Nanoscale Electrochemical Electrodes for Monitoring and Accessing Bioelectricity

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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

Single Cell Diagnostic Platform

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

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

Concept of Bio Solar Cell using Chloroplasts

- Research objective: Harvesting the high energy electrons using dual nanoscale electrodes
- Source of the high energy electrons: $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + \text{O}_2 + 4\text{e}^-$
- Two target electrochemical reactions:
  1. Oxidation of reduced ferredoxins in stroma
  2. Recombination of protons, oxygens, and electrons in thylakoid space

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)

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.