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Shear horizontal surface vibration stimulates dual-shifted peaks of localized surface plasmon under air and liquid environment

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1. Introduction

A localized surface plasmon resonance (LSPR) is a phenomenon when light and metal-nanoparticle have high resonance and produce a plasmonic E-field. It has advantages in optical performance for sensor application [1]. The development of LSPR with tuneability performance has attracted many researchers. There are several interesting methods to produce LSPR with tuning performance, such as mechanical tuning [2]. An external mechanical strain induces the movement of gold nanoparticles (AuNPs). However, the mechanical tuning method has drawbacks, such as needed the mechanic-external device to make the external strain and inconvenience. Another method is laser irradiation [3], flexible sustarte [4], colloidal material [5], and controllable deposition [6].

Moreover, another exciting phenomenon is piezoelectric. A piezoelectric based on shear horizontal surface acoustic wave (SH-SAW) vibration has high electric-mechanical coupling. It can detect liquid properties, including viscosity, density, relative permittivity, conductivity, and loaded mass on the SH-SAW propagating surface [7]. SH-SAW has excellent performance at electrical properties response with optimum frequency. The detection mechanisms of SH-SAW are based on the change of field distributions of particle displacements and electric potential [8].

However, the study about the interaction between the piezoelectric effect and LSPR is still limited. Here, we utilized the shear horizontal surface vibration to stimulate and investigate the interaction between the piezoelectric effect and LSPR, as shown in **Fig 1**. Shear horizontal surface vibration was produced by 36X-$LiTaO_3$ substrate after feeding it using an interdigital transducer. Moreover, the LSPR effect was obtained by depositing AuNPs on the 36X-$LiTaO_3$ substrate. As a result, the blue-shifted peak was obtained during the presence of vibration. Furthermore, after the

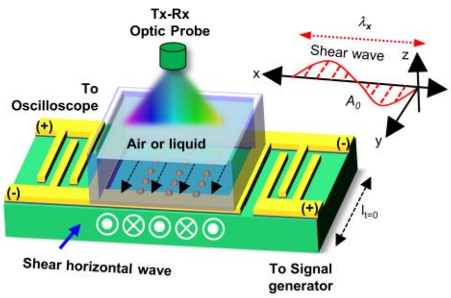

Fig. 1. Shear horizontal surface vibration stimulates AuNPs vibration on 36XY-$LiTaO_3$ substrate with air and liquid environment

environment was changed to liquid, the red-shifted effect was generated as, shown in **Fig 2.** This main finding has a high possibility to be utilized for multifunctional sensor applications.

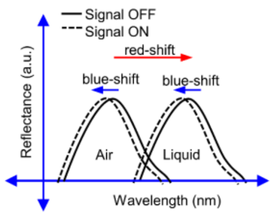

Fig. 2. The coexistence of blue-shift and red-shift effect

2. Fabrication of AuNPs on 36XY-$LiTaO_3$

The SH-SAW was fabricated on a 36YX-$LiTaO_3$ substrate, as shown in Fig. 1. The SH-SAW device has open propagation surfaces between the input and output interdigital transducers (IDTs). The AuNPs should be deposited at the center of SH-SAW propagation surfaces to integrate with the LSPR sensor. We use Au wire about 5.4 mg (Tokuriki Honten Co. Ltd., Japan) to develop gold thin film. During the deposition process, the IDT should be covered. After that, to make AuNPs, the sample was annealed at 500 ˚C for 5 minutes. The vector network analyzer (VNA HP 4395A) was used to investigate the electrical response. Furthermore, the optical reflection data response was taken by USB4000 UV-Vis spectrophotometer (Ocean Optics, Inc., USA), and data were collected using Opwave + software. The LSPR data were taken based on the reflectance method was performed for the LSPR [9–13], and the reflectance was obtained using the following equation:

$$R_r = I_s / I_r \qquad (1)$$

where R_r is the reflectance value *(a.u.)*, I_s is the intensity of the sample, and I_r is the intensity of the references.

3. Experimental dual-shifted peaks LPSR on

As mentioned above, the shear horizontal surface vibration stimulates the vibration of AuNPs, as shown in **Fig 3.** The particle displacement of SH-SAWs (Uy) can be calculated as follows [14].

$$U_y(x,z,t) = A_0\, e^{-\beta_s x} \cos(\omega t - k_{sr} x) \qquad (2)$$

Where A_0 is the maximum amplitude of the $U_y(x,y,z)$ displacement in the y-direction, k_{sr} is the real wave number, β_s is the damping coefficient in the x-direction, and $\omega = 2\pi f$ rad/s. This wave propagates along the x-direction with wavelength λ_x. **Fig 4** and **Fig 5** show the wavelength and reflectance peak LSPR value under air and under liquid environment, respectively.

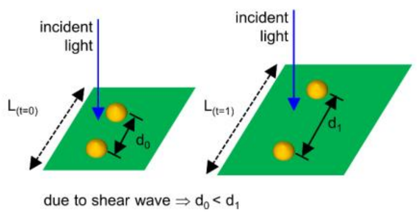

Fig. 3. Adjusting the AuNP inter-distance due to shear horizontal-surface acoustic vibration

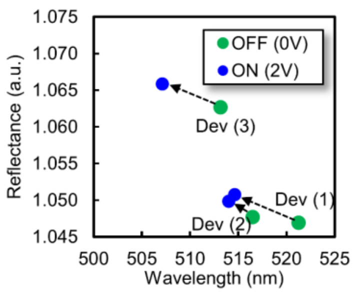

Fig. 4. Wavelength and reflectance peak LSPR value under air environment

We can see that by turn ON the power source or during the presence of vibration, the LSPR peak will be shifted to blue, however after we change the environment to the liquid (EtOH = 10%). The red-shifted has occurred. It should be noted that blue-shifted was also obtained in a liquid environment during the presence of vibration. In brief, dual-shifted peaks of LSPR under air and the liquid environment were successfully implemented.

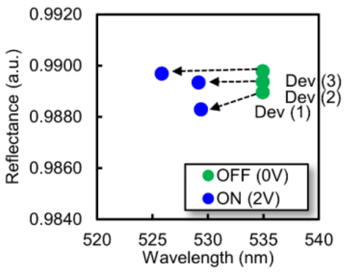

Fig. 5. Wavelength and reflectance peak LSPR value under liquid environment

3. Conclusion

We have successfully developed dual-shifted peaks of LSPR under an air and liquid environment. The device was developed by fabrication AuNPs on a 36X-LiTaO3 substrate. As a result, the blue-shifted peak was obtained during the presence of vibration. Furthermore, after the environment was changed to liquid, the red-shifted effect was generated. This main finding has a high possibility to be utilized for multifunctional sensor applications.

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