

Nanoscale Electrochemical Electrodes for Monitoring and Accessing Bioelectricity

Biological Applications Group

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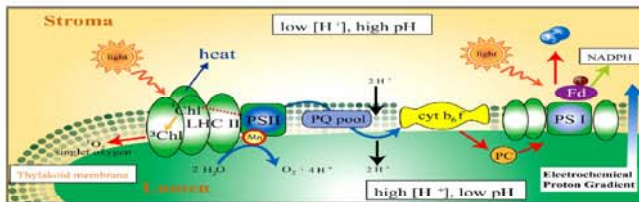
Department of Plant Biology, Carnegie Institution of Washington, Stanford University



Photosynthesis in chloroplasts of plant cells

Light reactions occurring in the thylakoid membranes of chloroplasts

- Create reducing power for the production of NADPH
- Generate a transmembrane proton gradient for the formation of ATP
- Produce oxygen and high energy electrons



Concept of Bio Solar Cell using Chloroplasts

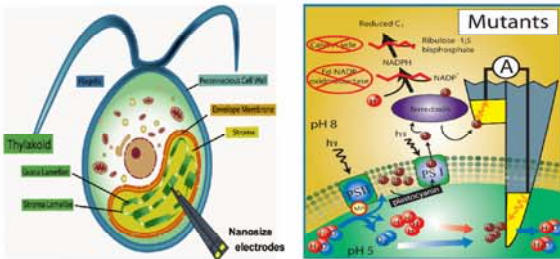
Research objective :

Harvesting the high energy electrons using dual nanoscale electrodes

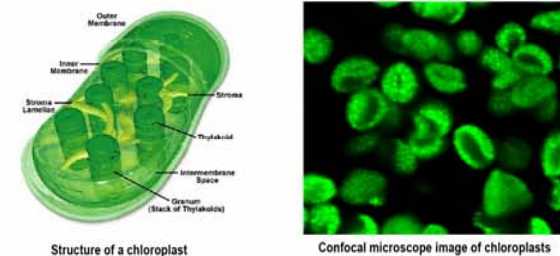


Two target electrochemical reactions :

1. Oxidation of reduced ferredoxins in stroma
2. Recombination of protons, oxygens, and electrons in thylakoid space



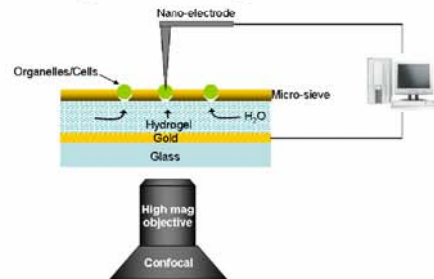
Schematic of bio solar cell using two nanoscale electrodes



Structure of a chloroplast

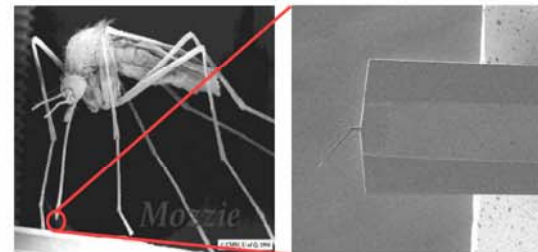
Confocal microscope image of chloroplasts

Single Cell Diagnostic Platform

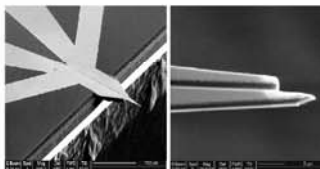


- Atomic Force microscopy combined with EC measurement setup
- Cell immobilization using Micro-sieve and hydrogel
- Confocal fluorescence microscopy

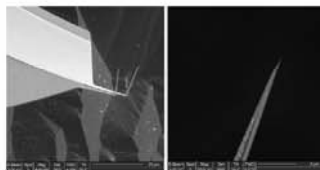
AFM and Planar Probes for Measuring Bioelectricity



Size comparison between mosquito proboscis and AFM tip



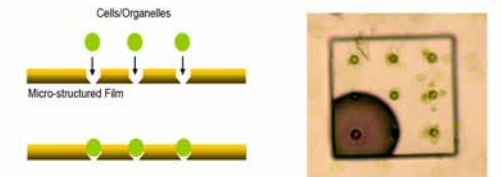
- Ultra sharp tips
- Nanometer size electrodes
- Dual-electrode system
- Suitable for penetrating a cell
- Customizable fabrication (FIB)



- Dual AFM-compatible tips
- SECM capability
- Sharp needle for penetration
- Capable of electrochemical sensing inside organelle

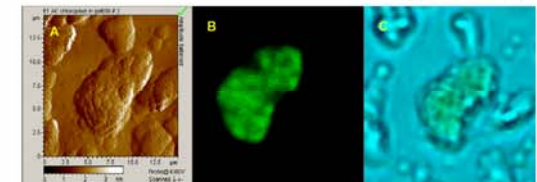
Experimental Results

Immobilization Method



Single organelle immobilization for electrochemical measurements

Different Visualization Methods of a Single Chloroplast



A : AFM deflection image B: Fluorescence image C: 100X Optical image

Electrochemical Measurements from Chloroplast

Amperometric measurements

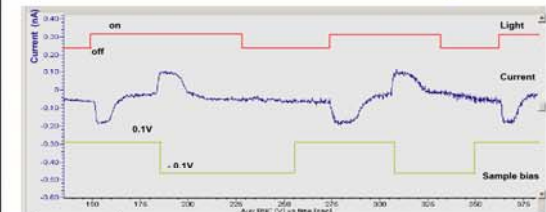
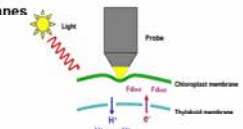
- Detect REDOX / Oxygen reactions *in vivo*
- Pt, Au, SAM-modified* electrodes

Potential measurements

- Measure potential across biological membranes
- Ag/AgCl electrodes

Capacitive measurements

- Measure transient / displacement currents near thylakoid stacks
- Pt, Au electrodes



Light-induced displacement currents are triggered by photosynthesis.

* Refer to Direct Oxidation of Ferredoxin at Modified Gold Electrodes