Abstract

Title: Optimisation of MOCVD growth of a heterostructure photodiode for high detectivity in the spectral range from 2 μm to 3.5 μm without cryogenic cooling.

Keywords: infrared, photodetectors, epitaxy, MOCVD, Mercury Cadmium Telluride

The scope of this work is the analysis and optimisation of HgCdTe heterostructures for high operating temperature (HOT) infrared photodetectors. A thesis was formulated:

High-temperature post-growth annealing results not only in compositional homogenization of MOCVD-grown HgCdTe but also in the reduction of trap states concentration. This will have a positive effect on the parameters of manufactured IR photodetectors.

The first chapter discusses the basic physical properties of HgCdTe, particularly those of interest to IR detection technology. The absorption coefficient, intrinsic concentration, carrier mobilities and effective masses, and the thermal generation process are presented. The material figure of merit α/G which defines the ratio of photon absorption and thermal generation is compared with other materials. The discussion then focuses on parameters of photodetectors such as quantum efficiency, dark current and signal-to-noise ratio. Various HgCdTe heterostructures of IR photodetectors are presented and thoroughly discussed.

The second chapter discusses selected aspects of HgCdTe growth by Metal Organic Chemical Vapour Deposition (MOCVD) including growth thermodynamics. Direct Alloy Growth (DAG) and Interdiffused Multilayer Process (IMP) are compared, with the latter being discussed in more detail as a method enabling better composition and doping control.

In the next chapter, Secondary Ion Mass Spectroscopy (SIMS) analysis was used to reveal residual inhomogeneities in epilayers grown by the IMP method. A post-growth annealing process was developed to ensure material homogenisation. As a result of annealing, material homogeneity and minority carrier lifetime have been significantly improved. Carrier transport studies, conducted using Hall effect measurements, revealed

that while the transport mechanisms remained unchanged, significant modification in the values of the electrical parameters were observed. After the annealing process, a reduction in residual donor doping, an increase in mobility and an increase in resistivity were measured. Low temperature photoluminescence measurements showed a significant reduction in trap states with a transition energy 22 meV below the energy band gap.

Post growth annealing was performed to grow the $N^+/\nu/p/P^+/n^+$ heterostructure. The effect of the thickness of the ν layer was investigated with the support of the numerical simulations. The optimum thickness was found to be 2.5 μm. Two small batches of 0.1 x 0.1 mm electrical area photodiodes were produced. The detector parameters were compared with archive data from VIGO Photonics. The resulting detectors exhibited significantly lower dark currents than previously fabricated detectors with an absorption edge of 3.5 μm. The tested heterostructures meet the requirements for use in photodiodes optimised for radiation detection in the 3.0-3.4 μm range. Studies showed that below the temperature of 210 K, the dark current density is lower than the estimated photocurrent from background radiation. It was stated that the main dark current mechanism is a diffusion current of carriers generated in the absorber. Further reduction of dark current could be achieved by reducing the doping in the absorber.

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