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Monitoring growth and antibiotic susceptibility of *Escherichia coli* with photoluminescence emitting semiconductor biochips

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Abstract

Growth and antibiotic sensitivity of *Escherichia coli* were evaluated with an innovative method based on photocorrosion of biofunctionalized GaAs/AlGaAs quantum well (QW) biochips. The formation of surface oxides and dissolution of a limited thickness GaAs cap material results in the appearance of a characteristic maximum in a time-dependent plot of the photoluminescence (PL) emitting biochip. A position of the PL maximum depends on the electrostatic interaction between bacteria and the biochip surface, and it becomes delayed with increasing concentration of bacteria growing on the biochip surface. We demonstrate detection of the bacteria reaction to antibiotics within less than 3 hours.

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Keywords: Escherichia coli; Antibiotic susceptibility; Quantum semiconductors; Photoluminiscence; Photocorrosion; GaAs/AlGaAs heterojunction

1. Introduction

Monitoring growth and viability of bacteria is essential in the fields of clinical diagnosis, water and food industries. The conventional methods used for this purpose are time-consuming and cannot be easily applied to

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provide same-day results. This deficiency leads to the inappropriate antibiotic use for a wide range of infections. The untargeted use of antibiotics leads to antibiotic resistance that is of a significant concern for public health.

2. Experimental results and conclusion

We have employed an innovative method of photoluminescence (PL)-based detection for monitoring the growth of *Escherichia coli* and susceptibility to ciprofloxacin and penicillin. The method employs specially designed GaAs/AlGaAs quantum well (QW) microstructures capped with a 10-nm thick GaAs layer. The microstructures were biofunctionalized with biotinylated antibodies through the link provided by biotinylated polyethylene glycol thiols and neutravidin. This architecture allowed cultivating specifically immobilized bacteria exposed to Luria Bertani (LB) broth. Following 30-min exposure to freshly cultured *E. coli* K12 suspended in phosphate buffered saline (PBS at 1X) at 2×10^8 CFU/mL, the biochips were exposed for 4.5 h to LB broth, with or without different antibiotics while the PL signals of the biochips were collected at ambient temperature over a period of 5 h. As the GaAs/AlGaAs biochip undergoes irradiation, photo-excited holes arriving to the surface of GaAs will contribute to the photocorrosion of the GaAs cap layer. The formation of a characteristic maximum in temporally dependent PL plots is related to the dissolution of the GaAs cap layer. Electrically charged molecules, such as bacteria immobilized in the vicinity of a biochip surface, could modify the rate of the photocorrosion. Based on this approach, we have developed a biosensor for rapid detection of *E. coli* [1] and *Legionella pneumophila* [2]. While immobilization of bacteria drives photo-excited holes away from the semiconductor-electrolyte interface toward the bulk and decreases the photocorrosion rate, the growth of these bacteria further amplifies this effect and slows down the photocorrosion (delays the PL maximum). Figure 1 shows an example of time dependent PL runs collected during the exposure of biofunctionalized GaAs/AlGaAs biochips to penicillin-sensitive live and UV-killed *E. coli* K12 bacteria in LB without antibiotics, or with ciprofloxacin at 10 µg/ml and penicillin at 50 µg/ml. By exposure of bacteria to LB medium, the bacteria grew on the surface of the biochip and the increased number of bacteria on the biochip enhanced protection of the surface from photocorrosion, resulting in postponed position of the PL maximum in comparison with the maxima produced by the exposure of bacterial solution to ciprofloxacin and penicillin, or to a solution of UV-killed bacteria. Based on this approach, we were able to distinguish *in situ* the susceptibility of bacteria to different antibiotics within less than 3 h.

The small size, low cost and the potential for automation of the PL apparatus could permit use of this approach for rapid determination of antibiotic sensitivity of bacteria in biological laboratories. This biosensor has the potential of being applied in clinical diagnostic laboratories for quick monitoring of antibiotic susceptibility of different bacteria immobilized by dedicated antibodies. The method could lead to a significant progress in the pharmaceutical fields and help medical personnel to rapidly identify suitable drugs for treatments.

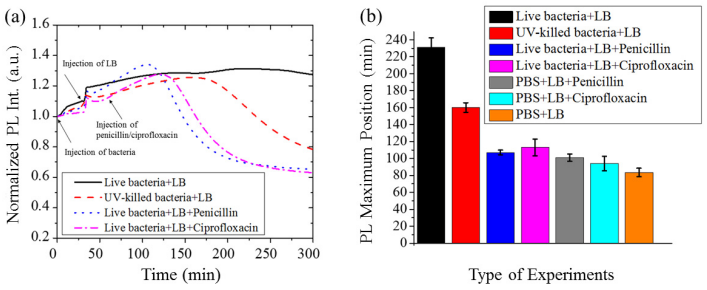

Fig. 1. (a) Normalized PL intensity (a) and (b) PL maxima positions observed for Ab functionalized biochips exposed to penicillin-sensitive *E. coli* K12 and LB without or with antibiotics.

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