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Transport and Optical Properties of Single Quantum Well Infrared Photodetectors

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1. Introduction

The quantum well infrared photodetectors (QWIPs) have attracted much attention due to their application to high performance infrared photodetectors[1]. Although numerous studies have been done on multiple quantum well QWIPs[1-3], single quantum well infrared photodetectors (SQWIPs) are particularly interesting since they are predicted to have a high optical gain due to photo-induced band bending effects [4-7]. Furthermore, their simple structure allows a better understanding of the physics in the QWIPs [4-7].

In this work, we have studied the optical and transport properties of AlGaAs/GaAs SQWIPs. The SQWIP showed a narrowband photocurrent at around 9.2 μm due to the intersubband transition. The bias voltage dependence of the magnitude and the spectral shape of the observed photocurrent indicates that the photocurrent is strongly affected by the tunneling escape process.

2. Sample Structures

The AlGaAs/GaAs SQWIPs studied in this work were grown on semi-insulating GaAs substrates by molecular beam epitaxy. The investigated *bound-to-bound* SQWIP structure consists of an L_w = 60 Å GaAs quantum well (doped with Si; $N_D = 1\times10^{18}$ cm^{-3}) surrounded by two L_b = 500 Å undoped $Al_{0.3}Ga_{0.7}As$ barriers. This was designed to yield two bound states in the quantum well. The active region was sandwiched between similarly doped top (0.5 μm) and bottom (1 μm) ohmic contact layers. All of the SQWIPs were processed into 0.4 × 0.4 mm^2 mesas. AuGe/Ni/Au was evaporated as the top contact and In was soldered for the bottom contact. The substrate beneath the mesa was polished at an angle of 45° to allow optical coupling to the active region. Figure 1 shows a band diagram of the conduction band edge of the SQWIP studied in the present work (Fig. 1(a)) and a schematic illustration of the device structure (Fig. 1(b)).

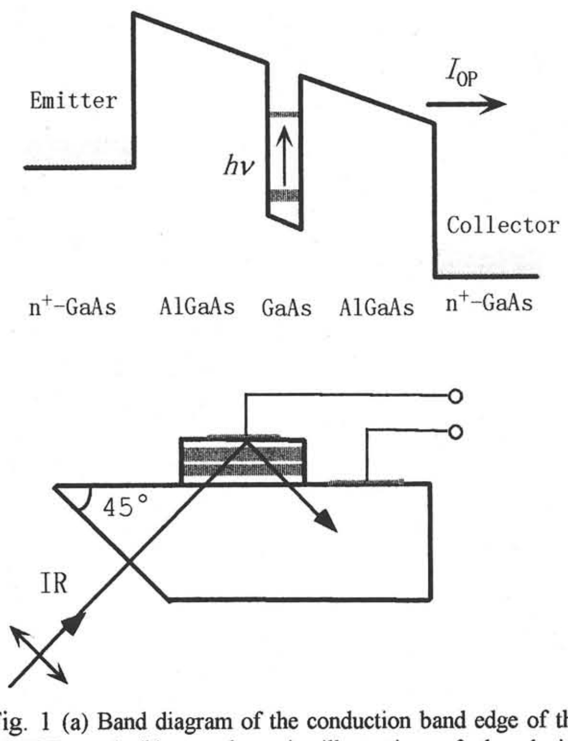

Fig. 1 (a) Band diagram of the conduction band edge of the SQWIP, and (b) a schematic illustration of the device structure.

3. Photoconductivity of SQWIPs

Figure 2 shows dc current-voltage characteristics of the SQWIP measured by using a semiconductor parameter analyzer. The dark current measured at 4.2 K in a radiation-tight cryostat is plotted by a solid line and the photocurrent measured at 10 K under a broadband illumination from a globar light source is shown by a dashed line. In the photocurrent measurements, short-wavelength radiation was cut by using a black polyethylene filter. As seen in the figure, the SQWIP is sensitive to infrared radiation for the bias range from 0.1 to 0.4 V. Similar but slightly asymmetric I-V characteristics were observed for the other bias polarity. By comparing the temperature dependent dark current (not shown here) with the observed photocurrent, the background limited performance (BLIP) of the present device was obtained up to 65 K.

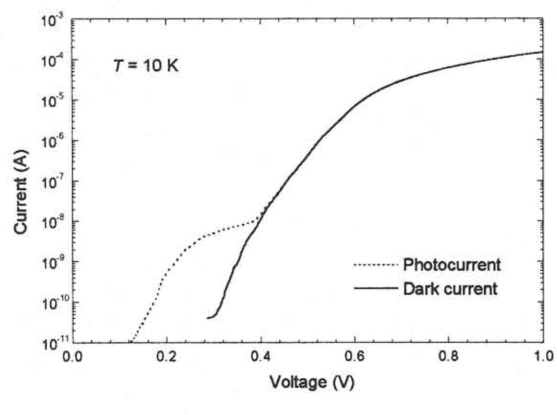

Fig. 2 The dark current measured at 4.2 K in a radiation-tight cryostat (solid line) and the photocurrent under illumination from a globar light source at 10 K (dashed line).

4. The bias voltage dependence of the photocurrent

Figure 3 shows the photocurrent spectra of the SQWIP measured for various bias voltages, V_B, by using a Fourier transform infrared spectrometer. The photocurrent shows a narrowband peak at around 9.2 μm with the spectral width $\Delta\lambda$ = 0.9 μm. The observed narrowband spectrum indicates that the photocurrent is induced by the intersubband transition between the ground and the first excited subbands in the quantum well. As seen in the figure, the spectral shape of the photocurrent is slightly asymmetric; the photocurrent on the longer wavelength side (lower energy side) of the peak decays more rapidly. This is due to the fact that although the intersubband photoexcitation spectrum of electrons in the quantum well has symmetric Lorentzian lineshape the tunneling escape rate of photoexcited electrons is smaller for lower energy electrons.

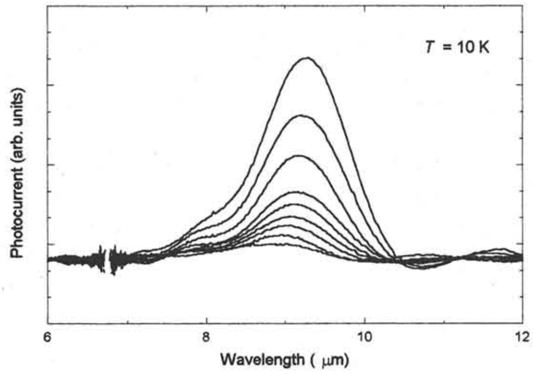

Fig. 3 The photocurrent spectra measured at T = 10 K for various applied voltage from 0.26 to 0.34 V with a voltage step of 0.01 V.

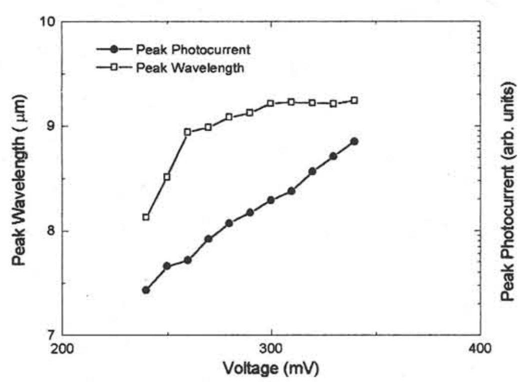

Fig. 4 The peak wavelength and peak photocurrent vs. applied voltage.

Figure 4 shows the bias-voltage dependence of the peak position and the magnitude of the photocurrent. It is found that the peak wavelength of the photocurrent gradually shifts to shorter wavelength side as the bias voltage is decreased. This is because the cutoff wavelength of the tunneling escape process shifts to shorter wavelength side as the bias voltage is decreased. Furthermore, the magnitude of the photocurrent decreases exponentially as the bias reduced, indicating that the magnitude of the photocurrent is controlled by the tunneling escape process.

5. Conclusions

In summary, we have studied the optical and transport properties of SQWIPs. The SQWIP showed a narrowband photocurrent at around 9.2 μm due to intersubband transition. The bias voltage dependence of the magnitude and the spectral shape of the observed photocurrent indicates that the photocurrent is strongly affected by the tunneling escape process.

Acknowledgments

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