2E5-3

Electrically tunable of LSPR using shear horizontal surface acoustic wave device

Teguh Firmansyah[1,2†], Gunawan Wibisono[2], Eko Tjipto Rahardjo[2], Jun Kondoh[1,3]
[1] Grad. School of Science and Technology, Shizuoka University. 3-5-1 Johoku, Naka-ku, Hamamatsu, 432-8561, Japan
[2] Dept. of Electrical Engineering, Faculty of Engineering, Universitas Indonesia. Kampus Baru UI Depok. 16245. Indonesia
[3] Grad. School of Integrated Science and Technology, Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu-shi, Shizuoka 432-8561, Japan

1. Introduction

Localized surface plasmon resonance (LSPR) phenomenon occurs when the collective electron oscillation at nanoparticles resonant with electromagnetic radiation [1]–[3]. 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 [4]–[6], laser irradiation [7]–[9], and controllable deposition [10], [11].

The use of polydimethylsiloxane (PDMS) substrate is the key of tuneable LSPR based on mechanical tunning. In detail, ref. [4] proposed to fabricate gold (Au) nanodisks onto an elastic PDMS substrate. Furthermore, the behavior of different AuNPs arrangements under an external mechanical strain (stretching or compression) was investigated [4], [5]. Moreover, in ref. [6] Mahmoud uses the silver as nanoparticles. The mechanical tuning method has drawbacks, such as needed the mechanic-external device to make the external strain and inconvenience.

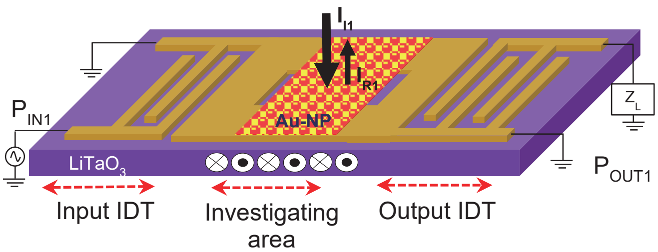


Fig. 1 Tunable LSPR using SH-SAW based on $LiTaO_3$ substrate

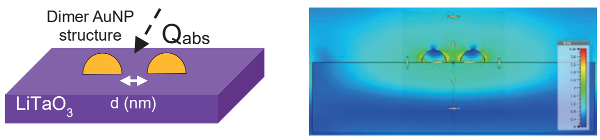
Furthermore, the laser irradiation method is a promising strategy to produce tunable LSPR. This method is proposed by [7]-[9]. However, the irradiation method needs additional pulsed laser up to 3W. This method is a little complex and requires laser protection for implementation. The controllable deposition method was proposed [10], [11]. This method has a pre-treatment part during the deposition process. Therefore, the LSPR tuneability performance of the method is low.

As a novelty, an electrically tunable of LSPR using shear horizontal surface acoustic wave device (SH-SAW) is proposed, as shown in **Fig. 1**. The method combines SH-SAW and LSPR based on AuNPs. The AuNPs were deposited on the center of SH-SAW. The tuneability performance was obtained by applying different electric power to the SH-SAW device. Therefore, the SH-SAW and AuNP of LSPR will move in the horizontal direction simultaneously.

The tunable LSPR with SH-SAW structure has several advantages: easy to fabricate, low power consumption, robust system, reusable, no need protection, and convenience. As shown in Fig 1, the SH-SAW was fabricated on a 36YX-LiTaO3 substrate. The gold nanoparticles (AuNPs) should be deposited to the center of SH-SAW propagation surfaces to integrate with the LSPR. The Au wire about 5.4 ± 0.1 mg (Tokuriki Honten Co. Ltd., Japan) was used to evaporate gold thin film. During the deposition process, the IDT should be covered. After that, to make AuNPs, the sample was annealed with 400 ˚C for 5 minutes [12].

2. Simulation of dimer AuNP based on $LiTaO_3$

The influence of the dimer AuNP structure and the interaction of AuNPs were simulated using CST Microwave Studio (CST MWS) software [13]. Moreover, **Figs. 2a and 2b** show the investigation AuNP dimer structure and E-filed at the AuNP deposited on 36YX-$LiTaO_3$ substrate, respectively.



(a) (b)

Fig. 2 (a) Investigation AuNP dimer structure, (b) E-filed at the AuNP deposited at $LiTaO_3$ substrate

As shown in Fig. 2a, our model for CST MW simulation was developed base on 36YX-$LiTaO_3$ substrate with depositing by AuNPs. Moreover, the E-field of the dimer can be seen in Fig. 2b. It can be seen that the inter E-field has stronger value compare to the outside part. It indicates that the high interaction between AuNP. According to Mie's theory, the relation of the extinction (Q_{ext}), scattering (Q_{sca}), and absorption (Q_{abs}) of the nanoparticle can be described as $Q_{abs} = Q_{ext} - Q_{sca}$ [14]. Furthermore, in this paper, the Q_{abs} response by varying distances of inter-nanoparticle *d (nm)* will be simulated and investigated. The result is shown in **Fig. 3**.

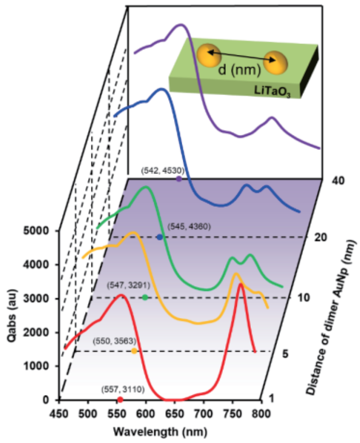


Fig. 3 The Qabs response with different distance d(nm) of AuNP

Fig. 3 illustrates Q_{abs} response with different distance *d(nm)* of AuNP. It can be seen that the longer distance of AuNP will be generated the blue shift. This result is also supported by ref [1]-[3] that the increased distance of the AuNP will reduce the E-field interaction and produce the blue shift.

3. Experimental LSPR based on $LiTaO_3$ substrate

For the experimental evaluation, the optical reflection data response was taken by USB4000 UV-Vis spectrophotometer (Ocean Optics, Inc., USA), and data were collected using Opwave + software. The result of the proposed method is shown in **Fig. 4**. Fig. 4 is shown the reflectance response with different input power to the SH-SAW structure.

The variances of the input power will generate different amplitudes of SH-SAW wave. Furthermore, the rise of power supply will be increased the distance between AuNPs. As a result, the LSPR response will be a blue shift. In conclusion, the inter distance of AuNPs will be changed depending on the amplitude of SH-SAW. It is also indicated that the LSPR structure can be electrically tuned by the SH-SAW device easily. Fig. 4 is shown the reflectance response with different input power to the SH-SAW structure. The variances of the input power will generate different amplitudes of SH-SAW wave. Furthermore, the rise of power supply will be increased the distance between AuNPs. As a result, the LSPR response will be a blue shift. In conclusion, the inter distance of AuNPs will be changed depending on the amplitude of SH-SAW. It is also indicated that the LSPR structure can be electrically tuned by the SH-SAW device easily.

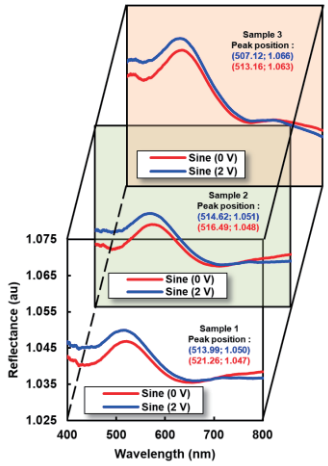


Fig. 4 The LSPR reflectance response with different input voltage to SH-SAW structure

4. Conclusions

An electrically tunable of LSPR using the SH-SAW device was successfully designed and implemented. The tuneability performance was obtained by applying different electric power to the SH-SAW device. Therefore, the SH-SAW and AuNP of LSPR will move in the horizontal direction simultaneously. The result shows that the increased distance of the AuNP will reduce the E-field interaction and produce a blue shift.

Acknowledgment

This research was subsidized by JKA through its promotion found from KEIRIN RACE

References

[1] C. Y. Chang et al: Sci. Rep. **8**. (2018).1.
[2] K. L. Kelly et al: J. Phys. Chem. B. **108**. (2013). 668.
[3] B. Lamprecht et al: Phys. Rev. Lett. **84**. (2000). 4721.
[4] G. E. Lio et al: J. Appl. Phys.**125**. (2019).1
[5] A. Mizuno et al: Appl. Surf. Sci.**480**. (2019). 846.
[6] M. A. Mahmoud: J. Phys. Chem. C. **119**. (2015)
[7] 19359.
[8] W. Sun et al: J. Alloys Compd. **839**. (2020). 155729
[9] W. Sun et al: Opt. Mater. (Amst). **96**. (2019). 109298.
[10] R. Hong et al: Opt. Mater. (Amst). **77**. (2018). 198.
[11] S. Kunwar et al: Appl. Surf. Sci. 504. (2019). 144545.
[12] H. Hou, et al: ACS Appl. Mater. Interfaces. **7**. (2015). 18038.
[13] T. Handoyo, et al: Sens. & Act. A **307** (2020) 112006
[14] CST Microwave Studio (CST MWS) software. https://www.3ds.com
[15] A. Amirmostafa., et al: Plasmonics. doi : 10.1007/s11468-020-01121-x