Poly(3,4-ethylenedioxythiophene)/Graphene composite neural microelectrodes

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I. INTRODUCTION

Conducting polymers (CPs) used as coating for neural microelectrodes are attracting wide attention in recent years. Poly(3,4-ethylenedioxythiophene) (PEDOT) is a CP which has been extensively explored due to its superior chemical stability [1]. It has been found that the safe charge injection (Q_{inj}) limit has been greatly improved by coating CPs, but the mechanical stability remains an unsolved problem. The failure of the PEDOT coating is likely due to delamination of the material from the underlying substrate [1]. As dopant is an important factor proposed to address the issue of the stability of CP coating and the adhesion to the electrode [2], this inspired us to search new composite electrodes. In this study, carboxyl-functionalized graphene (Gr) doped PEDOT microelectrodes have been investigated. The preliminary study aims to evaluate the feasibility of the fabrication as well as the electrochemical properties and biocompatibility, which is the first step towards to develop long-term stable CP/Gr composite neural electrodes. A further animal study will be carrying out based on the work.

II. EXPERIMENT AND RESULTS

PEDOT/Gr films were electrodeposited onto a platinum microelectrode (d=100μm) in an aqueous solution containing 0.015 M EDOT and 1 mg/mL Gr using a potentiostatic mode at 1.0 V (vs. SCE). The surface morphology was examined by scanning electron microscope (Sirion, FEI, Netherlands). The cyclic voltammogram (CV) and electrochemical impedance spectra (EIS) were obtained using Solartron 1260. Coating adhesion was qualitatively evaluated by inserting and removing coated microelectrodes from an agarose gel (3g/mL). Neural cells were used to investigate the neuronal differentiation and extension on PEDOT/Gr deposited ITO glass slides.

The cathodic charge storage capacity (CSC_C) of the PEDOT/Gr microelectrodes increased to 110.09 mC/cm^2, while bare Pt without the coating was only 1.4 mC/cm^2, calculated from Fig. 1(a). It implies that the PEDOT/Gr films were deposited onto the electrodes. The porous microstructure, shown in Fig.1 (b), can offer a high charge injection capability and low electrode impedance. The impedance of coated microelectrodes at 1 kHz was 2.04 kΩ (reduction of 96%), shown in Fig.1(c). Moreover, PEDOT/Gr microelectrodes exhibited a high Q_{inj} of ~ 7.1 mC/cm^2 (cathodic-first pulse) while Pt electrodes generally have a Q_{inj} value of only 0.15 mC/cm^2. The high Q_{inj} values may result from the porous deposit PEDOT/Gr films that facilitate the fast charge transfer at the interface. Coating integrity was evaluated by CV. The CV was almost unchanged after removing from the gel. This suggests that the composite film possesses good mechnical stability. Finally the study found that neural cells exhibited neurite outgrowth, and intricate the neurite network was formed on the PEDOT/Gr films (Fig. 1(d)), which implies that the films possess a good cytocompatibility.

III. CONCLUSION

This preliminary study has demonstrated the feasibility and advantages of deposition of PEDOT/Gr films on Pt microelectrodes in regards to the neural interface. PEDOT/Gr coated microelectrodes exhibit a remarkable high pseudo-capacitance, high Q_{inj} value and lower electrode impedance as well as good cytocompatibility. This provides a good basis for a further animal study.

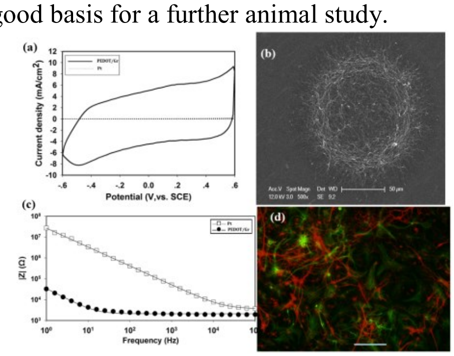

Fig. 1. (a) Cyclic voltammograms of PEDOT/Gr microelectrodes and Pt microelectrodes at a sweep rate of 50 mV/s in PBS. (b) SEM images of PEDOT/Gr microelectrodes (scale bar is 50 μm) (c) The EIS results of PEDOT/Gr and Pt microelectrodes in CBS/PBS. (d) Representative fluorescent images of tubulin and GFAP stained neural cells cultured on PEDOT/Gr deposited ITO substrate (scale bar is 100 μm)

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