Investigating Cross-talk in High Density Neurochemical Sensor Arrays

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Background & Goals

In recent decades, research in electrophysiology has driven our understanding of neurological disorders. However, monitoring neurochemical concentrations may offer further insight to medical professionals. Current technology for chemical detection in the brain is highly invasive and offers poor time resolution. Our work focuses on small, high density probes that offer real-time data while causing minimal tissue damage.

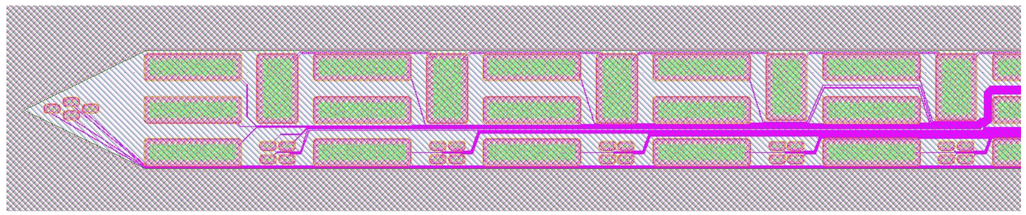
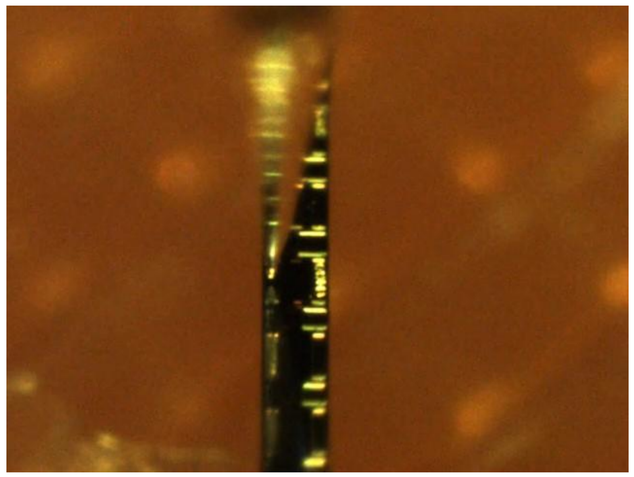


Figure 1: Schematic diagram of the tip of a probe. Sensor pads are indicated in green.

Our sensors are covered with enzymes that produce H_2O_2 in the presence of target chemicals. This generates an electrical signal when the H_2O_2 contacts the gold surface underneath. However, H_2O_2 molecules synthesized at one sensor pad may diffuse towards nearby sensors and generate false positive signals. By depositing catalase in between sensors, we hope to intercept stray H_2O_2 molecules and thereby reduce chemical cross-talk without compromising compactness.

Probe Functionalization



Probes were functionalized by depositing a BSA + enzyme solution on target areas. The BSA quickly hardened as the small volume of liquid evaporated. In order to prevent spillover of catalase into adjacent sensor wells, sub-20μm precision would be required. This was near the limit of our hardware's capabilities, so we first worked with 65μm spaced sensors. After depositing the desired enzyme, a vapor deposition of glutaraldehyde was carried out which prevented removal during measurement.

Figure 2: A Sonoplot Microplotter II with a 10μm glass tip was used to deposit liquid on the probe.

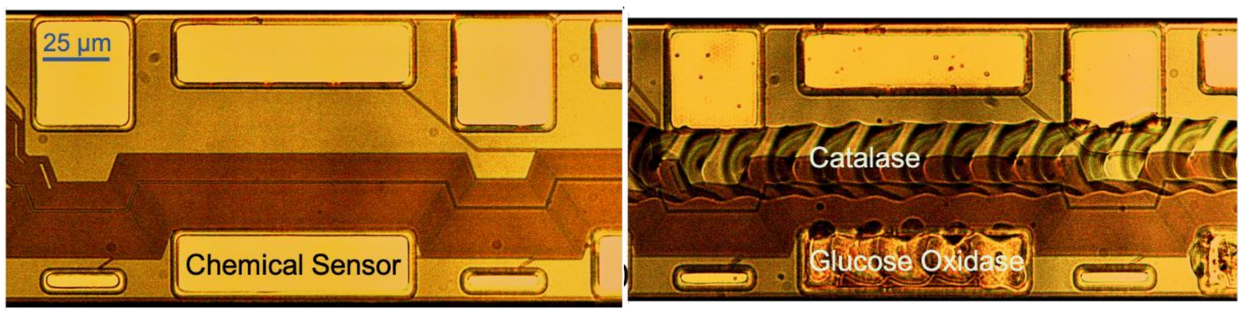


Figure 3: (**left**) Clean probe. (**right**) Successful deposition of BSA + glucose oxidase in a sensor well, and BSA + catalase between sensors.

Motivation

Prior to this summer, random walk simulations were developed and used to track individual H_2O_2 molecules from generation to detection. By changing simulation parameters, we compared cross-talk levels with and without the inclusion of catalase in between sensors.

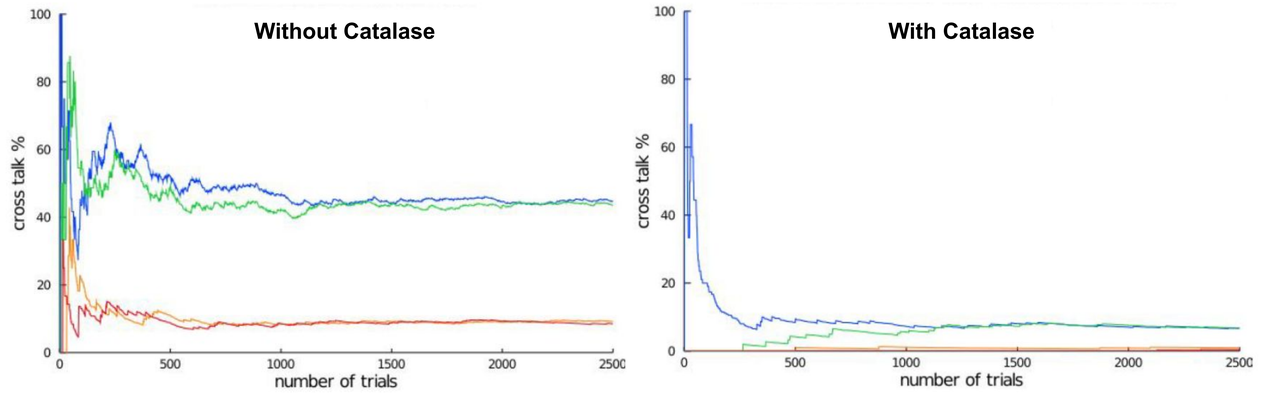


Figure 4: Simulations indicate that for sensors 50μm away from the target sensor (green & blue), the addition of catalase decreases cross-talk from ~45% to ~10%. For sensors 100μm away (red & orange), cross-talk is reduced from ~10% to nearly undetectable levels. Results from simulations without catalase are consistent with prior experimental results.

Data Collection & Preliminary Results

Measurements were carried out using an SP-300 potentiostat, which applied an electric potential to a target sensor and recorded the current generated by electrochemical reactions on the gold surface. Our two-channel instrument was able to make simultaneous measurements on two sensors, which would allow us to calculate cross-talk between them.

First, clean sensors were tested in dilute H_2O_2 for normalization. Next, glucose oxidase was deposited on the sensors on one side of the probe. Measurements were then taken in glucose solution of increasing concentration (up to 8mM). Finally, catalase was deposited in a long line separating the functionalized and unfunctionalized sensors, and another dataset was collected using the same glucose concentrations.

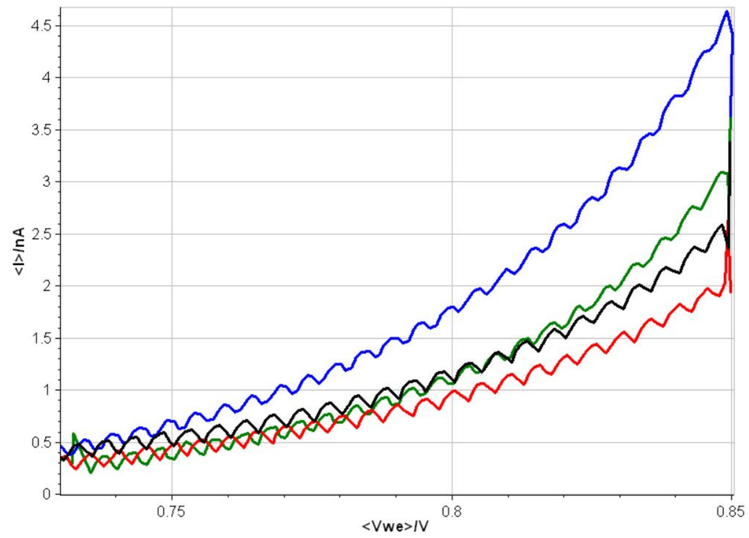


Figure 5: In 1mM glucose solution, a functionalized sensor (green) produced a stronger signal than its unfunctionalized pair (red). Measurements from the same sensors after the addition of catalase are shown in blue and black respectively.

Acknowledgements

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