인덱스 센싱을 위한 Al_2O_3 나노디스크를 사용한 협대역 완전 흡수체

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Narrowband perfect absorber using Al_2O_3 nanodisk for refractive index sensing

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Abstract

Optical biosensors have brought great interest in biomedical engineering due to their capability of real-time and label-free detection with high sensitivity. Among these optical sensors, absorbers showing narrow bandwidth and high absorption have been studied a lot. In this work, we report numerical results of narrowband perfect absorber based on Al_2O_3 nanodisk. The proposed design shows high absorption near unity (99.3 %) and high Q-factor over 1402 (FWHM = 0.48 nm) in the wavelength region from 600 nm to 700 nm. We expect that our approach can have great potential in the fields of refractive index sensor, biomedical engineering as a ultra-sensitive sensors.

1. Background

Optical biosensors are widely used in biology and chemistry because they are capable of real-time and label-free detection. Its advantages are high specificity, sensitivity, small size, and cost-effectiveness [1]. Recent studies of optical sensing show very narrow absorption band in near- and mid-infrared wavelength bands based on surface plasmon with plasmonic perfect absorber [2,3]. In the case of perfect absorber, the resonance wavelength of the absorption peak and the number of peaks within a certain wavelength range vary depending on the structure, arrangement, and substance of the structure [4]. By using various materials of the structure, various structures (square, triangle, circle, ring, etc.), or various arrangements, they can create various effects such as narrow full width at half maximum (FWHM), wide range of incident angle and polarization independence [5,6].

Here, we observed the form of an absorption band that changes with the radius of the aluminum oxide (Al_2O_3) nanodisk at a wavelength of 600 nm to 700 nm through a simulation. As Radius increased, the response length of the absolute peak became red-shifted and two absolute bands were formed. Among them, the FWHM of resistance generated near 678 nm was 0.48 nm, and the Q-factor was 1402, and the absorption was 99.3 %. Through this demonstration, it is possible to derive the optimal radius in disk-shape, and based on this, we can expect the development of optical biosensors in the future.

2. Method

The simulation program used Finite-difference time-domain (FDTD). The wavelength range of light was 600 nm to 700 nm plane waves. Al_2O_3 used as nanodisk and film, SiO_2 film, and Au substrate were used as components of the structure, and the refractive indices of the components from Palik and Johnson and Christy, respectively [7,8]. The size of the structure is d_1 = 30 nm, d_2 = 510 nm, d_3 = 1000 nm, d_4 = 1000 nm, and $P_X = P_Y$ = 500 nm (Figure 1). Radius (R) of nanodisk was progressed from 0.5 um to 1.5 um, and absorption according to radius was confirmed at wavelengths from 600 nm to 700 nm through sweep of FDTD. Absorption was calculated through $A = 1-R-T$. Under the conditions of simulation, in the boundary condition, the x and y directions were conducted as periodic and the z direction as perfect matching layer. In order to derive reliable and accurate results, the simulation time extension was set to 8000 fs [9].

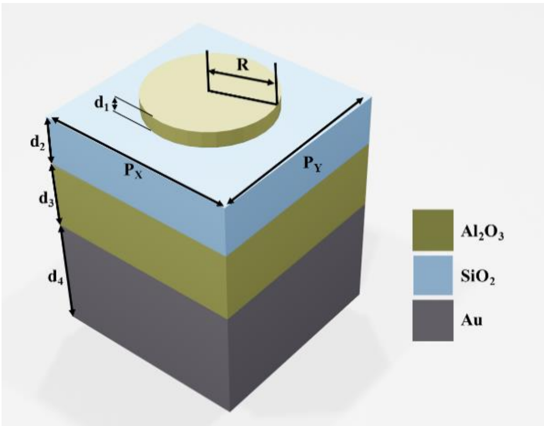

Figure 1. Schematics of absorber structure.

3. Result and Discussion

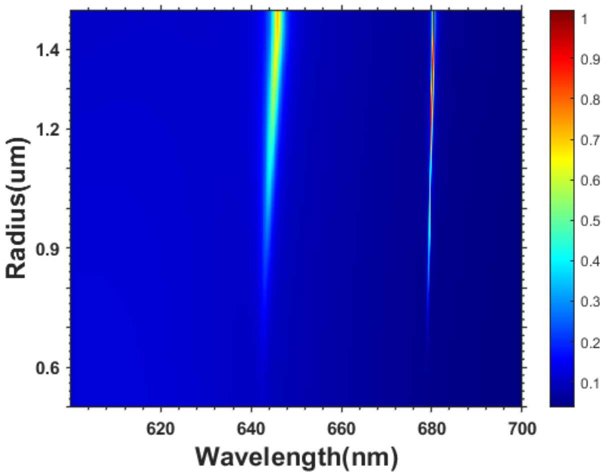

Figure 2. Absorption intensity depending on radius of Al_2O_3 nanodisk.

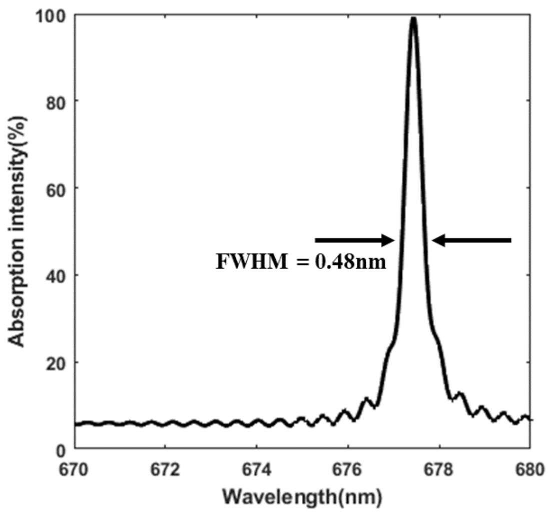

Figure 3. Absorption intensity at a radius of 1.5 um.

As a result of the simulation, two absorption bands were formed between 640 nm and 650 nm and between 670 nm and 680 nm as the radius increased (Figure 2). Among them, the second band (670-680 nm) was thinner and showed an increase in absorption as the radius increased and showed a maximum at 1.5 um. When the radius of nanodisk was 1.5 um, absorption was calculated from 670 nm to 680 nm (Figure 3). The wavelength with the highest absorption was 677.407 nm and the absorption was 99.3 %. The FWHM and Q-factor were calculated using resonance wavelength of the absorption peak and absorption intensity. The FWHM was 0.48 nm, and the Q-factor obtained 1402 through the formula $Q = \lambda_0/FWHM$ (λ_0 is the wavelength of maximum absorption) [10].
The radius suitable for the sensor of Al_2O_3 nanodisk was calculated using the sweep of FDTD. It is expected that various research will be conducted in biology and chemistry through optical biosensor made of Al_2O_3.

4. Reference

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