Electocatalytic carbon nanotube composites. for oxygen reduction and glucose oxidation. Application the production of electrical power

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For four decades, the development of biointerfaces has been the subject of increasing research efforts in the field of electroanalysis or energy conversion. These biointerfaces require, by definition, the immobilization of a catalytic system mimicking biomolecules or an enzyme.

Taking into account that the biointerface activity was related to the immobilized amount of catalysts and the specific surface of the conductive substrate, 3D structures were designed via the use of carbon nanotubes as building block [1,2]. Within the vast number of available nanomaterials, carbon nanotubes exhibit, between others, nanowire morphology, biocompatibility and excellent conductivity. These particularities are the reason why nanotubes are considered as very promising candidates in sensor and (bio)fuel cell devices. Nanotube based interfaces or matrices enable better approach to the active site of the enzyme by achieving electrical wiring between active sites of biomolecules and the bulk electrode. Furthermore, the possibility to add appropriate functionalities via organic functionalization enabled optimal tuning of such nanostructured electrodes by attaching specific docking sites for biomolecules or molecular catalysts. Furthermore, nanotube modified electrodes offer a large electroactive surface together with a highly porous three-dimensional structure. The fabrication of catalytic electrodes based on carbon nanotube will thus be reported for the development of oxygen-glucose bio inspired fuel cells.

This paper details the electrochemical investigation of a deuteroporphyrin dimethylester rhodium(III) complex, immobilized within a Multi-Walled Carbon Nanotube /Nafion electrode and its integration into a molecular catalysis-based glucose fuel cell. This two-electron system, is especially involved in the electrocatalytic oxidation of alcohols, was applied to the glucose oxidation. The catalytic oxidation mechanism exhibits an oxidative deactivation coupled with a reductive reactivation mechanism, which has previously been observed for redox enzymes but not yet for a metal-based molecular catalyst. The Multi-Walled Carbon Nanotube Rh^{III} electrode was exploited to design of an original glucose/O_2 fuel cell with a Multi-Walled Carbon Nanotube /Phthalocyanin Cobalt(II) electrode for the oxygen reduction reaction. This non-enzymatic molecular catalysis-based glucose fuel cell exhibits a power density of P_{max} = 0.182 mW.cm^{-2} at 0.22 V and an open circuit voltage of 0.6 V [3]. This work represents, to our knowledge, the first realization of a glucose fuel cell using uniquely molecular catalysts at both, the cathode and the anode (Fig. 1).

The production of electric power out of body fluids of animals, using the oxygen reduction and the oxidation of glucose, was envisioned with implanted abiotic glucose fuel cells using noble metals as catalysts. Indeed, glucose and oxygen are ubiquitously available in the extra-cellular body fluid at constant levels. However, the low specificity of the catalysts and the low power output density of these implanted devices precluded further developments.

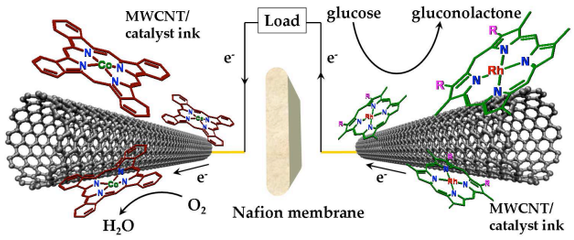

Figure 1: Schematic presentation of the functioning principle of a glucose-oxygen fuel cell with electrodes based on carbon nanotubes and molecular catalysts.

Biofuel cells often employ enzymes to catalyze chemical reactions, thereby replacing traditional catalysts present in conventional fuel cells [4]. The first implanted glucose biofuel cell, capable of generating sufficient power from a mammal's body fluids to act as the sole power source for electronic devices will be presented. This biofuel cell is based on carbon nanotube/enzyme electrodes, employing glucose oxidase for glucose oxidation, and laccase for oxygen reduction. The biofuel cells, implanted in the abdominal cavity of a rat, show an average open-circuit voltage of 0.57 V. This implanted biofuel cell delivered a power output of 38.7 µW corresponding to a power density of 193.5 µWcm^{-2} and a volumetric power of 161 µWmL^{-1}. We demonstrate that one single implanted enzymatic biofuel cell can power a light-emitting diode (LED), and a digital thermometer. In addition, no rejection or inflammatory effects on the rat's organism were observed for the GBFC sutured in a Dacron® bag after 110 days.

References

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