Detection of electrically charged biomolecules with digitally photocorroding GaAs/AlGaAs nanoheterostructures

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Intermittently photogenerated electron-hole pairs allow decomposition of GaAs/AlGaAs nanoheterostructures in aqueous environment with average rates better than 0.1 nm per cycle [1]. This, so called digital photocorrosion (DIP) process, conveniently monitored with the photoluminescence (PL) effect reveals formation of PL intensity maxima (PL_{max}) each time the photocorrosion front crosses a GaAs/AlGaAs interface. For instance, Fig. 1 illustrates formation of PL_{max} for 5 pairs of GaAs (12 nm)-AlGaAs (10 nm) nanolayers undergoing DIP in phosphate buffered saline (PBS) environment. We have investigated sensitivity of this process to perturbations induced by surface immobilized electrically charged biomolecules, which resulted in designing devices for specific detection of bacteria [2-5]. Consistent with reduced band bending of a semiconductor, and weakening of the internal electric field driving holes towards the surface, delayed DIP rates have systematically been observed in proportion to the concentration of surface immobilized bacteria. However, the opposite effect with accelerated DIP rates has been discovered for samples with specifically immobilized *Bacillus cereus* group spores. This cannot be explained by different charge properties of spores as their zeta-potential is comparable to that of negatively charged bacteria, such as *E. coli* and *L. pneumophila* investigated previously with our experiments. Fig. 2 shows a series of DIP runs, each collected with individual GaAs/AlGaAs biochip after capturing specific concentration of spores. Typical DIP rates observed in this case for suspensions at, respectively, 10^3, 10^4, 10^5 and 10^6 spores/mL are equal to 0.048, 0.054, 0.067 and 0.072 nm/cycle. This effect cannot be explained by changing *p*H as all biosensing experiments were carried out in PBS at nominally identical *p*H = 7.4. We argue that the accelerated DIP rates observed in this case are related to activation of the germination process of spores triggered by their contact with PBS. We propose that positive ions released by the activated spores are neutralized by electrons extracted from a GaAs/AlGaAs biochip, which leads to accelerated DIP rates. The efficiency of this process depends on the spore-biochip surface distance minimized in our case by the application of aptamers instead of, e.g., antibodies for capturing bacteria or spores on GaAs-based biosensors with high specificity [6].

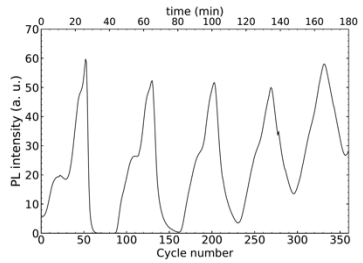

Fig. 1. Photoluminescence intensity maxima revealed during DIP of GaAs/AlGaAs nanoheterostructures.

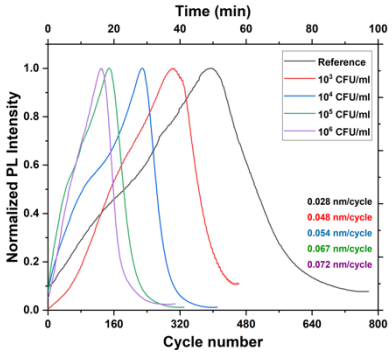

Fig. 2. Germinating spores accelerate DIP of GaAs/AlGaAs biochips.

The rapid response of a DIP biosensor to electrically charged molecules appearing in the vicinity of a biochip surface is the potentially attractive tool for research of dynamic processes involving reactions of molecules in liquids.

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