High Temperature Photocurrent Spectroscopy of InAs/GaAs Quantum Dots
Long-wavelength Infrared Photodetector

Jinsung Park, Se-Kyung Kang¹, Uk Hyun Lee, Yong Hoon Kang, Joon Ho Oum, Sang-Jun Lee³, Sam Kyu Noh¹, Donghan Lee², Songcheol Hong

Department of Electrical Engineering and Computer Science, KAIST, Daejon 305-701, Korea
¹National Research Laboratory on Quantum Dot Technology, Materials Evaluation Center, Korea Research Institute of Standards and Science, Daejon, 305-340, Korea
²Department of Physics, Chungnam National University, Daejon 305-764, Korea

1. Introduction

Recently, there are great attention to the long wavelength infrared photodectors utilizing intersubband transitions in quantum structure, such as quantum well infrared photodetectors(QWIPs) and quantum dot infrared photodetectors(QDIPs)[1,2].

Mature III-V material growth and process technique have made QWIPs one of the promising long wavelength infrared photodetectors. QWIPs have uniform characteristics that makes possible to fabricate focal plane array. However, normal incident light cannot be absorbed in QWIPs due to the selection rules of intersubband transitions in conduction band. Since Quantum dots(QDs) have very different electronic structure from QWs due to their 3 dimensional carrier confinement. QDIPs can respond to normal incident light and operate at high temperature. In this latter, we report on high temperature intersubband photocurrent spectroscopy on InAs/GaAs quantum dot Infrared detector.

2. Experiments and Results

The epitaxial layer structure of the n-i-n QDIP, shown in Fig. 1, was grown on a semi-insulating GaAs (100) substrate by using a RIBER 32P molecular beam epitaxy system. Self-assembled InAs QDs in GaAs matrix were grown in the Stanski-Krstanov mode. Absorption region of the detector consists of 5 periods of InAs/GaAs quantum dots/barrier layers. 3 nm thick GaAs layer doped by Si (5x10¹⁷ cm⁻³) lies 6 nm above the QDs, which enhances of detector responsivity. 450 μm diameter mesa device were fabricated by standard photolithography and wet etching techniques. The ohmic contacts are formed from alloyed AuGe/Ni/Au. The temperature dependent dark current of the device was measured using HP4145B semiconductor parameter analyzer in cryogenic chamber. Fig. 2 shows the dark currents of the QDIPs as a function of bias voltage measured at temperature of 11 K to 285 K. The dark current of the QDIP increased rapidly due to exponential temperature dependence[3].

The photoluminescence (PL) at 10 K is shown in Fig 3. The peak emitted from QDs is 1.21 eV and showed full width half maximum of ~66 meV.

![Figure 1](image1.png)

![Figure 2](image2.png)
The broad PL peak is due to the size fluctuations of QD, in which only one bound state exists in conduction band\textsuperscript{[4]}.

Fig. 4. (a) show the bias dependent normal incidence intersubband absorption photocurrent spectra of the QDIP measured at 11 K. The peak at $\sim$10 $\mu$m is ascribed to the transition between the bound state and continuum states in conduction band. The responsivity calculated from the photocurrent response is 112 mA/W at the bias 1.2 V. This is somewhat higher than reported ones of vertical type QDIPs\textsuperscript{[5]}. We believed that the high responsivity is originated from high photo-conductive gain mechanism. In Fig. 4. (b), we observed the photocurrent spectrum at 210 K. This is the highest temperature for vertical QDIPs operated in the wavelength range of 8 to 12 $\mu$m. This result shows the possibility of QDIPs detecting wavelength range of 8–12 $\mu$m at higher than cryogenic temperature.

3. Conclusions

A high temperature photocurrent spectroscopy of QDIP utilizing the electron intersubband transitions has been demonstrated. We observed the photocurrent spectrum at 210 K. This is the highest operating temperature for vertical QDIPs in the wavelength range of 8 to 12 $\mu$m. The responsivity of the QDIP was as high as 112 mA/W at 1.2 V. Further the increase of operating temperature is expected by introducing dark current reducing structure and by optimizing doping.

Acknowledgments

This work was supported, in part, by KISTEP (under IMT2000 R&D donation support program) and MOE BK21 programs. The authors would like to thank J. K. Kim for technical assistances.

References