# Using Conductive Textiles as Substrate to Electrically Stimulate Fibroblasts

+[1,2]Wang YL; [1]Rouabhia, M; [2]Zhang, Z
+[1]Groupe de recherche en écologie buccale, Faculté de médecine dentaire, Université Laval, Québec (QC), Canada; [2]Centre de recherche du CHU de Québec, Département de chirurgie, Faculté de médecine, Université Laval, Québec (QC), Canada

**Introduction:** Cells like fibroblasts are responsive to electrical stimulation (ES) that is known to affect numerous cellular activities [1] and has been arguably used in clinic to improve bone healing. We have previously reported a type of conductive polymer composite made of electrically conductive polypyrrole (PPy) and biodegradable polylactide (PLLA), which is able to mediate ES to modulate cell proliferation, viability and cytokine secretion. We also previously reported the electrically conductive textiles supporting the adhesion and proliferation of endothelial cells [2] and neurons [3]. Compared with the PPy/PLLA composite membranes that is relatively rigid, a conductive textile has obvious advantages in its flexibility and easy to manipulate (Figure 1). However the electrical stability of the conductive textiles is not satisfactory for its conductivity deteriorating rapidly in aqueous environment particularly when there is electrical current passing through. In this work we present an electrically conductive textile and an ES protocol by which the conductive textile was sufficiently conductive to mediate effective ES to up-regulate the growth of human skin fibroblasts.

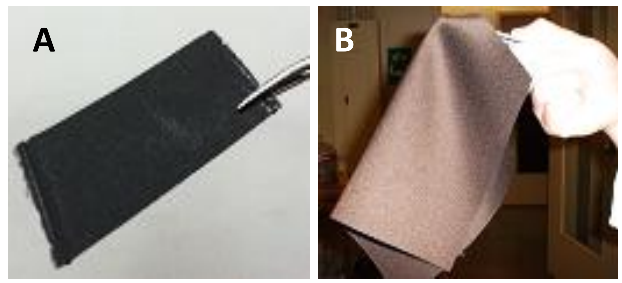


Fig. 1: Stiff PPy/PLLA membrane (A) and flexible PPy-coated PET fabric (B).

**Materials and Methods:** Freshly distilled pyrrole monomers (98%, Laboratoire MAT, Beauport, QC, Canada) was used to synthesize PPy on poly(ethylene terephthalate) (PET) fabric (Testfabrics, West Pittston, PA, USA). Before polymerization, the fabrics were thoroughly washed firstly in methanol (Laboratoire Mat) and then in isopropanol (Laboratoire Mat), followed by a final wash in water. This wash process was carried out in triplicate. To polymerize, the PET fabric specimens were firstly kept in a pyrrole solution and then transferred to a $FeCl_3$ (Laboratoire Mat) water solution to initiate polymerization. The final product is a black fabric without apparently change in handling property. The electrical conductivity of the specimens was measured using a standard 4-point method. The surface morphology was investigated using a scanning electron microscope (SEM). The surface chemistry was analyzed using an X-ray photoelectron spectroscope (XPS). The thermal properties of the fabrics were studied with differential scanning calorimeter (DSC) and thermal gravimetric analysis (TGA). The mechanical properties were tested using Instron mechanical property tester. Finally, a pulsed electrical stimulation protocol was developed and used to test the electrical stability and electrically stimulated culture of human skin fibroblasts. A *t*-test and an ANOVA test were used in data analysis.

**Results:** The microfibers of the PET fabrics were covered with a uniform and very thin layer of PPy (Figure 2). The cross-section of the PET microfibers showed no difference between the PPy-coated and non-coated specimens, meaning that the PPy coating is very thin. XPS spectra revealed the presence of high concentration of nitrogen atoms originated from PPy, and the presence of chloride anions acting as dopants. The oxidation of the nitrogen atoms was confirmed with the high resolution spectra of $N_{1s}$. DSC results showed no shift of melting point and no change in heat of fusion between the PPy-coated and non-coated PET fabrics (6~10mg; n=3; *t*-test). Similar results were also found in the TGA tests

(6~10mg; n=3; *t*-test). The stretch and strain curves of the fabrics changed little after PPy coating (5×50 $mm^2$; n=3; *t*-test). All these data support the conclusion that the PPy coating process did not bring any significant change to the molecular aggregation structures and the mechanical property of the fabrics, which was desirable because the mechanical strength and structural porosity of the PET textile are preserved. The pulsed electrical current generated a continuous but slow deterioration of the conductivity of the fabrics (n=8; *t*-test). However, compared to using the continuous electrical current, this deterioration was confined to a much less extent. In fact, in a period of 24 hour experiment, the fabrics lost only about 20% of its original conductivity. In comparison, continuous electrical current would have reduced the conductivity to almost zero. The same electrical parameters were used to stimulate the fibroblasts cultured on the conductive fabrics. While fluorescence staining did not show difference in the number of cells, cell viability test using MTT assay recorded a significantly elevated metabolic activity of the cells following electrical stimulation (n=3; *t*-test). This observation demonstrated that the conductive fabrics have sufficient electrical conductivity and stability to support electrically stimulated cell cultures.

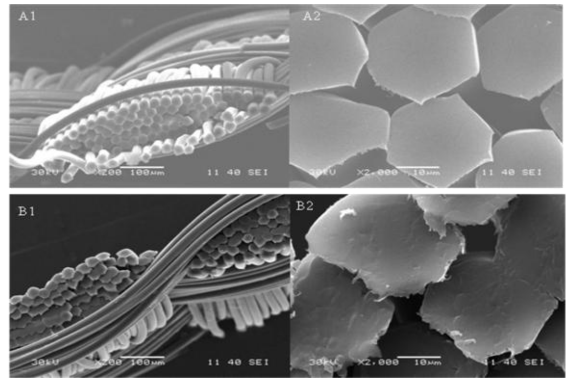


Figure 2. The SEM photos of the PPy-coated PET fabrics (B1&B2) in comparison with the original PET fabrics (A1&A2), showing similar morphology and cross-section.

**Discussions:** Electrical field is intrinsic in biological system. It also plays important roles in regulating basic cellular activities such as proliferation, migration and signalling. To take this advantage, a conductive substrate is required to mediate EF to the biological system. Compared with the PLLA/PPy membranes we reported previously, the PPy-coated textiles have the advantages in mechanical properties, processability and handing properties such as bending, folding and suturing. This work also means that this simple wet chemical process may be applied to the biodegradable textiles such as the non-woven polylactide textiles, which actually is part of our ongoing work. Compared with chemical or plasma assisted surface grafting of PPy, the process presented in this work is simple and favours the preparation of large size of conductive textiles. The pulsed electrical stimulation protocol established in work demonstrated for the first time the possibility of using conductive textiles as substrate to mediate ES. Because textiles are widely used in medical industry such as in vascular prostheses or as patching materials, this work broadened the territory where conductive biomaterials and ES can be used. *(This study was financially supported by a grant from the CHIR).*

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