Simulation of InAlAs/InGaAs/InAs Quantum Dots - Quantum Well Near-infrared Detector

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Abstract- **We systematically have studied the InAlAs/InGaAs/InAs quantum dots - quantum well with InP substrate by simulating and analyzed with Crosslight Apsys package. The S (signal)/D (dark current) has best working points at 3.5V and -1.3V at 300K and photocurrent spectrum based on quantum dot in well can tail up to 1.70µm. Simulation result still included InGaAs EL spectrum, dark current and photo-responsivity.**

I. INTRODUCTION

The response wavelength based silicon optical devices can only reach the 1.1µm due to the band gap limitation. And the near infrared band above 1µm is lying in the atmospheric window of astronomical observations and remote control which has Important application value. In this paper, by selecting different compound semiconductor materials, the detection wavelength will be extended to 1.7 µm near infrared band.

II. MODELING

The model based on an Si-doped 1µm $In_{0.53}Ga_{0.47}As$ buffer layer and an undoped 30 nm $In_{0.53}Ga_{0.47}As$ spacer, the undoped double barrier structure was designed in the sequence of the first 25nm $In_{0.52}Al_{0.48}As$ barrier, a 3nm $In_{0.53}Ga_{0.47}As$ interlayer, a 6 nm $In_{0.7}Ga_{0.3}As$ QW, a 45 nm $In_{0.53}Ga_{0.47}As$ well, a 1.8 ML self-assembled InAs QD layer with a 5nm $In_{0.53}Ga_{0.47}As$ overlayer, and the second 25nm $In_{0.52}Al_{0.48}As$ barrier. On the top, an undoped 30nm $In_{0.53}Ga_{0.47}As$ spacer and a Si-doped 30nm $In_{0.53}Ga_{0.47}As$ capping layer were overgrown. The ohmic contact was made both on the top and at the bottom. A square was left in the top contact to absorb light signals [1-3].

III. RESULTS AND DISSCUSSION

Figure 1 shows the comparison of the photocurrent spectrum of the structure under different temperature. The wavelength shift to the left and the photocurrent decreases with the decrease of temperature. This is because as the temperature decreases, the width of band gap becomes larger and the detection wavelength becomes smaller. Figure 2 is the comparison of the photocurrent spectrum under different bias voltage at 300K. With the bias voltage decreases, the electron-hole pairs generated by wide quantum well has not yet been separated and the composite probability increases, so the response current has also been reduced. Figure 3 shows I-V curves simulated at T=300K, 250K, 200K and 160K respectively. The difference between the forward and reverse bias I-V curves arises from the asymmetry of the device structure.

Therefore, the SNR (signal to noise ratio) is better as shown in Figure 4. A peak occurs in the forward bias and reverse bias and the peak under forward bias is larger, which is determined by the resonant tunneling (RT). The peak under

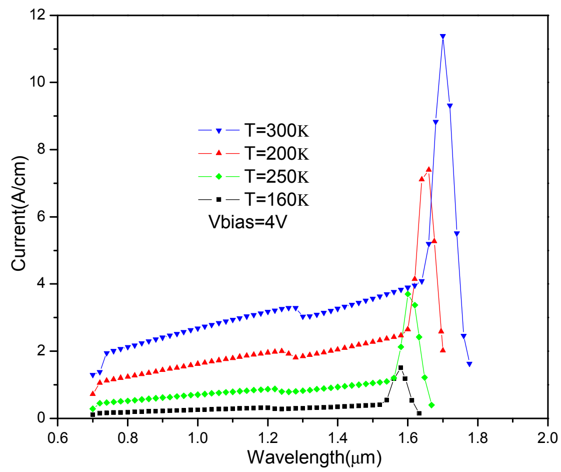

Fig. 1. Photocurrent spectra simulated under different temperature at 4V..

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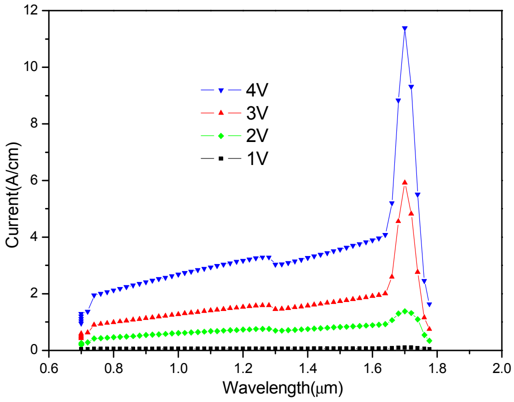

Fig. 2. Photocurrent spectra simulated under different bias at 300K.

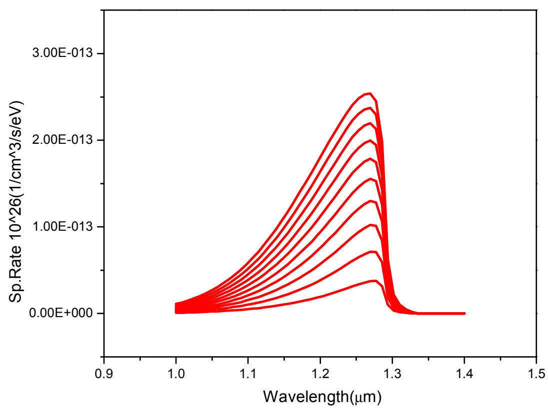

Fig. 5. EL spectrum of InGaAs.

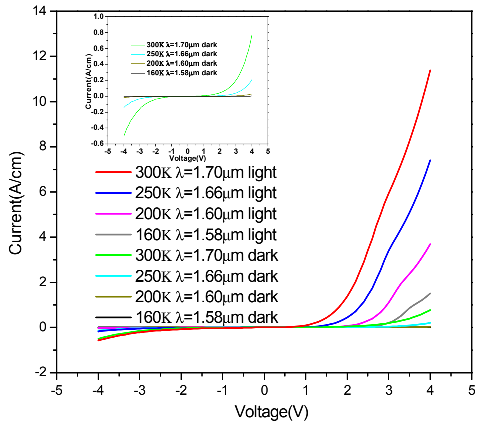

Fig. 3. The I-V characteristics at different incident wavelengths and temperature, insets shows the lower darkcurrent versus the bias.

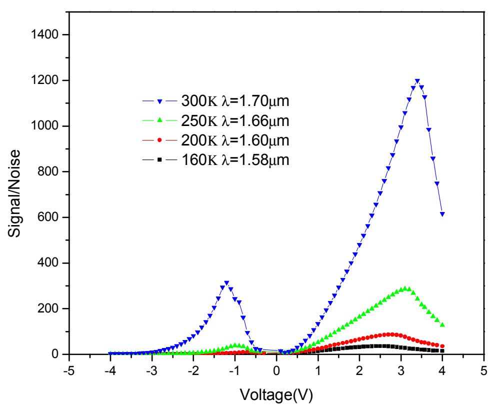

Fig. 4. The SNR as the bias voltage varies from -4V to 4V.

reverse bias is attributed to resonant tunneling quantum dot (QD-RT) [4]. Finally, the simulation of the EL spectra is as shown in Figure 5. Different curves correspond to the different carrier injection concentration.

IV. CONCLUSION

In the paper, we simulated and discussed the photocurrent spectral, photoelectric properities and EL spectral using APSYS. The response wavelength can reach 1.7μm and darkcurrent is only 0.77A/cm at 4V. Through analysis of signal to noise ratio, the best working bias is at 3.5V and -1.3V at 300K.

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