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Broadband Light Emission from InP Based Nanostructures using MOVPE

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Abstract: A novel nanostructured material embedded in a p-n diode structure is introduced. Excellent diode characteristics and a broadband emission spectrum with full width at half maximum of 220 nm centered around 1480 nm are measured

1. Introduction

Broadband light sources are highly desired for different applications such as optical communications, imaging and sensing, and especially for noninvasive health monitoring. The 1500 nm wavelength range is particularly useful [1], which benefits from the use of InP substrates as a well-established technology platform. The emission bandwidth of quantum well (QW) structures is limited to 50 nm and the common solution to extending the emission bandwidth is through the use of quantum dot (QD) structures. While molecular beam epitaxy (MBE) is the usual way to grow QDs [2], it is of great interest to use the industrially relevant metal organic vapour phase epitaxy (MOVPE) technique. In previous work, we have found that the MOVPE growth of a few monolayers of InP on lattice-matched AlInAs can result in a wide variety of Volmer-Weber induced interfacial nanostructure morphologies, including QDs, details of which depend on the growth conditions and, in general, only partially cover the underlying AlInAs layer even after several nanometers of growth. In an extension of that work, we have investigated the effects of the inclusion of a layer of (thin) InGaAs just after the nanostructured InP on AlInAs, followed by AlInAs capping. The resulting combination of, in part, InP dissolution after InGaAs deposition, together with the InGaAs segregation around the nm tall InP self-patterned aggregated nanostructures [3], resulted in novel (disordered) low bandgap layer(s) which could be exploited as the active material within a p-n junction to realise a broadband light source in the 1480 nm range.

2. Epitaxial Design, growth and device fabrication

An active region of 10 repeats of (20 nm AlInAs/ 0.75 nm InP/2 nm InGaAs/5 nm AlInAs/ 0.75 nm InP/2 nm InGaAs) was clad by $(Al_{0.59}Ga_{0.41})_{0.47}In_{0.53}As$ (100 nm / 220 nm) and by 200 nm of AlInAs on the p-side of the junction surrounded by p and n-type InP to make a diode structure. We experimented with structures where with the active region is partly p- and n- doped. Preliminary photoluminescence data (not shown) on calibration samples showed that the active layer so designed presented a broad emission over a few hundreds of nanometers, as expected by the implemented disorder growth process. To characterize the properties of material, circular mesa diodes with full and annular metal contacts with a range of diameters were fabricated.

3. Experimental results and discussion

The current density (J) with applied voltage and light output with current (LI) are shown in Fig. 1 (a) and (b) respectively. The current-voltage (IV) measurements for the devices indicate a high performing diode, with dark current remaining less than 10 nA at -2 V for 1 mm diameter mesa devices, and an electrical ideality factor of 1.54 between 0.4 - 0.6 V. The low dark current suggests low defect density, particularly in the active region. The current density depends on mesa diameter below 0.6 V due to sidewall leakage, indicating the nanostructures are not independent. The light output shows promising amount of received power, especially when compared to a conventional AlInGaAs 10 QW structure, as measured with a numerical aperture of 0.3. The photoluminescence (PL), absorption at 0 V, and absorption with voltage are shown in Fig. 2. The absorption spectrum was taken with a 1 mm diameter device by surface-normal illumination and measuring the photocurrent response. The response shows a very long absorption tail when compared to conventional QW material. The PL spectrum is also much wider than a conventional QW structure, with a peak at 1492 nm. The electro-luminesce (EL) measurements show broadband emission from the stacked nanostructures covering 210 nm at full width half maximum (FWHM) with a peak at 1478 nm, potentially providing a wide gain bandwidth.

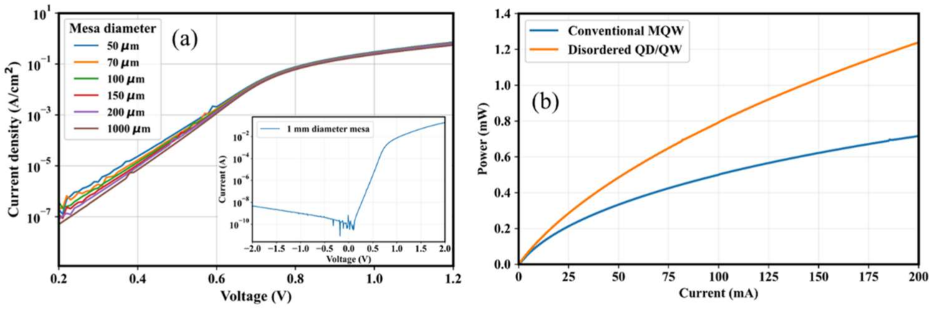

Fig. 1. (a) Current density with voltage for varying mesa device sizes, inset is IV for 1 mm diameter mesa device, (b) Power with applied current from top of uncoated mesa with annular contact.

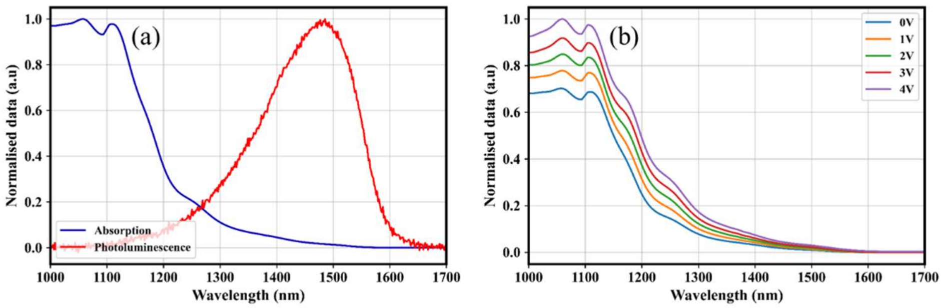

Fig. 2. (a) Normalised absorption spectrum at 0 V and PL of material, (b) Relative responsivity versus reverse bias.

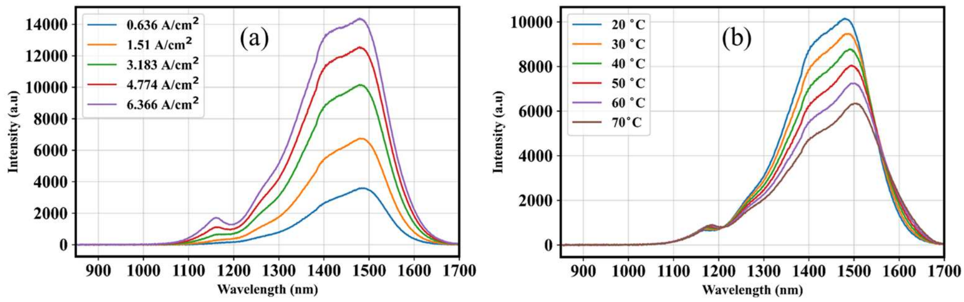

Fig. 3. (a) EL at different current densities, (b) EL variation from 20 to 70 ˚C at 3.183 A/cm^2.

4. Summary

We demonstrated a novel material structure that has broadband emission characteristics, making it suitable as an LED for a broadband source, emitting light from the O to L bands. The material shows over 200 nm FWHM. This material could also be a suitable medium for other light emitting and absorbing devices, which are being actively pursued.

Acknowledgements

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References

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