INTRODUCTION

Dopamine is a chemical in the brain that is vital in regulation of healthy neurological function. Some aspects of life that dopamine contributes to include movement, sexual arousal, memory, mood, and attention [1]. Due to its diverse use in the body, there are also many illnesses that are related to insufficient concentrations of dopamine in the brain. A few examples of such illnesses are Parkinson’s disease, Alzheimer’s disease, schizophrenia, Huntington’s disease, and ADHD. In order to understand the cause and find possible treatments for these diseases, it is highly important that we have the ability to measure dopamine concentration in the brain. To do this, an electrode needs be created that can be placed in the brain and take measurements at any time.

For this project, carbon fiber microelectrodes (CFE) are coated with PEDOT/CNT to measure dopamine concentrations in vitro. CFEs have been used in the past to measure changes in dopamine levels in the brain for decades, however, they have not been capable of measuring resting levels of dopamine [2]. I am coating the CFEs with Poly(3,4-ethylenedioxythiophen) (PEDOT) polymerized with carbon nanotubes (CNT). By running a potential through PEDOT, I am able to oxidize the compound and give it a slightly positive charge. The CNTs are pre-soaked in acid which to give them a negative charge. The opposite charges of these two compounds allows for them to copolymerize onto the electrode tip with a bird nest morphology. This morphology is significant because it has a large surface area allowing for more dopamine interaction [3].

OBJECTIVE

The objective of this project is to develop a highly sensitive microelectrode to measure resting dopamine concentration. Another objective is to determine how different thicknesses of PEDOT/CNT coating impacts dopamine sensitivity and the impedance of the electrode.

HYPOTHESIS

PEDOT/CNT coated CFEs will be capable of detecting resting dopamine concentration.

SUCCESS CRITERIA

The approaches taken in the lab will look to lower the impedance in PEDOT/CNT coated electrodes. By lowering impedance, we will be able to increase the signal received and optimize the sensitivity of the electrodes. Also, efforts will be taken to increase sensitivity of CFEs for resting dopamine detection.

METHOD

Many steps were taken to perform the experiments of this project. Prior to coating the electrodes with PEDOT/CNT, I had to perform pre-coating characterization of the electrodes. This allowed me to obtain the impedance of a bare CFE which is used as a control group in comparison to impedance of the coated electrodes. All electrochemical techniques are performed using the Autolab Potentiostat. This includes impedance tests, the polymerization technique, and dopamine sensing techniques.

Next, I created the PEDOT/CNT solution. This was done by mixing a 1:1:1 ratio of PEDOT, CNT, and water. The solution would be sonicated for fifteen minutes to allow for dissociation of CNT clumps. Following this, I coat a selected CFE using the polymerization technique, chronoamperometry. For this project, four different thicknesses of PEDOT/CNT coatings were studied. These are 10 mC/cm², 25 mC/cm², 50 mC/cm², and 100 mC/cm². A three-electrode system was used, with a Ag/AgCl electrode being the reference electrode, a platinum sheet being the counter electrode, and the PEDOT/CNT CFE being the working electrode.

After polymerization of the PEDOT/CNT onto the CFE, impedance measurements are taken again. Once impedance is measured, dopamine testing begins. I created a 500 µM stock solution of dopamine in PBS. I used an incremental injection technique to measure dopamine sensitivity of the electrode. Differential Pulse Voltammetry (DPV) tests are used to measure dopamine concentrations in the sample. Each electrode is first tested in phosphate-buffered saline (PBS) without any dopamine, where no detection is expected. Next, I would inject an amount of the stock solution into the electrochemical cell, increasing dopamine concentration to 100nM and run the DPV again to measure dopamine concentration. This step is repeated multiple times but injecting amounts of dopamine to achieve 250 nM, 500 nM, 1µM, 5µM, and 10µM. I performed this process for over 50 electrodes in order to optimize the tests and techniques used and to obtain the greatest dopamine sensitivity.

RESULTS

I found that PEDOT/CNT CFEs do have a lower impedance than that of the bare electrode. As seen in figure 1 below, the greater the thickness of the coating, the lower the impedance levels. It can also be seen that all impedance measurements of
PEDOT/CNT electrodes are all significantly lower than that of the bare electrode.

DISCUSSION

The goal of this project is to develop a highly sensitive microelectrode to measure resting dopamine concentration. This goal was accomplished by coating the CFE with PEDOT/CNT. Also, it was found that increasing the thickness of the PEDOT/CNT coating decreases the impedance, and thus increases the signal received. However, a greater signal is not always the best because there is also more noise resulting in graphs that less clear than those with lower signals. To account for noise, it was decided that the best option is to find a middle ground between noise and signal and the 25 mC/cm² is the optimal coating thickness for future experiments.

The next step in this project is to perform in vivo testing. So far, the electrodes have only been tested and approved for in vitro uses, and in vivo testing will bring insight to if and how the device can be used clinically.

A limitation to this project is that the technique used to measure dopamine sensitivity, the DPV, is a slow and small technique. A possible solution to this would be to use square wave voltammetry (SWV) instead. SWV are bigger and faster scans, but it tends to have non-flat backgrounds which makes comparing sensitivities of different electrodes difficult. DPV have a flat background which is why this test was used instead of SWV.

Overall, the success criteria of the project was met. This project proves an electrode that measures resting dopamine concentrations is possible, impedance of the electrodes can be decreased by applying a thicker coating of PEDOT/CNT, and the PEDOT/CNT electrodes created successfully sensed different concentrations of dopamine as predicted. A future goal with the device is to load and unload dopamine into the PEDOT/CNT CFE. This is a difficult goal, but with this ability, the electrode can sense the concentration of dopamine in the brain, and based on the result, load or unload dopamine until normal resting level is achieved. This will be able to combat dopamine related illnesses such as Parkinson’s disease, hopefully leading to an improved lifestyle of many patients suffering from these diseases.

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REFERENCES

