

InAs/InGaAlAs/InGaAs/InP Quantum Dot Infrared Photodetectors

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Abstract A novel quantum dot structure for infrared photodetectors is proposed. The results demonstrate great potential for operation under normal incidence and temperatures above liquid nitrogen.

Infrared photodetectors based on intraband transitions in quantum dots (QDIPs) should, in principle, outperform the ones using quantum wells (QWIPs), because of the possibility of absorbing normal incident light and operating at higher temperatures due to the electron longer lifetimes. The performance of QDIPs has greatly improved in the past few years. However, in order to seriously compete with the QWIPs, in addition to the control of the dots fabrication, the intraband absorption and the consequent generated photocurrent (PC) in these devices should be fully understood. In this work we present results of a detailed optical characterization of specially designed stacked self-assembled InAs/InGaAlAs/InGaAs/InP QDIP structures grown by metalorganic vapor phase epitaxy.

The QDIP active region consists of an InGaAs quantum well grown on InGaAlAs followed by a thin InGaAlAs layer on top of which the dots are nucleated. The introduction of the quaternary material leads to a higher dot density and to smaller quantum dots¹: both properties are desirable for improvement of the device performance. The ternary and the quaternary material are lattice matched to InP. The dots are then covered by a thin InP barrier which helps reducing the dark current and is more convenient to be grown at the same temperature as the dots themselves. The structure shown in figure 1 is repeated 10 times. Reference samples without the InGaAs quantum well and without the thin InGaAlAs barrier layer were also grown with equivalent growth conditions. Photocurrent measurements as a function of temperature, bias and polarization of the incident radiation, together with theoretical calculations, were used to characterize the structures in detail and to identify the different intraband transitions.

Figure 2 shows the photocurrent of the QDIP structure as a function of temperature. A photocurrent signal is observed around 5 and 11 μm . Two features are striking in these results. First, a strong signal is observed at temperatures as high as 120 K and second, $\Delta\lambda/\lambda$ for these intraband transitions are 0.16 and 0.07, respectively. To the authors' knowledge, the latter value is the smallest one for intraband transitions for such materials ever reported. Figure 3 shows the polarization dependence of the photocurrent signal at 5 K. The signal at 10 μm is reduced when s-polarized radiation is incident as compared to the other polarization, indicating that this transition should involve an energy level which has a hybrid character, meaning that the levels have 1D and 2D properties². The energy of the different electronic levels was calculated using a 1D model and the results are schematically shown in figure 1. Based on the temperature and polarization dependence of the photocurrent, we attribute the observed peaks to the transitions shown in figure 1. The excellent performance of these InAs/InGaAlAs/InGaAs/InP QDIPs reveal their great potential to outperform the available QWIPs.

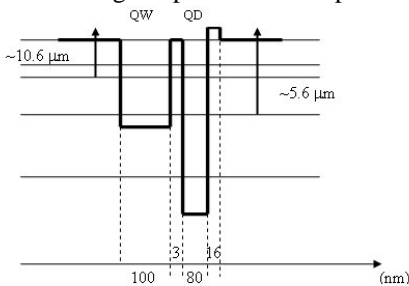


Fig. 1 Scheme of the sample structure.

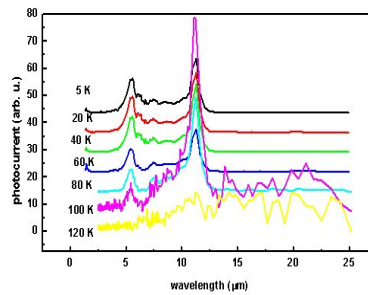


Fig. 2 Photocurrent as a function of temperature.

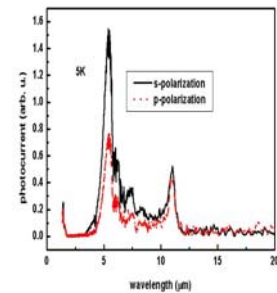


Fig. 3 Polarization dependence of the photocurrent.

Reference

- [1] M. Borgström, *et al*, Journal of Crystal Growth 252, 481 (2003).
- [2] F. F. Schrey, *et al*, Phys. Rev. B 72, 155310 (2005).