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In(Ga)As Quantum Ring Terahertz Photodetector

Jheng- Han Lee, Jon-Horng Dai, Yi-Tsung Chang, Chi-Feng Chan and Si-Chen Lee

Department of Electrical Engineering
Graduate Institute of Electronics Engineering, National Taiwan University
No. 1, Sec. 4, Roosevelt Road, Taipei, 10617 Taiwan
E-mail：f95943063@ntu.edu.tw

1. Introduction

Quantum type infrared photodetectors [1-3] have been developed these several years due to the high response speed, higher operating temperature and long capture relaxation time [4-5]. Quantum dot infrared photodetectors (QDIPs) attract intensively research because they have better performance than quantum well infrared photodetectors (QWIPs) for their intrinsic sensitivity to the normal incident light, longer life time, and lower dark and noise current.

For detecting virus, explosives and bio-images with their molecular vibration frequency locating at the 0.1-30 terahertz frequency range [6-10], a detector which can detect far infrared wavelength is necessary. Although QDIPs have advantages on detecting infrared light, the detection range is limited to the middle infrared (from several micrometer to tens of micrometer). The quantum ring infrared photodetectors (QRIPs) have the potential of high response speed, longer life time, low dark and noise current, and much better three dimensional confinement than those of QDIPs, it also exhibits the far infrared wavelength detection ability [11]. In this paper, the In(Ga)As quantum ring terahertz photodetector is demonstrated which has a cut-off wavelength at 175μm .

2. Experiments and results

The QDs and QRs are grown on semi-insulating (100) GaAs substrate using VG V80H MKII solid source MBE equipped with valved craker sources under As_2 beam. The structure consisted of 800nm n^+ GaAs/50nm GaAs/2ML InAs QD annealing at 520°C for 10 sec/ 1.14nm GaAs capping layer/50nm GaAs/400nm n^+ GaAs (Fig. 1). After two steps annealing (Fig. 2), the QR structure is completed (Fig. 3).The first annealing step of InAs QD is to make the QDs with uniform size and density. The second annealing step after the deposition of GaAs capping layer is to let the In atoms out-diffuse from the central QDs and form the QRs. The thickness of the GaAs capping layer is the important factor for the QRIPs detection wavelength [11].

After lithography and mesa etching process, the device region is defined. The AuGeNi alloy is deposited and annealed at 450°C to form the ohmic contact. Finally, the device is polished at the backside with 45° angle to complete fabrication process of QRIPs (Fig. 4). Using the FTIR, the responsivity of the QRIP can be measured.

Fig. 5 shows the uniformity and QD size of a sample after the first step annealing at 520°C by atomic force microscopy. The high density and uniform QD size can be seen from the figure. It provides good template for the fabrication of QRIP device. Fig. 6 shows PL spectra of various sample with different GaAs capping layer thickness. The thinner the capping layer, the closer the PL peak energy is to the GaAs bandgap. It means that there is opportunity to detect the long wavelength infrared radiation. Fig. 7 shows the responsivity of QRIP at a bias of 80mV and temperature 8K. It is very clear from the figure that the QRIPs can detect infrared signal at three ranges, i.e., 45-75μm, 75-100μm and 100-175μm.

3. Conclusions

In summary, QRIPs have been successfully fabricated, the cutoff wavelength reaches 175μm (1.7 terahertz) , which can be operated between -0.4V to 0.4V bias range.

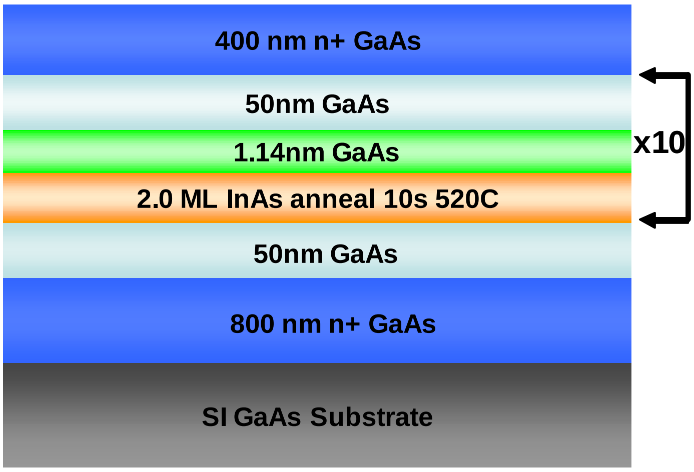

Fig. 1 QRIP device structure.

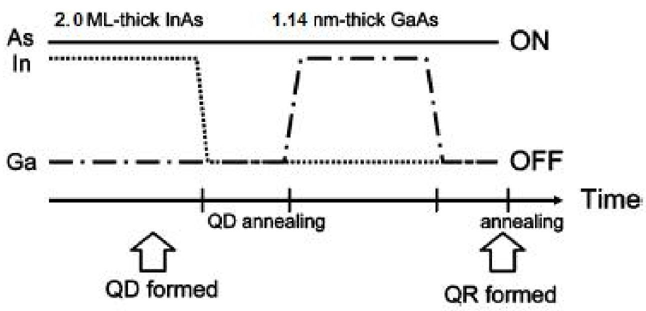

Fig. 2 Two steps annealing process to form the quantum ring.

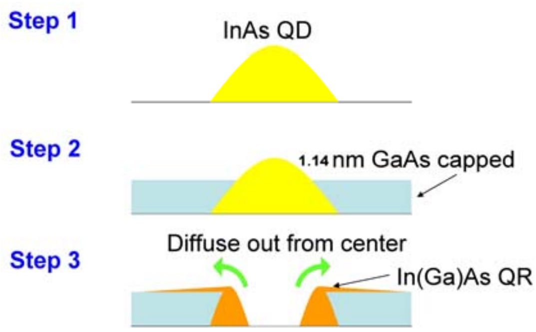

Fig. 3 Formation of the quantum ring from the quantum dot.

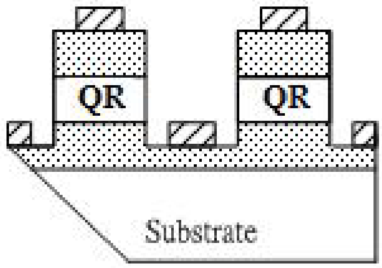

Fig. 4 The complete QRIP device structure.

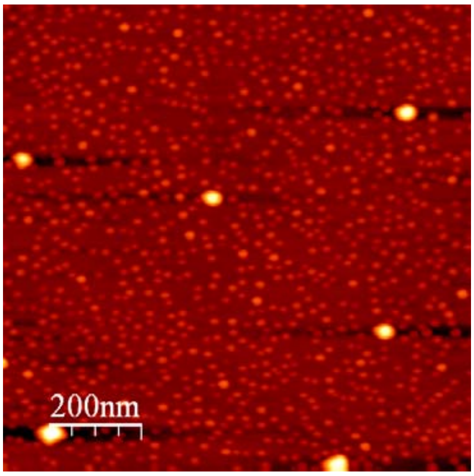

Fig. 5 QD AFM morphology annealing at 520°C 10sec.

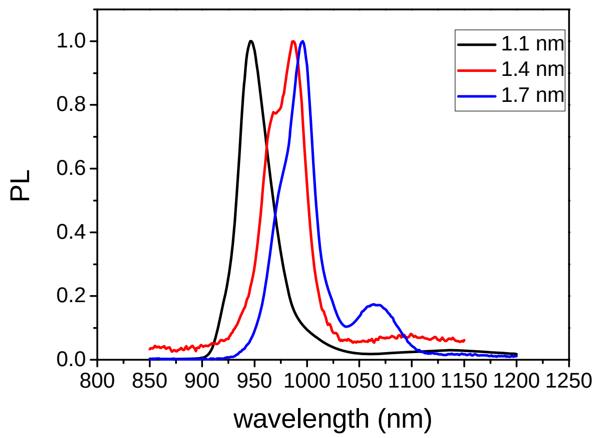

Fig. 6 PL Spectra of QD with different GaAs capping layer thickness.

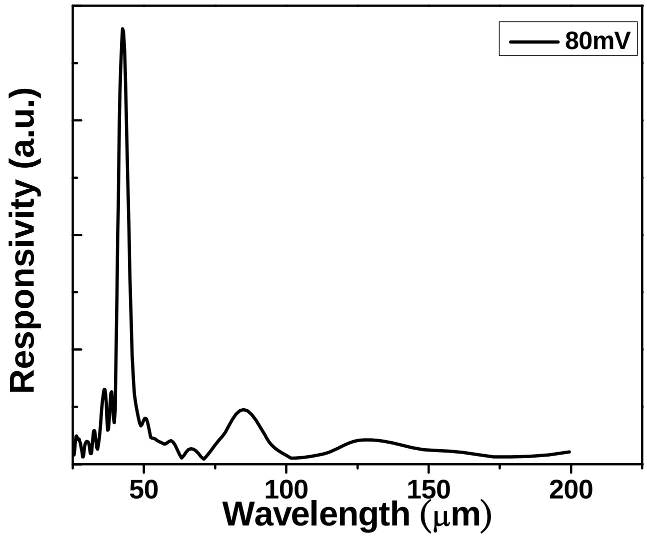

Fig. 7 Repsonsivity of QRIP with 1.14 nm GaAs capping layer thickness.

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