P2 – AFM Investigations of Layer-by-layer Films With Carbon Nanotubes Associated With Biosensing Properties of Field-Effect Devices

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The integration of carbon nanotubes (CNTs) with biological species has brought advantages for the development of specific (bio-)chemical sensors with enhanced properties and high performance. In this study, we describe the incorporation of single-walled carbon nanotubes (SWNTs) by using the layer-by-layer (LbL) technique on an electrolyte-insulator-semiconductor (EIS) field-effect sensor. The influence of the LbL film morphology on the sensor signal as well as its feasibility of applying as penicillin biosensor is presented.

Field-effect sensors have been one of the most attractive approaches for the development of (bio-)chemical sensors [1]. CNTs are a potential material for issues with respect to biosensing, due to their electronic properties in conjunction with their size and high surface area [1]. The assembly of CNTs for a sensing device in the form of an ultrathin film can be produced with the LbL technique that offers fine control over film thickness and architecture. The nanostructured film was prepared by alternating layers of SWNTs with layers of the polyamidoamine (PAMAM) dendrimer. The LbL film structure was analyzed by means of atomic force microscopy (AFM) for different amount of bilayers. With increasing quantity of bilayers the formation of more uniform and densely packed films was observed which was confirmed by the film's roughness and thickness [2].

To investigate potential benefits of the LbL films for biosensing applications, the enzyme penicillinase was adsorptively immobilized atop of the modified sensors. This incorporation of penicillinase yielded to sensors with high sensitivity to penicillin G. As an effect of the films porosity the H^+-ions resulting from the enzymatic reaction could easily penetrate through the film which led to an increased sensitivity and stability. At the same time, the presence of the LbL film caused a much more efficient adsorption and stable attachment of penicillinase on the sensor surface in contrast to an unmodified sensor surface.

References

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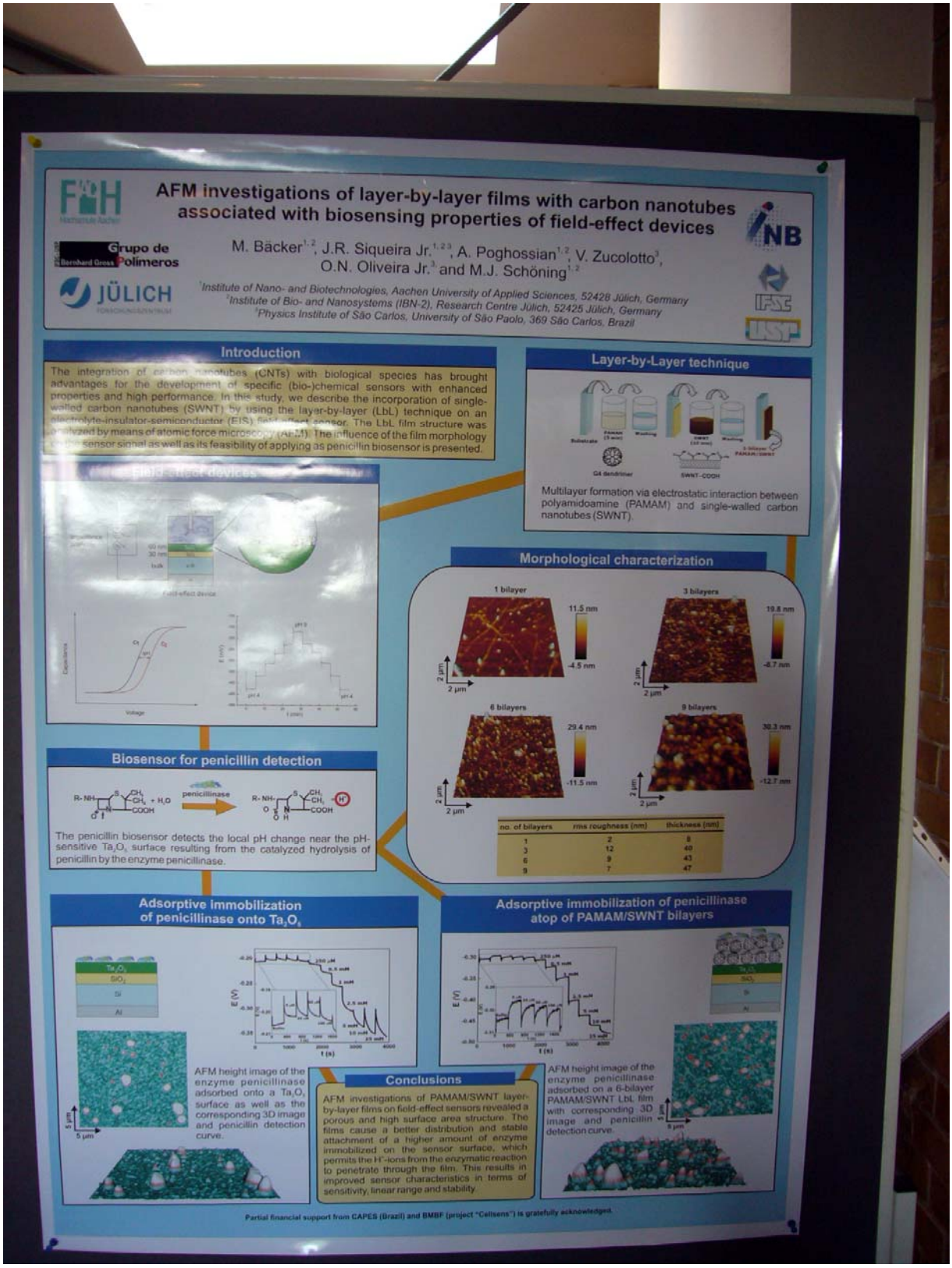
AFM investigations of layer-by-layer films with carbon nanotubes associated with biosensing properties of field-effect devices
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Introduction
The integration of carbon nanotubes (CNTs) with biological species has brought advantages for the development of specific (bio-)chemical sensors with enhanced properties and high performance. In this study, we describe the incorporation of single-walled carbon nanotubes (SWNT) by using the layer-by-layer (LbL) technique on an electrolyte-insulator-semiconductor (EIS) field-effect sensor. The LbL film structure was analyzed by means of atomic force microscopy (AFM). The influence of the film morphology on the sensor signal as well as its feasibility of applying as penicillin biosensor is presented.
Layer-by-Layer technique
Multilayer formation via electrostatic interaction between polyamidoamine (PAMAM) and single-walled carbon nanotubes (SWNT).
Field-effect devices
Morphological characterization
1 bilayer
3 bilayers
6 bilayers
9 bilayers
no. of bilayers | rms roughness (nm) | thickness (nm)
1 | 2 | 8
3 | 12 | 40
6 | 9 | 43
9 | 7 | 47
Biosensor for penicillin detection
penicillinase
The penicillin biosensor detects the local pH change near the pH-sensitive Ta_2O_5 surface resulting from the catalyzed hydrolysis of penicillin by the enzyme penicillinase.
Adsorptive immobilization of penicillinase onto Ta_2O_5
AFM height image of the enzyme penicillinase adsorbed onto a Ta_2O_5 surface as well as the corresponding 3D image and penicillin detection curve.
Adsorptive immobilization of penicillinase atop of PAMAM/SWNT bilayers
AFM height image of the enzyme penicillinase adsorbed on a 6-bilayer PAMAM/SWNT LbL film with corresponding 3D image and penicillin detection curve.
Conclusions
AFM investigations of PAMAM/SWNT layer-by-layer films on field-effect sensors revealed a porous and high surface area structure. The films cause a better distribution and stable attachment of a higher amount of enzyme immobilized on the sensor surface, which permits the H+-ions from the enzymatic reaction to penetrate through the film. This results in improved sensor characteristics in terms of sensitivity, linear range and stability.
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