Polymerization of Aniline by Photosystem I Proteins

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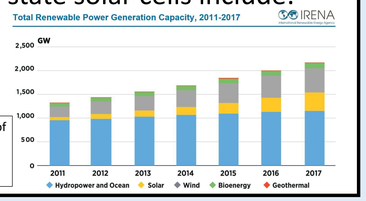
Renewable Energy

- The use of solar energy is increasing
  - Renewable energy makes up about 15% of all electricity in the US and solar energy generates about 7% of that electricity
  - Last year, solar energy produced 1% of the electricity used globally
- Problems with silicon solid-state solar cells include:
  - High production costs
  - Large energy waste



Graph A: This chart illustrates the growth of solar energy in the renewable energy sector reported by the International Renewable Energy Agency

Photosystem I (PSI)

- Essential photosynthetic protein
- Photosystem I is easy to extract, afford, and find
- Two reaction centers:
  - P_{700} and F_B site where oxidations and reductions happen respectively
- Electron transport is unidirectional

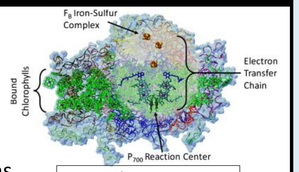


Figure A: Photosystem I protein

Natural photosynthesis

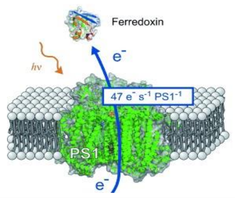


Figure B: Photosystem I in the thylakoid membrane demonstrating the electron transport chain. Once an electron is photoexcited at the P_{700} site from the environment, the electron travels to the F_B site.

Polyaniline (pAni)

- Polyaniline has been shown to have exceptional charge transfer materials when in redox mediated biohybrids cells
- Aniline undergoes oxidative polymerization to create pAni which would happen at the P_{700} site
- Water soluble and capable of being electropolymerized at potentials compatible with PSI
- Many different forms of pAni
  - All varying in oxidation states

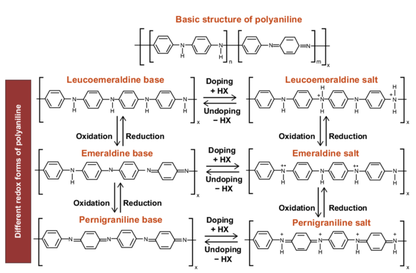


Figure C: There are multiple forms of pAni. Each form has a different oxidative state and can be interchanged using doping agents. The emeraldine salt pAni is the conductive form we wish to obtain.

Hypothesis

We can polymerize aniline using Photosystem I proteins. Since pAni is formed through an oxidative polymerization, it will attach itself to the PSI P_{700} site and create a protein polymer

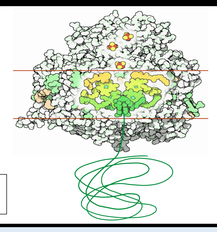


Figure D: Aniline attached to Photosystem I at the P_{700} site

Methods

- Extract PSI from spinach
- Add 30 mM of aniline to 3 µM of PSI solution
  - We began making solutions with pH 3-pH 6 yet we found pH 4 was the best for the pAni growth
- Let solution sit in direct light for 30 min to let photoexcitation reactions take place to promote pAni growth
- Dialyze solution overnight to remove excess aniline
- Characterization methods:
  - Cyclic Voltammetry
  - FTIR

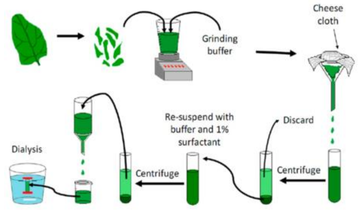


Figure E: The extraction process begins with destemming the spinach then going through a process to eliminate excess parts of the thylakoid.

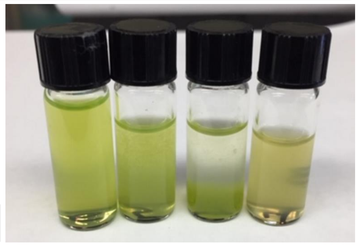
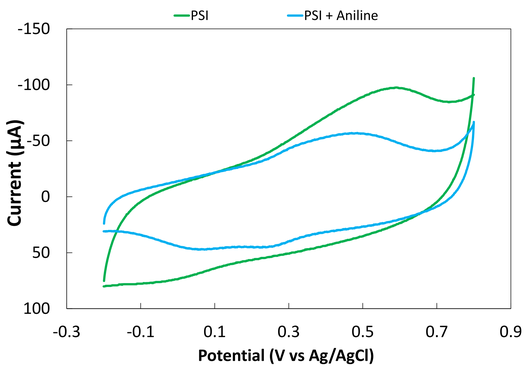


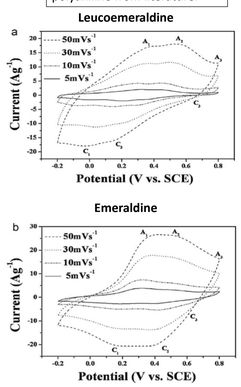
Figure F: The solutions, pH 6 to pH 3 from left to right, are photographed here after sitting in direct light for 30 minutes.

pAni Peaks in Cyclic Voltammetry



Graph B: Cyclic Voltammetry (CV) is an electrochemical technique which measures the current that develops in an electrochemical cell under conditions where voltage is in excess of that predicted by the Nernst equation.

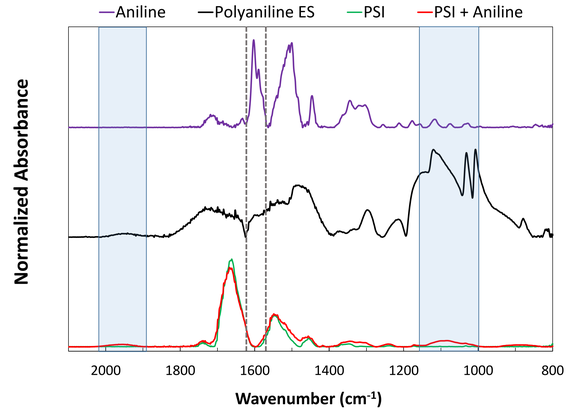
Graph C: CV results of various polyaniline from literature.



- Aniline + PSI decreases current and has different oxidation and reduction peaks compared to PSI control
  - Polyaniline is altering electrochemical properties of PSI
- Peaks and shape are most comparable to the leucoemeraldine salt form

FTIR for pAni Samples

- Small broad peak at 1000-1200cm^{-1} and 1900-2000cm^{-1} indicative of pAni
- No peak at 1600 cm^{-1} which means no aniline
- pAni peaks are difficult to see since PSI is much larger making it dominate the IR spectra



Graph D: We ran FTIR from 800-2100nm with a focus on 1600nm for each sample. This instrument demonstrates what organic groups are in our sample. This instrument was essential to understand which new bonds were formed.

Conclusions

We conclude that we have **polymerized pAni** with the PSI protein due to our results. We also conclude that the pAni we have made is attached to the PSI proteins.

Future Work

- More IR studies with just pH 4 and 5
- Vary the amount of aniline in solution
- Dope pAni using camphorsulphonic acid to increase conductivity
- Run UV-Vis to try and confirm pAni in our samples
- Run time study on with microscope to monitor growth

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Acknowledgements

We gratefully acknowledge financial support from the National Science Foundation (Grant No:1560414), the USDA (Grant No: 2019-67021-29857), in collaboration with Vanderbilt Institute of Nanoscale Science and Engineering (VINSE). I would like to especially thank Joshua Passantino, Dr. Kane Jennings, the Jennings Lab and the Cliffel Lab, Sarah Ross and Alisha McCord for their exemplary coordination and everyone from the VINSE team.