indicates the cutting direction. b) UFM amplitude (V) (T = 26.5°C, RH = 45%, mc ≈ 8.2%); c) Contact modulus (GPa) measured by RC-AFM (T = 21°C, RH = 51%, mc ≈ 9.2%).

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