Impact of silver nanospheres array for enhanced optical absorption in plasmonic-based InGaAs photodetector

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Abstract

A new structure of InGaAs photodetector with surface-modified Ag nanospheres array is proposed, which can obtain 50% optical absorptance at 1550nm and maintain good optical absorption performance when the light incident within 0-30 degree.

Structure of device

The structure of the photodetector designed in this paper is shown in Fig. 1. The active absorber for generating photo-induced carriers is a 0.8μm-thick InGaAs layer. Two 0.6μm-thick InP contact layers sandwich it with different doping types: the top contact layer is p-type, and the bottom contact layer is n-type. On the upper surface of p-doped InP, there is a periodic Ag nanospheres array and anti-reflection coating.

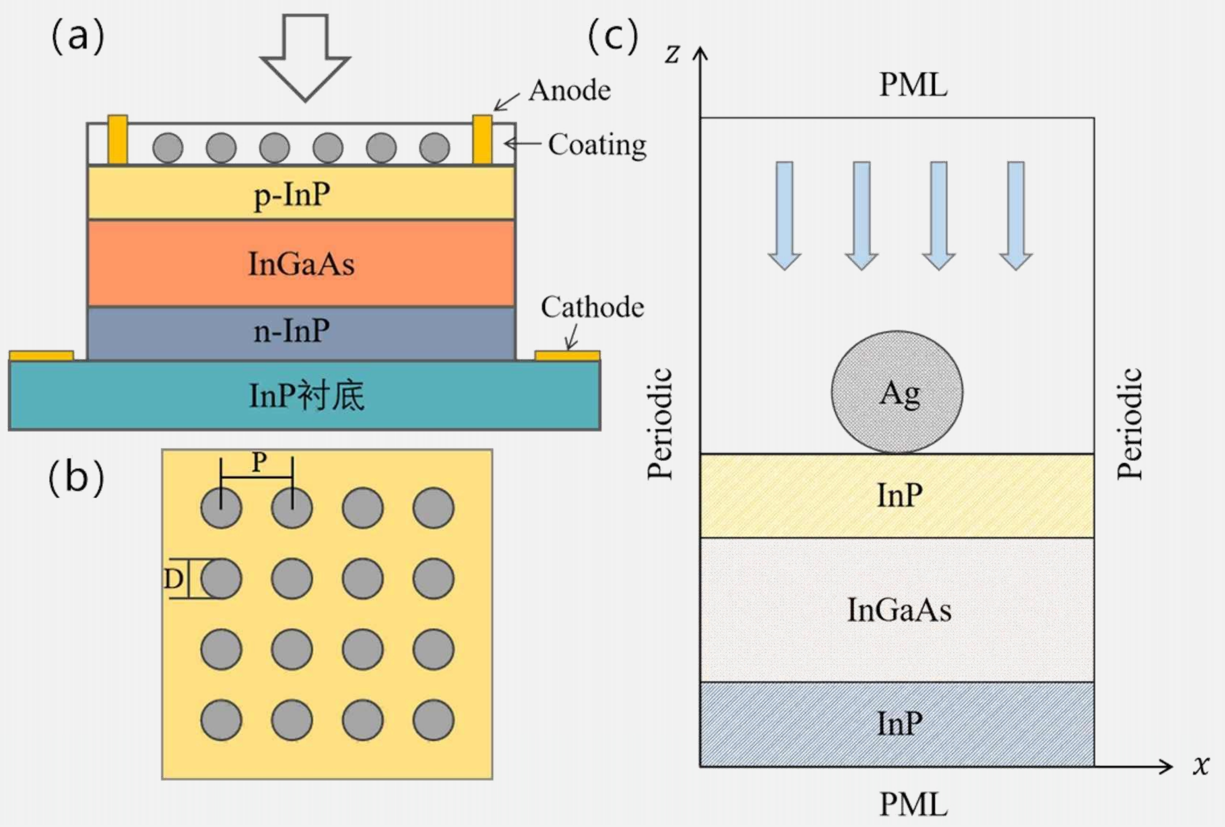

Figure 1. (a)Longitudinal section of InGaAs PD structure with Ag nanospheres array; (b)Top view of structure; (c)X-Z section simulation structure diagram.

Results and discussion

Ⅰ. Ag nanospheres array diameter and period

Fig. 2(a) shows the optical absorptance of InGaAs PD when D= 0.3μm-0.5μm and P= 0.55μm-0.95μm. As Fig. 2(b) shows that with the increase of the period, the diameter of the NSs corresponding to the optical absorption peak also increases.

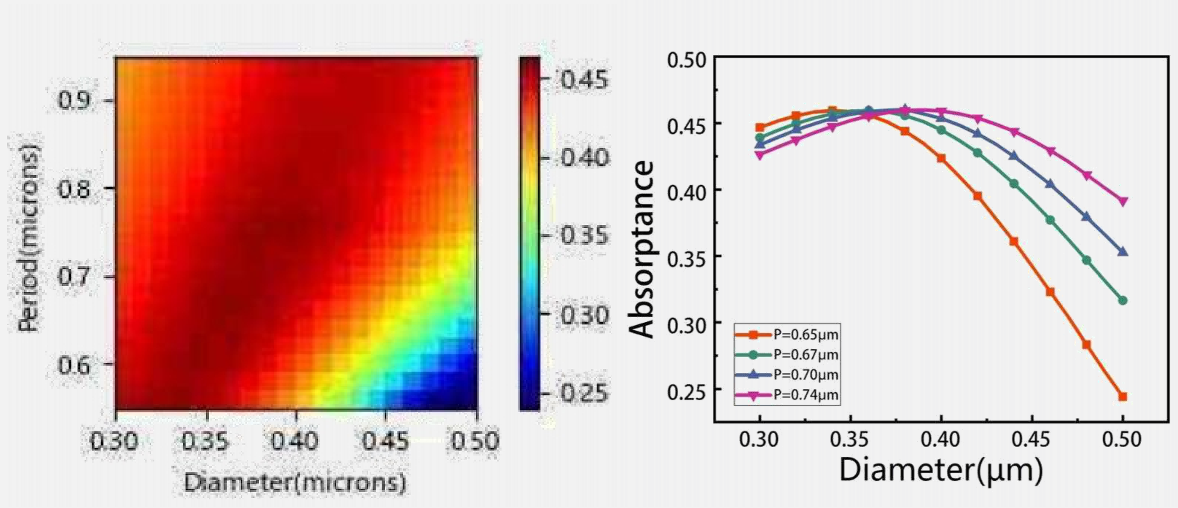

Figure 2. (a) A_{InGaAs} versus D=0.3μm-0.5μm and P=0.55μm-0.95μm. (b)A_{InGaAs} versus D with P=0.65μm, 0.67μm, 0.70μm, and 0.74μm.

Results and discussion

As is shown in table 1, when there is no modification on the input surface of the reference photodetector, the maximum optical absorptivity is 35.5%. When the Ag NSs array is modified, the maximum optical absorptance can reach 46%, and the duty cycle (D/P) is approximately 0.54.

TABLE I. Structural parameters of Ag NSs corresponding to the maximum absorptance of the InGaAs PD

No.	Structure parameters			Performance
	D	*P*	*D/P*	A_{InGaAs}
1	0	0	×	35.5%
2	0.34	0.65	0.54	45.9%
3	0.36	0.67	0.55	45.9%
4	0.38	0.70	0.54	46.0%
5	0.40	0.74	0.54	45.9%

Ⅱ. Thickness of the anti-reflection film

Fig. 3 shows the influence of film thickness on the optical absorptance of PD when SiO_2 and Si_3N_4 are used as anti-reflection film materials, respectively.

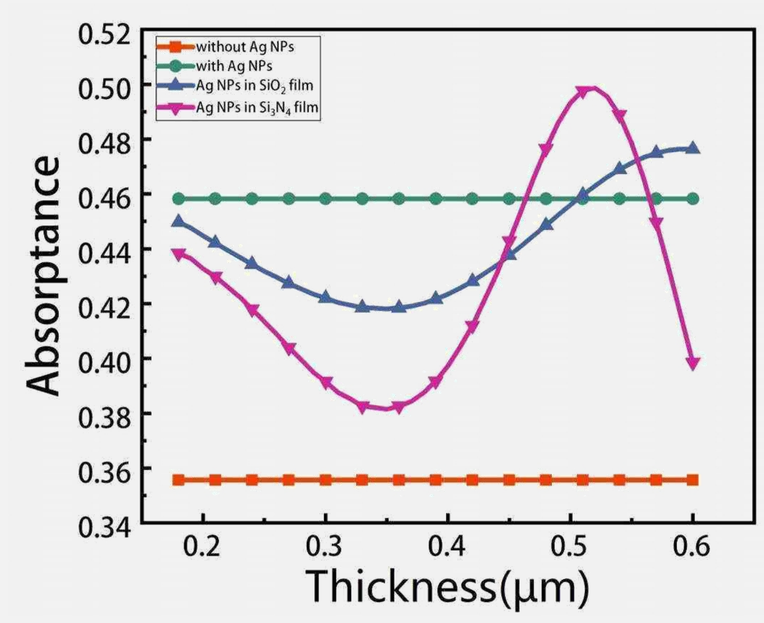

Figure 3. The variation of optical absorptance with the thickness of different anti-reflective layer materials .

The result shows that the absorptance gains relatively low when SiO_2 is applied, while the peak of absorptance is 50% when Si_3N_4 with a thickness of 0.52μm is used.

Ⅲ. Electromagnetic field distribution

We studied the distribution of electromagnetic fields of the Y-Z cross-section which is shown in Fig. 4.

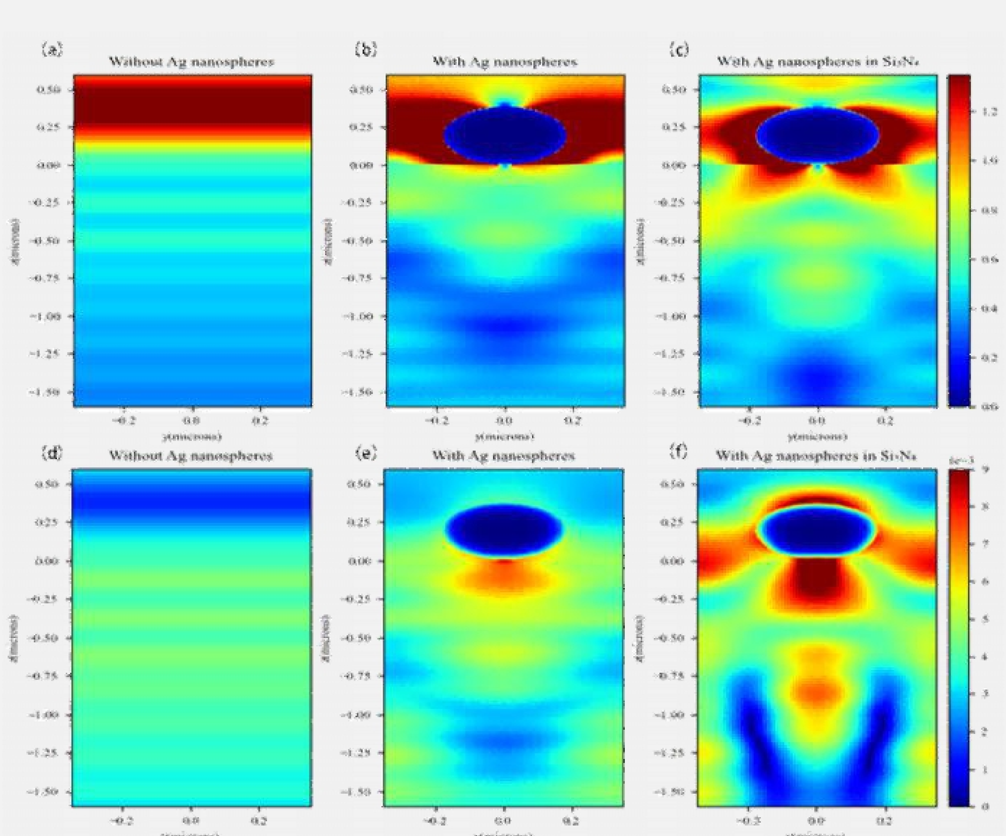

Figure 4. Electromagnetic field distribution: (a) |E| and (d) |H|of the reference PD, (b) |E| and (e) |H| of the PD with Ag NSs, (c) |E| and (f) |H| of the PD with Ag NSs in Si_3N_4.

Results and discussion

Ⅳ. Light source incident angle

Fig. 5 shows the effect of different light incidence angles on the absorption performance of the designed structure.

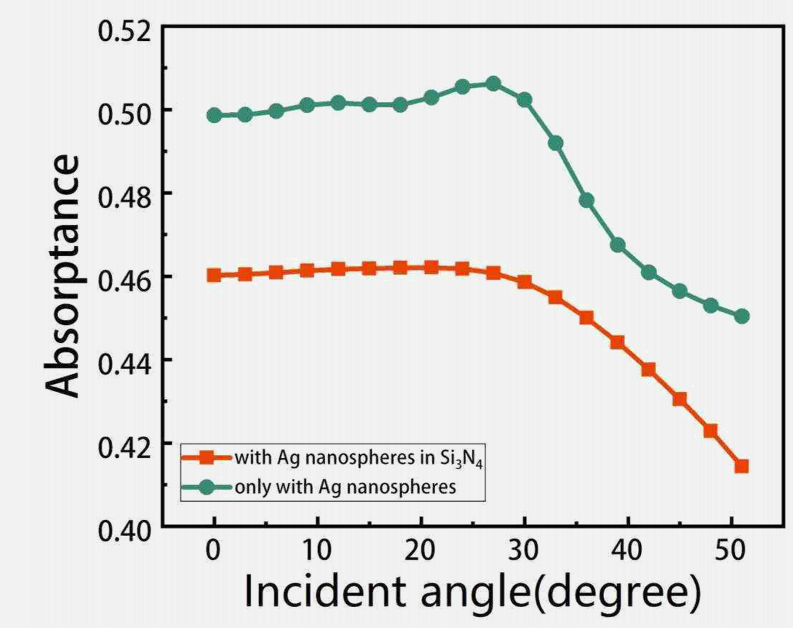

Figure 5. The absorptance of InGaAs PD versus incident angle of light when designing Ag NSs array with d = 0.38μm and P = 0.7μm on PD, and coating 0.52μm Si_3N_4 film on the Ag NSs array.

For the InGaAs PD structure with Ag NSs array, when the incident light deflection angle changes from 0° to 30°, the optical absorptance of the structure remains unchanged, which can be maintained at about 46%. When the Ag NSs array is embedded in the Si_3N_4 coating, the optical absorptance can be maintained above 50%.

Conclusion

In this paper,we proposed a new structure of InGaAs PD with surface-modified Ag NSs array. We found that when the diameter of the NSs is 0.34μm-0.4μm, and the duty cycle (D/P) is 0.54, the peak absorptance of the structure can reach about 46%. When the thickness of the Si3N4 coating layer is 0.52μm, the optical absorptance can be further increased to 50% and the absorptance is not affected when the incident light angle changes from 0° to 30°. The proposed InGaAs PD structure can achieve absorption enhancement in a wide range of light incident angles.

Acknowledgment

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