Entrapment of Photosystem I within a Polyaniline Matrix on Carbon Paper for Photocurrent Generation

Pamela Joy Tabaquin[1], Dilek Dervishogullari[2] Christopher Stachurski[2], Kody Wolfe[3], G. Kane Jennings[4], and David E. Cliffel[2]
Department of Chemistry[1], Queensborough Community College, Bayside, NY 11364
Department of Chemistry[2], Vanderbilt University, Nashville, TN 37235
Department of Interdisciplinary Material Science[3], Vanderbilt University, Nashville, TN 37235
Department of Chemical & Biomolecular Engineering[4], Vanderbilt University, Nashville, TN 37235

Introduction

Photosystem I (PSI) is a photosynthetic protein complex whose inherently efficient light-to-current conversion allows it to be utilized in variety of biohybrid solar cells. Once extracted from the thylakoid membrane of plants (e.g spinach), PSI's structure allows it to be interfaced with different electrode materials.

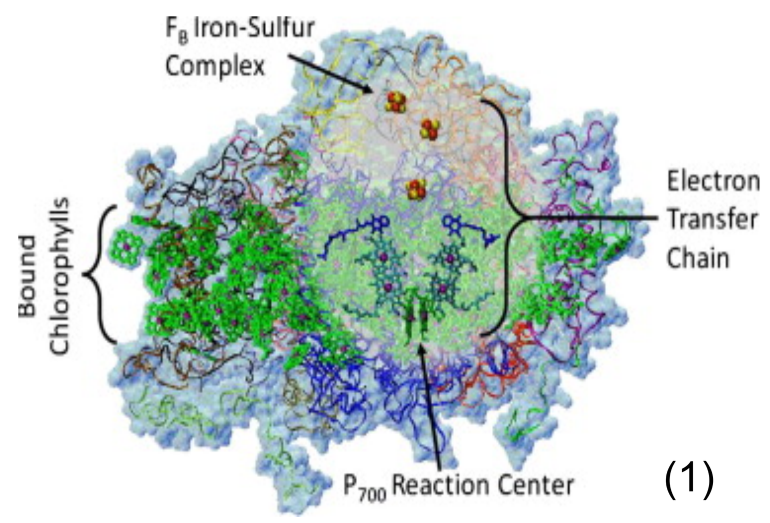
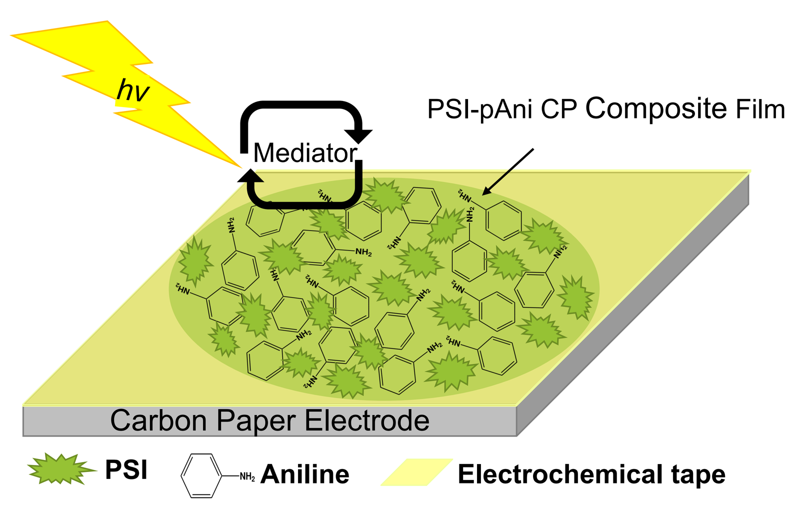


Figure 1: *Electron transfer from P_{700} reaction site to F_B iron-sulfur complex*



The high active surface area of carbon paper (CP) will enable the electrochemical polymerization of greater densities of PSI and conductive polymers like polyaniline (pAni), which in turn can lead to higher photocurrents.

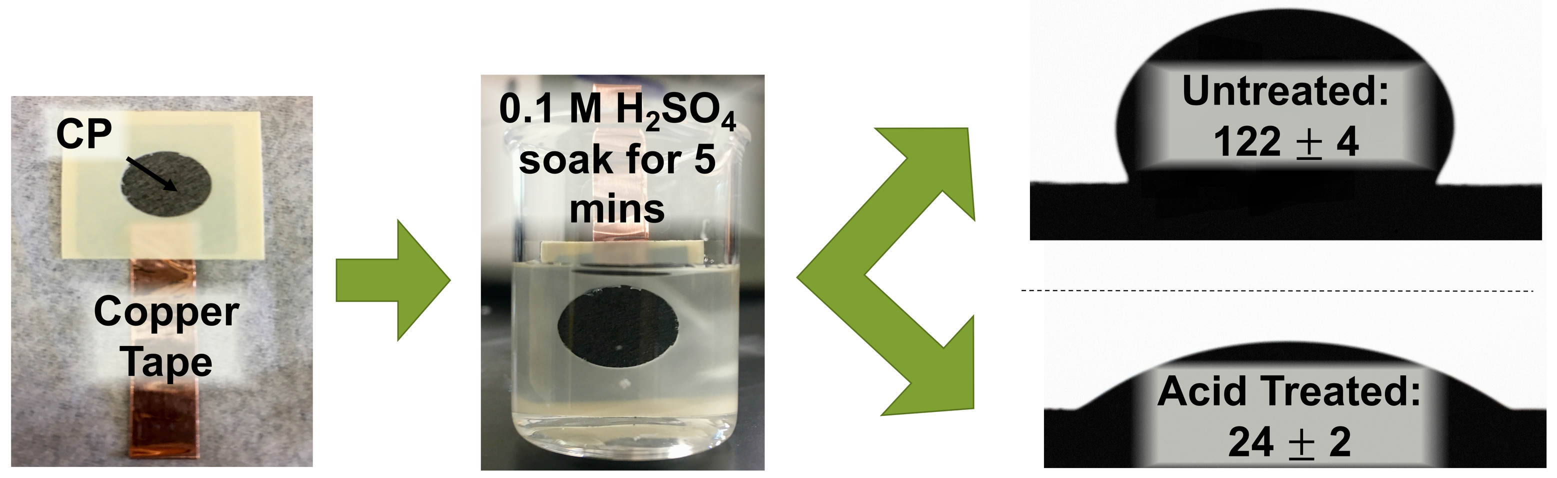
CP Electrode:
- ✓ High surface area
- ✓ Electrically conductive
- ✓ Low cost

Problem: PSI to electrode interface

Solution: Electron transfer via polyaniline

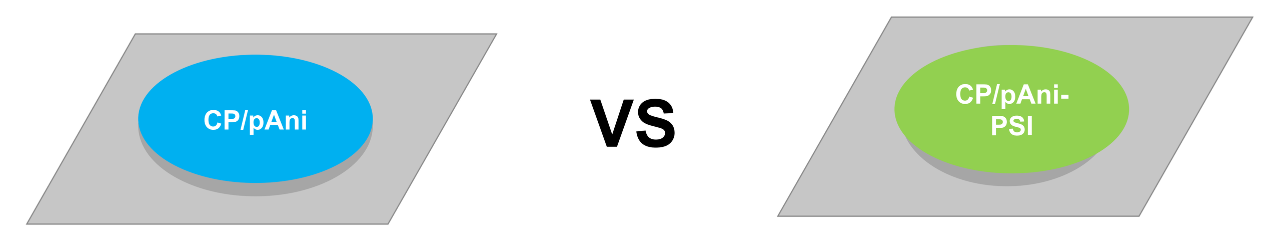
Objective: Deposit PSI on carbon paper electrode within a polyaniline matrix

CP Pre-Treatment



Mask CP **Pre-Treat in Acid** **Contact Angle Measurement**

Electropolymerization



Without PSI : 4 mL of aniline + 1 mL of phosphate-buffer saline (PBS)

With PSI : 4 mL aniline + 1 mL dialyzed PSI in phosphate-buffer saline (PBS)

Electrochemical Characterization

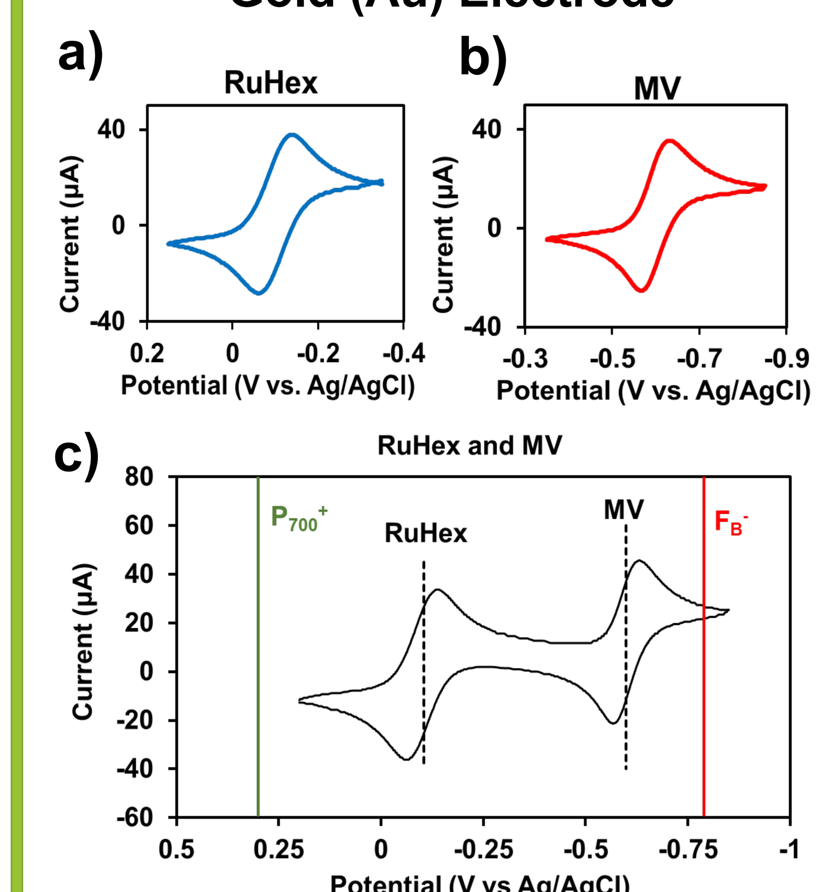


Figure 2: *Cyclic voltammograms on a gold electrode with 5 mM ruthenium hexamine (a), 5 mM methyl viologen (b) and both mediators (c)*

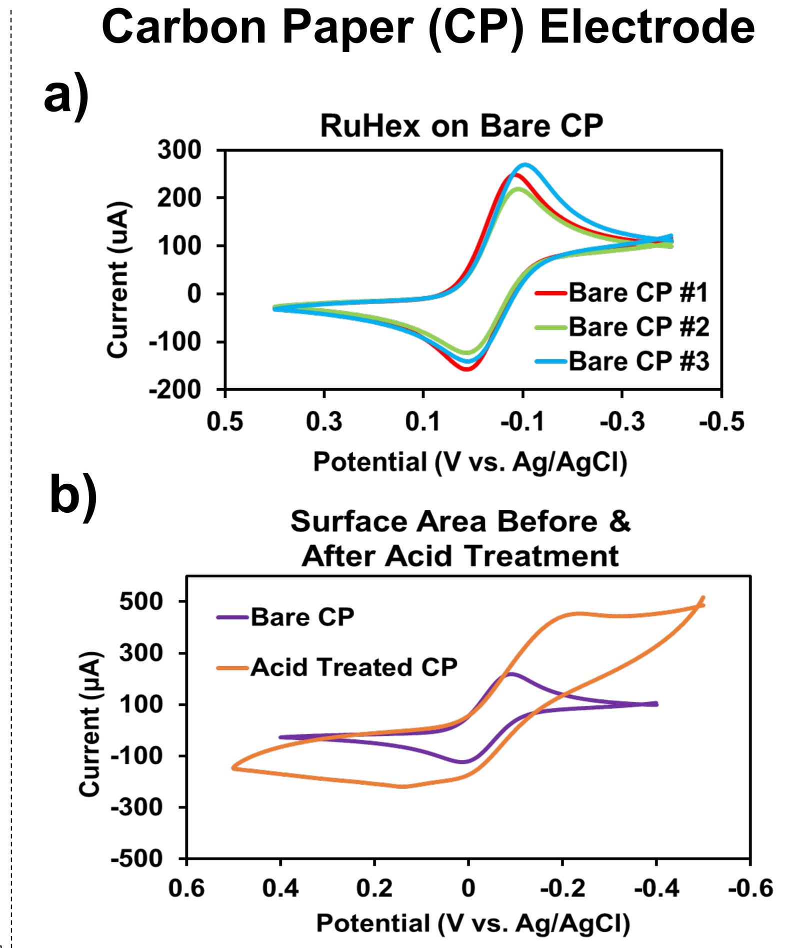


Figure 3: *Cyclic voltammograms of treated CP using 2 mM RuHex (a) and of untreated bare CP and acid treated CP with 2 mM RuHex (b)*

Scanning Electron Microscopy (SEM)

Courtesy of Kody Wolfe

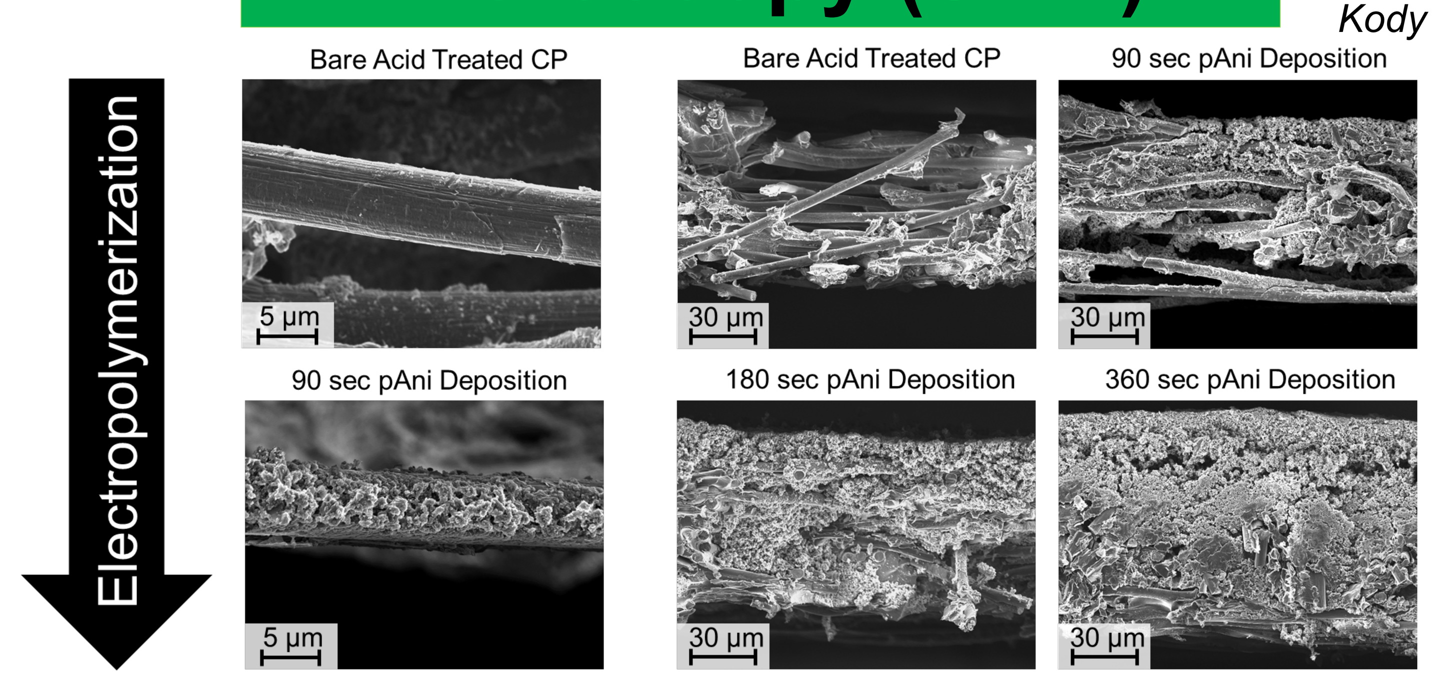


Figure 4: *Side view SEM images of bare CP and CP/pAni for different deposition times*

Photochronoamperometry (PCA)

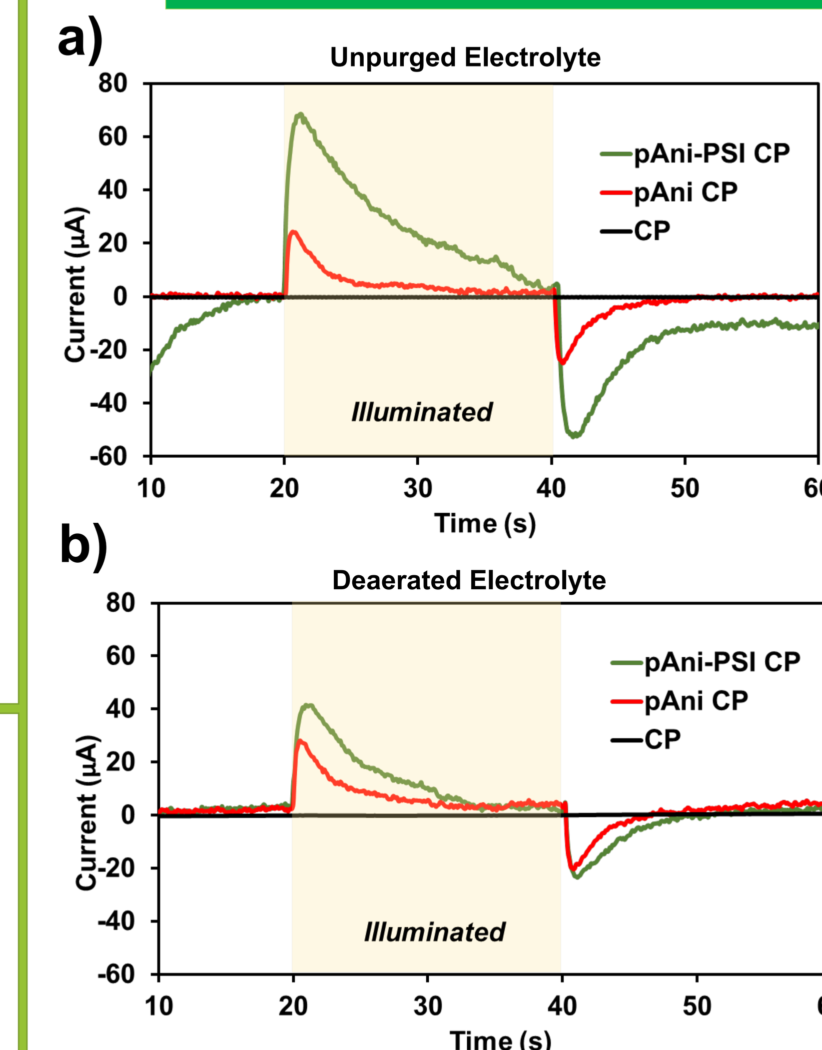


Figure 5: *PCA curves in unpurged electrolyte (a) and deaerated electrolyte (b)*

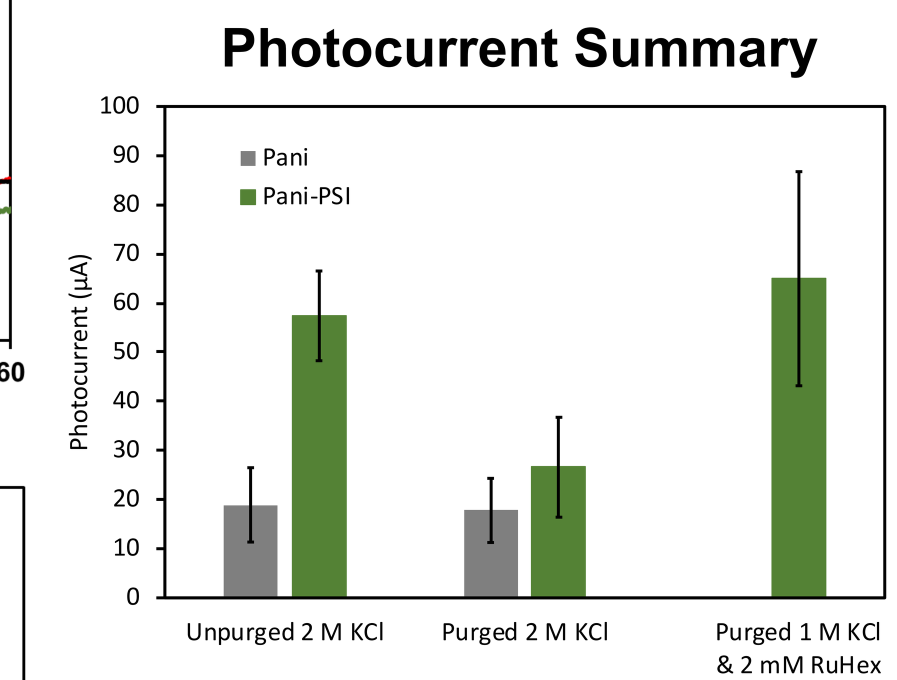


Figure 6: *Performance of pAni on CP with and without PSI and varied salt concentrations*

Conclusions and Future Work

Conclusions:
- Acid treatment increases the active surface area of carbon paper
- PSI was successfully entrapped into a conductive pAni matrix
- pAni-PSI CP electrodes produced higher photocurrents
- Dissolved oxygen species are the primary mediator in this system

Future Work:
- Optimize the electrochemical deposition of pAni on CP
- Find a mediator that will improve electron transfer

Acknowledgements

The author would like acknowledge the Vanderbilt Institute of Nanoscale Science and Engineering (VINSE) for their use of characterization tools as well as the National Science Foundation (NSF REU Grant No.1560414) and (DMR-1507505), as well as the U.S. Department of Agriculture (2019-67021-29857) for their financial support. In addition, special thanks goes to Kody Wolfe, Chris Stachurski, Dilek Dervishogullari, Dr. Cliffel and Dr. Jennings for their help with this project.

References

1) Ciesielski, P. N., et al. Bioresour. Technol. 2010, 101 (9), 3047–3053.
2) He, Y., et al. Appl. Surf. Sci. 2019, 469 (2018), 446–455.
3) Gizzie, E. A., et al. ACS Appl. Mater. Interfaces 2015, 7 (18), 9328–9335.
4) Reid, R. C., et al. J. Electrochem. Soc. 2013, 160 (9), 612–619.