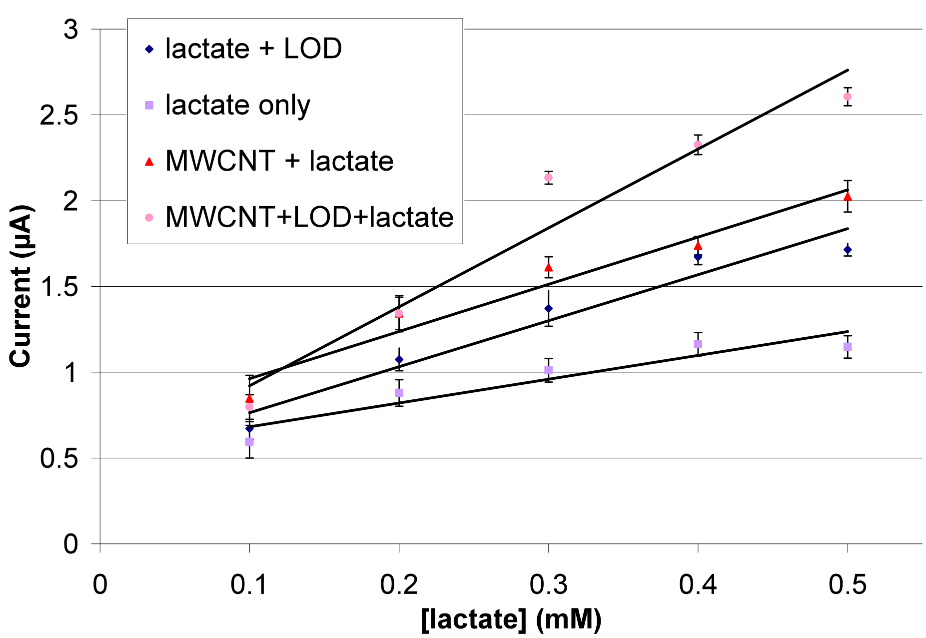
Design and Optimization of a Lactate Amperometric Biosensor based on Lactate Oxidase and Multi Walled-Carbon Nanotubes

Cristina Boero, Sandro Carrara, Giovanni De Micheli

Laboratoire des Systèmes Intégrés, Ecole Polytechnique Fédéral de Lausanne, Lausanne, Switzerland

Lactate concentration in physiological fluids is an indicator of the energy production under anaerobic conditions of the whole organism [1]. Normal value for lactate level in blood ranges from 0.5 – 2.5 mM. Blood lactate values exceeding 7-8 mM are sometimes associated with a fatal outcome. The lactate level in blood is elevated under number of conditions. It is a major indicator of ischemic conditions, e.g. under the category of tissue hypoxia, the individual causes include shock (hypovolemic, cardiogenic or endotoxic), respiratory failure (asphyxia) and severe congestive heart failure. Gauging blood lactate is also relevant for the results of exercise and athletic performance [2]. Several approaches were made to develop a number of improved methods for lactic acid determination, such ad optic techniques (HPLC, mass spectroscopy, ion exchange chromatography, etc.) and electrochemical techniques (potentiometric and voltammetric detections, FET-based sensors, etc.) [1]. The present study is focused on development of technologies for lactate detection based on amperometric measures employing lactate oxidase (LOD). The project's aim is double: the development of biosensors which can be integrated in Petri dishes for monitoring cell cultures, on one hand, and which can be integrated in point-of-care devices for human monitoring in personalized therapies, on the other hand. In both the cases, analysis of more than one substrate at the same time will be considered. Nanotechnology may be used in the optimization of electrodes with carbon nanotubes (CNT). Previous studies showed that CNTs can highly improve the electrocatalytic activity in electrochemical devices for monitoring metabolites [3].



Calibration curves of electrochemical lactate detection for different functionalized electrodes.

The ability of CNTs to promote the electron-transfer reactions suggests great promise for dehydrogenase- and oxidase-based amperometric biosensors [4]. Preliminary results from chronoamperometries on Screen Printed Electrodes (SPE) confirm that lactate electrochemical detection may be improved by the use of Multi Walled Carbon Nanotubes (MWCNT) (Figure 1).

The obtained sensitivity for the differently LOD immobilization corresponds to 2.683 μA/mM in case of LOD directly immobilized onto SPE, while it improve to 4.6008 μA/mM in case of LOD immobilized onto SPE nano-structured by using MWCNT. This sensitivity is much higher then that obtained from a direct electro-reduction of lactate onto SPE electrodes both in case of bare electrodes (1.389 μA/mM) and in case of nanostructured one (2.683 μA/mM). Moreover, it is worth noting that these sensitivity are much higher than the value of 0.79 μA/mM obtained in case of LOD entrapped in a matrix composed by mucin and albumin [5] and the value of 2.097 μA/mM obtained with LOD entrapped in a H_2O/TEOS sol-gel [4].

Therefore, as previous demonstrated by other authors, MWCNTs improved the electroactivity and the sensitivity of the sensor. Moreover, modified SPE with MWCNTs allows to carry out the chroamperometries at a lower potential respect to the one used for the first two experiments (-300 mV vs. -600 mV). The reason was that the MWCNTs modified SPE decreased the overvoltage for hydrogen peroxide oxidation and reduction [4]. It permits to enhance the efficiency of the biosensor by reducing electrochemical interferences due to the oxidation and reduction of interference substances, like acetaminophen, glucose, uric acid, ascorbic acid, and cysteine.

References

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