Design and Simulation of Two Dimensional Hole Array for Surface Plasmon Enhancement of InAsSb Based Infrared Photodetectors

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***Abstract*- We design and simulate the effects of various parameters on transmission through square hole array. We also compare the performance of square hole array with circular hole array so as to optimize the enhancement.**

I. Introduction

Mid-infrared photodetectors have attracted much attention because of highest transmission of energy through atmosphere in 3-5 μm [1-3]. But conventional photodetectors working in this wavelength range suffers from either difficulties in repeatable growth or having poor performance near room temperature. So InAsSb based infrared photodetectors have been considered as an alternative. However, for uncooled applications, the performance of the InAsSb only devices still needs to be improved. To enhance the performance, metallic hole array can be fabricated on top, which can efficiently couple incident wave and localize light as SPP in the vicinity of hole array.

The idea of surface plasmon enhancement has been studied theoretically and experimentally in recent years [4-7]. The incident light is coupled as surface plasmon, which leads to tight spatial confinement of light [5, 6]. This is very attractive for light absorption and enhancing performance of photodetector [8, 9].

A typical way of exciting SPP used for enhancing photodetector performance is to use two dimensional hole array (2DHA). But the effect of different parameters on transmission through 2DHA is still not clear. In this paper, we will present simulation results and analysis of all possible variables which may affect the transmission through 2DHA.

II. Simulation Results and Analysis

The structure we are interested in is shown in Fig. 1. The thin metal film is made by gold, and the material contacting metallic hole array is InAsSb, as shown in Fig. 1. The periodicity of hole array is p, hole width is w. metal film thickness is t. The simulation is done by finite-difference time-domain method.

A. Periodicity

Here, we consider effect of periodicity on transmission. The width of square hole is set as 0.48 μm. The gold film thickness is 20nm. The simulated transmission spectrum is shown in Fig. 2.

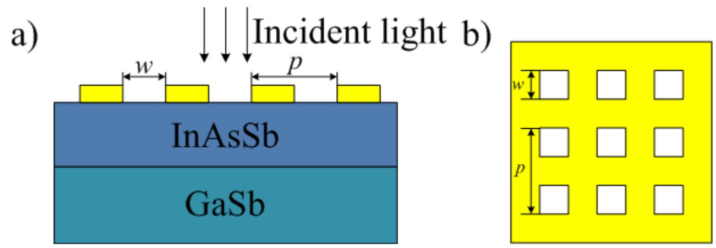

Figure 1. (a) Cross-sectional view of integrated structure. (b) Top view of hole array.

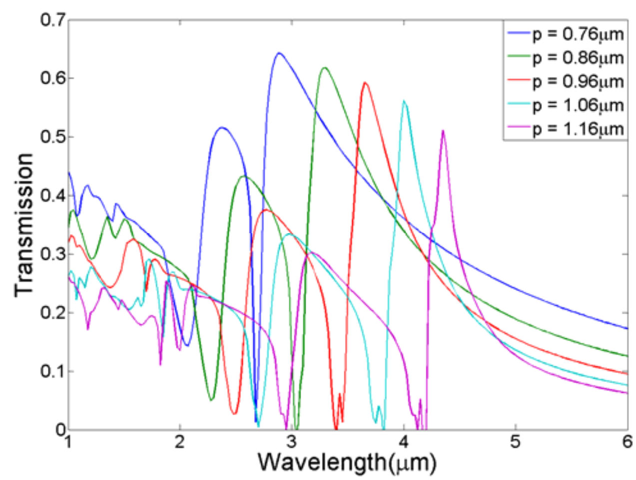

Figure 2. Simulated transmission spectrum through metallic hole array of different periodicities. The periodicity is varied between 0.76-1.16 μm, w = 0.48 μm, t = 20 nm.

As we can see from transmission curves, the transmission is orders of magnitude larger than conventional theory. And there are transmission peaks at wavelengths which are far beyond the diffraction limit. Besides, the wavelength of transmission peaks increases for larger periodicities. This is also verified by theoretical calculation.

B. Hole width

Next, we discuss effect of hole width on transmission. We analyze 2DHA with different hole width, while other parameters are the same. The simulation result is shown in Fig. 3. It is clearly shown that when only hole width is changed, the peak wavelength also remain unchanged. The wavelength of peak transmission is only slightly different for different hole width.

Besides, if we combine Fig. 2 with Fig. 3, and consider transmission efficiency through hole array, we will find that the highest efficiency will be achieved when hole width is around half of periodicity. This is very important when optimizing the parameters of hole array.

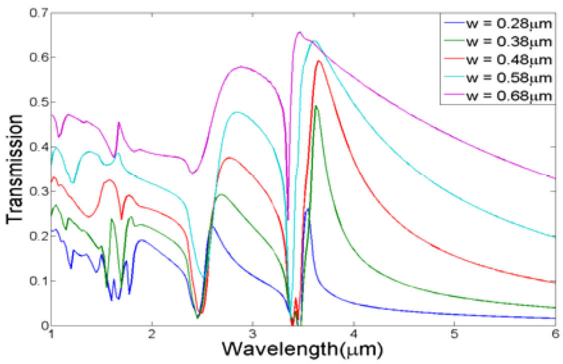

Figure 3. Simulated transmission spectrum through metallic hole array of different hole width. The hole width is varied between 0.28-0.68 μm, w = 0.48 μm, t = 20 nm.

C. Comparison with circular hole array

Now, we look at the electric field distribution and compare square hole array with circular hole array. The electric field distribution in cross-sectional plane is shown in Fig. 4 and Fig. 5. For both square hole array and circular hole array, the electric field distribution shows high concentration of electric field in the vicinity of hole array.

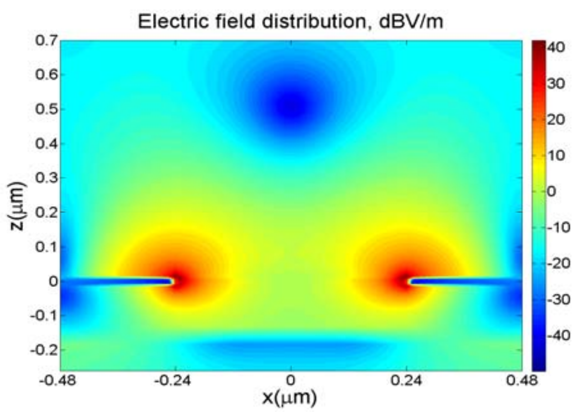

Figure 4. Electric field in cross-sectional plane in the vicinity of square hole array.

By comparing Fig. 4 and Fig. 5, we can find that for square hole array, the electrical field can only penetrate into the substrate around ~0.2um. This is only half of that in circular hole array. Small penetration depth means for enhancing performance of photodetector with plasmonic structure, active region should be placed nearer to metal-dielectric interface. Understanding this big difference in penetration depth between circular hole and square hole needs more research work.

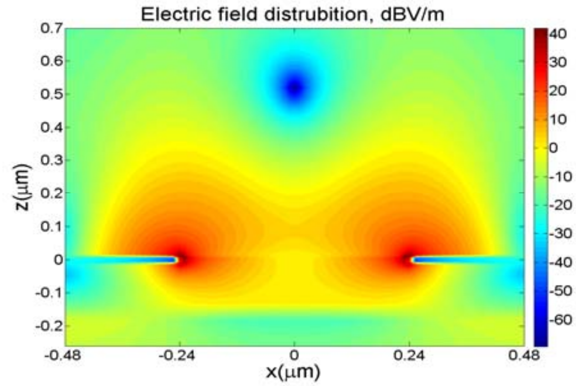

Figure 5. Electric field in cross-sectional plane in the vicinity of circular hole array.

III. CONCLUSION

In conclusion, we studied different parameters which may affect the transmission of metallic hole array. The simulated transmission spectra as a function of periodicity and hole width have been presented. Two kinds of hole arrays are compared. The circular hole array is found to give a better enhancement due to the high penetration depth of surface plasmons.

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