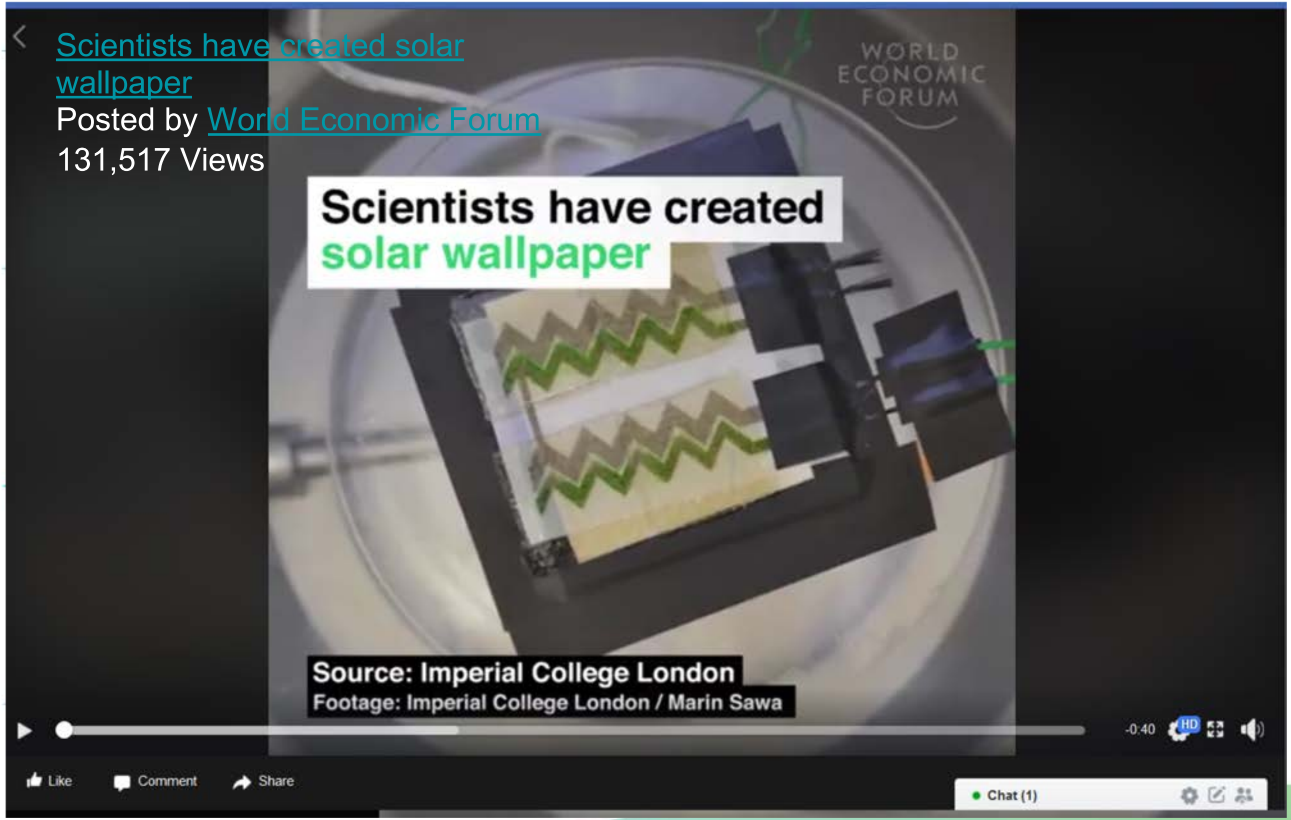
Arm Summit 2018
18 September 2018: Printed Electronics

Development of Printed Solar Biobattery for Use in Bioelectronics

Dr. Marin Sawa (Imperial College London)
m.sawa@imperial.ac.uk

The thin-film biophotovoltaic technology

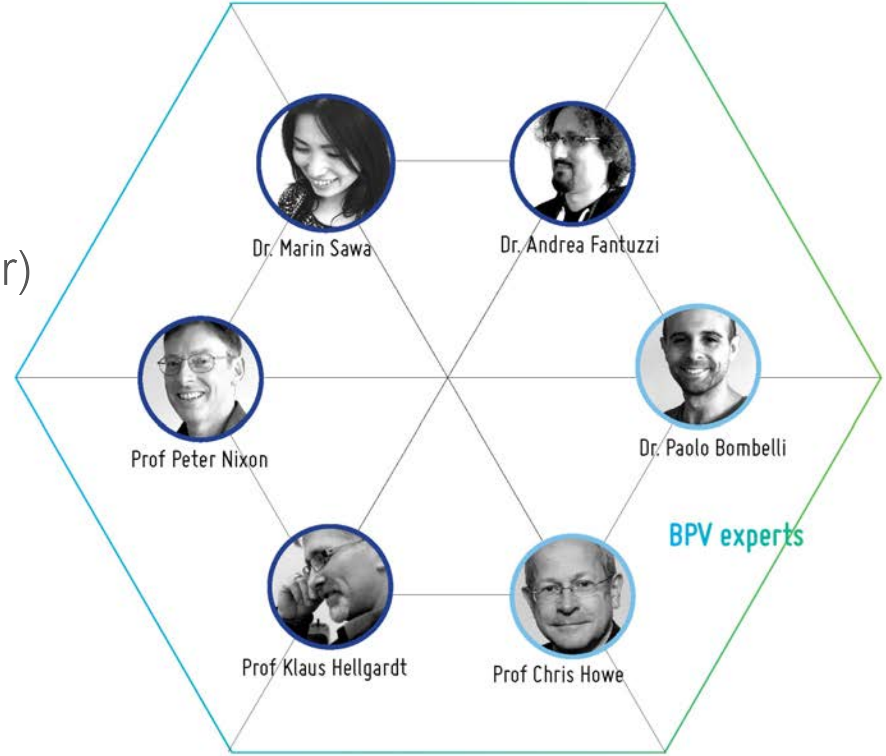


Sawa M, Fantuzzi A, Bombelli P, Howe C.J, Hellgardt K, Nixon P.J, 2017. Electricity generation from digitally printed cyanobacteria, Nature Communications, 8(1), 1327

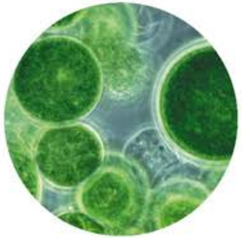
The cross-disciplinary collaborations

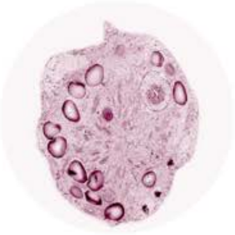
Imperial College Loddon
Dr. Andrea Fantuzzi (Electrochemist)
Prof. Klaus Hellgardt (Chemical engineer)
Prof. Peter Nixon (Biochemist)

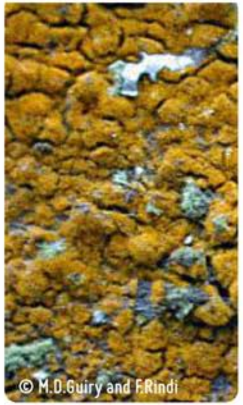
University of Cambridge
Dr. Paolo Bombelli (Biochemist)
Prof. Christopher Howe (Biochemist)



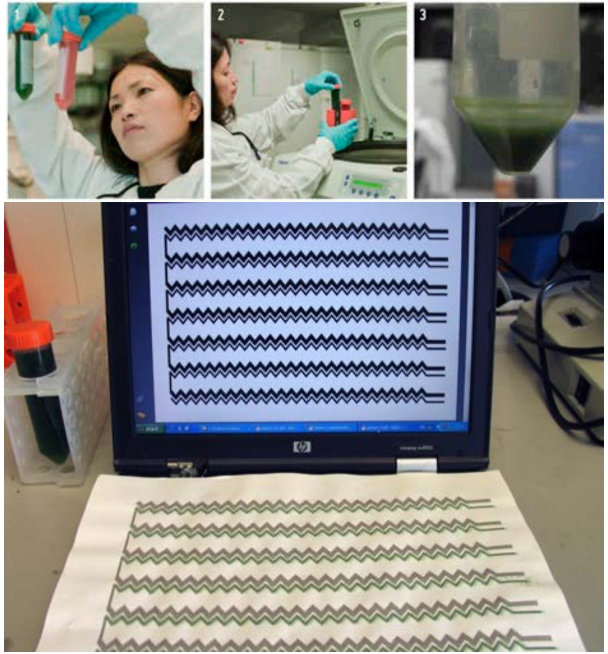
Cyanobacteria and algae





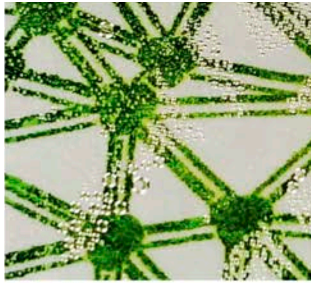


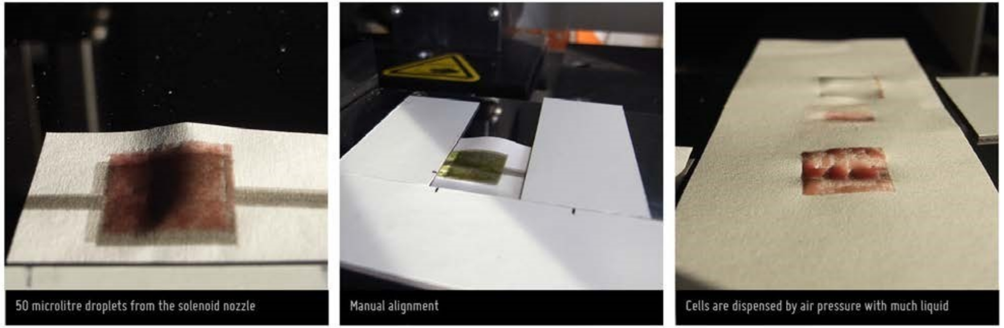
Inkjet fabrication method



Cells and conductor printed in two separate steps

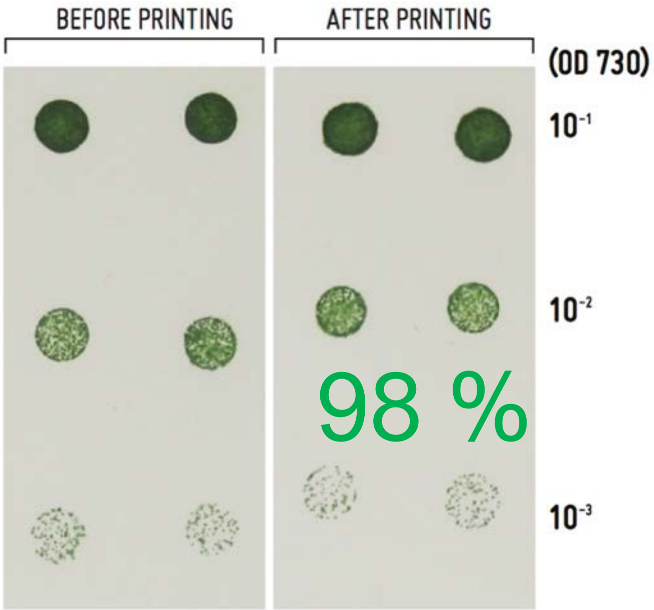
- Thermal
- 140 picolitre droplets
- 300 x 600 dpi
- CAD to CAM
- Uniform cell density





Low resolution by microvalve inkjet cell printer

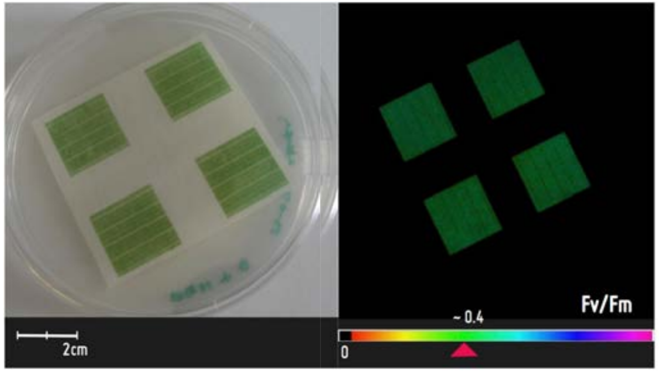
Cell viability and photosynthetic competency



98 %

Synechocystis cells

Printed cells on paper after 3 days growth

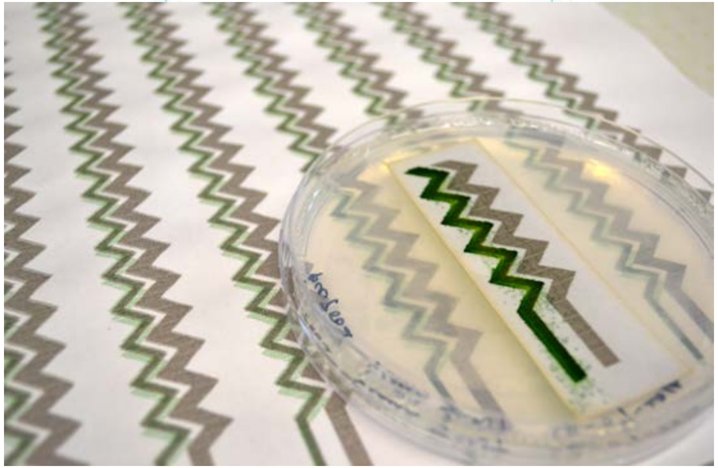


=

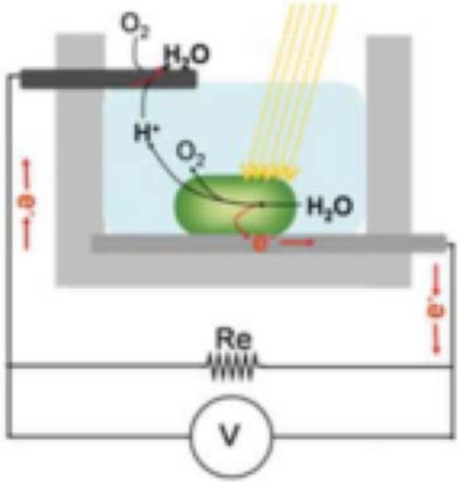
Chlorophyll fluorescence value 0.4

Imaging-PAM in further collaboration w/ Dr Petra Ungerer, Prof Alexander Ruban group (Queen Mary)

Solid and liquid culture systems

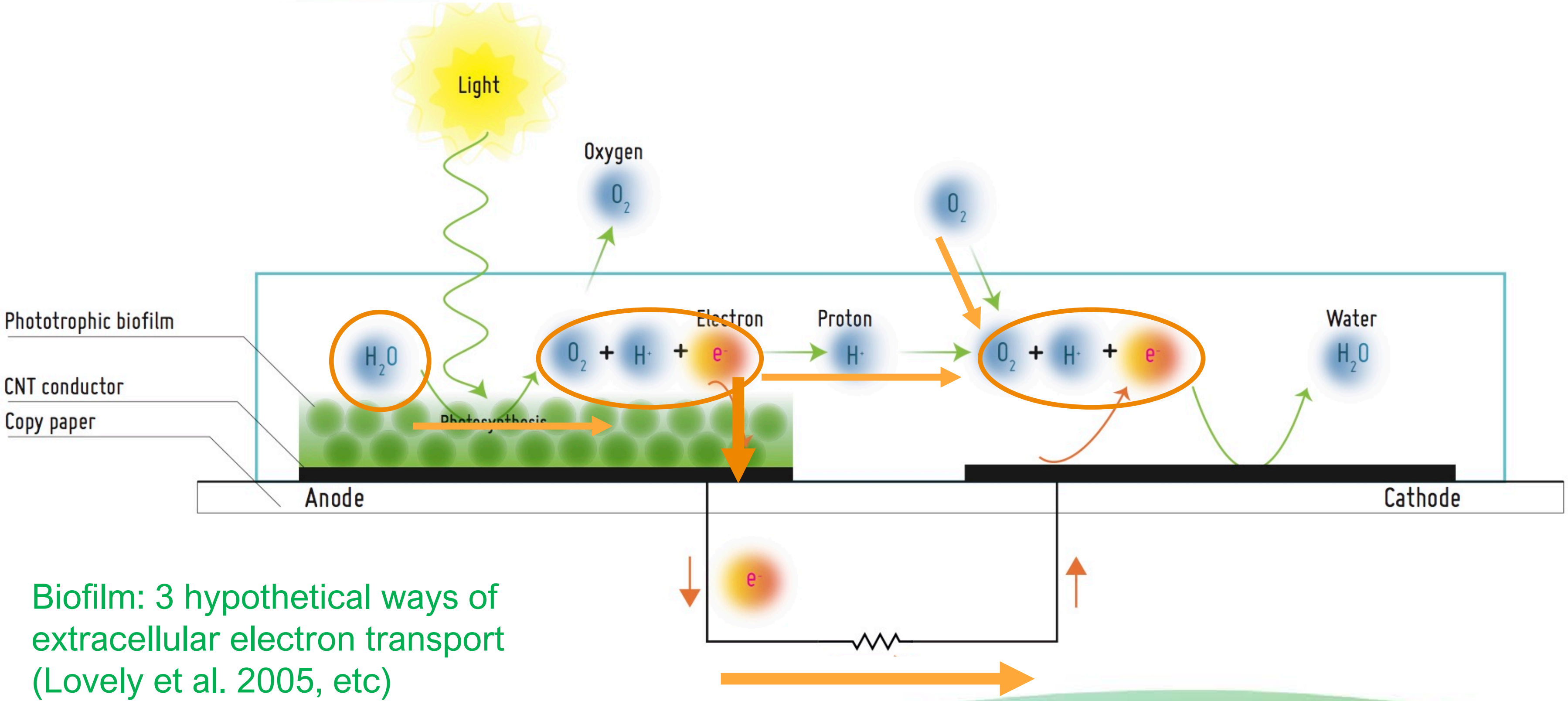


Digitally printed solid system
Synechocystis WT
0.38 mW m^{-2}
(Sawa et al. 2017)



Liquid culture system
Synechocystis WT
0.2–0.3 mW m^{-2}
(McCormick et al. 2011)

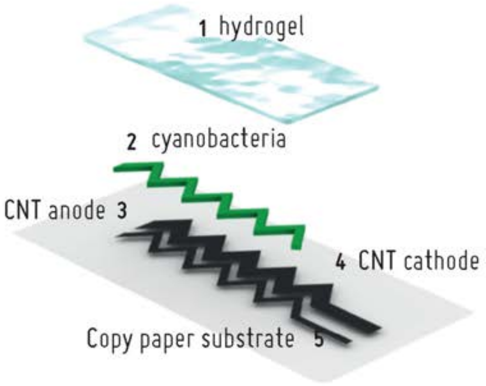
Electron generation and transport pathways

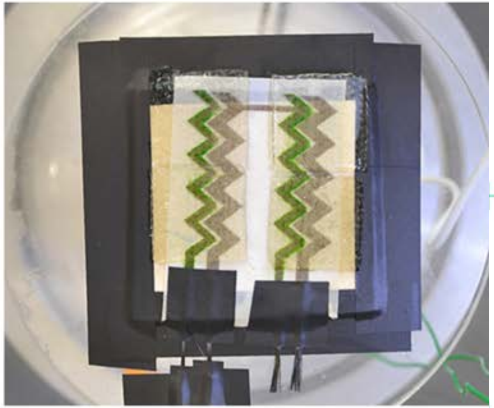


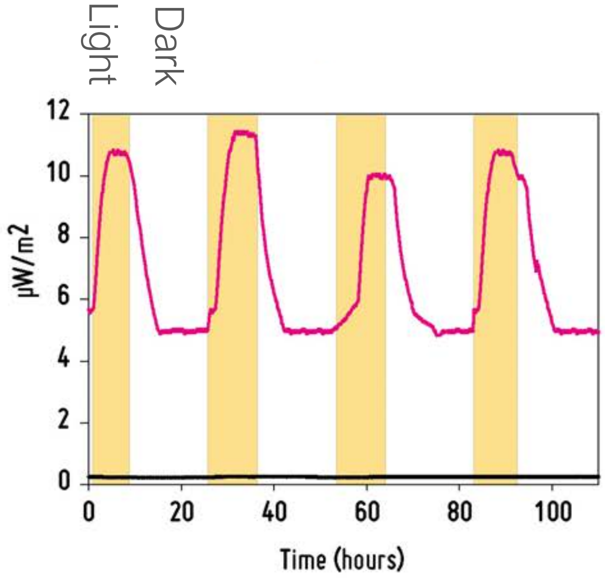
Biofilm: 3 hypothetical ways of extracellular electron transport (Lovely et al. 2005, etc)

Solar biobattery (PoC)

1: Inkjet-printable thin-film technology (semi-dry system)
2: Paper-based, biodegradable, cost effective
3: Current production in the dark (biobattery)
4: Power output 0.012 mW m^{-2}, >100 hrs

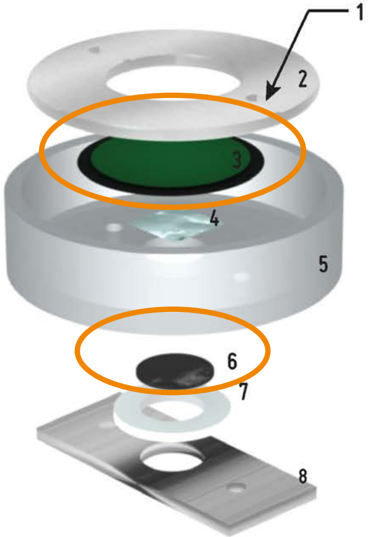


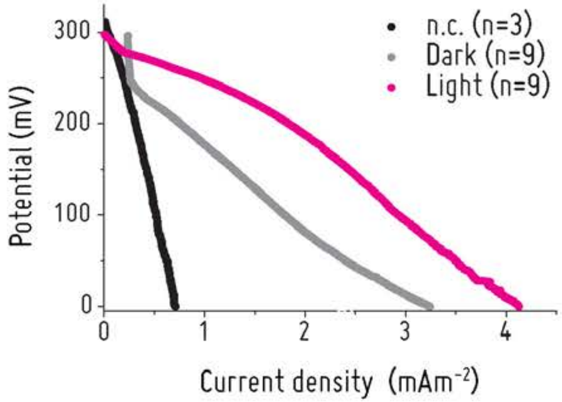




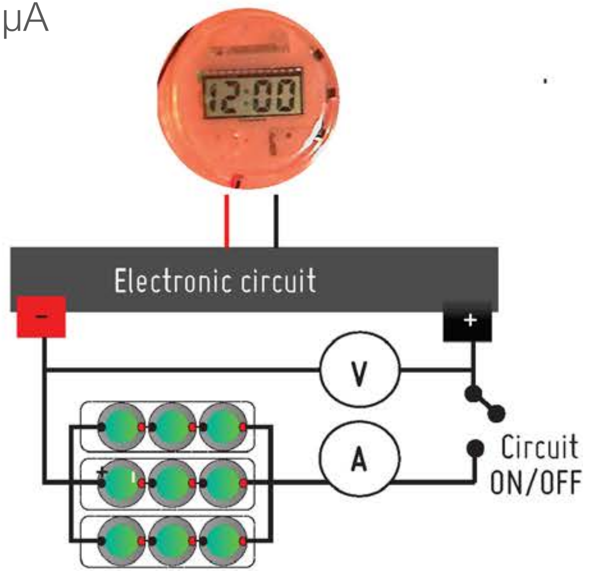
Parameter: cathodic oxygen reduction

1: Hybrid system, digitally printed bioanode + Pt-carbon cathode
2: Current Power output of 0.38 mW m^{-2} (light) & 0.22 mW m^{-2} (dark)
3: Powering of digital clock:
overall voltage output of 1.4–1.5 V & overall current output of 1.5–2 µA



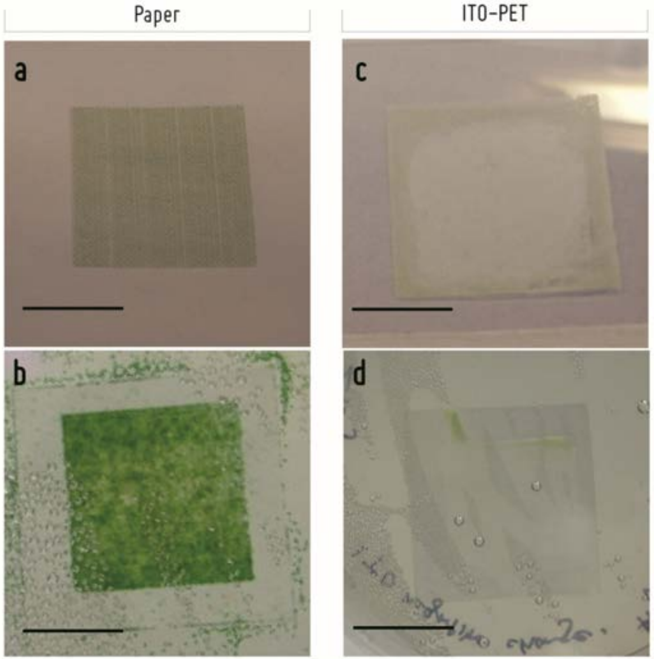


Synechocystis WT
4 mA m-2 in the light
3 mA m-2 in the dark

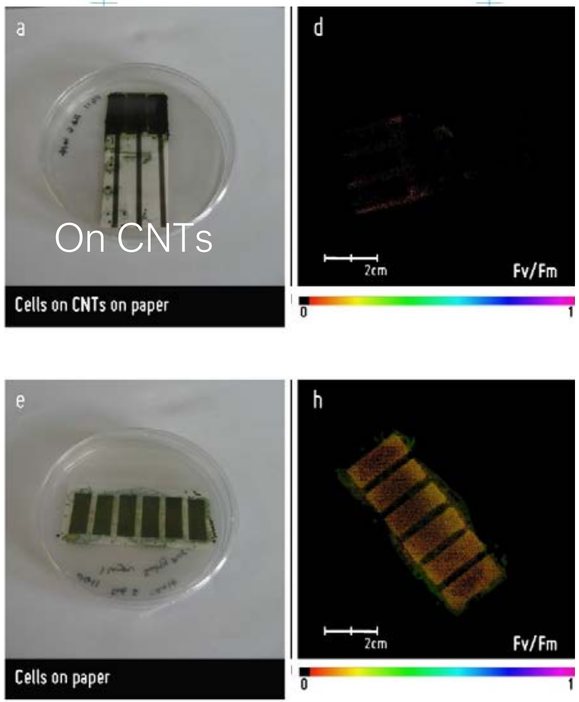


Parameter: biocompatibility

1: Substrate (porosity)
2: Conductor (porosity, cell-surface interaction)



Printed cells after 33 days growth



Parameter: species

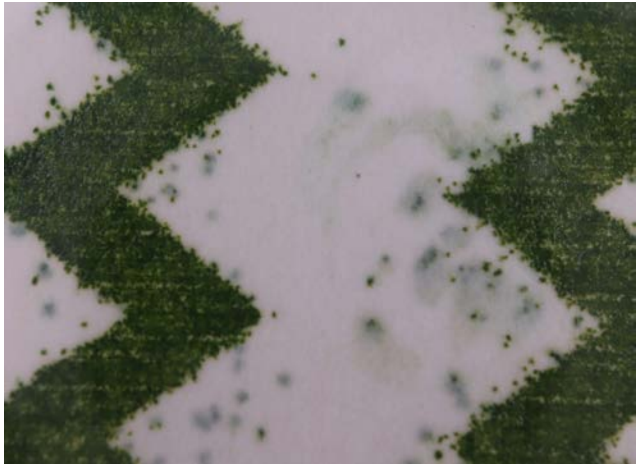
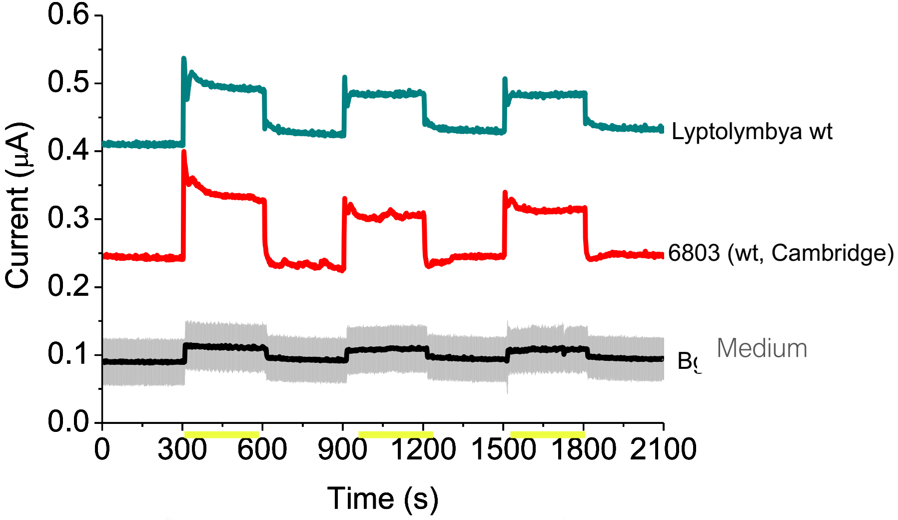


Image: Internet

6803 wt *vs* Lyptolymbya (biofilm)

Chronoamperometry (200mV bias), Dark/light (300s/300s), Ca. 500 uE m-2 s-1 (white LED)
Anode(12cm2, ITO), open air cathode(C-Pt).



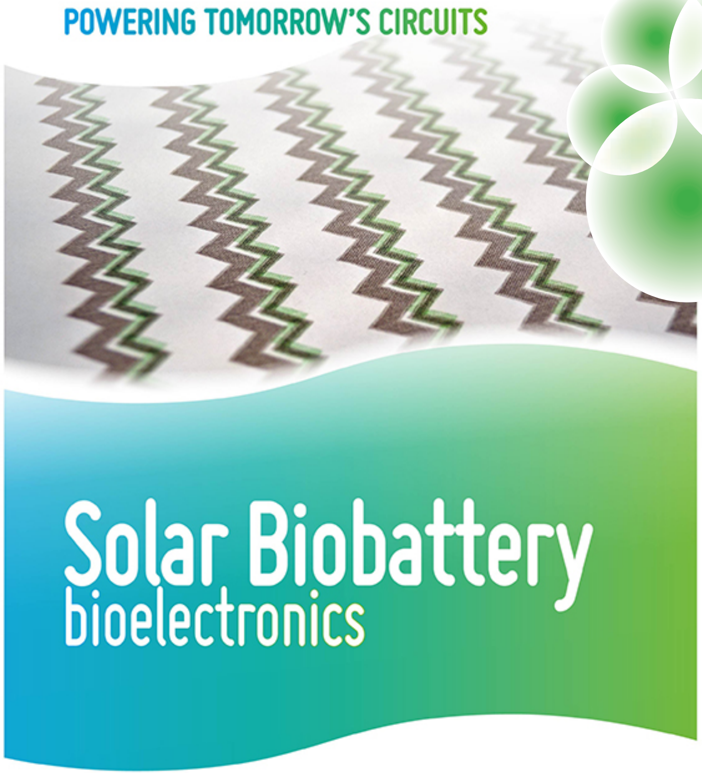
Unpublished data

We are very interested in understanding alternative energy-harvesting techniques to **power our ultra-low power IoT circuits and CPUs**. In particular, we would like to develop know-how and knowledge through collaboration and partnership on how to power the **future biomedical/non-biomedical IoT devices** using low-cost, environment-friendly, biodegradable, form-factor efficient biological energy storage systems such as microbial cells and biophotovoltaics.

Dr. Emre Ozer, Principal Research Engineer

arm


Up to 90% of world's electronic waste is illegally dumped (UN, 2017)
© QAMP



EPSRC
Engineering and Physical Sciences
Research Council

arm

Takeaways

- Successful inkjet printing of cells using thermal inkjet
- Parameters to be tested: species, biocompatibility, cathodic oxygen catalyst
- Tackle e-Wastes