Synthesis and characterization of GaAsSb-capped InAs-based QDIPs

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Quantum dot infrared photodetectors (QDIPs) are very attractive for infrared imaging applications due to its promising features such as high temperature operation, normal incidence response and low dark current [1]. However, the key issue is to obtain a high quality active region which requires a structural optimization of the nanostructures. With using GaAsSb capping layer, the optical properties, such as the PL intensity and its full width at half maximum (FWHM), of InAs QDs have been improved in the range between 1.15 and 1.5 μm, because of the reduction of the compressive strain in QDs and the increment of QD height [2]. In this work, we have demonstrated strong and narrow intraband photoresponse spectra from GaAsSb-capped InAs-based QDIPs.

The *n-i-n* QDIPs were grown on n^+ Si-doped (001) GaAs substrates using solid-source molecular beam epitaxy. As shown in Fig. 1 (a), the active region contains 20 periods of 16 ML-GaAsSb capped InAs QDs (2.5 ML) and separated by 50 nm-thick GaAs barrier layers. The dot density is 4.0 x 10^{10} cm^{-2} according to the atomic-force microscope (AFM) measurement, as shown in Fig. 1 (b). The δ-doping layer with carrier concentration of 1.6 x 10^{17} cm^{-3} and thickness of 2.5 nm, which is designed as 1 electron per dot, are located 2 nm below QD layer. The whole active region is sandwiched between top and bottom highly *n*-GaAs contact layers doped with Si to n = 2 x 10^{18} cm^{-3}. The samples were processed into mesa of 200 μm in diameter. A ring-shaped metallization using AuGe/Au was deposited on top of the mesas then alloyed for the ohmic contacts. InSn bottom contact was chosen as the ground in the all measurements.

Figure 2 shows the room temperature PL spectrum of the QDIP sample using He-Ne laser as an excitation source. The peak position is 1250 nm, at which PL spectrum is the narrowest as reported in Ref. 2. FWHM of the QDIP with 20 stacks is 61 meV, still comparable to the 1 QD-layer's PL FWHM of 40 meV, showing the small dot-size distribution among each layer.

The dark current-voltage (*I-V*) characteristics of the devices, shown in Fig. 3 (a) represent ohmic behavior under the voltage of +3, -2 V. Photoresponse of the QDIPs were taken at 12K by FTIR. Figure 3 (b) shows the intraband photoresponse spectrum under the forward bias of 2.5 V where a clear peak at the wavelength of 5.5 μm (equivalent to 225 meV) is observed. The spectral width is 1.8 μm and $\Delta\lambda/\lambda \sim 30$ %. This is to our knowledge the first observation of intraband response in GaAsSb based QDIP structures. The measured spectrum is stronger and narrower than that from GaAs-capped InAs-based QDIPs. This result indicates the feasibility of fabricating GaAsSb-capped InAs-based QDIPs and the better quality of this latter material system. We will show results on the dependence of photoresponse on Sb content in the capping layer.

References

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2. J. M. Ulloa, R. Gargallo-Caballero, M. Bozkurt, M. del Moral, A. Guzman, P. M. Koneraad, A. Hierro, Phys. Rev. B 81, 165305 (2010).

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Figures

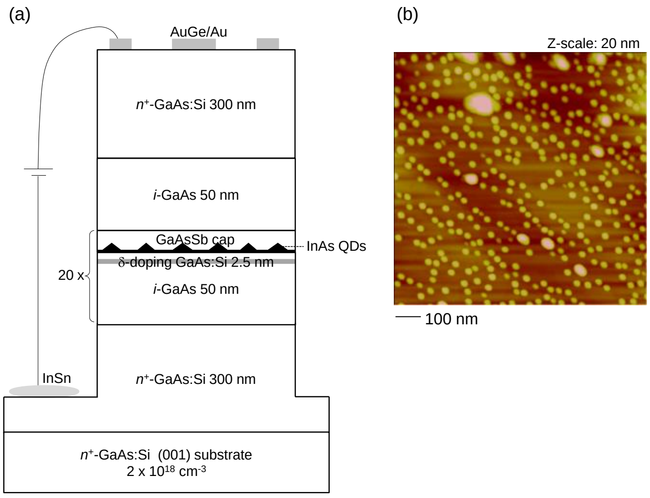

Fig. 1. (a) A schematic diagram of QDIPs composed of GaAsSb-capped InAs/GaAs QDs. (b) AFM-scanned QD image. The QD density is 4.0 x 10^{10} cm^{-2}. The height and diameter of the dots is 7.1 ± 1.9 nm and 22 ± 4 nm, respectively.

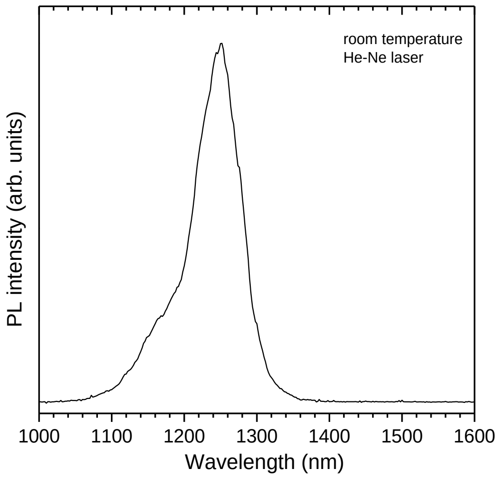

Fig. 2. Room temperature PL spectrum of the QDIPs.

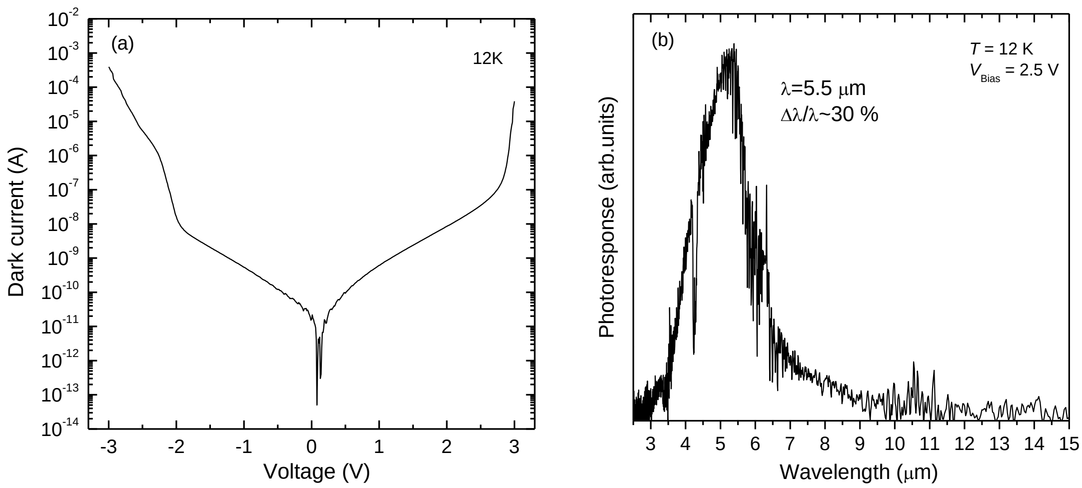

Fig. 3. (a) IV curve and (b) photoresponse spectrum of the QDIPs taken at 12K.