The Improvement of Photosystem I Deposition Using a Spin-Coating Method

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Introduction

Background and Motivation

- Photosystem I (PSI) is a photocatalytic protein complex that drives photosynthesis in green plants and cyanobacteria. Previous work has shown that PSI extracted from plants and deposited onto a surface can convert solar energy to electrical energy[1,3].
- Current deposition methods, such as vacuum-assisted assembly, face challenges when depositing PSI onto an active electrode, including lengthy deposition time and difficulty controlling the coverage and uniformity of the PSI film.
- An alternative route to fabricate PSI based electrodes is the spin-coating method.

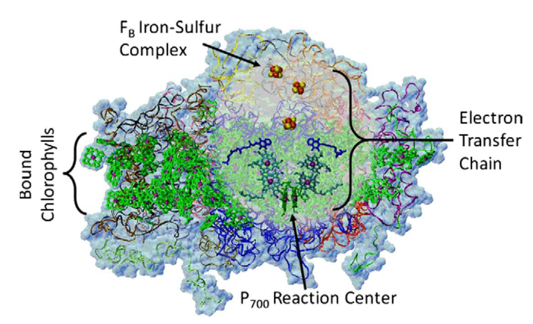

Figure 1: Photosystem I

Objectives

- Extract PSI from the spinach leaf and deposit onto a gold substrate using the spin-coating method.
- Maximize the coverage and photocurrent of the PSI layer.


Figure 2: PSI extraction

Spin-Coating Method

- The spin-coating method consists of adding 65 µL of PSI onto a gold substrate and then rotating it to remove the water from the system.
- A thick film of PSI can then be obtained and rinsed down to a dense monolayer.

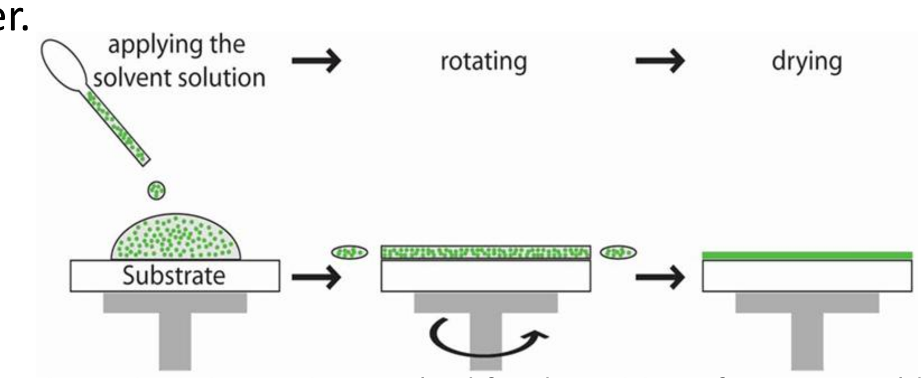

Figure 3: Spin-coating method for deposition of PSI onto gold.

- It takes approximately 7 minutes to complete the deposition of PSI onto gold.

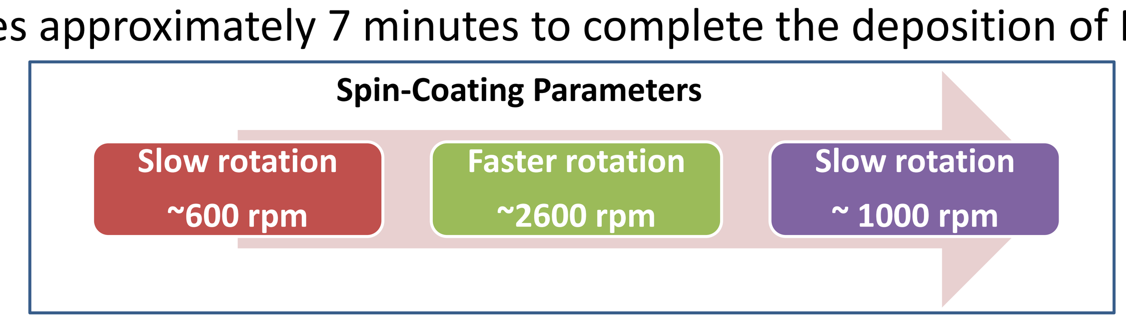

Figure 4: Parameters used in the spin-coating method.

Photosystem I Deposition Model

- Three attachment schemes for the deposition of PSI onto gold:
  - 2-aminoethanethiol- positive surface
  - Terephthaldialdehyde (**TPDA**)- covalent bond
  - Mercaptoacetic acid – negative surface

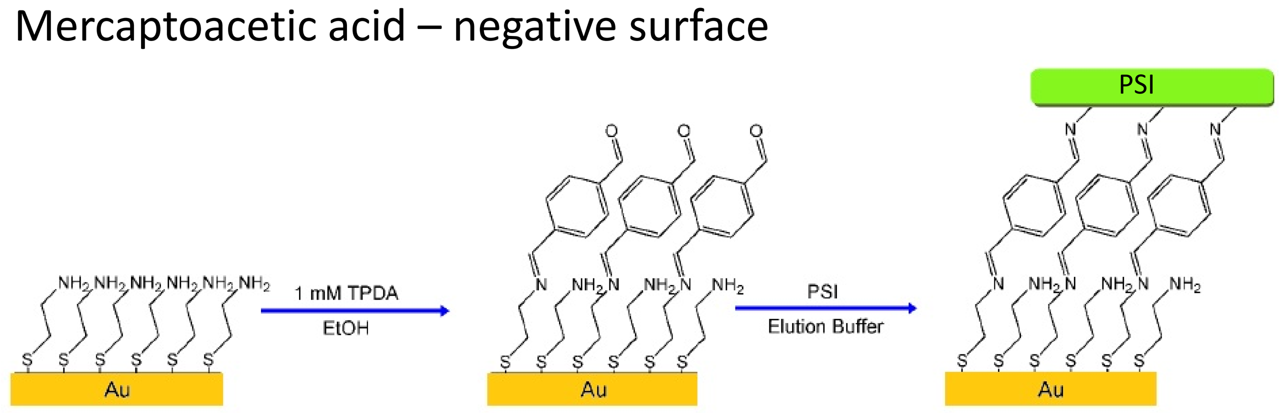

Figure 5: Attachment of PSI onto gold substrate. The formation of a covalent imine bond between TPDA and lysine residues of PSI creates the attachment between PSI and gold.

Deposition of PSI onto Gold

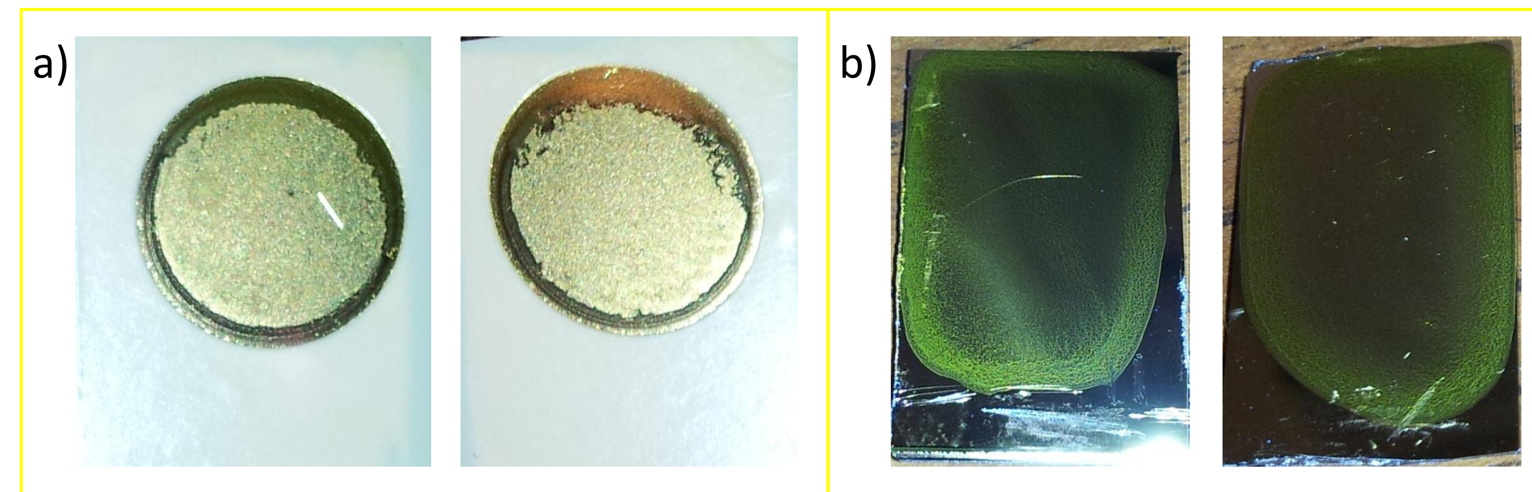

Figure 6: Coverage of PSI onto gold before rinsing the sample after a) spin-coating method , b) vacuum-assisted assembly.

- Using the spin-coating method (a) we obtain uniform coverage onto the gold surface. This improves the non-uniform coverage when compared to the vacuum-assisted assembly (b), where the maximum density is deposited on the border of the sample.
- After the rinse process, using Spectroscopic Ellipsometry we can obtain the thickness of the PSI.
- The results below suggest a **dense** and **consistent monolayer** of PSI when using the spin-coating method.

Method	# Samples	Thickness (Å)
Spin-coating method	10	74 ± 12
Vacuum-assisted assembly	4	58 ± 29

Table 1: Thickness comparison using a 2-aminoethanethiol attachment.

Surface Attachment Effects

- Electrochemical experiments using a custom 3-electrode cell show the photoresponse of the modified gold surface when exposed to white light.

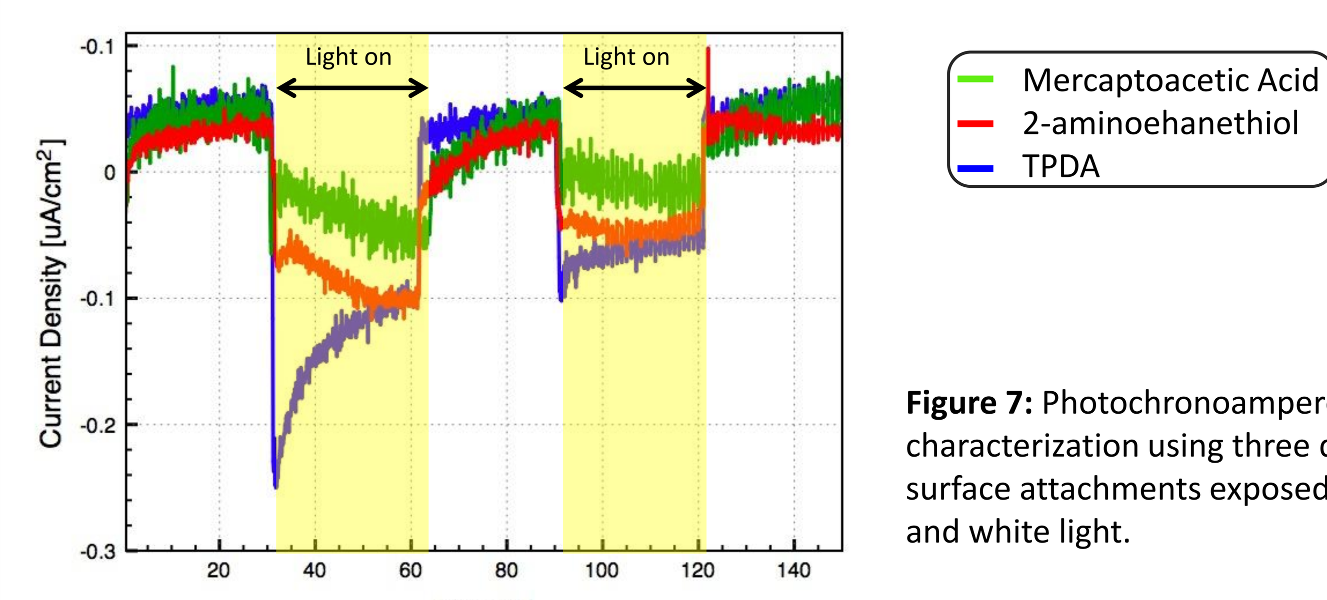

Figure 7: Photochronoamperometric characterization using three different surface attachments exposed to dark and white light.

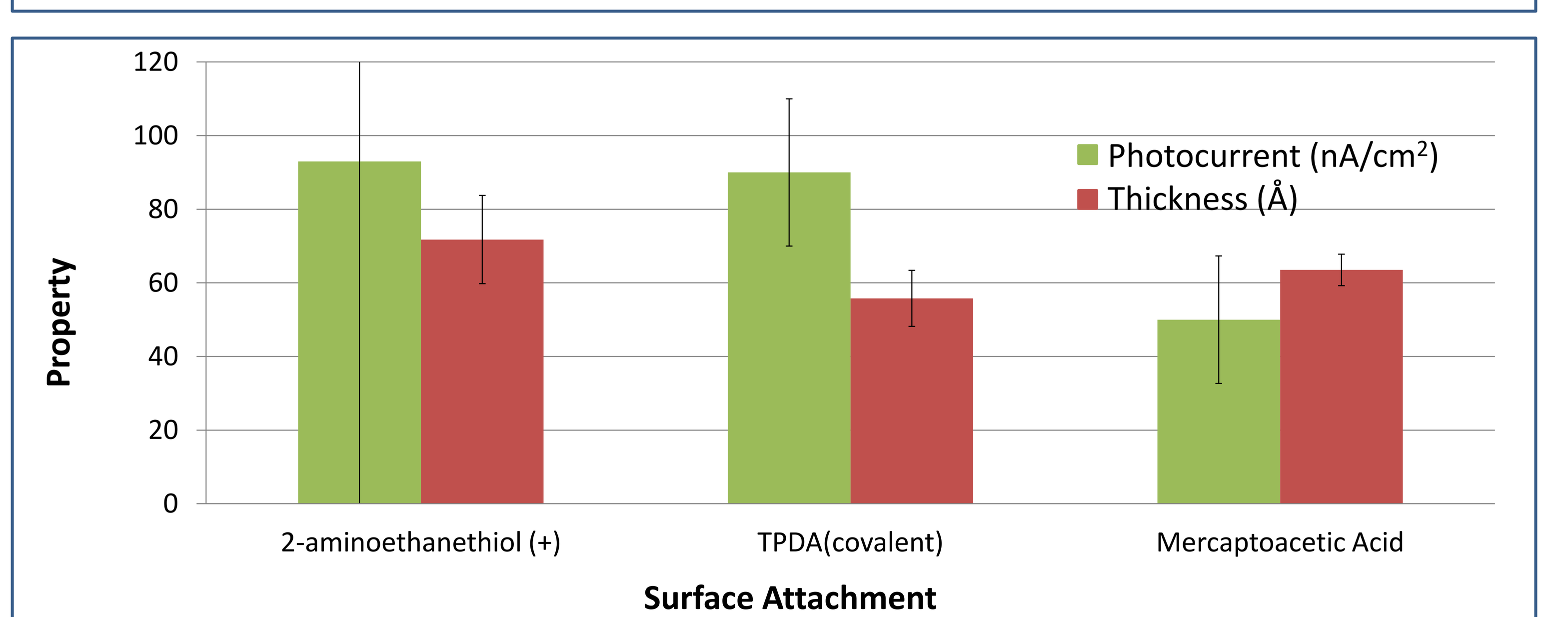

Figure 8: Comparison of the generated photocurrent and thickness using three different surface attachments.

Tafel Analysis

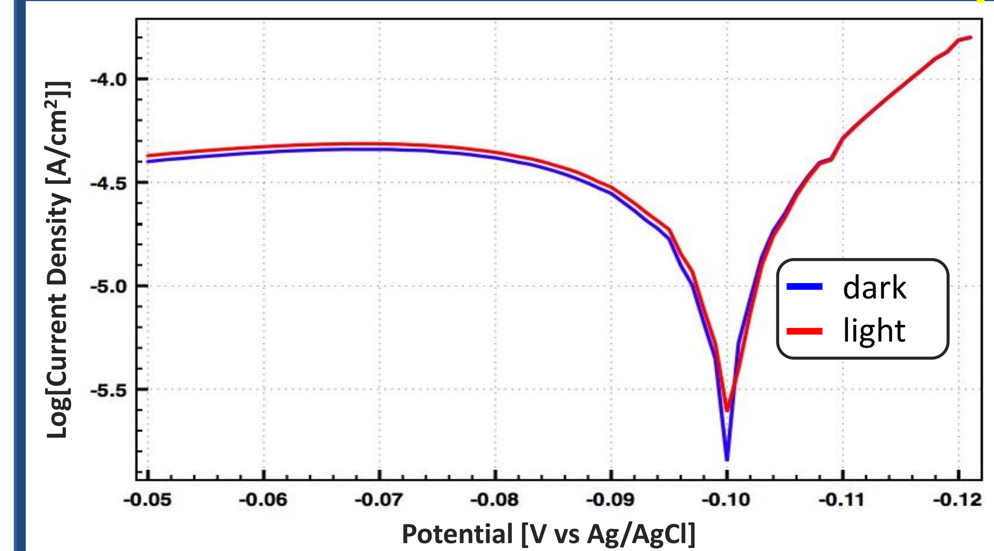

Figure 9: Tafel plot on TPDA surface exposed to dark and light.

- Control indicates almost no photoelectrochemical effects without PSI.

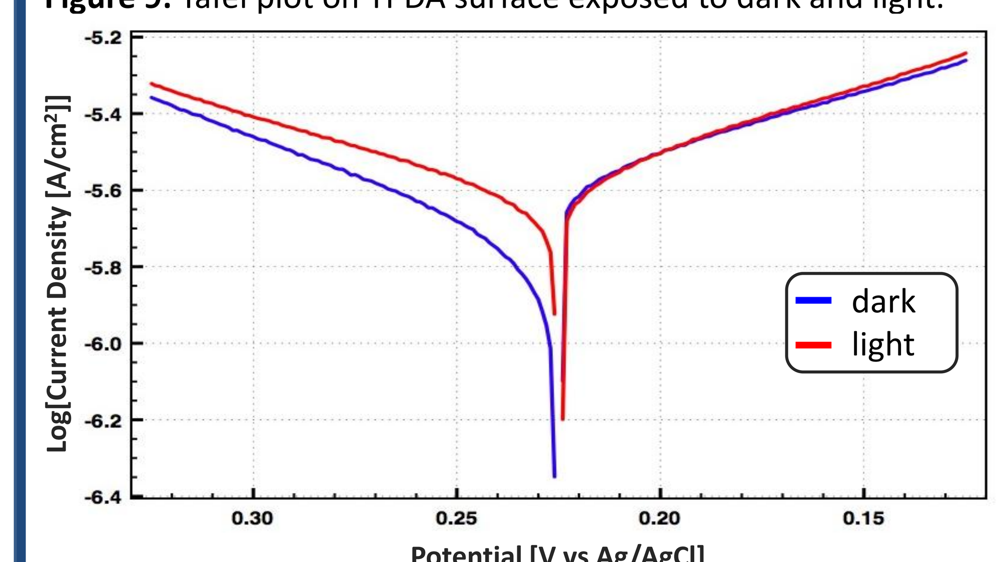

Figure 10: Tafel plot on PSI surface using TPDA attachment exposed to dark and light.

- Enhanced photocurrent at positive potential indicates electron transfer from PSI to gold.

Conclusion/Future Work

- The spin-coating method provides an improved uniform deposition of PSI in monolayers.
- The thickness data suggest a dense monolayer of PSI.
- The Spin -coating method is **an order of magnitude faster** than vacuum-assisted assembly.
- Using the Spin-coating method, we can create a consistent, light-induced current.
- The TPDA attachment is shown to be the more consistent for the PSI deposition onto gold.
- For future work, we will deposit thicker films of PSI with the aim of increasing the photocurrent response of the system.

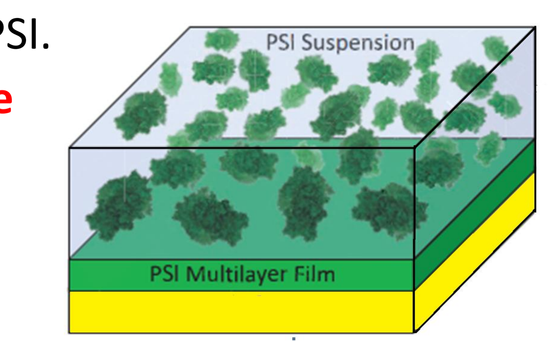

Figure 11: Multilayer deposition

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References

[1] Ciesielski, P. N., C. J. Faulkner, et al. (2010). "Enhanced Photocurrent Production by Photosystem I Multilayer Assemblies." Advanced Functional Materials **20**(23): 4048-4054.
[2] Ciesielski, P. N., F. M. Hijazi, et al. (2010). "Photosystem I – Based biohybrid photoelectrochemical cells." Bioresource Technology **101**(9): 3047-3053.
[3] Faulkner, C. J., S. Lees, et al. (2008). "Rapid Assembly of Photosystem I Monolayers on Gold Electrodes." Langmuir **24**(16): 8409-8412.