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Nanocellulose Based Electrodes for Bio-Electrical Plant Interface

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Abstract: The study of plant bioelectricity has provided a unique perspective to understand how plants sense their environment and adjust their morphology, physiology and phenotype accordingly. In this review, we exhibit nanocellulose based novel dry cathodes reasonable for use as non-intrusive bioelectrical plant interfaces. These cathodes were particularly intended to screen plant electrochemistry without altogether irritating their physiology. Using electrochemical impedance spectroscopy enabled us to construct an equivalent circuit model to evaluate the performance of the electrodes. The preliminary characterization of the electrodes *in vitro* and *in vivo* using *Arabidopsis thaliana* provided promising results.

Key words: Electrophysiology, nanocellulose, graphene, electrochemical impedance spectroscopy, botanic sensors, physiology

INTRODUCTION

Plants employ bioelectricity to communicate changes in their environment throughout the organism. Similar to a mammalian nervous system, these electrical signals can communicate changes in light, temperature, touch, sound, wounding and environmental chemicals (Telewski, 2006; Volkov and Brown, 2014). The electrical properties of the plant cells change due to ionic currents flowing through ion channels or ion pumps to relay messages (Yan *et al*., 2009; Tuckett *et al*., 2013; Wang and Zhang, 2010).

Different strategies exist for measuring plant electrophysiology. The larger part of current techniques are unrefined and require inclusion of wires or braces into the plant tissue to recognize changes in the electrical properties of the plant (Repo *et al*., 2004; Hamed *et al*., 2016). The principle issue with these strategies is the injuring reaction of the plant conceivably meddling with the coveted flag. In this review, we display, interestingly, the utilization of graphene covered nanocellulose substrates to empower non-intrusive anodes that join to the surface of the leaf through electrostatic strengths and allow the exchange of oxygen, carbon dioxide and water, along these lines giving estimations less ancient rarities possibly.

MATERIALS AND METHODS

Electrode fabrication and characterization: Plant leaf electrodes were constructed on a substrate of bacterial nanocellulose. All bacterial nanocellulose pellicles were grown by standard culture of Gluconoacetobacter xylinus, as previously described (Volkov, 2000; Rios-Rojas *et al*., 2014). The nanocellulose pellicles weredried on glass wafers resulting in sheets with a thickness between 10-40 μm. Manifestations studies is explained by Ramalingam *et al*. (2015) is based on enzyme profile of *Vibrio parahaemolyticus* MTCC451 inoculated Black Tiger Prawn *Penaeus monodon* is described by Sagadevan and Podder (2015). The research study by Taj and Kumaravel (2015) talks about an investigation of structural, SEM, TEM and dielectric properties of $BaTiO_3$ nanoparticles. Survey on fuzzy petri nets for classification. Mining the amino acid dominance in gene sequences is given by Balamurugan and Marimuthu (2015).

Plant leaf electrodes were attached to the abaxial surface of the leaf with an aqueous wetting agent and evaporative drying (Fig. 1). We have previously shown the use of pullulan, a sugar as a viable biocompatible wetting agent and adhesive for application of nanocellulose electrodes (Lisdat and Schafer, 2008). For conformal adhesion to the plant leaf, dry electrodes were soaked in a 5% (W/V) aqueous solution of pullulan for 45 sec and then pressed gently onto the leaf with the electrode side down. The electrode was allowed to dry in place for 1 h. Anisotropic conductive film with an encapsulating polyimide layer was used for connecting the electrodes to ribbon connectors for ultimate connection to any characterization device or sensor. The nanocellulose electrodes maintained a bond to the plant leaves for several weeks, beyond the scope of this study as shown in Fig. 2.

Plants were grown for ~6 weeks at the University of North Carolina Chapel Hill development chambers (in soil under bright lights at 23°C with 12 h light (150 μ Einstein/m^2/sec) and 12 h dull) and exchanged to NCSU for examinations in a controlled domain with comparable conditions. The moistness was kept at a level in the

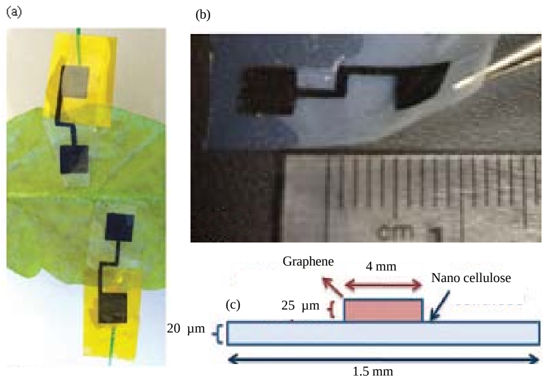

Fig. 1: a) Abaxial nanocellulose electrode application on *Arabidopsis thaliana*; b) Flexible nanocellulose graphene electrode with scale and c) Diagram of nanocellulose electrode cross-section

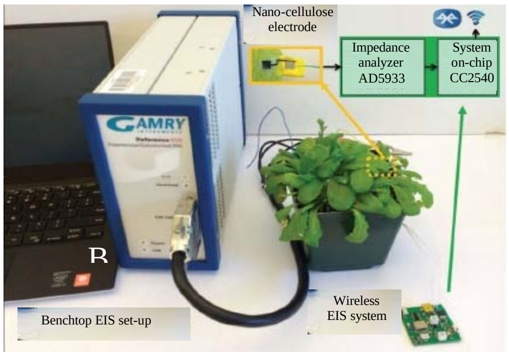

Fig. 2: Gamry potentio stat along with the custom, wireless plant experiment system with the model plant, *Arabidopsis thaliana*

vicinity of 60 and 70%. A light level of 7,000 lux was given by a 300 W full range LED development light (Vipar Spectra, Shenzhen Bailuo Technology Co.).

RESULTS AND DISCUSSION

Post electrode characterization, nanocellulose grapheme electrodes were applied to the abaxial surface of the *A. thaliana* leaf using an aqueous wetting agent and evaporative drying. Pullulan wetting provided a conformal adherence of the electrode to the leaf and upon evaporative drying the electrode was attached to the leave's surface similar to the application of a decal. After electrode attachment, we repeated EIS runs on the plant interface for two separate plants. Both electrodes produced similar results. We modeled this interface using the RC network in Fig. 3 and 4. The consistency of the impedances both in these preliminary *in vitro* and *in vivo* measurements is promising for use of the presented electrodes to track electrical properties of plants.

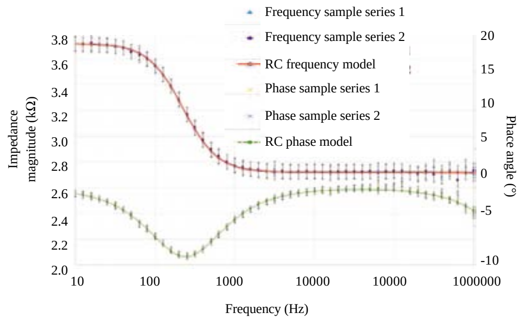

Fig. 3: Sample potentiostat results for *in vitro* electrode testing: *in vitro* impedance and phase angle vs. frequency

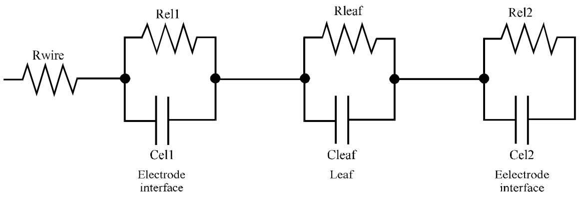

Fig. 4: Electrode interface model

CONCLUSION

The nanocellulose electrodes would give a promising interface to detect plant electrochemistry without fundamentally irritating its physiology. We introduced a model circuit for such a plant terminal interface for both *in vitro* and *in vivo* testing. Additionally, research utilizing the Arabidopsis is in progress to test the impact of ozone on rleaf and cleaf impedances to empower plantbased sensor. The nanocellulose electrodes are comprehensively appropriate to different plants and can be utilized to study harvest's reactions to ozone changes or other ecological boosts.

REFERENCES

Balamurugan, V. and T. Marimuthu, 2015. Mining the amino acid dominance in gene sequences. Indian J. Sci. Technol., 8: 1-11.

Hamed, K.B., W. Zorrig and A.H. Hamzaoui, 2016. Electrical impedance spectroscopy: A tool to investigate the responses of one halophyte to different growth and stress conditions. Comput. Electron. Agric., 123: 376-383.

Lisdat, F. and D. Schafer, 2008. The use of electrochemical impedance spectroscopy for biosensing. Analytical Bioanalytical Chem., 391: 1555-1555.

Ramalingam, K., D.R. Shyamala, N.S. Kumaran, R. Karthik and M.C. Vanitha, 2015. Manifestations studies on enzyme profile of *Vibrio parahaemolyticus* MTCC451 inoculated black tiger prawn *Penaeus monodon*. J. Fish. Aquatic Sci., 10: 477-488.

Repo, T., E. Oksanen and E. Vapaavuori, 2004. Effects of elevated concentrations of ozone and carbon dioxide on the electrical impedance of leaves of silver birch (*Betula pendula*) clones. Tree Physiol., 24: 833-843.

Rios-Rojas, L., F. Tapia and L.A. Gurovich, 2014. Electrophysiological assessment of water stress in fruit-bearing woody plants. J. Plant Physiol., 171: 799-806.

Sagadevan, S. and J. Podder, 2015. Investigation of structural, SEM, TEM and dielectric properties of $BaTiO_3$ nanoparticles. J. Nano Electron. Phys., 7: 4008-1-4008-1.

Taj, S.M. and A. Kumaravel, 2015. Survey on fuzzy petri nets for classification. Indian J. Sci. Technol., 8: 1-8.

Telewski, F.W., 2006. A unified hypothesis of mechanoperception in plants. Am. J. Botany, 93: 1466-1476.

Tuckett, V.F.F., A.G. Volkov and V.S. Markin, 2013. Electrochemical interfaces in plants. Proceedings of the 224th ECS Conference on Abstracts, October 27-November 1, 2013, ECS, San Francisco, California, pp: 2830-2830.

Volkov, A.G. and C.R. Brown, 2014. Citrus greening (Huanglongbing): Fast electrochemical detection and phytomonitoring of the trees diseases. ECS. Trans., 58: 9-17.

Volkov, A.G., 2000. Green plants: Electrochemical interfaces. J. Electroanalytical Chem., 483: 150-156.

Wang, A. and G. Zhang, 2010. Effects of drought on electrical impedance spectroscopy parameters in stems of *Pinus bungeana* Zucc seedlings. Frontiers Agric. China, 4: 468-474.

Yan, X., Z. Wang, L. Huang, C. Wang and R. Hou *et al*., 2009. Research progress on electrical signals in higher plants. Progress Nat. Sci., 19: 531-541.