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Monolithic Multiple Wavelength Integration Using Quantum Well Intermixing

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Abstract

The ability to create multiple-wavelength chip with high spatial bandgap selectively across a III-V semiconductor wafer for monolithic photonic integration using a simple postgrowth bandgap engineering process such as quantum well intermixing (QWI) is highly advantageous and desired. Preferably, this process should not result in drastic change in both optical and electrical properties of the processed material. In addition, the process should also give high reproducibility to both lattice-matched and strained quantum well (QW) structures. In this paper, we report a new method that meets these requirements. This process is based on the low energy, neutral species impurity induced QWI technique reported elsewhere [1]. However, here, a pre-QWI annealing cycle performed at below the QWI activation energy of the material was introduced to reduce the localized point defect density, hence reducing the complex and defect cluster formation during high temperature annleaing. Prior to QWI, the samples were pre-annealed at 600 °C for 20min. Subsequently the annealing temperature was ramped up 700 °C and stayed constant for 120s for QWI. Blue bandgap shift of over 140 nm relative to the as grown and control samples has been obtained from both lattice-matched and strained InGaAs-InGaAsP laser structures. Compared to the as-grown lasers, an improvement in threshold current density has been observed from broad area lasers fabricated from the InGaAs-InGaAsP strained QW samples shifted to different degrees (Fig. 1). This result indicates that the quality of the processed material has been significantly improved after intermixing.

To demonstrate the integration capability using this process technology, optically amplified photodetectors (PDs) have been fabricated on a tensilely strained InGaAs-InGaAsP structure. This integrated device consists of semiconductor optical amplifier (SOA), low loss passive waveguide and p-i-n waveguide PD. A sensitivity of –25dB, polarization dependent loss as low as 1.5dB, dark current 100nA, and bandwidth 8GHz and gain of 10 at wavelength 1580nm have been measured from devices with SOA and PD lengths of 300µm and 80µm respectively (Fig. 2).

Using similar process technology, 8-channel spectrometers consist of an input tapered waveguide, Echelle grating, and PD array have been demonstrated. This compact integrated spectrometer, which can be used as optical performance monitor, gave a dark current of 17nA, responsivity of ~0.02mA/mW/Channel, and signal to noise ratio of ~-25dB (Fig. 3).

Other integrated devices fabricated using this QWI process such as multiple wavelength laser chips, integrated high-speed waveguide detector will also be discussed in this discussed in the paper.

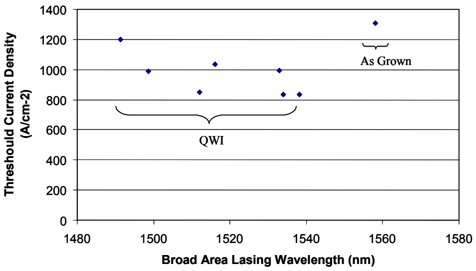

Fig. 1: Threshold current density as a function of lasing wavelength from broad area lasers fabricated from InGaAs-InGaAs strained QW structures.

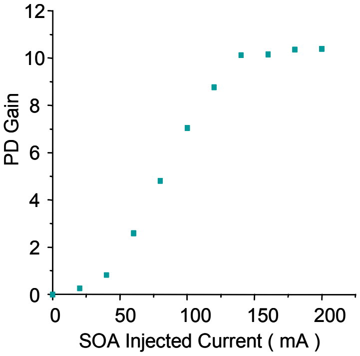

Fig. 2: Photodector gain as a function of SOA injected current for optically amplified photodetector. The lengths of the PD and SOA are 80µm and 300µm respectively.

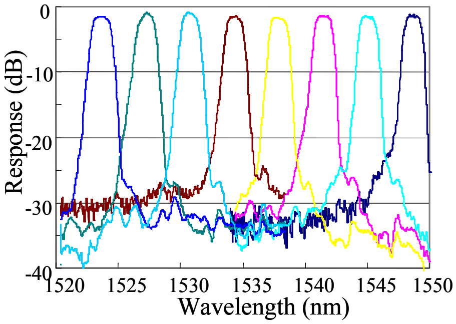

Fig. 3: Response spectra from the 8-channel optical spectrometer.

References

[1] V. Aimez, J. Beauvais, J. Beerens, D. Morris, H.S. Lim, B.S. Ooi, *IEEE J. Select. Topics Quantum Electron.*, **8**, 870 (2002)