The Photoelectric Conversion Behavior of GaAs/ InGaAs/InAs QuantumDots-in-well in Double Barrier

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Abstract *—A GaAs/InGaAs/InAs quantum dots - quantum well in double barrier is discussed in this paper, because it has shown a specific inner multiplication in test and lower dark current accompanied by high current gains. The S (signal)/D (dark current) has reached* 10^6 *at a certain light power and bias. For further know its electronic transport and photoelectric characteristic, we are contrastive analysis sensitivity and dark current of quantum dots and quantum well in double barrier respectively, and interrelation under different illumination intensity respectively.*

I. INTRODUCTION

With the deepening of the nanometer materials and technology research and progress of quantum dots self-organized growth process, the research of nano optoelectronic devices has become the focus attended. Low dimensional semiconductor device research and application has shown broad prospects. But lower quantum efficiency and higher dark current, lower temperature operating and electron lifetime are inadequate in QW while the single quantum dot QD has lower density and absorption efficiency. Therefore, the quantum QW and QD is taken into combine for mutually reinforcing [1-8].

II. MODELING

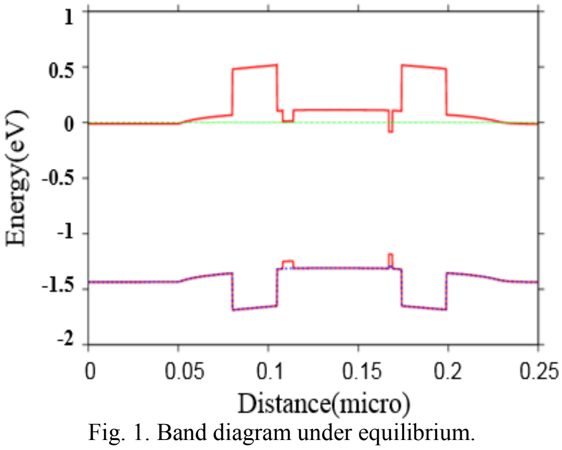

Fig. 1. Band diagram under equilibrium.

The model based on an Si-doped 1µm GaAs buffer layer and an undoped 30 nm GaAs spacer, the undoped double barrier structure was designed in the sequence of the first 25nm AlAs barrier, a 3nm GaAs interlayer, a 6 nm $In_{0.15}Ga_{0.85}As$ QW, a 45 nm GaAs well, a 1.8 ML self-assembled InAs QD layer with a 5nm GaAs overlayer, and the second 25nm AlAs barrier. On the top, an undoped 30nm GaAs spacer and a Si-doped 30nm GaAs capping layer were overgrown. The ohmic contact was made both on the top and at the bottom. A square (45µm ×45µm) was left in the top contact to absorb light signals [2]. The band structures of QW and QD is calculated based on the K.P theory. The temperature is set to be normal temperature. Figure 1 is the energy band diagram simulated at equilibrium. The quantum well in AlAs potential barrier, and Γ and X band in conduction band tilt as bias changed.

III. RESULTS AND DISSCUSSION

The model was biased at −0.9 V, the ratio of the photoelectric current to dark current was the largest as shown in Figure 2. The magnitude of the photocurrent versus the dark current is higher than 280dB. The current voltage characteristics at 725nm wavelength were simulated for different light intensities as shown in Figure 3. The current increase as bias and electric field increased. When bias is positive, InAs quantum dots capture a large number of electronic raising the electric potential near quantum dots. When bias is negative, InAs quantum dots capture hole decreasing the potential of near the quantum dots. The inset shows nearly linear relationship between current and light intensity [6]. The photocurrent of lower light intensity can be obtained according to the linear relationship.

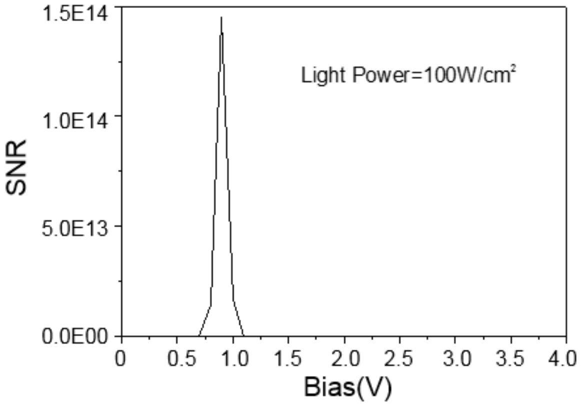

Fig. 2. The SNR as the bias voltage varies from 0V to 4V.

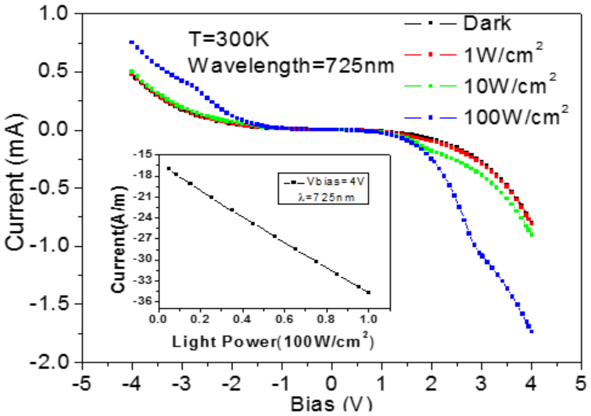

Fig.3. Current-voltage characteristics at different illuminations. The insets shows the photocurrent versus the excitation power at bias 4V.

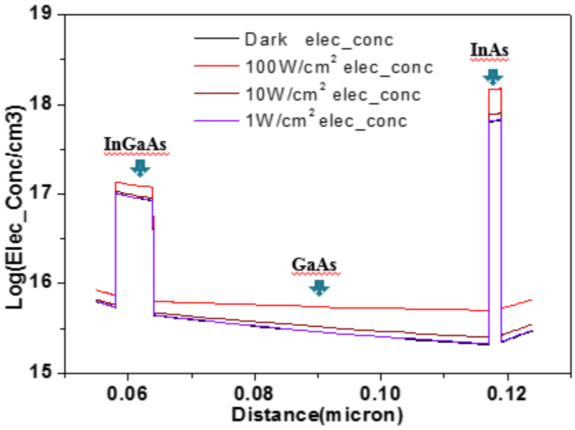

Fig.4. Different light intensities and zero bias, the distribution of the three active regions excited electrons.

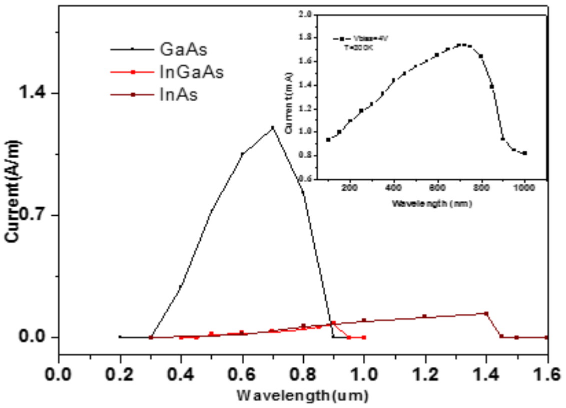

Fig.5. Photocurrent response spectrum of GaAs QW, InGaAs QW and InAs QD at bias 4V, the insets shows their spectrum combined.

Figure 4 shows total photocurrent is produced by GaAs quantum well, InGaAs quantum well and InAs quantum dots excited electrons. The quantum dots capture more electrons than others. Figure 5 shows each photocurrent response spectrum simulated for GaAs QW, InGaAs QW and InAs QD at bias 4V. The GaAs QW optical excitation is about at 700 nm, InGaAs QW near 900 nm and InAs QD near1400 nm. The inset is their respose spectrum total at room temperature. The photocurrent response range is from 100nm to 950nm and the photocurrent signal about 10^{-3} orders.

IV. CONCLUSION

The quantum dot in well double barrier model has been built and simulated. The current-voltage characteristics and signal to noise ratio (SNR) has gained by APSYS software. The sensitivities of GaAs QW, InGaAs QW and InAs QD can been discussed and compared respectively. By setting the bias and light intensities changed, the distribution of electrons ， photoelectric conversion and multiplier effect in the active region can reflected.

ACKNOWLEDGMENT

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