Running wave form Extended states in charactering the photocurrent of multiple quantum well and superlattice structured GaAs/AlGaAs solar cells

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Abstract

The numerical simulations of the contribution of GaAs/AlGaAs multiple quantum well and superlattice to photocurrent in solar cells are presented. Effects of thickness of barrier and period on the extended and localized states, photocurrent have been investigated. Running wave method of calculation on the extended states of the two structures are adopt and compared.

I. INTRODUCTION

A combination of increased energy prices and fears over global warming are pushing up demand for photovoltaics (PVs), which drives many governments offering a lot support on the generation solar cells (SCs). Many theoretical and experimental works have been done to seek for a highly efficiency and lower price SCs [1-3], and with the improving manufacturing technology, the solar cells inserted with multiple quantum well (MQW) or superlattice (SL) have a optimistic market. By changing the width of barrier and period of quantum well, the SCs with low-dimensional structure present unique photocurrent characters. To improve the device performance, detail analysis of mechanisms of structure-related characteristics for SCs structured with MQW or SL is needed [5-12]. Different structural details such as layer thicknesses provide key insights into device simulation and design [4].

In this paper, the electrons and holes are assumed in running wave form to investigate the extend states and corresponding photocurrent in MQW or SL structured SCs. Effects of thicknesses of barrier and period on the performance of SCs are theoretically studied compared with single QW.

II. METHODS

The average optical transition rate in the multiple quantum well (QW) or superlattice (SL) from the initial state to the final state can be obtained by using the Fermi's golden rule [4]. The corresponding photocurrent (PC) spectrum from extended of valence band (VB) to extended states of conduction band (CB) is determined by the absorption coefficients and Fermi distribution of electrons and holes. Also is the PC spectrum from the inverse transition. In this article, we suppose the carriers transporting in a running wave form as

$$\psi(z)=\begin{cases} e^{ikz}+re^{-ikz}, & z<-W/2 \\ Ae^{ikz}+Be^{-ikz}, & -W/2\le z<W/2 \\ te^{ikz}, & z\ge W/2 \end{cases}$$

Here, we suppose the QW is along z direction with the width of QW being *W*. In the following calculation we suppose the electrons entering from one side while the holes from another side of the structure.

III. RESULT AND DISCUSSION

Figure 1 compares the extended states of electrons and holes at 2 and 10 periods when the well width being 5 nm and the barrier being 30 nm respectively.

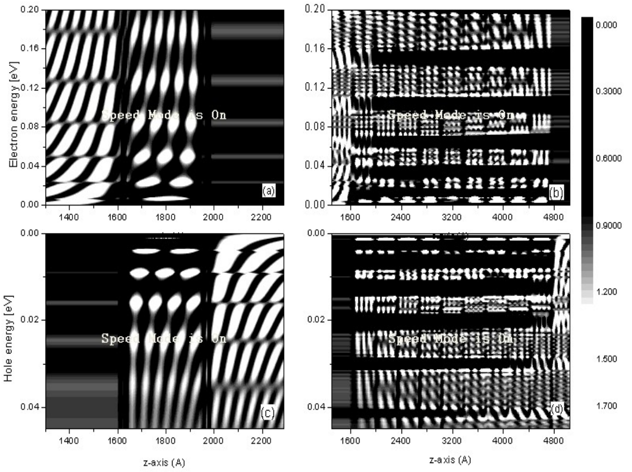

Fig. 1. The amplitude of extended state of electrons (upper) and holes (down) at 2 periods ((a) and (c)) and 10 periods ((b) and (d)) multiple QW.

Fig 1(a) and (c) show the amplitude of extended states of 2 periods QW after supposing the electrons entering from the left side and the holes entering from the right side. The extended states for 10 periods are presented in fig 1(b) and (d).

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We can see that the holes are extensively reflected near the edge of QW. The sublevels of electrons and holes can be obviously observed at 10 periods QW. And the probability for electrons and holes to transit from the MQW is extensively reduced when the carriers' energy is very low, which will derive the PC in 10-periods MQW decreasing in turn.

Figure 2 shows the PC spectrum as a function of the thickness and periods of QW. In order to have a clearing view on the relationship of the barrier width and period of QW, the PC spectrum of single QW is inserted in every figure. Fig. 2(a), (b)and (c) present the PC spectrum at different period of 2, 3, 4, 5 and 10 with 2 nm barrier width, and we can see that it is a typical SL structure (the value of the barrier width is around that of the QW width). As shown in Fig. 2(a), (b) and (c), the PC spectrum is obviously improved comparing the single QW which agree well with the experimental results. However, for the 10 period SL, the PC is decreased because the electron is obviously reflected in the extended states.

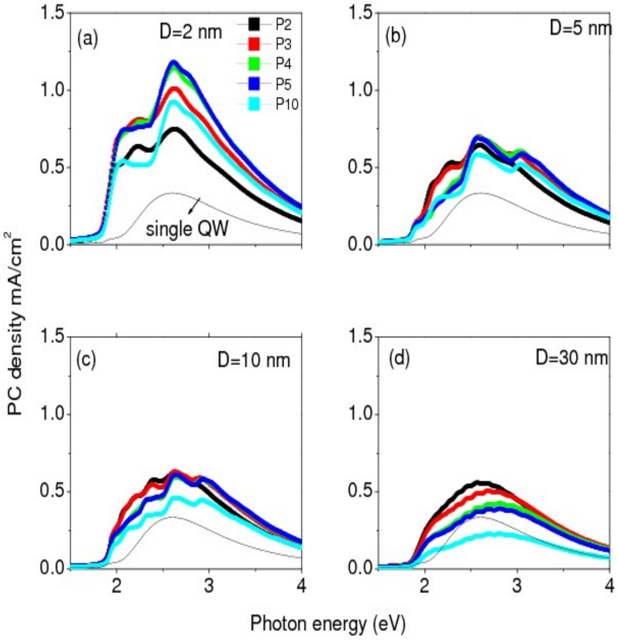

Fig. 2. PC spectrum as a function of barrier thickness (D) and periods (P). Here (a), (b), (c) and (d) correspond the PC at 2, 5, 10, 30 nm width barrier and P2 respects the period of QW being 2.

The PC spectrum as a function of period of MQW is shown in Fig. 2(d). Here the width of barrier is 30 nm which is 6 times of QW width, which means the structure is a typical MQW structure. The running wave assumption does not agree well with the experimental results. Usually, the carrier will relax in the barrier and reach a new balance, then transport to another QW. The lake of relax process in running wave assumption will introduce the decrease of PC due to extensively reflect of carriers as shown in Fig. 1(b) and (d). The Bloch wave assumption should be considered for the extended states distribution in MQW structure.

IV. CONCLUSION

The extended states of multiple quantum well (MQW) and superlattice (SL) structure in solar cells (SCs) are calculated in running wave assumption. The corresponding PC spectrum is simulated at different barrier and periods. The simulation results show that the carriers are extensively reflected at the bandage of MQW and SL structure, and the PC spectrum can be calculated for short period of SL when the carriers act in running wave form, while the running wave assumption can not work well in MQW and long period structure.

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