The quantum wells and quantum dots structure comparison on suppressing dark current

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***Abstract*- We design and simulate three different quantum optoelectronic devices to study the effects of the quantum wells and quantum dots on suppressing the dark current. Through the simulation of the samples, we find that the inhibition ability of quantum wells is stronger than quantum dots at room temperature; at low temperature, quantum dots is stronger than quantum wells. The simulation result shows, when applied bias is about 0.01 V, the dark current of samples A is 9×10^{-13} A; at around 3 V, its dark current is about A. Sample A has already been made of the samples tested, the test found that the actual dark current and dark current simulated are almost the same. At the same time, we tested the PL spectra of samples A to further explain this phenomenon.**

I. INTRODUCTION

The quantum structures based on GaAs have been successfully used for infrared detection, especially after having succeeded in the transition from pure quantum physics of the system to the direct engineering of the photon detection process involving quantum coherence.[1-2] The underlying quantum structures of quantum dots (QDs) and the dots-in well (DWELL) structure is proposed.[3-4]As a basic device characteristic, the dark current properties of the quantum dot infrared photodetectors (QDIPs) based on the DWELL structure have been investigated. One relevant issue on the optimization of photodetectors is the suppression of the dark current. Being a fundamental source of electronic noise, it ultimately limits the sensitivity of the device, and affects the achievable signal to noise ratio (SNR). Moreover, high dark current can negatively affect the detector's efficiency by increasing the recombination losses and the power consumption. On this basis, we research the influence of quantum dots and quantum well structure on the dark current, and temperature on the dark current for quantum detector.

II. MODELING

The sample in use was simulated by apsys on a n+-type (1 0 0) GaAs substrate. After the growth of a Si-doped () 1 mm GaAs buffer layer and a undoped 30 nm GaAs spacer, the undoped double barrier structure was deposited in the sequence of the first 25 nm 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 5 nm GaAs overlayer, and the second 25 nm AlAs barrier. On the top, an undoped 30nm GaAs spacer and a Si-doped (() 30 nm GaAs capping layer were overgrown [5], and ohmic contacts were separately made on the top and back contact layers [6]. The conduction band structure of Sample A with quantum dots and quantum well is shown in Fig.1. Sample B only has quantum well structures without quantum dots. Sample C only have quantum dots structure without quantum wells.

III. RESULTS AND DISSCUSSION

Figure 2 is the dark current of Samples A and C at different temperatures. We found that simulation dark current of samples A and B is almost the same, samples A and C show that the influence of quantum dots on the dark current is less than the quantum well at room temperature. The dark current near the zero bias is main reverse diffusion current at room temperature. As the voltage increase, the recombination current increases and the contribution of ohmic current to the total current is gradually increased. Also, when the bias voltage is greater than 2 V, the indirect tunneling effect of dark current gradually increases with bias increasing.

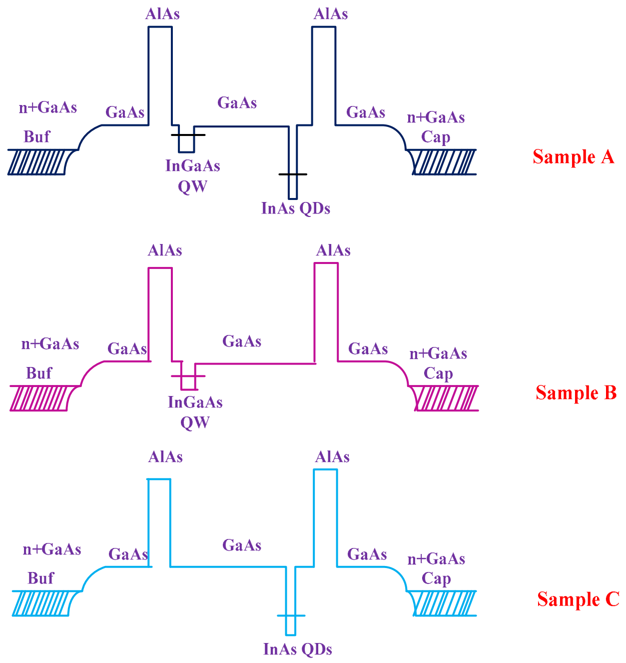

Fig.1 Three different kinds of samples

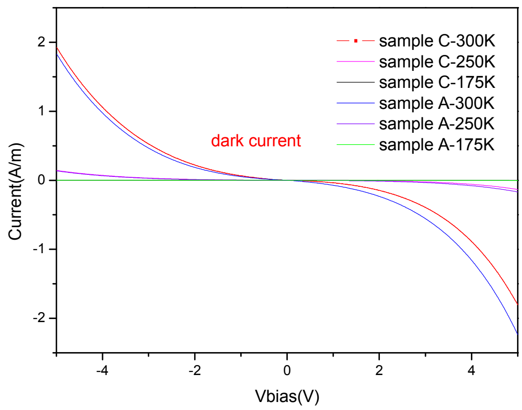

Fig.2 The dark current of sample C at different temperatures.

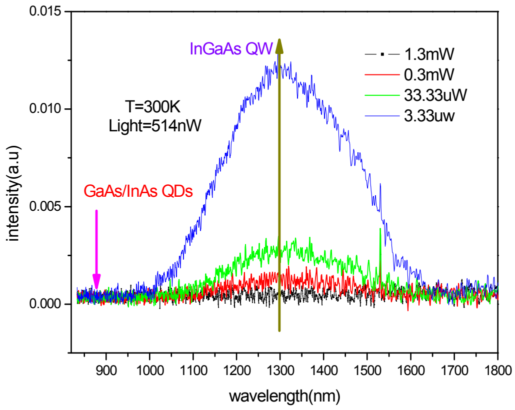

Fig.3 PL diagram under different light intensity at 300 K.

Compared samples A with C, it can be found that dark current of samples A with the quantum well and quantum dot, is significantly smaller than the non-quantum-well sample C. This is because the quantum well which is introduced in wide GaAs well can reduce quantum dot internal electronic energy levels, thereby reduce dark current. The tunneling dark current of sample A is significantly less than the sample C. The absorbing layer introduced can reduce deep level recombination centers. Thereby reduce the tunneling current indirectly. At different temperatures, the quantum wells and quantum dots different play roles on dark current. The simulation result shows when samples A applied bias is about 0.01 V, the dark current is 9×10^{-13}A at around 3 V, its dark current is about 10^{-9} A.

Sample A test found that the actual dark current and dark current simulated are almost the same. Quantum dots detector dark current is from thermally excited carriers, carriers direct tunneling of quantum dot and field-assisted tunneling carriers. The thermally excited carriers have the greatest impact on the dark current, in order to reduce the thermal excitation of carriers, quantum dots often operated and tested at low temperature. The test results further show that the effect of the quantum dots on temperature sensitivity, but also indirectly imply that the regulation of quantum dots at low temperature as shown in Fig.3 and Fig.4. The actual test results are basically consistent with simulation results, further evidence of the role of the quantum dots on reducing the dark current.

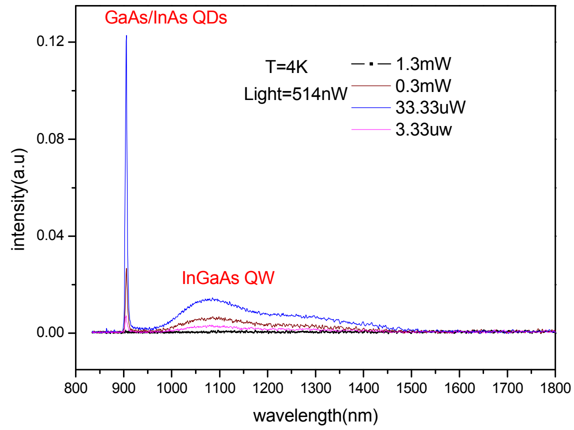

Fig.4 PL diagram under different light intensity at 4 K

IV. Conclusion

We design and simulate three different quantum optoelectronic devices to study the effects of the quantum wells and quantum dots on suppressing the dark current. The quantum well is introduced in wide GaAs well can reduce quantum dot internal electronic energy levels, thereby reduce dark current. The simulation result shows, samples A when applied bias is about 0.01V, the dark current is 9×10^{-13}A; at around 3 V, its dark current is about10^{-9} A.

Acknowledgment

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