Study on Frequency-dependent Saturation Characteristics of Modified Uni-traveling Carrier Photodetector

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Abstract

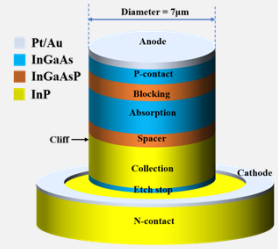
The frequency-dependent RF output characteristics of the modified uni-traveling carrier photodetector are studied. The results show that RF saturation output power of the device decreases linearly with increasing of the incident signal frequency.

Structure of device

Uni-traveling carrier photodetector (UTC-PD), only uses electrons as carriers, which can reduce the transportation time of carriers to a certain extent, weaken the space charge effect. The UTC-PD has unique advantages in high frequency signal and THz technology

The modified uni-traveling carrier photodetector (MUTC-PD) with a highly doped cliff layer between the absorbent layer and the collecting layer, so that electric field at the interface of the heterojunction has been enhanced. The electric field intensity increases, which is conducive to the barrier of electrons through heterogeneous junction, enhances the drift speed of the electrons, reducing the deposition of the electrons in the absorbent zone, and increasing the 3dB bandwidth of the MUTC-PD.

The structure of MUTC-PD is shown in Fig. 1, whose active area is 38.5μm².



(a)

3×10^{19}/cm³	50nm
2×10^{19}/cm³	20nm
1×10^{18}/cm³	220nm
1×10^{17}/cm³	8nm
1×10^{19}/cm³	16nm
1×10^{15}/cm³	6nm
1×10^{18}/cm³	7nm
1×10^{16}/cm³	267nm
5×10^{18}/cm³	50nm
1.5×10^{19}/cm³	10nm
1.5×10^{19}/cm³	500nm

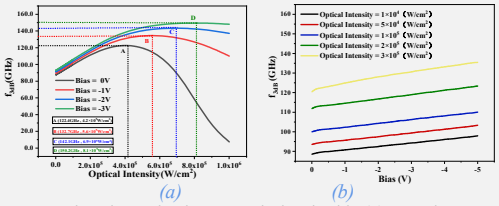
(b)

Fig.1. (a) Epitaxial layer structure and (b) parameters of MUTC-PD

Results and discussion

A.f_{3dB} characteristics of MUTC-PD

Fig. 2 (a), (b) simulate the optical intensity dependent 3dB bandwidth and bias dependence 3dB bandwidth of the MUTC-PD, respectively. the f_{3dB} of the MUTC-PD increases with incident optical intensity, but then decreases, while the optical intensity less than 3×10^5 W/cm², the f_{3dB} has a significant linear relationship with the bias.

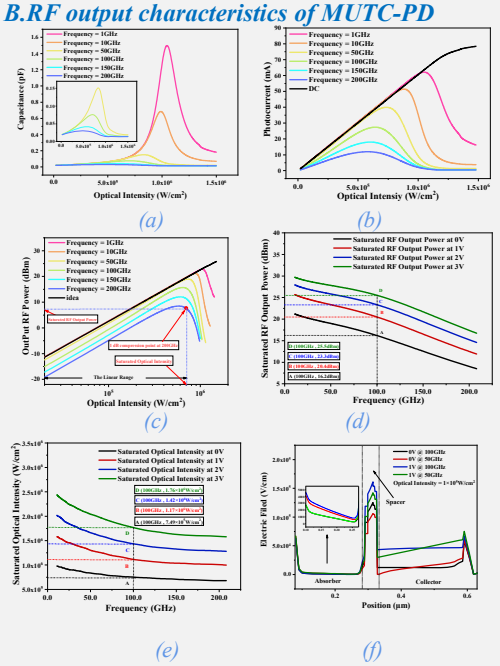


(a) (b)

Fig. 2. The relationship between 3dB bandwidth, (a) optical intensity, (b) reverse bias.

As shown in Fig. 2 (a), the maximum f_{3dB} is increased with the rise of the reverse bias, at -3V bias, the maximum f_{3dB} reaches 148GHz. Meanwhile, If the incident optical intensity is less than 3×10^5 W/cm², the 3dB bandwidth of MUTC-PD shows a significant linear relationship with the reverse bias. So, we can estimate the f_{3dB} of the device by fitting the equation between reverse bias and f_{3dB}.

B.RF output characteristics of MUTC-PD



(a) (b) (c) (d) (e) (f)

Fig. 3. (a) optical intensity dependent capacitance characteristics of MUTC-PD at 0V (b) the photocurrent of MUTC-PD at 0V (c) the RF output power of MUTC-PD at 0V, (d) optical intensity dependent capacitance characteristics of MUTC-PD at 0V (e) the photocurrent of MUTC-PD at 0V (f) the RF output power of MUTC-PD at 0V.

Results and discussion

In order to calculate the RF output power and the 1dB compression points of MUTC-PD, it is necessary to first simulate the relation between junction capacitance and incident optical signal. As is shown in Fig. 3 (a), it is similar to AC output current, the junction capacitance of MUTC-PD increases with incident optical intensity, and compared with Fig. 3 (b), the peak of the device junction capacitance is in the MUTC-PD's nonlinear region.

As shown in Fig 3 (d), increasing the bias voltage of MUTC-PD can effectively improve the saturated RF output power of the device. Fig. 4 (e) shows the variation trend of the linear range of the incident optical intensity of the MUTC-PD with the signal frequency. It can be seen that the linear range of the incident optical intensity of the MUTC-PD decreases with the increase of the signal frequency. Compared with Fig. 2 (d), We can find out that the device's output is in the linear range when it works at the optical intensity of the maximum bandwidth.

Conclusion

The bias dependent high-speed characteristics and frequency dependent saturation characteristics of MUTC-PD are studied. The capacitance and output photocurrent of the device under different incident optical intensity, signal frequency and bias voltage were simulated, and the 3dB bandwidth, RF output power and linear range of MUTC-PD were calculated based on the above data. For the high-speed characteristics of the device, when the optical intensity is less than 3×10^5W/cm², the 3dB bandwidth of MUTC-PD increases linearly with the increase of bias voltage. For the saturation characteristics of devices, the RF saturation output power of MUTC-PD decreases linearly with the increase of incident signal frequency. Increasing the bias voltage can improve the RF output power and the linear range of the MUTC-PD.

Acknowledgment

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