A soft and electrically stable polypyrrole membrane reinforced with electrospun polyurethane and poly-L-lactic acid fibres for biomedical applications

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Background

Polypyrrole (PPy) has been extensively investigated for biomedical applications owing to its intrinsically electrical conductivity, environmental stability, and tissue compatibility [1]. However, due to its extensively conjugated and crosslinked molecular structure, PPy is rigid, insoluble and infusible, presenting poor processability. To improve its processability, PPy is usually polymerized as a thin coating layer, or in form of powders serving as fillers. The former cannot guarantee a stable conductivity in a physiological environment; and the latter exhibits a heterogeneous conductive surface because of the PPy domains [2]. Recently, a soft, free-standing and microporous PPy membrane was successfully synthesized, showing a stable conductivity but limited mechanical strength [3].

Objective

To improve the mechanical strength of the free-standing soft PPy membrane without compromising the electroactivity.

Hypothesis

PPy membrane can be reinforced without compromising electroactivity through eletrospun polyurethane (PU) and poly-L-lactic acid (PLLA) fibres.

Method

Step 1: Synthesis of free-standing soft PPy membrane.
Step 2: Electrospinning of PU and PLLA fibres on the bubble side of the PPy membrane (*Figure 1*).
Step 3: Wash membrane to reduce cytotoxicity.
Step 4: Characterization of the reinforced membrane:

- SEM: Surface morphology and microstructure.
- Tensile tester: Stress - strain property.
- FTIR and XPS: Chemical properties.
- Four point probe: Surface conductivity.
- A home-made electrical stimulation device: Electrical stability in saline.

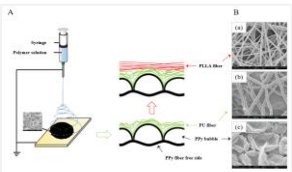

Figure 1. A, Schematic illustration of how the electrospun fibers are assembled on top of the free standing PPy membrane; B, SEM observations of the stiff PLLA fibers (a), the compliant PU fibers (b), and the bubble surface of the PPy membrane (c).

Result

The synergy between the compliant PU fibers and with the rigid PLLA fibers played a key role in the good adhesion between fibres and membrane

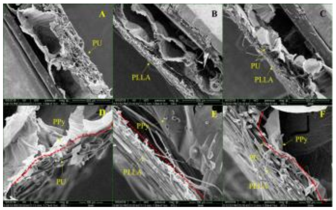

Figure 2. SEM microphotographs at cross section of the Ppy membranes reinforced with different fibers at low and high magnifications: A&D: PPy membrane reinforced by electrospun PU fibers; B&E: PPy membrane reinforced by electrospun PLLA fibers; C&F: PPy membrane reinforced firstly by PU and then by PLLA fibers.

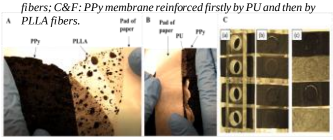

Figure 3. A, Peel test of electrospun PLLA fibers on PPy membrane; B, Peel test of electrospun PU fibers on PPy membrane; C, Manipulation test of electrospun the PU/PLLA fiber strengthened PPy membrane: (a) PPy membrane and PU/PLLA strengthened PPy membranes assembled into a cell culture device; (b) Membranes disassembled from device; (c) Bottom side of the disassemble membranes in (b).

Electrospun PU and PLLA fibers significantly increased the tensile strength of the Ppy membrane

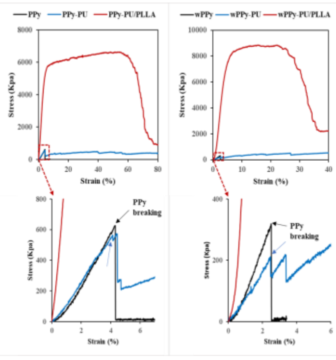

Figure 4. Strain-stress curves of the membranes before (left) and after 7 days washing (right).

Result

Surface electric conductivity and long-term electric stability were not affected by the electrospun fibres.

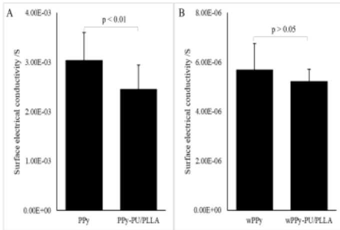

Figure 5. Surface electrical conductivity of the membranes (A) without wash and (B) after 7 days of wash.

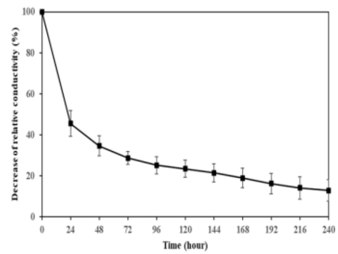

Figure 6. Electrical stability of the wPPy-PU/PLLA membrane.

The decrease of the surface conductivity after 7 days of wash is related with reduced oxidation of PPy

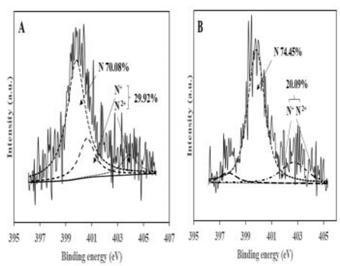

Figure 7. Curve fittings of the high resolution XPS spectra of N1s. (A) before 7 day wash and (B) after 7 day wash.

Result

Electrospunning had no effect on chemical components of the fibre free side of the membrane.

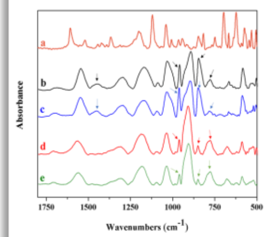

Figure 8. Infrared spectra of a, MO; b, PPy; c, PPy-PU/PLLA; d, wPPy; e, wPPy-PU/PLLA.

Conclusion

Through electrospinning, the compliant PU fibers and the rigid PLLA fibers showed a synergy effect on reinforcing the soft PPy membranes. The conductivity and surface chemistry of the reinforced membrane were not affected by the electrospun fibres. The reinforced soft PPy membrane can be manipulated easily without broken, representing an effective and practical way to use the soft PPy membranes.

Acknowledgements

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References

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