A Multifunctional Stretchable Sensor for Continuous Monitoring Long-term Leaf Physiology and Microclimate

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Abstract

Communication with plants to understand their growth mechanisms and interaction with surrounding environment may improve production yield in agriculture and facilitate prevention of plant diseases and negative influence of environmental stress[[1](#_ENREF_1)]. Typical sensing technologies in plant biology and precision agriculture largely rely on techniques with low spatial and temporal resolutions, unable to determine localized variation in leaf physiology and microenvironments[[2](#_ENREF_2), [3](#_ENREF_3)]. Here, techniques to develop multifunctional stretchable leaf-mounted sensor have been developed to offer optimized adaptability to plant growth and monitor leaf physiological and environmental conditions in continuous and highly sensitive manners. The multifunctional leaf sensor contains multiple heterogeneous sensing elements made of metal, carbon nanotube matrix and silicon (Figure 1a), leading to temperature, hydration, light illuminance, and strain sensing capabilities on a leaf (Figure 1b). The entire sensor can withstand different deformations and grow together with the host leaf in a measurement period of 7 days (Figure 1c).

The sensor can be connected to a miniaturized multifunctional sensing circuit equipped with wireless transfer capability to conduct remote data transmission(Figure 2a). Indoor experiments are conducted to demonstrate the multifunctional monitoring ability of the sensor in real situations (Figure 2b-e). As shown in temperature measurement result (Figure 2b), the sensor can timely respond to four different external conditions that induce rapid temperature changes as large as 4.9 °C in local environment. The sensor is also able to monitor temperature changes that caused by natural conditions, resulting in a slow room temperature change of 5.4 °C in a day. It can be observed that the sensor has very sensitive responses to in-door lighting as well as external sunlight (Figure 2c). Its responses closely follow the variation of sunlight during the day and instantly adapt to the change in in-door lighting after the light has been switched off. The hydration sensing element has also demonstrated stable responses to slow hydration changes on the leaf as well as rapid environmental humidity changes caused by fog generation and water spraying (Figure 2d). The result of strain sensing indicates that the leaf grew steadily during the test (Figure 2e). It is noticeable that growth of the leaf is mainly in the width (y-direction), causing large deformation (15.5%) of the sensor in length as compared with 2.4% strain in width. These experimental results indicate that the multifunctional stretchable sensor holds the promise to advance monitoring techniques in plant biology and precision agriculture, resulting in improved capability to record slow and subtle physiological changes in plants and plant/environment interaction.

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| Figure 1: a) Schematic diagram and exploded view of a leaf sensor. b) Top view of the leaf sensor. c) A leaf sensor attached on a leaf grows together with the leaf throughout 7 days.    Figure 2: a) Images of an multifunctional leaf sensor attached on a corn leaf and connected to the measurement circuit. Results of b) ambient temperature, c) light intensity, d) hydration, and e) strains measured by an leaf sensor on a scindapsus leaf obtained in a period of 2 days. |

References

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