2PL

Digital microfluidic system using SAW devices

SAW デバイスを利用したデジタル式マイクロ流体システム

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1. Introduction

Surface acoustic wave (SAW) devices have a high potential not only for filters, but also sensors and actuators. When liquid is loaded on a SAW propagating surface, longitudinal wave is radiated from the SAW[1] (see **Fig. 1**). In 1988, Shiokawa et al. reported that a droplet on the SAW device was manipulated by the SAW when the amplitude of the SAW was amplified[2]. If sensors is fabricated on the propatation surface, an integrated system of sensors and actuators are realized. In previous research, an electrochemical sensor was fabricated and measured impedance changes due to mixture of liquids, urease reactions, and blood cauglations[3]. In this paper, we review the fundamentals of droplet manipulation by the SAW and experimental results using the DMFS. Also, we describe interaction SAW with a localized surface plasmon (LSPR), which is an optical sensor integrated on the DMFS.

2. Longitudinal wave radiation from SAW and droplet manipulation

Longitudinal wave radiation on the SAW device was observed using water vessel. The SAW device was erected on the water surface and only propagation surface was immersed into the water. Fig. 1 shows the observed results[4]. When a droplet is placed on the SAW device, the longitudinal wave also radiates into the droplet. However, the size of a droplet is limited and the circular current caused by the longitudinal wave is observed, when a droplet stands still[5]. When a droplet is manipulated by the SAW, the current is vanished and particles, which are mixed in a droplet for visualization, concentrate tip of droplet[6].

It is important to measure the acting force to droplet manipulation. Using the flat spring[6], the force was measured. **Fig. 2** shows schematic of the measurement and results. The longitudinal wave attenuates during propagation. The force at (i) is larger than it at (ii). The water droplet of 10 μl was manipulated, when the applied power was 1.5 W. From Fig. 2 (b), 0.186 mN is needed to manipulate of it. Also, the droplet heating is possible due to attenuation of the longitudinal wave[7].

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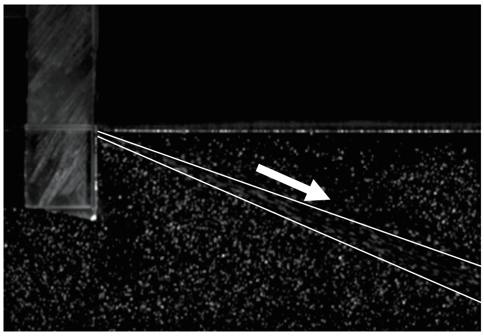

Fig. 1 Radiation of the longitudinal wave from the SAW device.

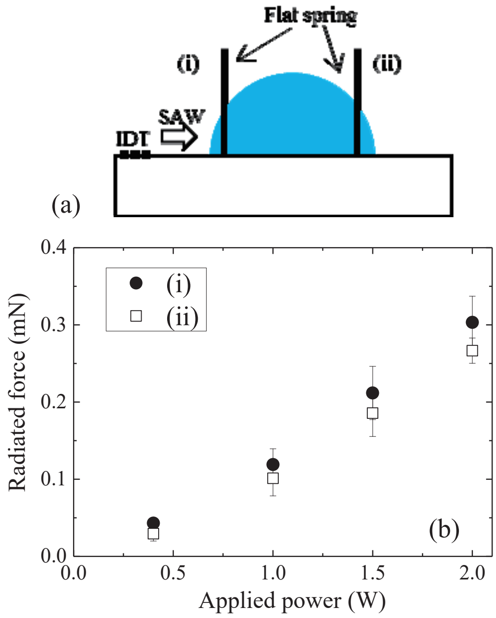

Fig. 2 (a) Measurement method and (b) results of the acting force in 10 μl water droplet.

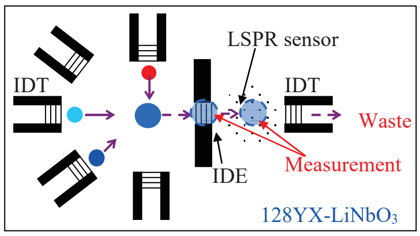

Fig. 3 Conceptual figure of the DMFS.

3. Digital microfluidic system using SAW device

Fig. 3 shows the conceptual figure of the DMFS fabricated on 128YX-$LiNbO_3$. Interdigital transducer (IDT) was fabricated on the surface for generating SAW and for an electrochemical sensor.

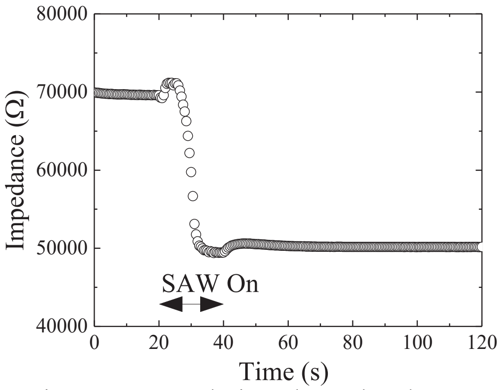

Fig. 4 Time responses during glycerol and water mixture on the DMFS.

We demonstrated glycerol and water droplets mixture and measurements. **Fig. 4** shows the time responses of droplet impedance change during mixture, measured by an LCR meter at 100 kHz[3]. First, glycerol droplet was placed on the sensor and water droplet was manipulated. Using the DMFS, real time monitoring is possible.

If an optical sensor is fabricated onto the DMFS, optical properties, such as refractive index of droplet, are obtained. It is possible to integrate an optical waveguide in a piezoelectric substrate surface[7]. However, in this research, a localized surface plasmon resonance (LSPR) is focused. In the next section, the results of the interaction between the SAW and LSPR are discussed.

4. Interaction between SAW and LSPR[9]

The LSPR is generated around metal nanoparticles, when the particles are illuminated by the light. Gold nanoparticles (AuNPs) were selected due to chemical stabilities against a liquid. The AuNPs were fabricated using thermal annealing at 400 ºC and 72 hours. **Fig. 5** shows the AFM image after annealing. AuNPs was formed on the surface. The AuNPs layer was fabricated on the SAW propagating surface between the IDTs. One IDT was used for a reflector and the reflected signal was observed with an oscilloscope. When a white light is illuminated, the LSPR is caused. The reflected signals of the SAW without and with illuminating the light are plotted in **Fig. 6**. The figure indicates that the SAW is amplified by the LSPR. We considered that the enhanced electric field by the LSPR interacts with the electric field of the SAW and then the SAW is amplified.

5. Conclusions

The SAW device is promising for the digital microfluidic application. Compare other droplet manipulation methods[10], the advantage to use the SAW is not only manipulation but also mixing and temperature control. In future, other sensor will be integrated for simultaneous measurements of droplet properties. Also, the amplification of the SAW by the LSPR was observed. Theoretical consideration of this effect is our future work.

Acknowledgment

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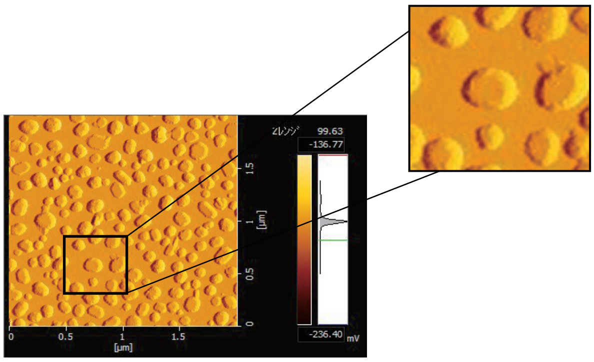

Fig. 5 AFM image of the AuNPs fabricated by the thermal annealing method[9].

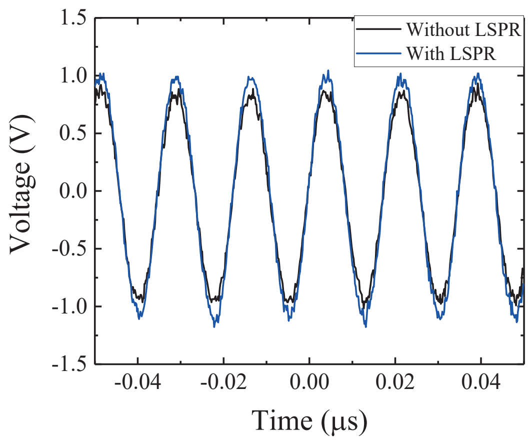

Fig. 6 Comparison of the reflected signals of the SAW without and with the LSPR excitation[9].

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