Research on Performance of Uni-traveling Carrier Photodetector Operating Three Light Illuminating Ways Under Low Bias*

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***Abstract*—In this paper, the performance of uni-traveling carrier photodetector is investigated operating back, front and double light illuminating ways. The simulation results show that the back illuminated device shows the best performance. And the 3-dB bandwidth and responsivity are 26 GHz and 0.179 A/W, respectively. The front illuminated device shows the highest saturation characteristics, reaching to 1.9e5 W/cm^2. The active layer radius of device is 14 μm and reverse bias is 0.1 V. In addition, the reasons account for the performance difference can be summed up as the following three points:Absorption of light by p-contact layer, the reflection of anode and the differences of electric field profile in the absorption layer.**

***Index Terms*—Three light illuminating ways, responsivity, p-contact layer, anode reflection, electric field**

I. Introduction

Photodetectors, as an important part of optical communication system, are developing towards the trend of high speed, high power and high saturation output. In 1997, the NTT Laboratory of Japan proposed the uni-traveling-carrier photodiode (UTC-PD) [1]. In 2000, They increased the bandwidth to 310 GHz by reducing the junction capacitance and optimizing the device size[2]. In 2013, Taiwan National Central University increase the bandwidth of new back illuminated NBUTC-PD to 325GHz[3].From the perspective of the development of UTC-PD, most teams acquiesce in the way of back illuminated and seldom use the front illuminating way [4].

In this paper, InP-based uni-traveling carrier photodetectors are irradiated in three different light illuminating ways. The double light illuminating, a new light illuminating way proposed in this article, is to divide light into two parts, one part is front incident, the other part is back incident. The light power of the three ways keep the same. The simulation results show that the back illuminated device show the best performance, the 3-dB bandwidth and responsivity characteristics of which are 26 GHz and 0.179 A/W, respectively. The front illuminated device show the highest saturation characteristics. Finally, through the analysis carrier concentration and electrical distribution to find the reasons account for the performance difference.

II. Structure and Simulation

A. Cross-correlation Algorithm

A schematic diagram of the structure used in this article is shown in Fig. 1, which is a classical MUTC structure. And we call this structure as MUTC1. Layer parameters of structure are shown in the Fig. 1. [5].

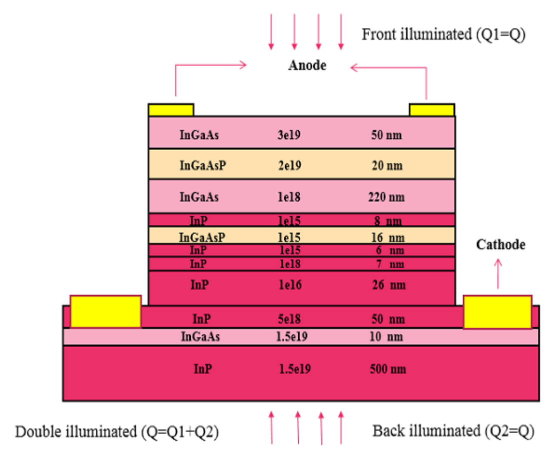

Fig. 1. Cross-sectional schematic diagram of the MUTC1.

B. Parameter Characteristics

By calculating, we can see that the responsivity of the back illuminated device is the highest, reaching to 0.179 A/W, which is larger than 0.135 A/W of double illuminated, and is also larger than the 0.092 A/W of the front illuminated.

Fig. 2 shows the curve of the bandwidth with light intensity of MUTC1 structure under different light illuminating ways. It can be find, the bandwidth of back illuminated device is larger than the front illuminated device. The front illuminated device show the best responsive range. Fig. 3 is the curve of the capacitance changing with the light intensity of MUTC1 under different light illuminating ways. It can be seen that the capacitance value of the three devices is the same under low light intensity.In high light intensity, the back illuminated device first tends to saturate.

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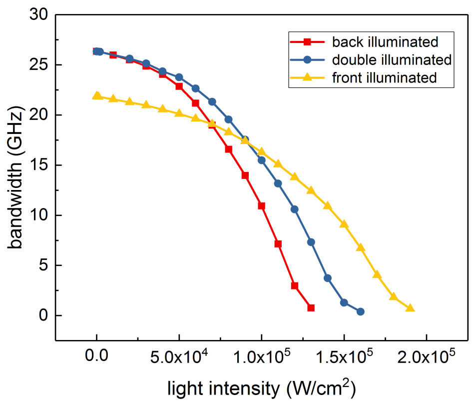

Fig. 2. Dependence of bandwidth on light intensity at -0.1 V bias for MUTC1 under different light illuminating ways.

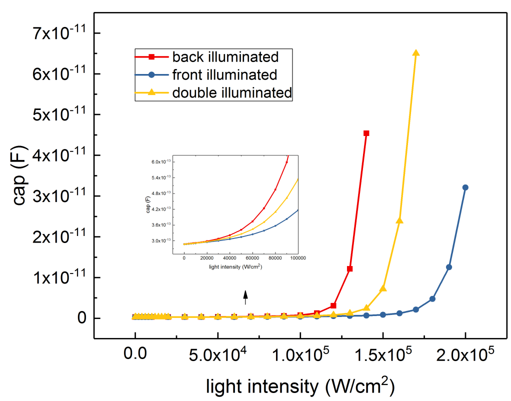

Fig. 3. Capacitance-light intensity characteristics for MUTC1 under different light illuminating ways.

III. Theoretical Analysis

A. Absorption of light by p-contact layer

For the UTC-PD structure of Fig. 1 , the p-contact layer are adopted In $_{0.53}$ Ga$_{0.47}$As material, same as the absorption layer material. And In$_{0.53}$Ga$_{0.47}$As can absorb wavelength of 1.55 µm light, so the p-contact layer has a certain absorption of light, while InP has a wide band gap [6], do not absorb 1.55 µm light, so light is transparent for InP. Therefore, for front illuminated device, the light is first absorbed by the p-contact layer, which makes the light intensity reaching the absorption layer decrease, leading to the decrease of responsivity.

B. Reflection of Anode

MUTC1 uses a ring anode, which is the anode covered area when x is 12-14 µm and the 7-12 µm is anode-uncovered area. Under anode-covered area, the electron concentration distribution of absorption layer, barrier layer and p-contact layer is significantly different. However, under the anode-uncovered area, the gap is small. So anode has a great influence on the distribution of electron concentration and the reflection of the anode can give a good explanation of the phenomenon.

C. Electric field of absorption

For UTC-PD, the diffusion of electrons is dominant in the absorbing layer, and the speed of [7] diffusion is much smaller than that of the collection layer and the heterogeneous interface. Therefore, the bandwidth of UTC-PD is largely determined by the electric field of the absorber layer. Fig. 4 is the distribution of electric field curve of the absorbing layer under different light illuminating ways. The back illuminated device has the largest electric field intensity, so its bandwidth is the highest. This gives a good explanation to the change in bandwidth in Fig. 2 .

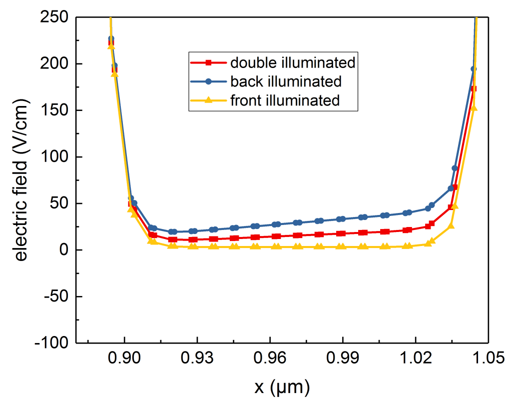

Fig. 4. The distribution of electric field of the absorbing layer under different light illuminating ways.

Acknowledgment

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