A flexible and electrically stable conductive polypyrrole membrane for biomedical applications

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Statement of Purpose: Polypyrrole (PPy has been extensively investigated for biomedical applications owing to its electrical conductivity, electrochemical activity, cyto- and tissue compatibility, easy synthesis, and potential of a variety of chemical modifications[1,2]. However, due to its extensively conjugated and crosslinked molecular structure, PPy is rigid, insoluble and infusible presenting poor processability. In order to be used as a conductive element, PPy is usually polymerized either as a coating layer, or in form of powders serving as fillers. Noticeably, a thin surface coating cannot guarantee stable conductivity in a physiological environment; and PPy filler-based composites cannot offer a microscopically uniform conductive surface because of the island structures of PPy particles. Therefore, a single component PPy membrane with stable conductivity and processability is highly desirable. Recently, a highly flexible PPy membrane was prepared in our group[3]. In this method, methyl orange (MO) is used as a template to form PPy nanotubes on one side of the PPy membrane. The complete removal of MO needs an onerous washing process. PPy nanotubes also cause test errors due to their high absorption capacity to biomolecules and ions. Consequently, in this work, the nanotubes were removed to reduce cytotoxicity and biological test errors, and to shorten the preparation time without any significant impact on the electrical conductivity and flexibility of the PPy membrane.

Methods: The flexible PPy membranes with PPy nanotubes on one side (PPy-N) were synthesized through a template assisted interfacial polymerization (TIP), a process described in detail in our previous work[3]. Prior to washing, the nanotubes were swept away by pipetting and brushing to obtain a nanotube free membrane (PPy-R). To test the biocompatibility of the PPy membranes, human skin fibroblasts were cultured on the membrane for 24, 48 and 72 hours. Fibroblast adhesion was ascertained by Hoechst staining. The cell viability and growth were measured by a colorimetric assay using MTT with optical absorbance recorded at 550 nm.

Results: The flexible PPy-N membrane presents an asymmetrical morphology, i.e., a bubble side and a nanotube side (Fig. 1). The morphology of the nanotube side of the PPy membrane was significantly changed after removal of the nanotubes. This change was also supported by the specific surface area decreasing from 14.5 to 0.1 m^2 g^{-1}, as well as by water contact angle. Mechanical measurement confirmed that the break stress, ultimate elongation and strain increased after removal of the nanotubes. Compared to the PPy-N, PPy-R showed a similar flexibility even in liquid nitrogen. The PPy-R can also be easily manipulated into different shapes without any damage (Fig. 2). This testifies that the flexibility of the PPy-N is not related with the nanotubes but with other membrane structures. The PPy-R membrane not only presents a similar conductivity as PPy-N (1.60 s cm^{-1} vs 1.54 s cm^{-1}), but also has a stable conductivity (10^{-3} s cm^{-1}) for a long time (180 hours) in culture medium. Figure 1 also shows the density and distribution of the cells on the nanotube remove side of the membranes. Similar result could be also observed on the PPy-N membrane. But MTT test showed inconsistent results. The absorbance of the PPy-R was only slightly lower than that of the control group and it gradually increased with culture time from 8 to 96 hours. Yet, MTT reading of the PPy-N was much lower than that of the control and PPy-R groups, likely the result of the high absorption capacity of the PPy nanotubes to MTT reagent and/or formazan.

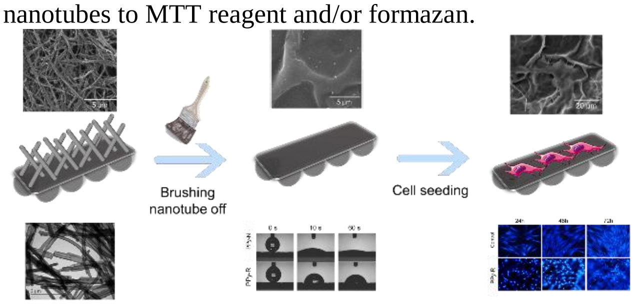

Figure 1 Diagram of preparing and characterizing PPy-R membrane

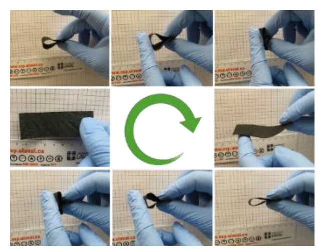

Figure 2 Flexibility of PPy-R membrane.

Conclusions: The PPy-R membrane retained the high flexibility of the original PPy-N, and showed improved mechanical properties and an excellent long-term stability in conductivity. The PPy-R membrane was not cytotoxic and supported fibroblast growth. Removal of the PPy nanotubes eliminated their interference to biological tests. The high flexibility, cytocompatibility, mechanical processability and electrical properties may find this type of PPy membrane useful in biomedical applications.

References:

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