An InP-InGaAs-NiO p-i-n photodiode with partially depleted-absorber and depleted nonabsorbing region

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ABSTRACT

An InP-InGaAs-NiO p-i-n photodiode achieving p-side full coverage electrode and top illumination by using NiO films is proposed. This structure increases DC saturation current by about 27mA than conventional structure and has better bandwidth.

STRUCTURE DESIGN

Fig.1(a) showed the epitaxial layer structure of a conventional partially depleted-absorber p-i-n photodiode with a depleted nonabsorbing region.We first simulate the relative frequency response of the conventional PD, The 3-dB bandwidth has reached 35.15GHz with the p-InGaAs is 150nm and the i-InGaAs is 450nm.
Then replace the InGaAs contact layer and the InAlAs electron barrier layer with transparent NiO film. At the same time, NiO film is also used as an electrode. This is the InP- InGaAs-NiO p-i-n PD we proposed,as shown in Fig.1(b).

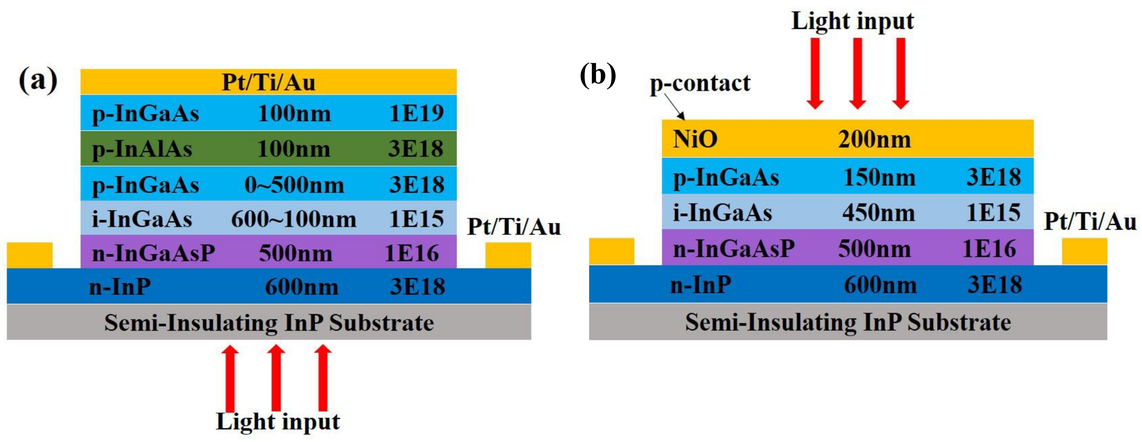

Figure 1. The epitaxial layer structure of (a) conventional photodetector and (b) InP-InGaAs-NiO p-i-n photodetector.

RESULTS AND DISSCUSSION

With the device diameter of 20μm and a reverse bias voltage of 3 V, the simulated results are shown in Fig.2.

Figure 2. (a) The bandwidth (b) the DC saturation current of different photodetectors in different illumination methods.

As shown in Fig.2(a), the bandwidth of new InP-InGaAs-NiO p-i-n PD reaches 37.62 GHz under top illumination, it is slightly higher than the conventional p-i-n PD at 36GHz under top illumination and 35.15GHz under back illumination. It is due to the NiO transparent conductive film in the new structure used as a full coverage electrode, which makes the electric field inside the depleted region more evenly distributes in the radial direction than the annular electrode.
Fig.2(b) shows the DC saturation current of the different structures with the loadimpedance is 50Ω, the InP-InGaAs- NiO p-i-n PD reaches 35.5 mA at the optical power of 110mW, while the conventional PD reaches 8.75mA at 22mW under back illumination and 8mA at 31mW under top illumination. The increase in DC saturation current of the new structure is mainly due to the reduction of carrier accumulation and the amelioration of the space charge effect. We further explore the electric field and potential of the device in the radial direction at 5e3 W/cm², the results are shown in Fig.3.

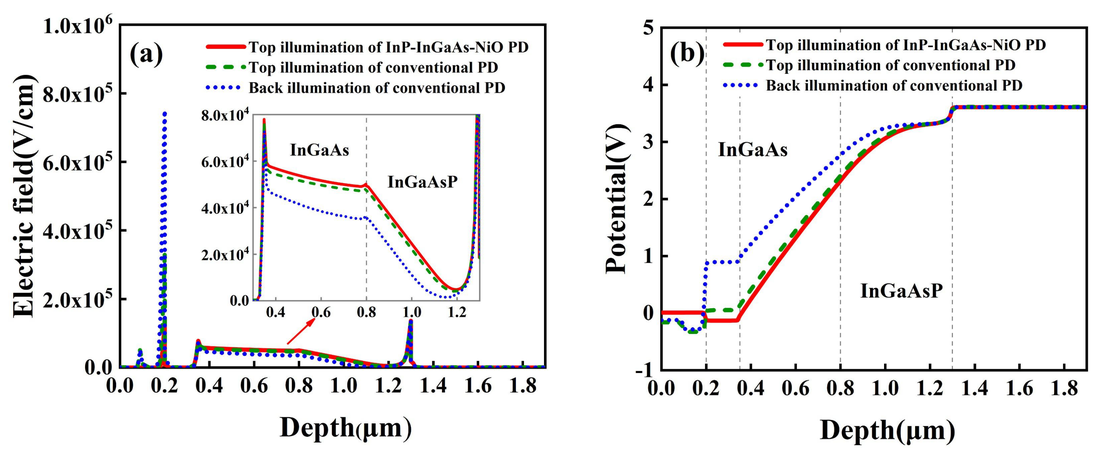

Figure 3. Distribution of (a) electric field and (b) potential of different photodetectors in the radial direction.

Under top illumination, the difference in the bandwidth of photodetectors is small, and the electric field in the depleted region is almost identical. However, under back illumination, the electric field intensity of conventional p-i-n PD is significantly reduced, shown in Fig.3(a), indicating that the accumulation of carriers in the device causes serious space charge effects. The performance decreases can be verified from the hole concentration in Fig.4(a), holes accumulate significantly in depleted region under back illumination of conventional p-i-n PD.
Fig.3(b) shows the potential distribution inside the photodetector. When the potential difference between the two ends of the absorbing layer is large, it is helpful to increase the velocity of carriers in the absorbing region, it can be verified from the hole velocity in Fig.4(b).

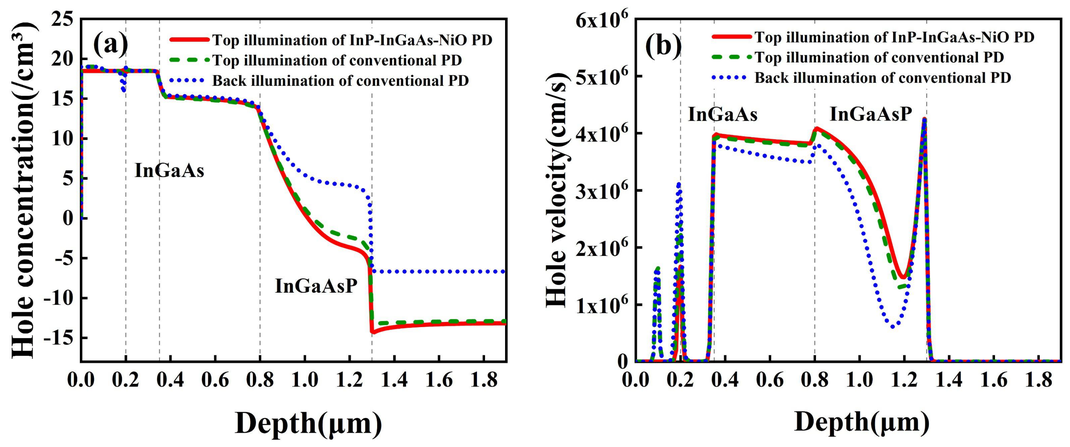

Figure 4. (a) The hole concentration (b) hole velocity of different photodetectors in the radial direction.

CONCLUSION

In this paper, we propose an InP-InGaAs-NiO p-i-n photodiode with partially depleted-absorber and depleted nonabsorbing region. Achieving the p-side full coverage electrode and top illumination at the same time. The DC saturation current of the new PD achieves 35.5 mA when the input optical power is 110mW at 1550nm. The 3-dB bandwidth is also improved than conventional p-i-n PD, which is 37.62 GHz. The new InP-InGaAs-NiO p-i-n PD ameliorates the space charge effect inside the device and improves the linear performance, has a better application prospect in high linear links.