The electroactivity and stability of conductive PPy/HE/PLLA membranes

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Statement of Purpose: Polypyrrole (PPy) is an important intrinsically conducting polymer studied for tissue engineering and bioelectrical applications. Its composites with biodegradable polylactide (PLLA) can be used as substrate for electrically stimulated cell growth. Heparin (HE)-doped PPy/PLLA composite membranes (PPy/HE/PLLA) are developed in our lab for biomedical applications. We had hypothesized that the HE-doped PPy should have a superior electrical stability and proved it in a direct current stability experiment. But the stability of electroactivity, i.e., the ability of maintaining ion exchange during multiple redox cycling, has not been studied. The current work employed the cyclic voltammetry method to investigate the environment stability of electroactivity of the PPy/PLLA membranes with or without HE as dopant. X-ray photoelectron spectroscopy (XPS), Fourier transform infrared (FTIR) and scanning electron spectroscopy (SEM) were used to investigate these PPy/PLLA composites before and after the cyclic voltammetry experiment.

Methods: The PPy/PLLA membranes with or without HE were synthesized according to previously described methods (1,2). The PPy/PLLA membranes (PPy:PLLA = 5:95, w/w) were subjected to cyclic voltammetric experiment in an aqueous solution with *p*-toluenesulfonate (0.1mol/L) as the electrolyte. The solution was purged with nitrogen gas for 10 minutes before experiment and protected with nitrogen during the entire experiment. The experiment was at room temperature (ca. 21 ^{o}C). The Epsilon Potentiostat/Galvanostats (BASi, West Lafayette, Indiana, USA) was used to control the experiment. The PPy/PLLA membranes of 0.5 mm in thickness were cut into 2.5 mm x 25 mm specimens and used as working electrode. Platinum wire and Ag/AgCl were used as auxiliary and reference electrodes, respectively. One thousand cycles were performed between -800~1200 mV at a scanning rate of 50 mV/s.

Results: The electroactivity of both the HE-containing and non-containing membranes showed distinct redox behaviors, of which the intensity diminished gradually with the number of redox cycling. There was however clear difference among the two types of membranes. As showed in Figures 1 and 2, over the entire course of 1000 cyclings, the HE-containing membranes (PPy/HE/PLLA) maintained a higher percentage of both the original redox current and the surface area in comparison with the membranes that did not contain HE (PPy/PLLA). This means that the PPy/HE/PLLA membrane is more likely to sustain a stable electrical stimulation during cell culture experiment. On the other hand, compared with the PPy/HE/PLLA, the PPy/PLLA membranes recorded a higher response current and a larger electroactivity variation, meaning higher electroactivity. The XPS revealed a higher oxygen and lower nitrogen content in the PPy/PLLA membrane than in the PPy/HE/PLLA membranes. Following the cyclic stability test, the variation in elemental composition in all the PPy/PLLA membranes was larger than that in the PPy/HE/PLLA membranes. FTIR and SEM did not show significant change in the PPy/PLLA membranes before and after the stability test.

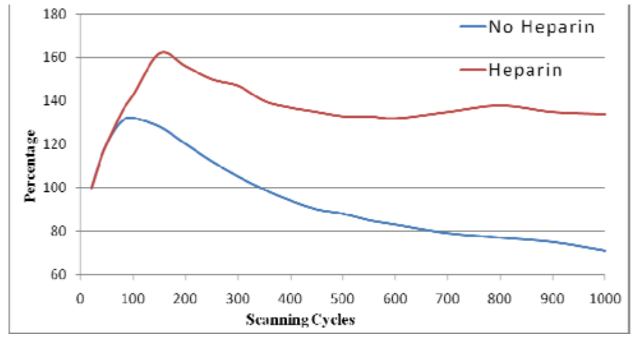

Figure1. Change of current value at oxidation and reduction switch point with different circles

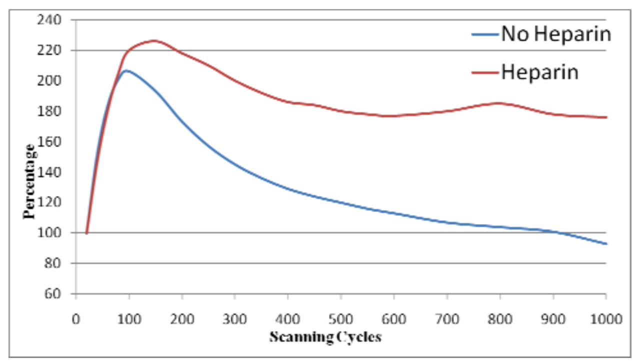

Figure2. Change of area of redox cycle with different circles

Conclusions: The cyclic voltammetry experiment showed that the conducting PPy particles doped with HE has a superior stability in electroactivity. While the HE molecules positively contributed to the electrical stability, they slightly lowered the electroactivity and conductivity of the PPy/PLLA membranes in the aqueous environment. Consideration must be given to the specific applications when what membrane is to be selected.

References:

1. S. Meng, M. Rouabhia, G. Shi, Z. Zhang. Heparin dopant increases the electrical stability, cell adhesion, and growth of conducting polypyrrole/poly (L,L-lactide) composites. J Biomed Mater Res A. 2008;87:332-44.
2. G. Shi, M. Rouabhia, Z. Wang, LH. Dao, Z. Zhang. A novel electrically conductive and biodegradable composite made of polypyrrole nanoparticles and polylactide. Biomaterials 2004; 25:2477–2488.