Deposition of Photosystem I onto Graphene for Photoactive Electrodes

Jia Jia Zhang[a], Darlene Gunther[b], Dhiraj Prasai[b], Kirill I. Bolotin[c], David E. Cliffel[d], G. Kane Jennings[e]

Harvard University, School of Engineering and Applied Sciences[a], Cambridge, MA 02138

Vanderbilt University Interdisciplinary Materials Science Program[b] and Departments of Physics[c], Chemistry[d], and Chemical Engineering[e], Nashville, TN 37235

Abstract

Thin film, bio-inspired systems utilizing the photoactive protein complex Photosystem I (PSI) hold great promise in advancing solar energy conversion technologies. Monolayer (~7nm) and multilayer (~700nm) films of PSI deposited on conducting electrodes exhibit photocatalytic capabilities when incorporated into electrochemical cells. In this project, I rapidly assemble monolayer and multilayer films of PSI onto graphene, a one-atom thick carbon material that could one day become ubiquitous in the production of low-cost, transparent, flexible electronic devices. Cyclic voltammetric experiments demonstrate that increasing PSI film thickness (from bare to monolayer to multilayer PSI) decreases electrode peak currents, indicating the additional adsorption of insulating material onto the surface of graphene. Further, photochronoamperometric measurements show that PSI-coated graphene electrodes exhibit a greatly amplified photoresponse which varies with redox mediator used. Future work in the optimization of graphene-PSI interfaces could lead to improvements in the efficiency and cost of solar devices.

Background and Motivation

Through photosynthesis, plants and some bacteria convert solar energy to chemical energy at a global rate that exceeds our current fossil fuel consumption by 8-fold[1]; thus, depositing the photosynthetic protein PSI onto conducting electrodes of electrochemcial cells is of great interest.

Previous work has shown that, using a vacuum-assisted approach, PSI can be deposited onto CH_3-terminated self-assembled monolayers (SAMs)[2], which exhibit surface chemistry similar to that of graphene. Thin, transparent, and conductive, graphene electrodes coated with PSI could greatly enhance electron transport in organic solar cells.

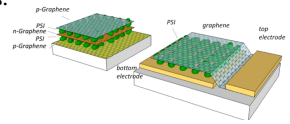
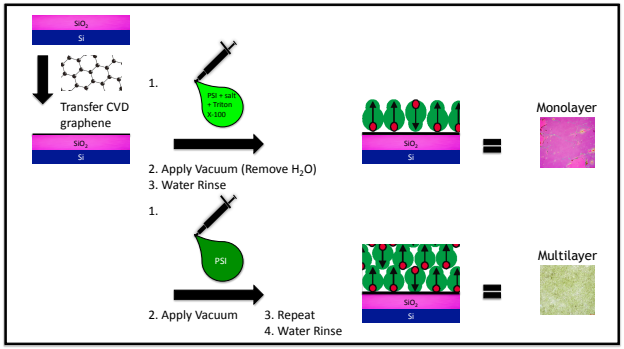


Figure 1. Long term goal: fabricate graphene-PSI sandwich and stacked structures for wet and dry solar cell configurations

Methods

Figure 2. Vacuum-assisted procedure for depositing PSI monolayers[2] and multilayers[3] onto graphene



Results

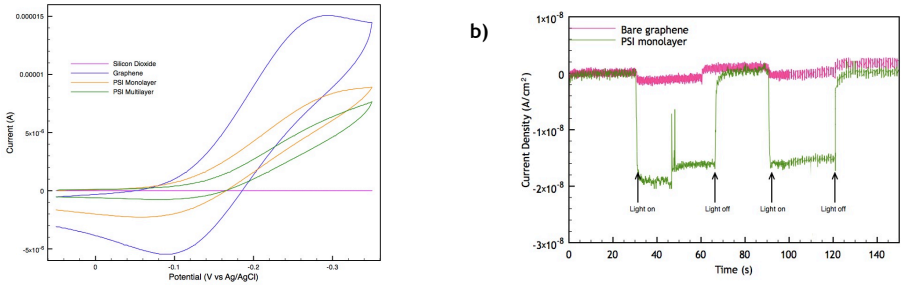


Figure 3. Electrochemical characterization of PSI-coated graphene electrodes. **(a)** Cyclic voltammograms showing decreasing peak current for bare vs. monolayer vs. multilayer electrodes, indicating the electrode surface is blocked by PSI after deposition. **(b)** Enhanced photocurrent with PSI monolayer compared to a bare graphene control.

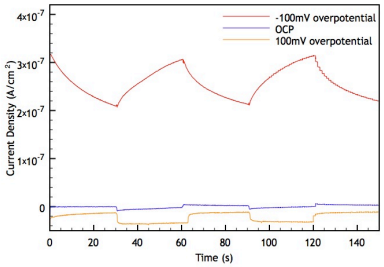


Figure 4. Photocurrent for graphene-PSI monolayer at open circuit potential, negative, and positive overpotentials; negative overpotential maximizes current generation.

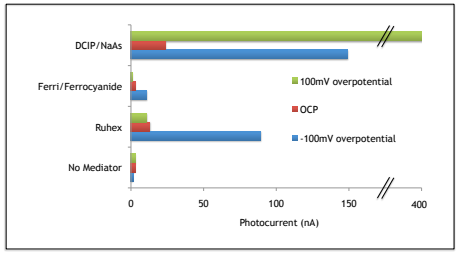


Table 1. Photochronoamperometric characterization with different electrochemical mediators also suggests PSI monolayer formation on graphene.

Conclusions and Future Work

Electrochemical characterization strongly suggests that PSI is adsorbed onto the surface of CVD graphene through deposition using a vacuum-assisted approach.

Future work will focus on further quantitative characterization of PSI monolayers on graphene and explore graphene surface modifications for better protein attachment. Additionally, advances in graphene growth and transfer techniques will also allow us to investigate the deposition of a graphene counter-electrode atop a PSI mono- or multilayer.

Acknowledgements

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References

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(2) Faulkner, C.J.; Lees, S.; Ciesielski, P.N.; Cliffel, D. E.; Jennings, G. K. *Langmuir* ***2008***, *24*, *8409*.

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