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Designing advanced anode structure for Biophotovoltaic system via additive manufacturing

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Introduction

Biophotovoltaic systems (BPVs) :

- Light-harvesting electrochemical devices.
- Use photosynthetic microorganisms to convert light energy into electrical output (Figure 1).
- A promising avenue for future Green Energy [1,2].

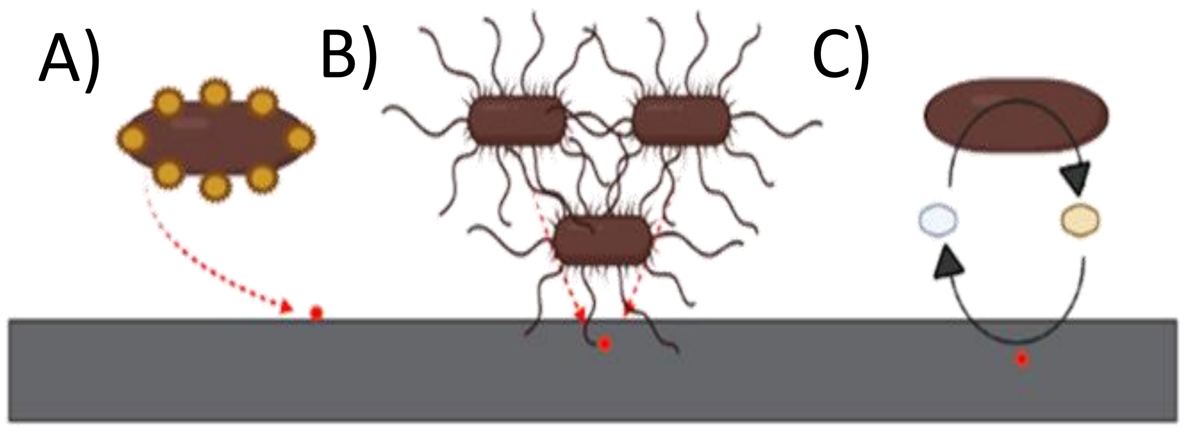

Figure 2: Mechanisms of electron transfer in biophotovoltaic (BPV) system. A) direct electron transfer by surface redox proteins B) network of nanowire appendages between cells in a biofilm transfers electrons to neighbouring cells or to the electrode C) indirect electron transfer via cycling of endogenous electron mediators or artificial electron mediators [2]

Contemporary BPVs suffer from low current:

- Electrochemical losses at biofilm-anode interface [1].

<u>**The key challenges:**</u> limited anode surface area, electrical conductivity and opacity of anode, and extraction of electron from microbial electron transport chain [3].

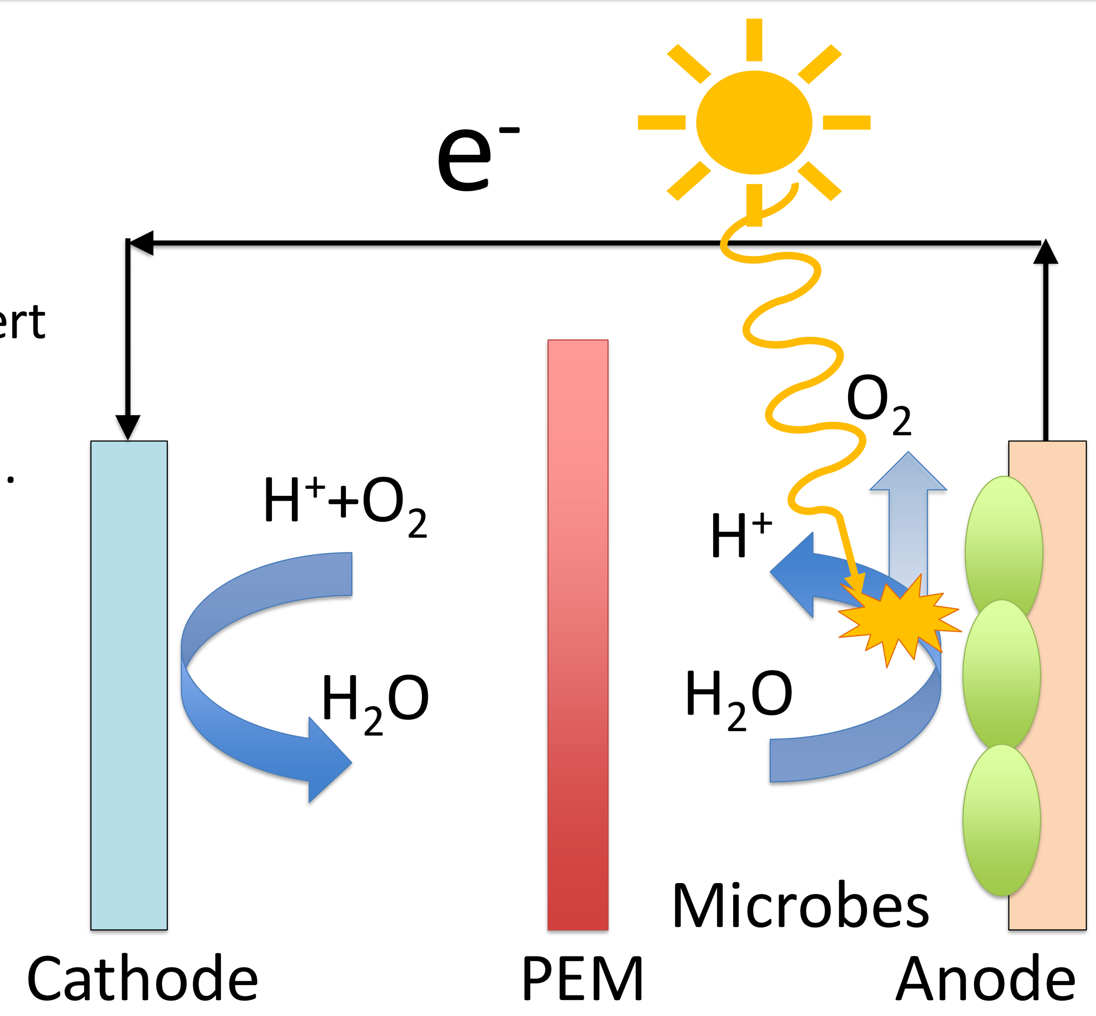

Figure:1 Schematic illustration of biophotovoltaic (BPV) system showing biotic anode and abiotic cathode chamber separated by proton exchange membrane [3]

Photosynthetic microorganisms use sunlight to "extract" electrons from water.

- Electrons are transferred to the external environment by protein cellular machinery (Figure 2) [3].
- BPVs collect these metabolic electrons at an anode, as generated current.

Research Gap

Few studies investigate new anode materials.

- Optically transparent anodes would allow "multi-anode" stacked BPVs, with greater light capture efficiency.
- Optically transparent and electrically conductive polymer Poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) (PEDOT:PSS) could be employed.

Currently, no studies report the use of additive manufacturing to fabricate anodes.

- PEDOT:PSS can be AM inkjet-printed.

Aim and objectives

- Develop a chemically stable three-dimensional (3D) microporous PEDOT:PSS electrode *via* additive manufacturing.
- Demonstrate the biocompatibility of PEDOT:PSS for *Synechocystis* sp. PCC 6803
- Evaluate the performance of PEDOT:PSS printed on PET film in BPV system.

Methodology & Results

Ink formulation

Figure 3: Ink formulation based on PEDOT:PSS dispersion in water

Figure 4: Dimatix inkjet printer

Dimatix ink jet printing

Characterization of printed anode

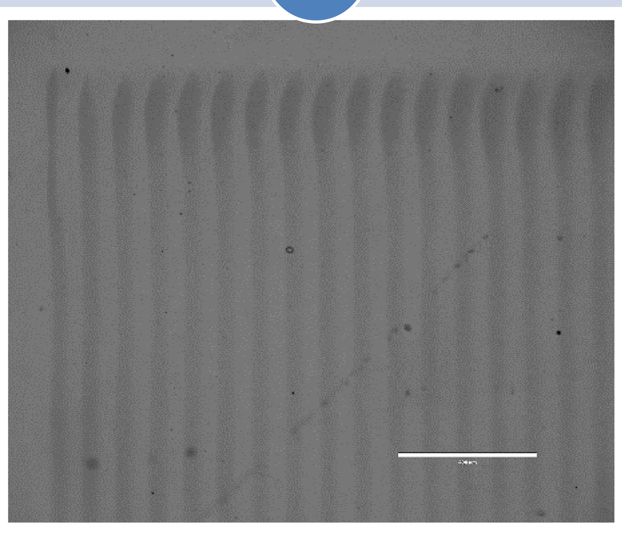

Figure 5: PEDOT:PSS printed on PET film under light microscope

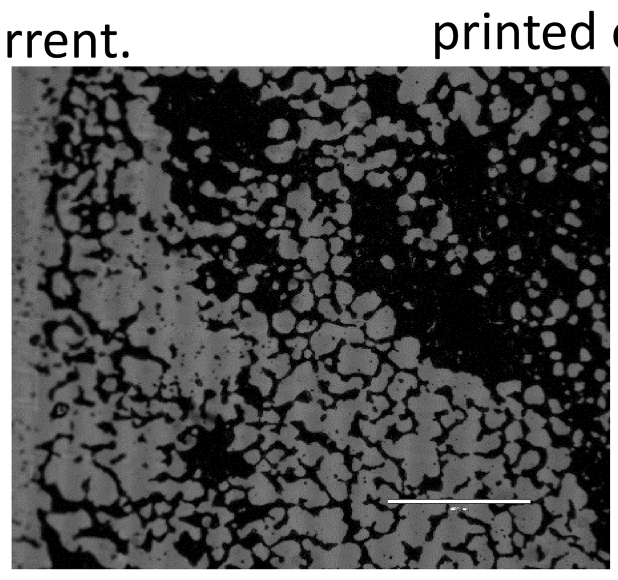

Figure 6: Synechocystis sp. PCC 6803 biofilm attached to PEDOT: PSS printed on PET film

Biocompatibility test & biofilm development

Assembling BPV with printed anode

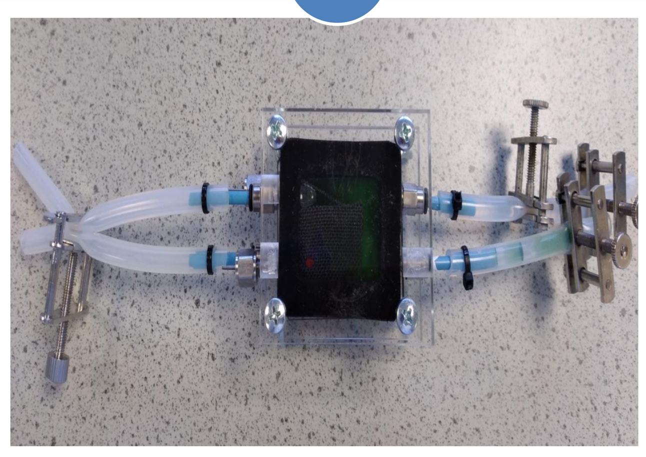

Figure 7: Biophotovoltaic (BPV) system inoculated with 6803 in lab

This research showed:

- Optical transparency (> 80%) and electrical resistivity (up to 500 S·cm) for PEDOT:PSS ink jet printed on PET film (2 Layers, 1 Nozzle, Dimension: L6cm x W4cm) (Figure 5).
- Biocompatibility of PEDOT:PSS printed on PET film anode was confirmed with a dense biofilm coverage of *Synechocystis* sp. PCC 6803 wild-type observed under light microscopy (10x magnification) (Figure 6).
- Attempts to assemble BPV with inkjet printed anode and record voltage output are still in progress (Figure 7).

Conclusion & Future work

Initial confirmation of biocompatibility, optical transparency and electrical conductivity of PEDOT:PSS printed anode for BPV application have been obtained.

Next steps include electrochemical characterization of PEDOT:PSS anode, and direct comparison of PEDOT:PSS anode with other, literature standard, anode materials.

References

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4) L. Groenendaal, F. Jonas, D. Freitag, H. Pielartzik and J. R. Reynolds, *Advanced materials*, 2000, **12**, 481-494.

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