Properties behavior of InAs quantum dots and InGaAs quantum well on the photodetector

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***Abstract*-- In this paper a photodetector model containing InAs Quantum dots (QDs) and InGaAs Quantum well (QW) is discussed. We discover absorption peaks of InAs QDs and InGaAs QW in the photoluminescence (PL) spectra simulated. The photocurrent spectra shows that the most appropriate wavelength which can get best photocurrent response is 0.86μm and photocurrent response under positive bias is better than the negative bias. It can be seen from the current-voltage curve that current-voltage characteristics of photodetector model have resonant tunneling phenomenon under both the positive bias and negative bias, however the function part is different which is energy level of QDs under the positive bias while energy level of wetting layer under the negative bias.**

I. INTRODUCTION

The QDs structure has caused widespread concern in the past few years because of its potential application in electronic, magnetic and optoelectronic. Its electrical and optical properties can be changed by three-dimensional quantum confinement effect which makes the semiconductor QDs widely used in single-electron devices and optoelectronic devices. Meanwhile, its longer electron lifetime in the confined states and inherent sensitivity make them ideal for the photodetector. In this study, a photodetector model including InAs QDs and InGaAs QW is chose due to their unique properties and potential applications. We found that QDs have a great effect on the current-voltage characteristics at any different bias. Also, we observe a negative resistance phenomenon under both the positive bias and negative bias.

II. MODELING

The model based on a 0.6μm GaAs buffer layer n-doped at $2\times10^{18}cm^{-3}$, and an undoped 500nm GaAs spacer layer was grown on the bottom contact. A 15 nm $In_{0.22}Ga_{0.78}As$ quantum well follows the GaAs spacer. InAs QDs capped by 2 nm of $In_{0.3}Ga_{0.7}As$ wetting layer, were separated from 2 nm of GaAs spacer, 2nm of AlGaAs barrier and 5 nm of GaAs spacer. On the top contact region, an undoped 10nm GaAs spacer and a 0.3μm GaAs cap layer n-doped at $2\times10^{18}cm^{-3}$ were overgrown. A window of 10×10 μm^2 opens for optical access. Both contacts on the top and bottom were ohmic contact. The structure of the entire model is asymmetrical. The band of structure is calculated by Apsys device. The layer structure of the model is shown in Fig 1.

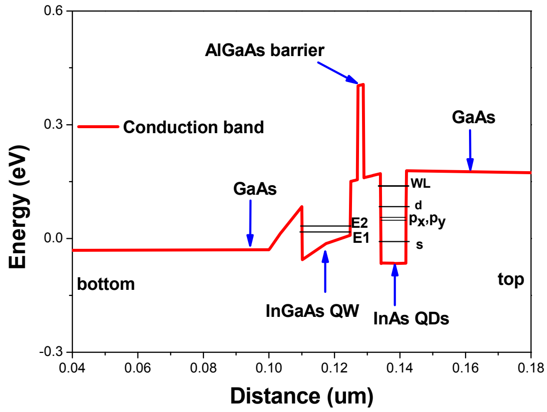

Fig. 1. Schematic band diagram

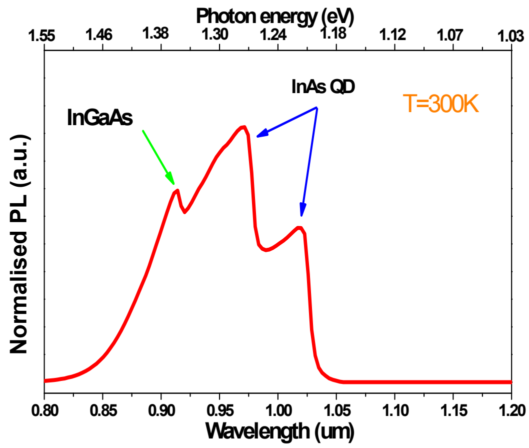

Fig.2. Photoluminescence properties

III. RESULTS AND DISCUSSION

Fig.2 shows typical photoluminescence spectra of the model including three main peaks. The simulation temperature is set to room temperature and the InAs QDs PL band is observed at ~0.97μm and 1.02μm which corresponded to the energy 1.27eV and 1.21eV. The peak of InAs QDs PL at the lower energy is associated with the first (s) level and second (p) level. The absorption peak observed at high energy is related to the InGaAs well. The corresponding wavelength is 0.92μm and energy is 1.35eV.

Fig.3. (a) is the room temperature photocurrent spectra of the model at the different negative bias voltages (-3V、-2V and -1V). With the negative voltage increasing, the photocurrent

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increases significantly while the position of the peak does not change significantly. Response range of the light is approximately 0.43µm to 1.06µm. Photocurrent response achieves the best performance when the wavelength is 0.86µm. Photocurrent response under positive bias is an order of magnitude larger than under negative bias.

The model is the relationship between the photocurrent and excitation power under light irradiation of different excitation energies as shown in Fig.3. (b). Excitation light intensity range is from 0 W/m^2 to 10^7 W/m^2. From the picture we can see that the size of the photocurrent and excitation power is a linear relationship, and high slope illustrate the model has a better response to this intensity of the excitation. It is shown that when the excitation energy is 1.37eV the slope reaches 4.02 which is the best response in this figure.

As shown in Fig. 4, the current-voltage curve under positive bias (forward voltage is applied to the bottom) at different light intensity has two resonant tunneling peaks at DC sweep voltage range from 0V to 4V, and the intensity of the second peak is much higher than the first peak. As the light intensity increasing, the intensity of tunneling peak greatly increases and the position of tunneling is shifted to the right. There is no remarkable tunneling phenomenon at the dark.

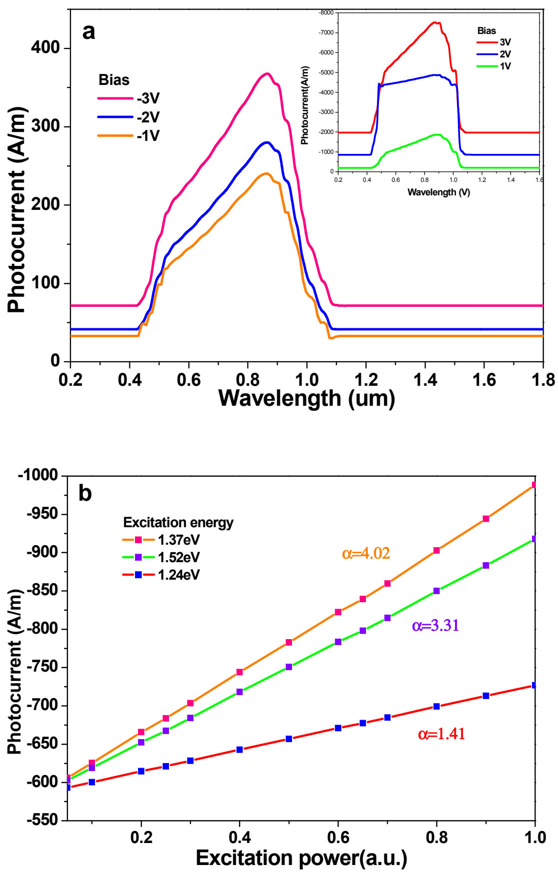

Fig.3. (a) Room temperature photocurrent spectra of the model, insets: photocurrent spectra at positive bias voltage. (b) The photocurrent at different photon energies with excitation intensity changed.

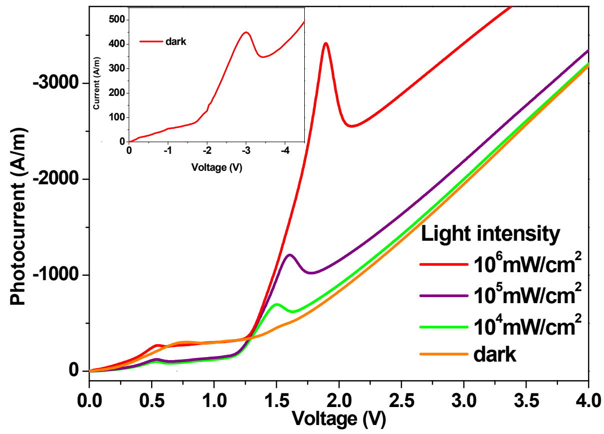

Fig.4. Current-voltage characteristics at different light intensity

With increasing light intensity, the number of electrons in the s state of the QDs and resonant tunneling electrons increase, thus tunneling current increases. At the same time, because the number of electrons in the s state of the QDs increase, the position of the level will be sinking and closer to the fermi level, so it needs more bias to align to the E_1 and E_2 states of the QW then the position of tunneling shifted to the right. The simulation also finds that current-voltage characteristics of the model in the dark and negative bias also have resonant tunneling peak (inset of Fig. 4). The most outstanding peak corresponds to the alignment of the ground level of InGaAs QW and the WL state of the QDs' wetting layer.

IV. Conclusion

The photodetector model including InAs QDs and InGaAs QW has built and simulated by Apsys software. We have studied the optical and electrical properties of this model and find that QDs' energy level and wetting lay's energy level have a great influence on the optical and electrical properties of photodetector model.

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