STICKER MICROFLUIDIC CHIPS WITH ON-CHIP PIEZOELECTRIC ULTRASONIC TRANSCEIVER ARRAY FOR HIGHLY-SENSITIVE DETECTION OF ANTIBIOTIC DRUG

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ABSTRACT
A novel on-chip piezoelectric ultrasonic transceiver array has been designed for ultrasensitive detection of doxycycline antibiotic drug. The piezoelectric polymer ultrasonic biosensor contains a transmitter and a receiver, which are made of electrodeposited P(VDF-TrFE), and is integrated with a 60 μm sticker-based microfluidic channel. This developed biosensor has been characterized for detection of doxycycline, which is frequently used in animals, for different concentrations within 2 minutes, and the limit of detection reaches 50 ppb. In future, the developed sticker microfluidic chips with on-chip piezoelectric polymer ultrasonic transceiver array has the advantages of low cost, ease of fabrication, and highly-sensitive detection.

KEYWORDS: ultrasonic transceiver, piezoelectric polymer, biosensor, lab on a chip

INTRODUCTION
Piezoelectric materials is often used in QCM sensors for highly-sensitive detection of biomolecules [1]. Most of the devices used in biomedical applications are based on polymer-based substrates. However, it is difficult to integrate a silicon-based MEMS process, which is used for fabricating capacitive ultrasonic transducers, with polymer-based devices or biochips. Previously, we have reported the enhanced piezoelectricity of sub-20 nm PVDF–TrFE nanograss [2]. In this study, a novel sticker microfluidic chip with on-chip piezoelectric ultrasonic transceiver array is proposed for detection antibiotic drug at ppb-level concentrations. In this paper, we develop electrodeposition technique to realize on-chip piezoelectric polymer ultrasonic transmitters and receivers, which can be fully integrated on a microfluidic chip, and use them as antibiotic drug biosensors.

DESIGN AND FABRICATION
Figure 1 shows the schematic illustration of our proposed biosensors. The piezoelectric polymer ultrasonic biosensor contains a transmitter and a receiver, which are made of electrodeposited P(VDF-TrFE). The sticker microfluidic channel is between the transmitter (top layer) and the receiver (bottom layer). The sticker with a thickness of 60 μm is directly bonded with two blank COC layers to form a
microfluidic chip. When the input sine signal is sent to the on-chip transmitter, it will generate ultrasonic wave up to 1 MHz. The ultrasonic wave will pass through sample medium and be received by the on-chip receiver (biosensor). The received electric signal will change with drug concentrations in liquid samples due to mass change on the biosensor surfaces, which is related to the amount of target antibiotic drug.

The solution of P(VDF-TrFE) is dropped on the circle-shaped interdigitated electrode and an electric field is applied to deposit P(VDF-TrFE) on the patterned electrodes, as shown in figure 2. At the same moment, the deposited material is poled during the process. After the fabrication, the scanning electron microscope (SEM) is applied to characterize the patterned piezoelectric film and surface morphology of the fabricated devices, as shown in figure 3. According to the results, the optimized parameters in this study is 2.5 V (current density of 34.7 \( \mu \text{A/cm}^2 \)) in 10 minute at 25 \(^\circ\) C. The photos of the fabricated devices are shown in figure 4.

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**Figure 2.** Schematic illustration of fabrication process of the on-chip piezoelectric ultrasonic biosensors.

**Figure 3.** The result of the measurement: the SEM results of on-chip piezoelectric polymer thin film.

**Figure 4.** The on-chip piezoelectric ultrasonic array: (a) The transceiver chip and (b) the on-chip P(VDF-TrFE) transceivers.

**EXPERIMENTAL RESULTS**

After the fabrication, the piezoresponse force microscopy (PFM) is applied to characterize the piezoelectric response of the fabricated devices, as shown in figure 5. Finally, on-chip transceivers are applied to detect doxycycline at different concentrations. Doxycycline is a kind of the antibiotic and
often used for pig, cow and poultry. According to the result, as shown in figure 6(a), the voltage signals from the receiver vary with doxycycline concentrations, and the results show the limit of detection can reach 50 ppb. Also, the sensor surface is further modified with chitin for increasing drug adhesion and show the improvement of the sensitivity, as shown the figure 6(b).

CONCLUSION
This developed biosensor has been successfully designed, fabricated, and characterized for detection of doxycycline, which is frequently used in animals, for different concentrations within 2 minutes, and the limit of detection reaches 50 ppb. In future, the developed sticker microfluidic chips with on-chip piezoelectric polymer ultrasonic transceiver array has the advantages of low cost, ease of fabrication, and highly-sensitive detection.

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REFERENCES

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Figure 5. The result of the measurement: (a) piezoresponse for different deposition time, (b) the original PFM result and 3D model

Figure 6. Measured result of the detection for doxycycline: (a) the relation between the received voltage and concentration of doxycycline at different frequencies and (b) the comparison of the sensor modified with chitin.