PEDOT/GO CARBON FIBER MICROELECTRODES FOR DOPAMINE SENSING

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INTRODUCTION

Dopamine (DA) sensing has become an important emerging technology due to the regulatory role of DA signaling in neurological diseases such as schizophrenia, addiction and Parkinson’s1,2. However, due to its low concentration in the CNS relative to coexisting species such as ascorbic acid (AA), DA can be difficult to detect accurately. When using traditional electrodes, the recorded oxidation potentials of DA and AA are so close that their voltammetric responses often overlap, causing an interfering signal from the AA6.

The biologically compatible, structurally robust carbon fiber microelectrode (CFME) offers a superior alternative to the traditional electrode. CFMEs have already been extensively electrochemically characterized. They are relatively inert and resistant to fouling, while also showing good detection of catecholamines like DA4. Furthermore, they are 7µm in diameter, making them less intrusive and damaging than conventional electrodes to delicate brain tissue. The deposition of a biocompatible conducting polymer (CP), such as poly(ethylenedioxythiophene)/graphene oxide (PEDOT/GO) composite, onto the surface of the CFME further improves the electrode’s sensitivity toward DA. PEDOT has been shown to increase the separation of AA and DA peaks, thus reducing the interference from AA and increasing the precision of the DA sensing5.

The addition of the GO nanoparticle dopant to the PEDOT CP further increases the mechanical strength of the film as well as the sensitivity toward dopamine through π-π interactions. The sensing capacity of the CFME, used in conjunction with fast scan cyclic voltammetry (FSCV) and the PEDOT/GO composite, is optimal for use in identifying small and rapid changes in DA due to its continuous fluctuation in the brain. In this study, we will characterize the DA sensing ability of the PEDOT/GO film on CFMEs in vitro to further the advancement of a tool that will help us elucidate the effect of DA in the brain in vivo.

METHODS

Custom-made CFMEs consisted of carbon fibers (7µm diameter) threaded through tapered borosilicate glass capillaries filled with mercury, as shown in figure 1.

All electrochemical procedures were carried out with a three-electrode setup with a CFME working electrode, Ag/AgCl reference electrode and a Pt counter electrode using a Gamry Potentiostat, FAS2/Femtostat (Gamry Instruments). The CFMEs were modified by electrodepositing PEDOT/GO from a solution of 0.01 M EDOT and 5 mg mL⁻¹ GO, using multiple parameters (3.5 nA 15s or 30s, 5 nA for 15s or 30s) with chronopotentiometry. The electrodes were then electrochemically characterized using cyclic voltammetry (CV). FSCV experiments carried out in solutions of 10 µM DA were used to evaluate the electrocatalytic activity of the PEDOT/GO modified CFME toward DA. The electrode potential was swept from -0.5 V to 1 V at 400 V/s and the oxidation peak and location values were evaluated. Slow scan experiments were carried out using 20µM solutions of DA and 1 mM AA, with the voltage endpoints being -0.5 to 1 V at 100 mV/s. The physical properties of the film were characterized using scanning electron microscopy (SEM) imaging.

RESULTS/DISCUSSION

As seen in Figure 1, PEDOT/GO-modified electrodes pass at least six times more current than the bare CFME at the DA oxidation peak location. The shift of the oxidation peak is likely due to a faster oxidation reaction facilitated by interactions between the PEDOT/GO film and DA molecules. The film deposited at 5 nA 15s had narrowest oxidation peak and the best specificity for DA relative to its peak value, making it the most promising possibility for in vivo sensing with the least amount of interference from AA. However, we can see in 1c that the even the coated electrodes provide little peak separation between DA and AA.

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Figure 1. Tip of 200 um in length of custom made carbon fiber microelectrode.
For all further testing, only the electrodes fabricated with chronopotentiometry at 3.5 nA and 5 nA at 15s were considered since they showed a better peak definition and specificity for DA using FSCV. Figure 4 presents a slow scan cyclic voltammogram showing the comparison of electrodes coated with PEDOT/GO and PEDOT doped with polystyrene sulfonate (PEDOT/PSS), which is another commonly used CP film well characterized in literature.

The slow scan cyclic voltammogram differs from the FSCV in that the DA response appears smaller. Even so, the electrode coated with the PEDOT/GO film has a larger charge storage capacity than either the bare or PEDOT/PSS coated electrode. Furthermore, the PEDOT/GO electrode gives the most the most DA specific response.

Figure 4. SEM images of PEDOT/GO deposited on (a) CFME and (b) flat gold macroelectrode.

CONCLUSION

Although there was little peak differentiation seen between AA and DA, the CFMEs coated with PEDOT/GO film offer improved sensitivity toward DA detection over bare sensing electrodes. To further characterize the film on the CFME and its sensing capabilities toward DA, the electrodes will be tested in solutions of DA and AA with concentrations that mimic those found in vivo. The results thus far suggest that the PEDOT/GO coated CFME can be implemented in vivo and help further our understanding of DA’s role as a neurotransmitter in the brain.

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REFERENCES