Cotton-based Biosensors—Non-invasive Biomonitoring for Personalized Nutrition

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Personalized nutrition is a future tool for large scale health management. Tools to define personal dietary needs have to be simple of use and robust. CSEM is working in this direction exploring new materials for optimized sensing solutions. Cotton-based screen printed electrodes (SPE) and nanocellulose (NC) based hydrogels as functional layers are given as examples.

Personalized optimization of nutrition is one of the pathways medicine is taking to maintain an optimal health management and prevent diseases in the large population. To be implemented to its best, this approach will need some feedback loop: a simple, robust system for the identification of individual dietary needs. Urine and saliva biomarkers monitoring is foreseen as one of the potential tools to help the correct health management at home or at a medical doctor's cabinet. In this farmework, CSEM has been working for years in the development of novel point-of-care technologies. In recent years, innovations in substrate material and design for printed sensors fabrication have been in focus. Cotton and cotton-derived materials have been selected as ideal candidates, because of the versatile nature of the materials, as well as low cost, wide availability and renewable sourcing. Cotton's high porosity makes this material very effective to adsorb liquids, and this feature can be useful in liquid transport but as well as a filter. Cotton being 99% cellulose based can be easily functionalized to achieve a chemical composition for an optimized, tailored sample manipulation.

For example, non-woven cotton tissues have been used as substrate for sensor fabrication (H2020 project grant agreement 761145 - MANU-SQUARE). Briefly a hydrophobic wax barrier was printed on the cotton surface to make it impermeable and then electrodes printed by using screen printing technology (Figure 1). Subsequently the electrodes have been modified to achieve pH sensitivity. A comparative characterization of standard polyester based pH sensors and cotton-printed pH sensors. The sensors were characterized by using cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) as electrochemical techniques. Even though the unmodified SPEs show a better performance, in terms of electrons transfer and charge transfer resistance when polyester has been used as substrate, nevertheless once they are modified with pH sensitive material (Figure 2) the performance of both is comparable.

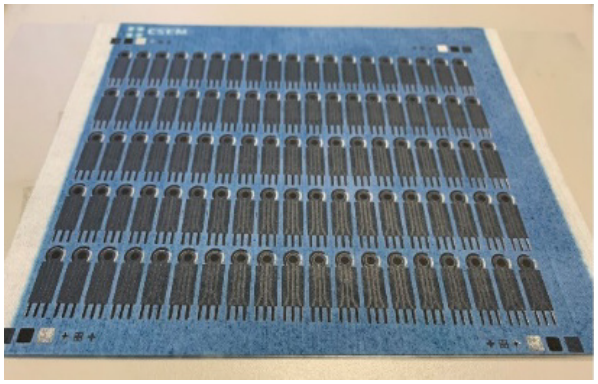

Figure 1: pH sensors printed on a cotton substrate.

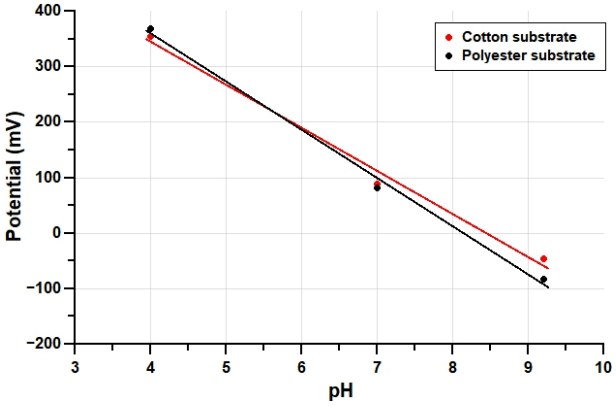

Figure 2: Response at 3 different pH (4.01-7.00-9.18) made by using pH sensors printed both on cotton and polyester.

Nanocellulose, a derivative of cotton, is another interesting material whose properties of porosity, microstructure, surface energy can be tailored to optimize for example the anchoring and transportation of biomolecules (*i.e.*, antibodies, enzymes). Its peculiar characteristics can be summarized in:

- Excellent mechanical properties
- Good biocompatibility
- Tailorable surface chemistry
- Tailorable optical properties

Commercial cellulose nanofibrils have been chemically and mechanically treated in order to produce scaffolds (see Figure 3) for optimized liquid transport and sensitivity in the biosensor's domain.

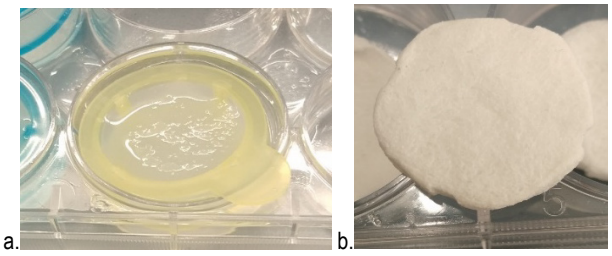

Figure 3: (a) Mixing of the nanofibrils and reagents for cross-linking; (b) Finished nanocellulose scaffold.

The synergic effect of the cotton-based substrate to be used as a material for the SPE fabrication together with the application of NC hydrogels able to capture and transport specific biomolecules will be applied in the development of improved, simple and quantifying sensing solutions for the use out of the analytical laboratory.