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Basic research on microfluidic systems integrating surface acoustic wave and localized surface plasmon resonance sensors
弾性表面波と局在表面プラズモン共鳴センサを集積したマイクロ流体システムの基礎研究

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1. Introduction

For liquid inspection in the medical and biotechnology fields, there is a need for a microfluidic system that can transport, mix, and measure droplets by integrating liquid pretreatment and sensors on a single substrate. We are developing a new microfluidic system by integrating a surface acoustic wave (SAW) actuator for droplet transport and mixing and a localized surface plasmon resonance (LSPR) sensor for droplet inspection on a single substrate. The schematic diagram of the new microfluidic system is shown in **Fig. 1**. SAW is a wave that can be excited by creating a weeping electrode (IDT) on the surface of a piezoelectric crystal and propagates while concentrating its energy on the surface of the object. LSPR is a phenomenon in which metal nanoparticles absorb light of a specific wavelength depending on the surrounding environment when irradiated with light. The change in the dielectric constant of the target can be detected as a shift in the LSPR peak.

In our previous study, we created an LSPR sensor on the propagation path of SAW as a basic research to realize a microfluidic system, and experimentally investigated the interaction between SAW and LSPR[1]. As a result, it was confirmed that the LSPR peak shifted with the SAW propagation. The cause of this shift was thought to be the temperature increase of metal nanoparticles due to SAW propagation and the change of distance between metal nanoparticles due to mechanical deformation. However, there is still a challenge to quantify the effect of each factor on the LSPR peak shift.

In this study, the temperature rise of metal nanoparticles due to SAW propagation was measured and its effect on the peak shift of LSPR was experimentally investigated by simultaneous excitation of SAW and sensing by LSPR.

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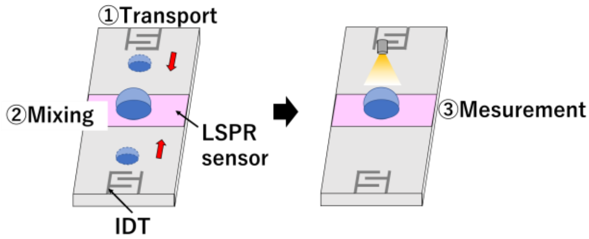

Fig. 1 Schematic of a new microfluidic system.

2. Experimental method

The experimental system used in this study is shown in **Fig. 2**. The piezoelectric crystal used in this study is 128YX-$LiNbO_3$. A IDT for SAW excitation was fabricated on the crystal, and gold nanoparticle structures (AuNPs) were fabricated on the SAW propagation path. For LSPR, the AuNPs were irradiated with light from a white light source, and the reflected light was detected by a spectrometer. Then, the reflectance was derived by using Eq (1).

$$\mathrm{Reflectance} = \frac{I_{AuNPs}}{I_{LN}}. \qquad (1)$$

here I_{AuNPs} is the intensity of the reflected light when irradiating AuNPs on the SAW device, and I_{LN} is the intensity of the reflected light when irradiating 128YX-$LiNbO_3$ without AuNPs. **Figure 3** shows the actual reflectance spectrum obtained. It can be seen that there is a peak at 550 nm. In this experiment, we investigate how this peak shifts by SAW excitation.

In this experiment, the reflectance was measured using a spectrometer, and the SAW was excited by applying a sinusoidal signal from a function synthesizer and a power amplifier connected to an IDT. The input sinusoidal signal was a continuous wave with a frequency of 51.45 MHz and an amplitude of 25.6 Vp-p. At the same time, the temperature of the AuNPs was measured using a non-contact thermometer, to measure the temperature rise of the AuNPs due to SAW propagation.

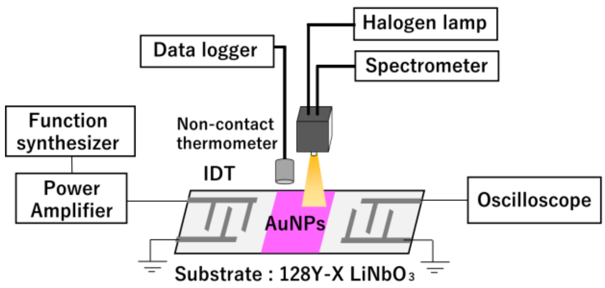

Fig. 2 Experimental system.

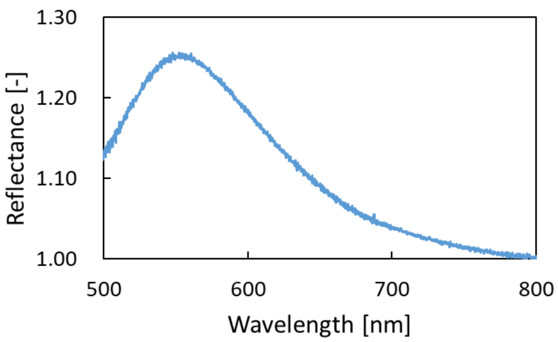

Fig. 3 Obtained reflectance.

3. Result and discussion

Figure 4 shows the relationship between temperature and peak reflectance. The reflectance was normalized by dividing the reflectance at each time by the reflectance at 0 s. A temperature increase of 5.5°C was observed in AuNPs after 500 seconds of SAW propagation. When the temperature of the AuNPs started to rise, the peak reflectance started to decrease, and it reached its lowest value when the temperature of the AuNPs peaked. The peak reflectance reached its lowest value when the temperature of AuNPs peaked, and this lowest value was 0.998 times lower than the initial value at 0 s. The peak reflectance also returned to the temperature before the start of SAW excitation when the temperature returned to normal. The peak reflectance returned to the level before the start of SAW excitation when the temperature returned to the original level. This result indicates that the temperature increase caused by SAW excitation causes the peak reflectance to decrease. **Figure 5** shows the relationship between temperature and peak wavelength shift. The peak wavelength shift was calculated by the difference between the peak wavelength at each time and the peak wavelength at 0 s. The peak wavelength shift was not observed when the temperature of AuNPs increased. The reason for the lack of shift in the peak wavelength is that the difference in the dielectric constant of AuNPs with wavelength is very small. The temperature change of AuNPs changes the dielectric constant of AuNPs, and the LSPR peak wavelength shifts because the change of dielectric constant varies with wavelength. We believe that the difference in the dielectric constant of AuNPs with wavelength is too small for the temperature rise of 5.5 °C in this experiment, and therefore the peak wavelength of LSPR was not changed. Therefore, the temperature rise of AuNPs caused by SAW excitation has little effect on the peak wavelength shift of the LSPR sensor.

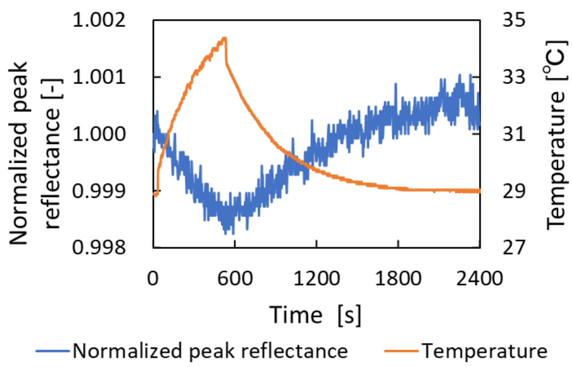

Fig. 4 Relationship between AuNPs temperature and peak reflectance shift.

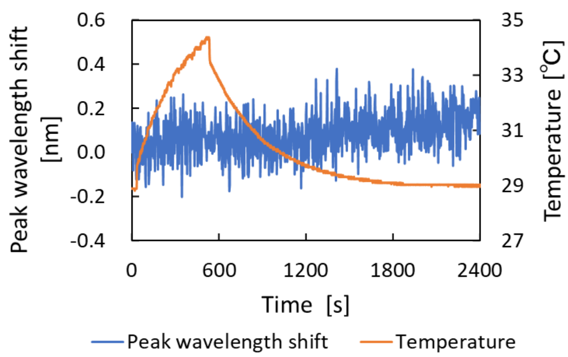

Fig. 5 Relationship between AuNPs temperature and peak wavelength shift.

4. Conclusion

In this study, the effect of SAW with the LSPR sensor was experimentally investigated as a fundamental experiment for the realization of a new microfluidic system. As a result, it was confirmed that the temperature of AuNPs increased due to the propagation of SAW, and the peak reflectance decreased due to the temperature increase. On the other hand, no shift of the peak wavelength was observed when the temperature of AuNPs increased. Our future work is to quantitatively show the effect of mechanical deformation caused by SAW on the LSPR sensor.

Reference

1. H. Sano, et al., Jpn. J. Appl. Phys., vol. 58, SGGA02 (2019).