Photocurrent studies of GaAs/AlGaAs coupled quantum well solar cells

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Intermediate band (IB) solar cells have attracted considerable interests because of their potential for improvement of energy conversion efficiency [1]. In this type of solar cell, an IB formed between the conduction and valence bands of the host semiconductor plays a key role. To realize an IB, the coupling of neighboring states is necessary. So far, we have studied current-voltage (*I-V*) characteristics of a solar cell in which coupled multiple quantum wells (MQWs) are embedded, and found a substantial decrease in the photocurrent (PC) at low bias voltages [2]. This reduction of PC is explained by the suppression of carrier escape processes and resultant carrier accumulation in the well, which could cause a band bending in a MQW structure. In this work, we study in detail photocurrent spectra of a coupled MQW solar cell at various bias voltages and discuss the results in connection with *I-V* characteristics.

A sample having *pin* structure was grown on n-type GaAs(100) by molecular beam epitaxy. The MQW layer consisting of 10 periods of 4 nm GaAs well and 3 nm AlGaAs barrier were embedded in the middle part of a 1-μm thick *i*-AlGaAs layer. Structural details were reported in ref. [3]. The sample was processed into a mesa-shaped diode with an area of about 6.6×10^{-7} m^2. PC measurements were done at 10 K by using a monochromator and a halogen lamp.

Figure 1 shows PC spectra at different bias voltages. For large negative biases (V < ~1 V), a series of peaks are clearly seen, reflecting the localization of electron wavefunction under high electric fields. As the bias increases to the forward direction, the peak structure is smeared due to the delocalization of electron. In addition, as V is raised, the PC decreases as a result of carrier confinement in the MQW. The inset plots the PC as a function of bias voltage (*I-V* curve) under 720-nm excitation. The PC remains constant at V < -1 V since almost all carriers escape out of the MQW before recombination. Then, as electric fields decreases, the PC drops off owing to the carrier confinement. Interestingly, the disappearance of peak structure in the PC spectra becomes noticeable at V = -1 V, which implies that the band for the MQW region is rather flat at an early stage of the carrier confinement. As discussed in Ref. 3, the accumulation of carriers in a *coupled* structure causes the partial screening of the electric field inside, which leads to the formation of relatively flat band. The combination of PC and *I-V* studies will provide fruitful information on important features of IB solar cells.

[1] A. Luque and A. Marti, Phys. Rev. Lett. **78**, 5014 (1997). [2] T. Noda, et al. Phys. Status Solidi C **8**, 349 (2011). [3] T. Noda, et al. Jpn. J. Apply. Phys. **51**, 10ND07 (2012).

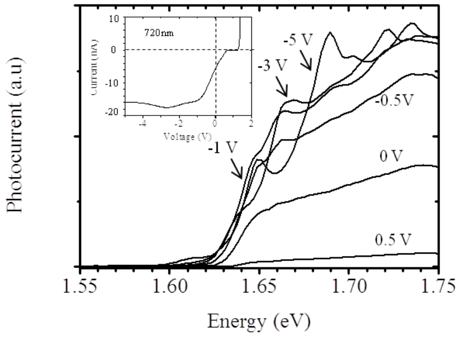

Fig.1 Photocurrent spectra at different bias voltages. The power of light was ~1 μW. Inset: current-voltage characteristic at 10 K.

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