Nanometrology of biomass for bioenergy

Background

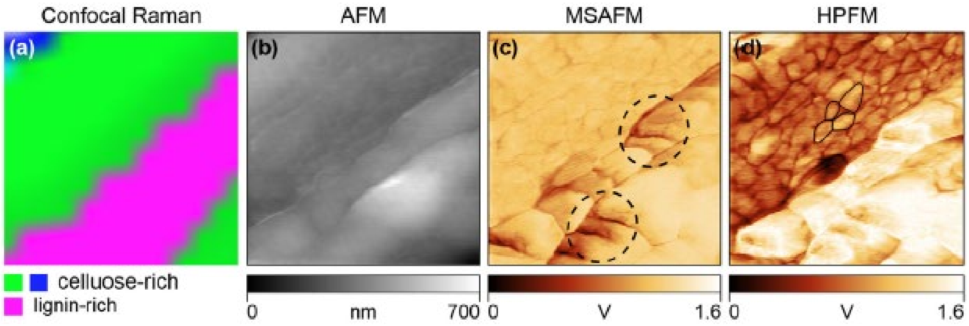
Atomic force microscopy (AFM), capitalizing on the interfacial nanomechanical forces, can provide a suite of measurement modalities for nondestructive material characterization.

Approach

Identifying the utility of the various techniques, this review paper encompasses the AFM-derived approaches to plant cell wall topography (AM-AFM), quantitative mechanical properties (QFM), surface/subsurface (MSAFM) and chemical composition (HPFM) imaging.

Outcome

The AFM-based measurement approaches for exploring, understanding, and relating the different properties of plant cell walls constitutes an emerging area of research within the plant biological material characterization. AFM, via its versatile dynamics, while enabling nondestructive determination of many important cellular properties under native conditions, needs to advance towards quantitative measurements, analysis, and correlation.



Demonstration of dynamic modalities and comparison of AFM based plant cell nanometrology: application of confocal Raman imaging, AFM, mode synthesizing AFM (MSAFM), and hybrid photonic force microscopy (HPFM) for the characterization of extractive-free poplar cell walls. (a) Confocal Raman image showing lignin-rich (pink) and cellulose-rich (blue, green) regions. (b) Simultaneous AFM image showing only topography. (c) MSAFM image at difference frequency, $\omega_- = 26$ kHz, brings additional clarity to the lignin structures indicated by the dashed circled regions. (d) HPFM image at photonic actuation using a quantum cascade laser (QCL) with an amplitude modulation of $\omega_{QCL} \rightarrow \omega_- = 26$ kHz, reveals additional detail of the near-surface cellulosic globules shown outlined. Adapted from Farahi et al., Sci Rep (2017).

Significance

For physical and chemical characterization of plant and microbial systems relevant to bioenergy and environmental research, ORNL's emerging AFM-based configurations of MSAFAM and HPFM for high-resolution morphological and spectroscopic studies hold great potential. It is predicted that novel and targeted AFM-based studies will help establishing the basic properties of the plant cells during chemical pre-treatment and phenotyping as well as contributing to streamlining of biofuel production.

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