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(Bio-)Chemical Sensors based on Field-Effect Devices Functionalized with Carbon Nanotubes

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Abstract – Field-effect devices (FEDs) have been one of the most attractive approaches for the development of new (bio-)chemical sensors. In this study, we report on the incorporation of CNTs by using the layer-by-layer (LbL) technique on two types of FEDs, a capacitive electrolyte-insulator-semiconductor (EIS) sensor and a light-addressable potentiometric sensor (LAPS) and their biosensing feasibility to detect penicillin.

The integration of nanomaterials and biological substances into electrical devices is the key for the development of new biosensor concepts [1,2]. Carbon nanotubes (CNTS) are promising materials for a common platform suitable for electronic control and biological sensing [2,3]. In this study, we present a new (bio-)chemical sensor concept based on field-effect devices (FEDs) [1] functionalized with layer-by-layer films [3] of single-walled carbon nanotubes (SWNTs) combined with the polyamidoamine (PAMAM) dendrimer. The generic approach was implemented using a capacitive electrolyte-insulator-semiconductor (EIS) structure and a light-addressable potentiometric sensor (LAPS) as field-effect transducers. The capacitive EIS sensor was characterized by capacitance-voltage, constant-capacitance and constant-voltage-mode methods, while for the LAPS device, current–voltage (I–V) curve and constant-current mode (CC) measurements were carried out. Atomic force microscopy (AFM) and field-emission scanning electron microscopy (FESEM) revealed the formation of a unique highly interconnected nanostructure of SWNTs-network into the dendrimer layers with a high pH sensitivity of ca. 58 mV/pH. The biosensing ability of the devices was tested for penicillin G via adsorptive immobilization of the enzyme penicillinase atop the LbL film as illustrated in Figure 1. EIS and LAPS structures modified with the CNT-LbL film exhibited enhanced sensor properties, with a higher sensitivity, fast response time and small drift in comparison with unmodified FEDs. This demonstrates the potential application of the CNT-LbL film in field-effect-based (bio-)chemical sensors as a versatile nanostructure responsible for the integration of a biological recognition element into a well-established silicon device technology.

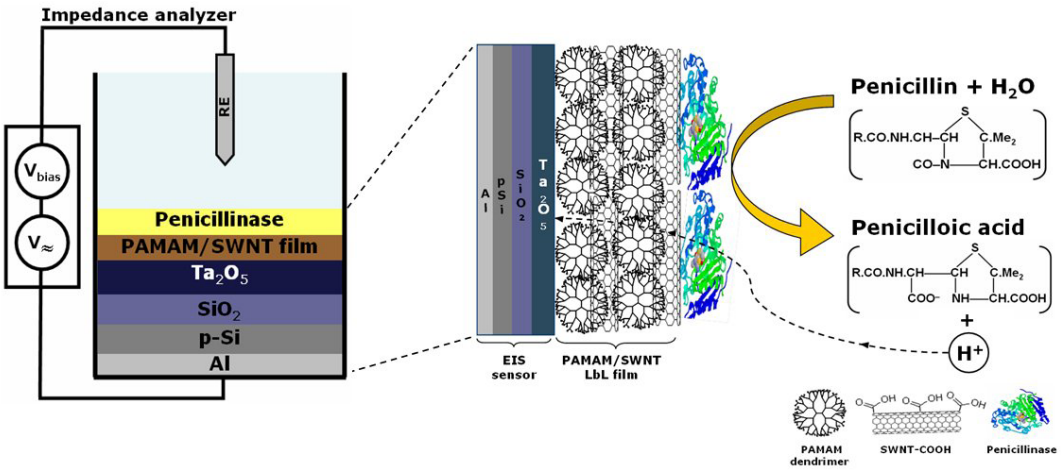

Figure 1: Schematic representation of the structure, operation principle and chemical reaction of the penicillin biosensor based on an EIS structure functionalized with PAMAM/SWNT LbL film.

References

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