Fabrication and characterization of a tunable microelectrode array for simultaneous electrochemical detection

Nicholas A Volya, Dr. Robert A Lazenby
Department of Chemistry & Biochemistry, Lazenby Group, Florida State University, Tallahassee, FL

INTRODUCTION

Microelectrode array (MEA)

Microelectrode arrays offer faster scan rates, smaller currents, higher flux, greater spatial resolution, and improved temporal resolution compared to a single microelectrode.

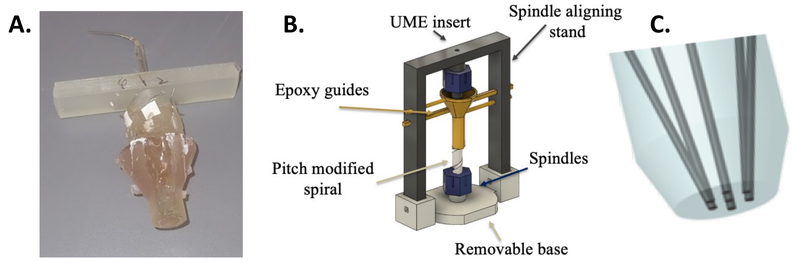

Figure 1. (A) Photograph of array prototype. (B) Schematic representation of the 3D printed device used to fabricate the array using a twisted bundle of metal wires. (C) Schematic of the final sealed MEA after polishing

OBJECTIVES

Objective 1: To design and optimize a 3D printed device that will enable fabrication of a platinum MEA.
Objective 2: To characterize the individual electrodes of the array using microscopy and voltammetry.
Objective 3: To use the array in generation-collection (GC) experiments and for electrochemical biosensing.

METHODS

Tuning the array

Through mechanical polishing we can tune the array for different spacing and different bundle configurations.

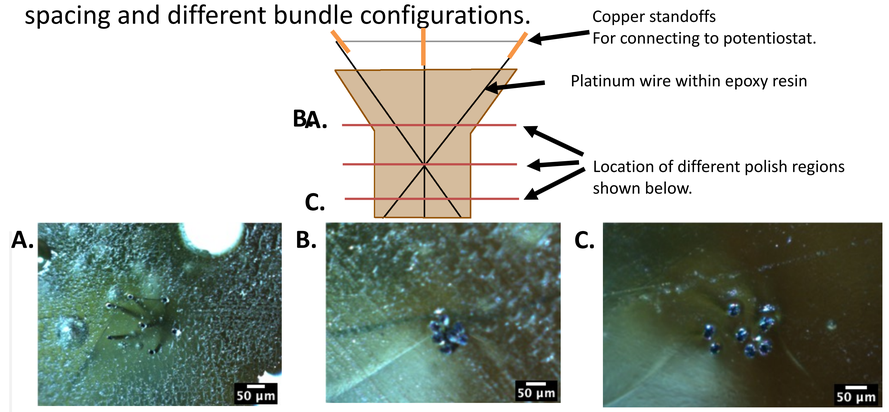

Figure 2. Optical microscope images of the exposed surface of the MEA at three positions: (A) below the bundle region (B) at the bundle region and (C) beyond the bundle to reveal the individually addressable electrode

RESULTS

Characterization of electrodes

Through electrochemical and optical we can investigate the quality of the array in the sealing methods characteristics, quality of surface polish, and the diffusional characteristics observed in voltammetry

Steady state limiting current analysis

Steady state limiting current is the region of the cyclic voltammogram in which current is diffusion limited and can be used to determine the expected current for differently sized electrodes.

$$I_{lim} = 4nFDac^*$$

Pt 25µm:

$$4(1\ \text{mol e}^-)(96500\,\tfrac{\text{C}}{\text{mol}})(6.5*10^{-6}\,\tfrac{\text{cm}^2}{\text{s}})\left(\tfrac{0.0025\text{cm}}{2}\right)\left(2*10^{-6}\,\tfrac{\text{mol}}{\text{cm}^3}\right)$$
$$= \mathbf{6.2725 * 10^{-9}\ A}$$

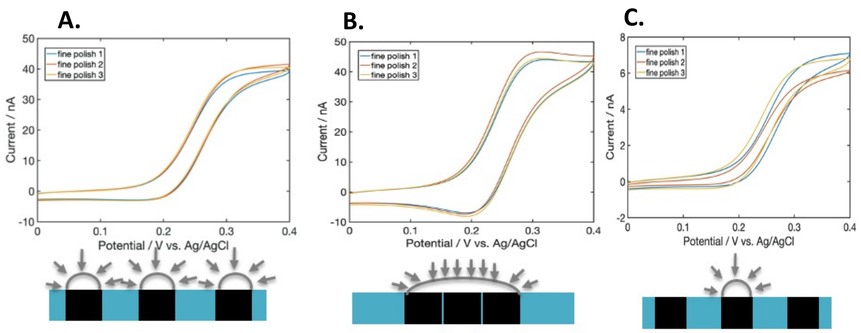

Figure 3. Cyclic voltammograms with different diffusion profiles at the different bundle positions in fig 2.

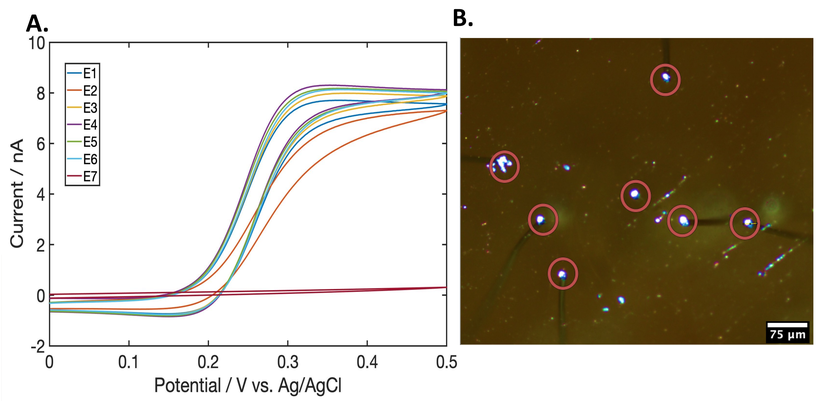

Figure 4. Characterization of post bundle array region
(A) Six electrode voltammetry from a single array. (B) Optical image of array surface

MAIN FINDINGS

- A 3D-printed apparatus was designed and used to fabricating MEA comprised of seven evenly-spaced electrodes.
- The device was optimized for an epoxy sealing step, and after polishing resulted in electrodes with well-behaved voltammetry with a steady state current close to the expected calculated value.
- The spacing distance between neighboring microelectrodes was adjusted by changing the amount of mechanical polishing.

FUTURE DIRECTIONS

Simultaneous detection of analytes

With a closely spaced array multiple species can be studied within a localized system.

Generator collector: By generating a species on one electrode and collecting it on an adjacent electrode a collection efficiency can be determined, or it can be further used to analyze multiple unstable species simultaneously.

Biosensors: The electrodes could be modified for biosensing and could then be used in the simultaneous detection of multiple biological compounds.

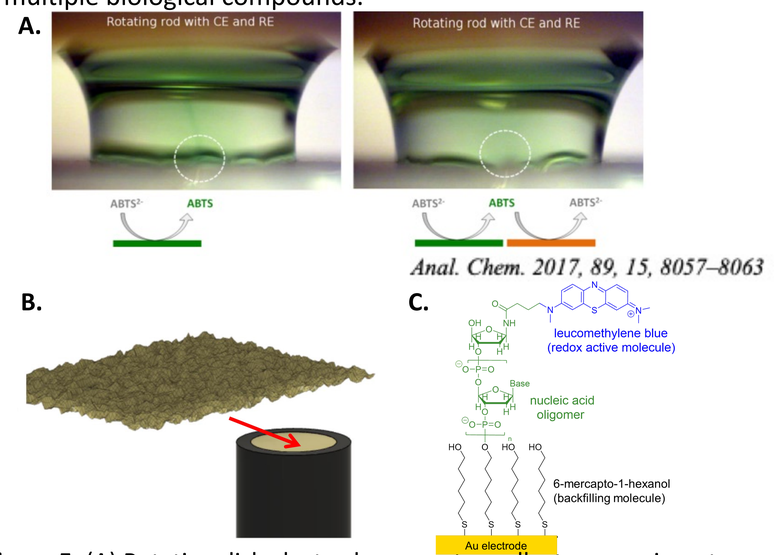

Figure 5. (A) Rotating disk electrode generator collector experiment showing absorption of a species. (B)Schematic of surface modification on an electrode surface. (C) Schematic of an Aptamer based biosensor.

ACKNOWLEDGEMENTS

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