

Biosensors based on carbon nanotubes and aptamers for the detection of proteins and bacteria: towards optimum performance parameters

PROJECT SUPERVISORS

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DESCRIPTION

Overview:

The proposed project is a multidisciplinary work combining several characterization techniques and the analytical detection of a target bio(analyte) to evaluate the performance of biosensors based on carbon nanotubes and aptamers. Several techniques (e.g. cyclic voltammetry and electrochemical techniques) will be used to quantify the aptamer surface density and potentiometric measurements will be used in order to correlate this surface density with the detection ability of several (bio)analytes such as proteins or whole bacteria.

Background and State of the Art:

Our research group recently reported the **immediate** and **selective** detection (in **a few seconds**) of an **extremely low amount** of a target analyte in a **very simple and easy way** using a carbon-nanotube-based potentiometric biosensor,^{1,2} able to be used either in synthetic or in real samples³ with minimum pretreatments. Potentiometry was the selected detection method because is one of the simplest and most cost efficient instrumental techniques for sensing and is available worldwide. This biosensor is based on two key elements that form the hybrid material carbon nanotubes/aptamers:

* **Single-walled carbon nanotubes** (SWCNTs), which are the transducer layer of the biosensor. Carbon nanotubes display some distinctive characteristics that make them better transducers⁴ than other materials used so far. All the atoms in SWCNTs are located at the surface; therefore, the current flows at the surface and small variations of the local chemical environment can be detected. From a practical point of view, carbon nanotubes are easy to handle and the spaghetti-like structure of the network of SWCNTs can be deposited in a reproducible way and allows an easy interconnection among the nanotubes.

* **Aptamers**, which are the recognition layer of the biosensor. Aptamers are artificial nucleic acid ligands (DNA or RNA), expressly generated against specific targets, that are characterized with a high affinity and specificity for their targets, comparable to, if

not better than, their monoclonal antibody counterparts. The currently used selection protocols of aptamers are easy and effective and they avoid the need of animals since they are performed in vitro. Aptamers exhibit slow degradation kinetics, low toxicity and relatively small size compared with antibodies and they can recover their native conformation after denaturalization.

The hybrid material carbon nanotubes/aptamer is easily deposited over a conducting support (e.g. a glassy carbon rod), and the potential change of the biosensor upon the addition of the target analyte is measured against a reference electrode.

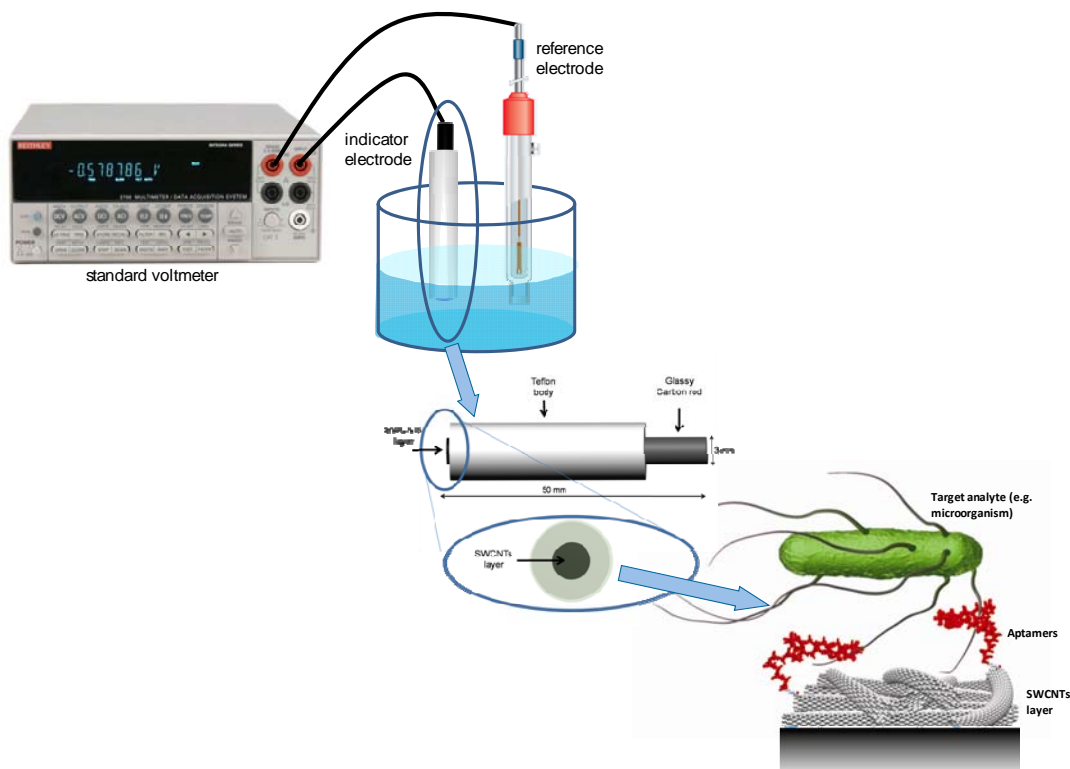


Figure 1. Scheme of a biosensor functionalized to detect a target microorganism

Nowadays, there is an increased demand on rapid methods for living micro organism detection (e.g. the Escherichia coli outbreak in Germany in early 2011). Traditional detection method is based on culturing techniques which requires several days to be achieved and need to be confirmed. In addition, culturing techniques usually require laboratory facilities and skilled staff. The biosensors developed in our group present the suitable characteristics to meet the current demands of the society: rapid, highly selective and sensitive, easy to handle and cheap. Nevertheless, despite the excellent results using this type of biosensors for the specific detection of a target analyte, some challenges concerning fundamental aspects still remain to be faced. The surface density of aptamers, type of chemical bond between SWCNTs and aptamers such as covalent (amide, “click chemistry”)/non covalent immobilization, the number of

oligonucleotide bases of the aptamer or type of the target analyte to be detected have to be carefully optimized in order to be related with the performance characteristics of the biosensor.

The objective of this project is therefore to **systematically** and **fully characterize** the **hybrid material SWCNTs/aptamers** using, among others, electrochemical techniques, cyclic voltammetry, electrophoresis or electronic microscopic techniques, in order to find the **optimum configuration of SWCNTs/aptamers** that leads to the **best performance parameters of the biosensor**.

Project contribution and methodology:

The proposed project combines a multidisciplinary work where several characterization techniques are complemented with the analytical detection of a target (bio)analyte. Our research group (www.quimica.urv.cat/quimio/nanosensors) has all the facilities and the experience for the construction and characterization of biosensors based on single-walled carbon nanotubes and aptamers. The methodology includes a review of the state of the art of surface characterization. The experimental work will consist of the following steps:

- 1) Designing a strategy to fully characterize the surface density of aptamers over the layer of SWCNTs
- 2) Designing a strategy in order to remove the aptamers non-covalently linked to the SWCNTs from those covalently linked
- 3) Making an experimental design taking into account parameters such as functionalization process, size of the aptamer or type of SWCNTs, to reach the suitable surface density of aptamers for the biosensor
- 4) Correlating the surface density of aptamers with the performance parameters of the biosensor
- 5) Validating the performance parameters of the biosensor detecting different target analytes: from proteins to microorganisms

Candidate profile:

Our group is looking for a master's student having sound knowledge of chemistry, electrochemistry and biochemistry.

References:

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