LABEL-FREE SURFACE ACOUSTIC WAVE-BASED EMBEDDED FLOW SENSOR

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ABSTRACT

This paper presents a label-free flow sensor embedded in a microfluidic system. This sensor is based on surface acoustic waves, where the acoustic intensity is dependent on the flow rate of the propagating medium. The range of flow rates studied was between 10 µL/min to 1 mL/min, with a sensitivity of 7 µV/(µL/min). Different to readily available sensors that need tracers (*e.g.*, particles, fluorophores) or the use of temperature distribution to measure flow, this sensor requires no external optical components, and can be used with any type of liquid at a broad range of temperatures and liquid conditions.

KEYWORDS: Flow Metrology, Electroacoustics, SAW Sensor

INTRODUCTION

Interdigitated (IDT) electrodes can generate surface acoustic waves (SAW) within a piezoelectric material. The propagation medium interacts with the SAW altering the SAW's acoustic frequency and intensity. This interaction makes SAW transducers useful as both actuators [1] and sensors [2]. SAW have previously been used in microfluidic systems to measure the flow rate [3] of the propagating medium. However, current SAW flow sensors used in microfluidic systems, based on thermal, doppler shift or time-of-flight measurements, are not label-free sensors. In this work, we report a new method for flow measurement over the range of 10 µL/min to 1 mL/min in a microfluidic channel. The technique presented here relates to the ability of the fluid to absorb the acoustic waves as a function of the flow rate.

EXPERIMENTAL

A complete description of the fabrication process can be found in [4]. Three pairs of IDT electrodes (Figure 1) are fabricated using a lift-off process and an e-beam evaporator on a 128 Y-cut lithium niobate (LN) wafer. The electrode is composed of 90 nm of gold on 10 nm of titanium. A 100 nm thick silicon oxide layer is sputtered on the chip. Figure 1A shows the IDT electrode E1 has a single-phase unidirectional transducer (SPUDT) structure, while E2 has a standard IDT structure. Each transducer studied (E1 and E2) has 32 pairs of fingers, which are 3 mm long with a pitch (p) of 80 µm. The 80 µm deep microchannel in polydimethylsiloxane (PDMS) is fabricated using soft lithography techniques.

Our assumption was that the acoustic intensity depends on the flow speed (v_F). E1 is excited with a 10 V peak-to-peak sine wave (V_{in} in Figure 2) at the acoustic resonance frequency. E2 is connected to an oscilloscope to measure the amplitude (V_p) of the received wave at E2 for different v_F. Deionized water is injected in the microchannel using a syringe pump. The flow rate is controlled from 0 µL/min to 1,000 µL/min.

RESULTS AND DISCUSION

As shown in Figure 2 (insets), the peak amplitude increases with an increase in v_F, but the received signal has a low Signal/Noise ratio. We calculated that the average error in the measurement is 1 mV. To extract the sensor response to v_F, the difference between the received signal at different v_F and the one at no flow is calculated (noted as $V_p - V_p(0)$). In Figure 3, the amplitude variation, $V_p - V_p(0)$, of the 1st, 2nd and 5th peaks, is represented as a function of flow, and a linear fit was obtained for each of them. The first peak is not sensitive to v_F, while the others have an average sensitivity of 7 µV/(µL/min). The mean-squared error between the measured value and the linear estimation is 1 mV. These results confirm that the acoustic intensity depends on v_F.

CONCLUSION

This work shows that the acoustic intensity of a SAW is dependent on the flow rate of the propagating medium. This technique represents a step forward towards the development of a calibration-free flow device. This system could, ultimately, become a standard reference device to be used in any microfluidic system and application.

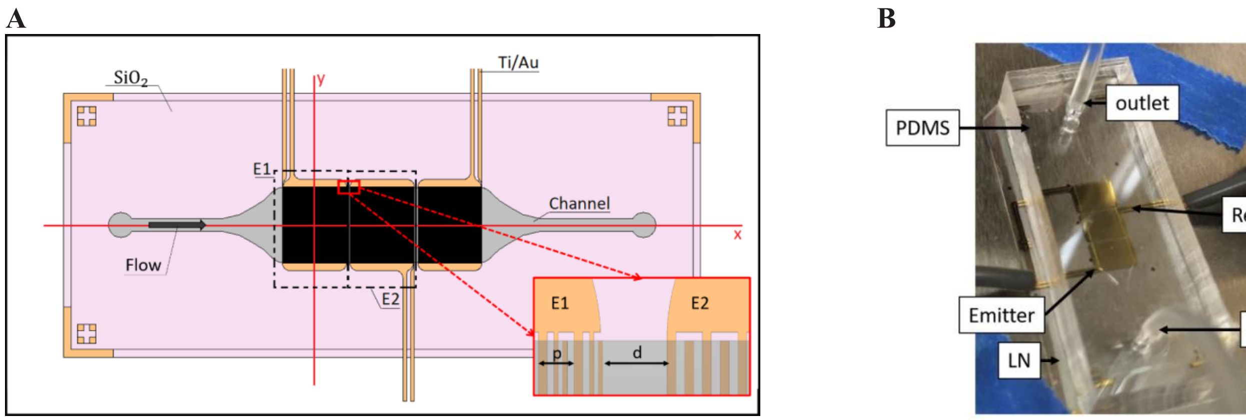

Figure 1: Sensor structure. (A) Top view sketch of the lithium niobate (LN) chip, with 3 pairs of IDT electrodes (in orange), coated with a SiO2 layer (in pink), and the imprint of the microfluidic channel (in grey). A close view of the pairs of IDT electrodes E1 and E2. (B) Image of the chip with the embedded flow sensor under the probe station, where E1 emits and E2 receives.

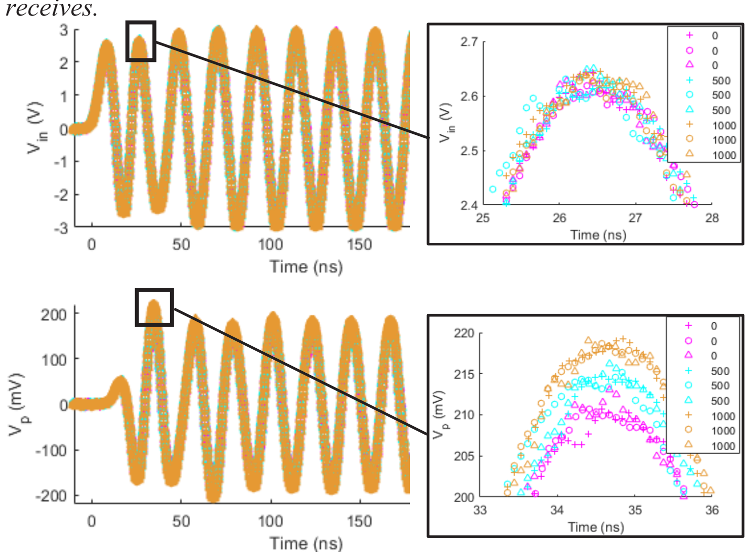

Figure 2: Emitted (V_{in}) and received (V_p) signals at different flow rates (0, 500 and 1000 µL/min). A closer view at each peak shows an increase in peak amplitude with an increase in flow.

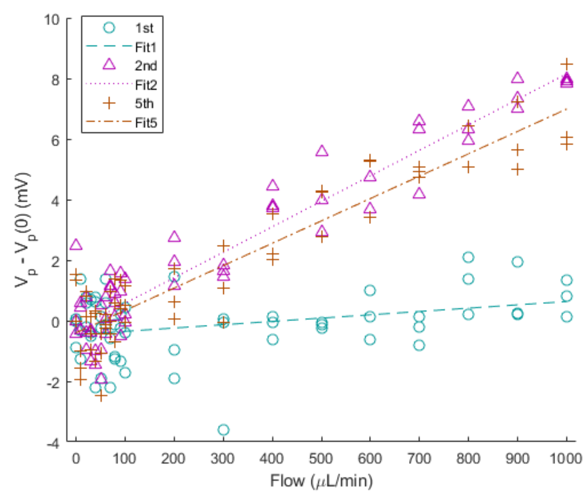

Figure 3: Evolution of $V_p - V_p(0)$ of 1st, 2nd and 5th peaks. The 2nd and 5th peaks present a linear response dependent of flow rates with a sensitivity of 7 µV/(µL/min) and an error of 1 mV.

ACKNOWLEDGEMENTS

A.Q., J.J.G. and D.R.R. were supported by the NIST on a Chip Initiative. This research was performed in part at the NIST Center for Nanoscale Science and Technology.

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