Emerging Techniques in Modern Microscopies

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Dissolution dynamics of lignin of poplar fiber cell wall during hydrothermal pretreatment by analytical microscopy approaches

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Increasing attention has been paid to the converting lignocellulosic materials (LCMs) into bio-energy, bio-chemicals and bio-based materials in the biorefinery. However, the efficiency of the conversion has been limited due to the native recalcitrance of plant cell walls, which can be partially eliminated through various pretreatments [1]. Therefore, a detailed investigation on the chemical and structural changes in different morphological regions of the cell walls during the pretreatment process is critical to the development of optimal pretreatment conditions**.** In this study, poplar that is a potential feedstock for bioethanol production was subjected to liquid hot-water pretreatment at the desired reaction time. Confocal Raman microscopy (CRM) and scanning electron microscopy (SEM) were utilized to analyse the influence of the hydrothermal pretreatment time on the chemical composition of the cell wall at the sub-cellular level. The Raman images demonstrated that the removal of lignin was mainly from the middle layer of secondary wall (S2) and compound middle lamella (CML) and remarkably increased with increasing reaction time (Figure 1a-1e). Meanwhile, the removing rate in S2 was found to be faster than in CML and CCML after 20 min, whereas there was an opposite trend for 10 min (Figure 1f, 1g). SEM images revealed that a small amount of droplets appeared in the CCML after 5 min (Figure 2b). A high density of droplets accumulated in the CML and S2 over time (Figure 2c-2e). As the pretreatment time extended to 40 min (Figure 2f), droplets principally existed in the CML. These results suggest that the migration of the lignin from the cell wall matrix could be oriented on the whole both from the S2 adjacent to CML to CC and from the S2 close to S3 to cell lumen although it actually occurs from every direction. Furthermore, the distribution of the residual lignin and redeposited lignin in the different morphological regions of the cell walls varies with the hydrothermal pretreatment time. This study provides valuable new insights towards the dissolution dynamics of lignin during hydrothermal pretreatment and can potentially contribute to the development of efficient cell wall deconstruction using liquid hot-water.

1. Y. Q. Pu, F. Hu and A.J. Ragauskas, 6 (2013), p. 1.
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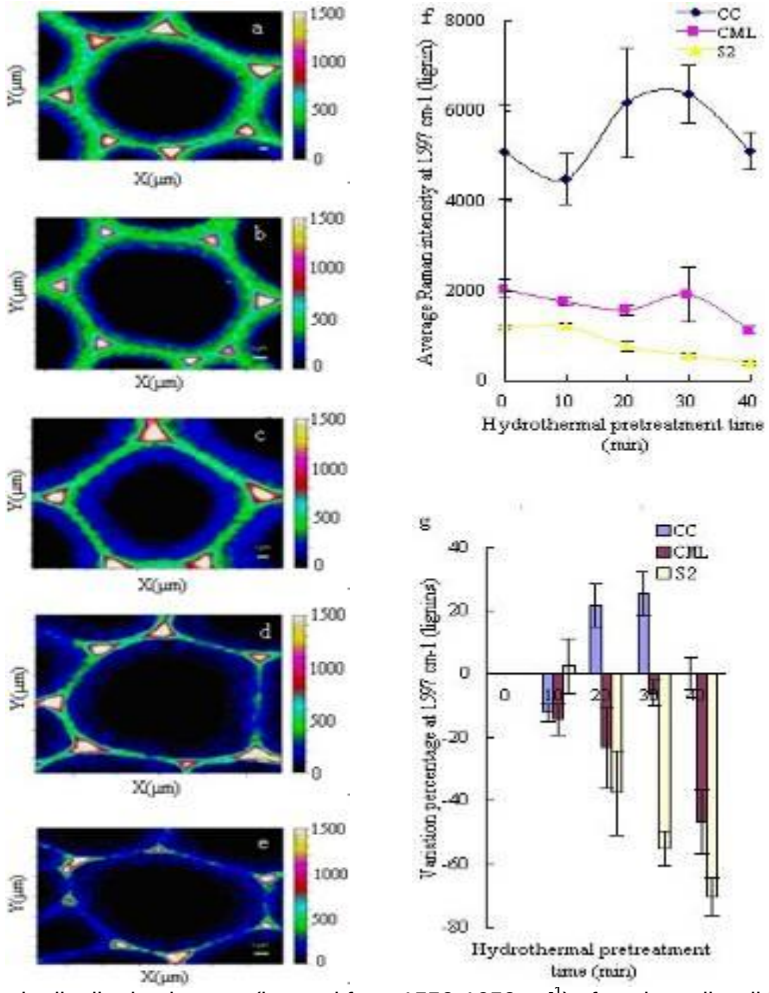

Figure 1. Lignin distribution images (integral from 1550-1650cm^{-1}) of poplar cell wall in cross section before (a) and after hydrothermal pretreatment (b-e) at 170°C for 10, 20, 30, 40 min respectively. Changes in average Raman intensity at 1597cm^{-1} (f) located in different morphological cell wall regions with the increasing pretreatment time. Variation percentage in average Raman intensity at 1597cm^{-1} (g) located in different morphological cell wall regions with the increasing pretreatment time.

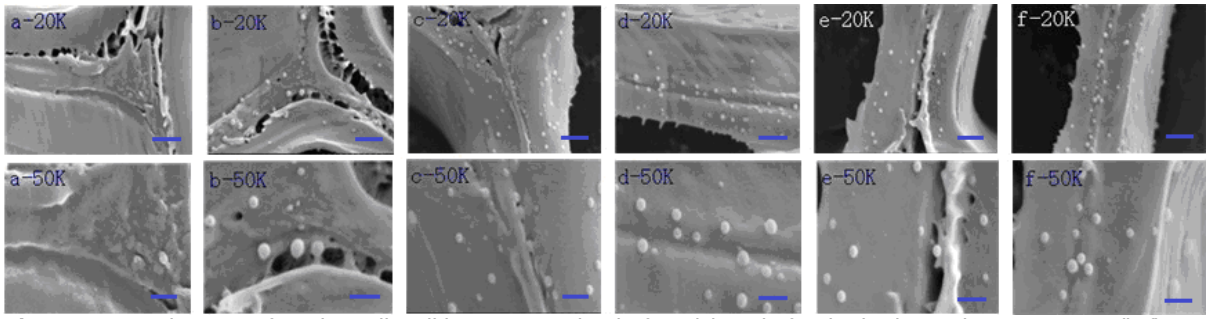

Figure 2. SEM images of poplar cell wall in cross section before (a) and after hydrothermal pretreatment (b-f) at 170°C for 5, 10, 20, 30, 40 min respectively. Scale bar: 1 μm (a-f, 20K), 0.5 μm (a-f, 50K)