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High Sensitive Detection of A549 Cancer Cell by Bilayer Oval Nanodisk Localized Surface Plasmon Resonance Biosensor

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Abstract

In this study, a bilayer oval nanodisk localized surface plasmon resonance (LSPR) biosensor was demonstrated, and the device was also applied for the detection of A549 human lung cancer cells. The absorptivity of the index sensor is sensitive to small local refractive index changes that occur after A549 human lung cancer cells. This high-sensitivity optical bio-sensor platform realizes a real-time, noninvasive cell detection method. The bilayer oval disk has a high sensitivity of 1460 nm/RIU.

1. Introduction

The pollution of the environment, foodborne illnesses and dread disease have become a class of important issue associated with the public health, resulting in a great significance to develop the rapid, accurate and sensitive detection. Most biosensors use the surface-sensitive analytical techniques such as surface plasmon resonance (SPR) and localized surface plasmon resonance (LSPR) sensors to fabricate cancer cell detection, food safety monitoring and environmental detection.[1-2] SPR sensors based on metal thin films can achieve higher sensitivity and selectivity of the optical properties changes by adsorption. The metal-based nanostructure localized surface plasmon resonance (LSPR) sensors exhibits the localized collective oscillation of free electrons, which provided the great opportunities to control optical properties by changing the sizes and geometry of the sensors. Beside, LSPR waves in metal–insulator–metal (MIM) structures also provide the advantages in wide angular and broadband absorption and emission.

N. Liu et al. have reported the single-metal-layer circular disks LSPR sensors to detect the changing of the refractive index at the infrared regime and its sensitivity is approximately 400 nm/RIU.[3] Actually, the single-metal-layer circular disks LSPR sensors is difficult to realize the detection of cancer cell. Because the refractive index change of cancer cell in the buffer solutions is very little difference. In this study, we demonstrated the bilayer oval nanodisk LSPR index sensor in MIM structure to enhance refractive index sensing capability for the detection of A549 human lung cancer cells. The LSPR wave of the bilayer oval nanodisk LSPR is simulated by using COMSOL Multiphysics software. It would be promising a high-sensitivity optical bio-sensor platform to realize a cell detection method.

2. Experiment and Results

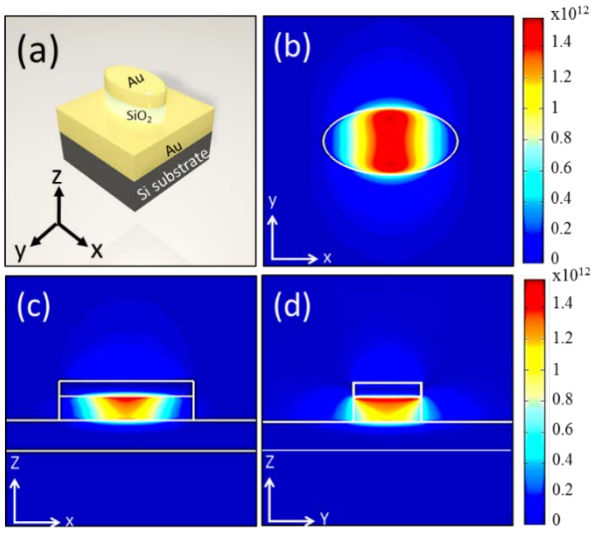

Fig. 1 (a) The schematic diagram of bilayer oval nanodisk LSPR sensor structure. (b) The top view of mode profile of magnetic field for bilayer oval nanodisk LSPR wave. The cross section views of the calculated magnetic field mode profile of the LSPR wave in bilayer oval nanodisk in (c) the x-z plane and (d) the y-z plane.

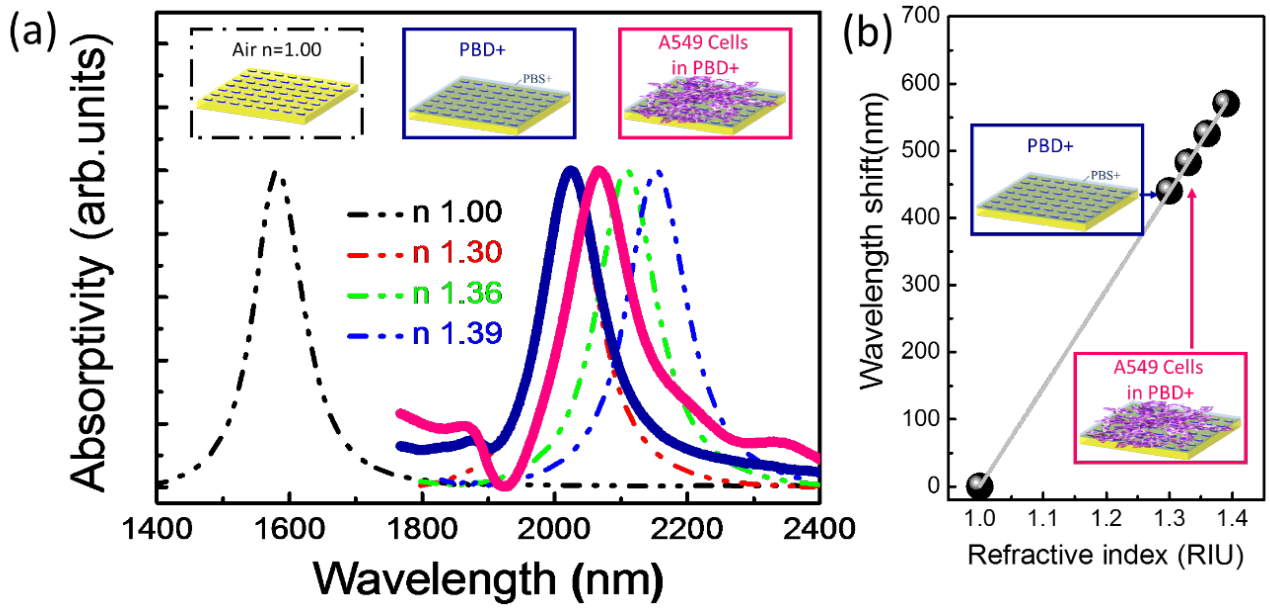

Fig. 2 (a) The absorption spectrum of bilayer oval nanodisk array LSPR sensor with varying the ambience refractive index from n=1.0 to n=1.39 or covering the PBS+ solution without A549 cell seeding (blue line) and without A549 cell seeding (pink line). (b) The wavelength shift of bilayer oval nanodisk array LSPR sensor as a function of the different refractive index.

The schematic diagram of bilayer oval nanodisk LSPR in Au/SiO_2/Au structure shows in the Fig. 1(a), The deposition layer includes a 30 nm Ti adhesion layer and a 100 nm gold layer on a Si substrate by using an e-gun evaporator. And an 80 nm thickness of SiO_2 layer was deposited by using plasma-enhanced chemical vapor deposition. Finally, a 50 nm gold layer was deposited using the e-gun evaporator. The bilayer oval nanodisk arrays were defined by electron beam (e-beam) lithography. The oval shape was transferred to SiO_2 layers. The period, long- and short-axis lengths of oval nanodisk are approximately 1μm, 440 and 230 nm, respectively. Fig. 1 (b)-(d) show the mode profiles of magnetic $|Hy|^2$ field in the ambience for bilayer oval nanodisk LSPR structure. It can be observed that the $|Hy|^2$ field leak out the ambience along short-axis. The geometry sharp of oval structures causes the increasing in-plane $|Hy|^2$ field overlap with the ambience. The cross section mode profile of $|H_y|^2$ field for MIM LSPR structure shows that the LSPR wave mainly localized in the SiO_2 layer. The SiO_2 layer exposed into ambience to enhance the leakage ratios of out-plane $|H_y|^2$ field. We believe that bilayer oval nanodisk LPSR sensor has a high sensitivity of refraction index change.

The absorption spectrum and peak wavelength shift of the bilayer oval nanodisk array LSPR sensor with varying the ambience refractive index were measured by using Fourier transform infrared spectroscopy (FTIR) as shown in the Fig.2. The wavelength peak is red-shift with increasing the ambience refractive index from n=1 to n=1.39. The Fig. 2 (a) also shows the absorption spectrum of the bilayer oval nanodisk LSPR biosensor arrays capped the PBS+ buffer solution without and with A549 cells. The refraction index of PBS+ buffer solution is estimated approximately 1.3. It can be obtained obviously the wavelength shift (Δλ) of 40 nm with A549 cancer cell in PBS+ buffer solution. Linearly fitting Δλ and Δn obtains sensitivities of 1460 nm/RIU for the bilayer oval nanodisk LSPR sensor. The refraction index change of A549 cancer cell in PBS+ buffer solution is estimated approximately 0.03.

3. Conclusions

In this study, a bilayer oval nanodisk localized surface plasmon resonance (LSPR) biosensor was demonstrated, and the device was also applied for the detection of A549 human lung cancer cells. The absorptivity of the index sensor is sensitive to small local refractive index changes that occur after A549 human lung cancer cells. This high-sensitivity optical bio-sensor platform realizes a real-time, noninvasive cell detection method. The bi-layer oval disk has a high sensitivity of 1460 nm/RIU.

Acknowledgements

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