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Functional optical coherence tomography (fOCT) based on biospeckle to monitor environmental stresses on plants

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Introduction

Resently a demand to monitor the biological condition of plant has been increased due to the improvement of environmental pollution. Processes such as cytoplasmic streaming, organelle movement, cell growth and division, and biochemical reactions are the functional activities occurring inside of plant leaf. These activities are changed under the influence of environmental stresses. In this study, we proposed to utilize a biospeckle signal to achieve a functional optical coherence tomography (fOCT) to monitor the biological activities of plant. The dynamic speckle pattern obtained when a laser light illuminates leaf is characteristic for living objects and these functional activities and has been called a biospeckle.

Experiments and discussion

To examine the fOCT biospeckles, OCT cross-sectional images were acquired successively at a time period (0.1 seconds). Two different methods were used to analyze biospeckle signals coming from different spatial positions of the cross-sectional image. In first method, magnitude of biospeckle signal, in other words, standard deviation (SD) of the signal was calculated along time axis of each spatial position from the array of OCT cross-sectional images. Then a fOCT biospeckle image was constructed from the SDs of biospeckle signals. Chinese chive was exposed to 0, 80, 120, and 240ppb O_3 concentrations for 3hours separately, following another 3hours of charcoal filtered air (CF). Data acquired before, at 1, 2, and 3 of exposure (averaged as *within*) as well as 1, 2, and 3hours after exposure (averaged as *after*). The effects to back side of the leaf were observed. Increment in averaged and normalized SD (ANSD) of fluctuation in epidermal layer with O_3 exposure and concentration was observed (Fig.3). Further, cell structure became more clear in the fOCT biospeckle (Fig. 2) image than conventional OCT cross-sectional image (Fig. 1).

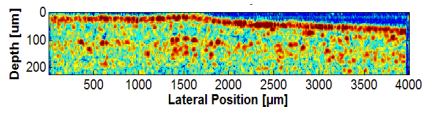

Fig. 1

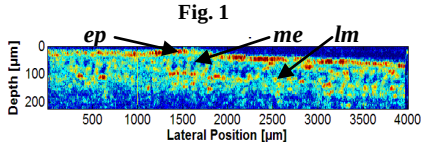

Fig. 2, *ep*-epidermal layer, *me*-mesophyll cell layer, *lm*-layer bellow mesophyll cell layer.

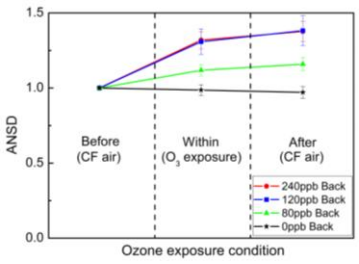

Fig. 3

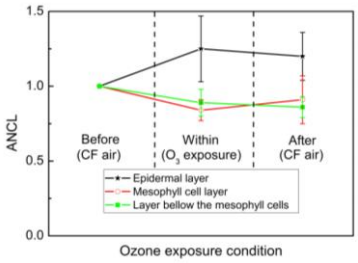

Fig. 4

In our second method, temporal characteristics of the biospeckle signals were analyzed by acquiring biospeckle signals from different depth positions at fixed lateral positions, and their autocorrelation functions were calculated. Next, correlation lengths (CLs) were calculated to quantify the temporal characteristics of the biospeckle signal. Experiments were conducted with Chinese chive under 240ppb of O_3 exposure for 3hours (data acquired as first approach). Significant change in biospeckle signal coming from mesophyll cell layer could be seen (Fig. 4). First approach could not identify the effect of O_3 for mesophyll cells as the magnitude of fluctuation of the signal from more deeper layers was weak. However, with second method the immediate impact of O_3 on these cells was observed clearly as it is based on temporal characteristics of the fluctuations.

Conclusion

fOCT based on biospekle, could investigate the immediate impact of environmental stresses, specially O_3 stress, in very short span of time quantitatively and qualitatively, which is not possible with conventional experimental methods and even with conventional OCT imaging.

Reference

1. Srimal L. K. T. *et.al*, Proc. of SPIE Vol. 8881, 88810H, 2013