

Electrospun cellulose-based membranes for bioelectrochemical devices

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Research applications in biomedical science and technology usually require various portable, wearable and implantable devices that can be used in biological and biomedical systems. The development of portable micropower sources has become a demanding and a challenging goal [1]. The decreasing of power requirements for portable electronics and nanodevices has improved the design of flexible energy-storage devices. If integrated structures containing the three essential components (electrodes, separator, and electrolyte) of the electrochemical device can be made mechanically flexible, it would enable these to be embedded into various innovative and functional devices [2]. In order to power electronic medical implant, power-supply systems must be capable of operating independently over a prolonged period of time, without the need of external recharging or refueling [3].

The present work aims the production of thin and flexible bioelectrochemical devices able to generate electrical energy from physiological fluids to supply small biomedical implants and biosensors for health care diagnostics.

Common energy-storage devices such as batteries and capacitors rely on large-surface-area electrodes to function. Due to that a cellulose-based membrane was produced by electrospinning. The electrospun matrix is highly porous, flexible and has a high surface area which are important properties for the present application. The electrospun membrane works both as the separator and as the support of the electrochemical device.

The membrane's electrochemical behavior was analysed by cyclic voltammetry. In pristine membranes the current density obtained is low, in the range of 20 nA.cm^{-2} . However, when impregnated with a salt solution a change of the electronic behavior is observed (Figure 1) as a consequence of the incorporation of ions and solvent molecules into the polymer matrix. Reversible redox reactions were detected and the current density obtained range from 20 nA.cm^{-2} to 0.6 mA.cm^{-2} . The salt solution added (less than 0.1ml of NaCl 0.9% (w/w) in water) intends to simulate a body fluid, such as blood plasma or sweat.

After membrane's electrochemical characterization, thin films were deposited on both sides of membrane to form the electrodes (Figure 2). The power generated by these devices depends not only on the materials used as electrodes but also on the membrane thickness.

To demonstrate the great potential of these bioelectrochemical devices, some of them were tested, and promising results were found. For instance, using silver and aluminium as electrodes in a thin film form, the device with 1 cm^2 showed a voltage of 0.62V and a current of $54 \mu\text{A}$ when in contact with sweated skin (Figure 3).

References:

- [1] P. Xian Gao, J. Song, J. Liu, and Z. Lin Wang, *Adv. Mater.*, **19** (2007), 67–72.
- [2] V. Pushparaj, MM. Shaijumon, A. Kumar, S. Murugesan, L. Ci et al., *PNAS*, **104** (2007), 13574-13577.
- [3] S. Kerzenmacher, J. Ducreé, R. Zengerle and F. von Stetten, *Journal of Power Sources*, **182** (2008), 1-17.

Figures:

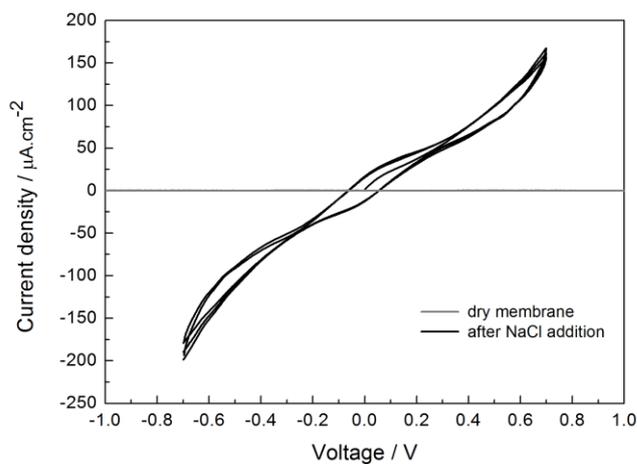


Figure 1 – Cyclic voltammogram obtained for a dry pristine membrane (grey line) and after salt solution addition (dark line). This measurement was processed at a voltage scan rate of 40 mV/s. The membrane used has 26.7 μm of thickness.

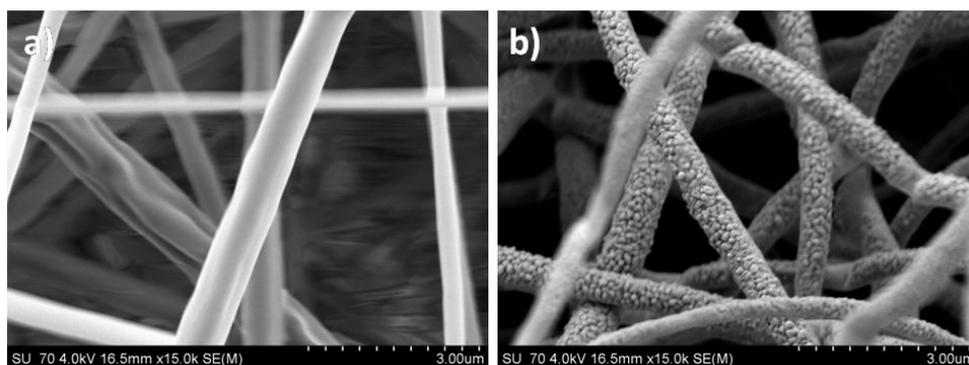


Figure 2 – SEM image of membrane's superficial fibres a) uncoated and b) after thin film deposition.

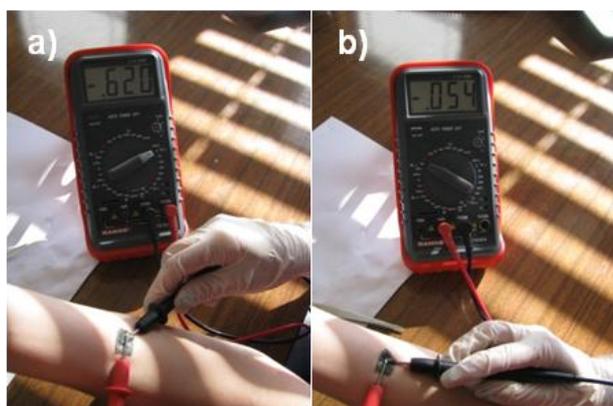


Figure 3 – Demonstration of the bioelectrochemical device's performance in sweated skin: a) voltage value (V) and b) current value (mA).