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MID–infrared light emitting diode based on InGaAsSb/AlGaAsSb quantum well for gas sensor applications

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ABSTRACT

In this study, we present the device performance of dual color infrared light emitting diode (IR–LED) based on InGaAsSb/AlGaAsSb quantum well structure. The LED sample was grown on *n*–type GaSb substrate using the molecular beam (MBE) with As_2 and Sb_2 cracker cells. The active layer of device structure consists of three different quantum well widths (5, 10 and 15 nm) of InGaAsSb and a 200 nm thick $Al_{0.35}Ga_{0.65}As_{0.03}Sb_{0.97}$ barrier. The structural and electrical characterization of LED sample was measured by high–resolution X–ray diffractometer (HR–XRD) and current–voltages (I–V). The LED sample was processed by the conventional photolithographic technique. By using the e–beam evaporation system, ohmic contact was formed on the *p*– and *n*–type of the layer. The electroluminescence (EL) of the device was observed 1.94 and 2.1 ㎛ at room temperature.

KEYWORDS: Infrared LED, Gas detection, MBE growth, InGaAsSb

1. INTRODUCTION

The future of the role of infrared sensor technology to gas detection application (1.6–2.6 ㎛ wavelength) in the world is limitless[1-2]. Especially, the gas sensors need to precisely, fast selective and stabilizing time, multi–detections, and low power consumption, non–dispersive infrared and friendly environments. Currently, sseveral research group are looking at various ways to develop this technology for enhancing the performance, improving the capability of these systems to each purpose [2]. They have used various structures such as photodiodes (PD), light source/ detector (LED/PD) pair. Material systems have used to grow such predominantly based on type–II InAs/GaSb superlattice (T2SL), mercury cadmium telluride (MCT) and extended indium gallium arsenide (InGaAs) and quaternary InGaAsSb materials [3]. Among them, the InGaAsSb material system have been developed for IR–LED and PD. There is a dual color LED set of LED/PD module instead of two LEDs. At same injection current, measuring LED (λ_1) acts as emitting radiation at wavelength corresponding to the maximum absorption of the analyte and reference LED (λ_2) emits at wavelength that is not absorbed by the analyte. Signal difference between the measuring LED that is partially absorbed in the optical cell and the reference LED is proportional to the concentration of the analyte.

2. EXPERIMENTAL

The structural dual color IR–LED sample was grown on *n*–type GaSb substrate using the molecular beam epitaxy (MBE). The structural quality and composition of each of epi–layers were investigated using the HR–XRD technique. The spectral electroluminescence was measured by the Nicholet 570 Fourier transform infrared spectrometer (FTIR) using a calibrated HgCdTe detector at room temperature.

2.1 MBE GROWTH OF DUAL COLOR IR–LED

A *n* type GaSb was used as substrate for dual color IR–LED structure with an As_2 and Sb_2 valve cracker sources. An active layer of structure consists of three different quantum well widths (5, 10 and 15 nm) of InGaAsSb and a 200 nm thick $Al_{0.35}Ga_{0.65}As_{0.03}Sb_{0.97}$ barrier. The cladding layers of $Al_{0.9}Ga_{0.1}As_{0.08}Sb_{0.92}$ were grown on top and bottom of active layer. The device structure consist of a 500 nm thick *p*–type ($1x10^{18}$ cm^{-3}) and 300 nm thick *n*–type GaSb

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for top contact layer and buffer layer, respectively. The structural quality of device were determined by HR-XRD. The result indicated that the epi layers of LED structure was latticed match to the GaSb substrate.

2.2 DEVICE FABRICATION AND CHARACTERIZATION

For LED device fabricate process, *n*–GaSb substrate was lapped and polished to a final thickness of 200 ㎛ to roughness as 12 nm. Standard photolithography techniques used to fabricate a 230 ㎛ of external and a 200 ㎛ of inner contact (inserted in Fig. 2(a)). Then circular contact layer were formed by deposition of Ti (30 nm)/Pt (40 nm)/Au (300 nm) and Ni (5 nm)/Ge (17 nm)/Au (500 nm) for the *n*–and *p*–contact, respectively. Subsequently, the rapid thermal annealing at 330 °C for 1 min, the contact annealing was performed to ohmic contact of device. The LED chips were mounted onto TO–18 package for the characteristic measurement. The spectral electroluminescence of LED device was measured by a Fourier–transform infrared spectrometer using a calibrated HgCdTe detector under different injection currents at RT. The EL peaks observed at 1.94 and 2.1 ㎛ emission at RT (Fig. 2(b)), which is suitable for moisture and C_2H_4 gas detection applications.

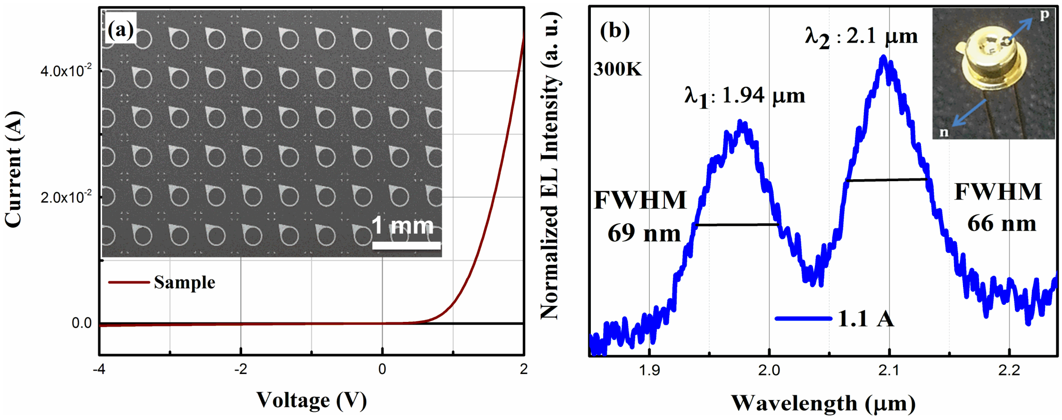

Fig. 1 (a) *I–V* characteristic of a single dual color IR–LED device, (b) Electroluminescence spectra of dual color IR–LED at 1.1A of injection current.

3. CONCLUSIONS

We designed the dual color IR–LED based on different InGaAsSb/AlGaAsSb quantum well widths grown lattice matched to GaSb substrate. The HR–XRD result and I–V characterization indicated structural growth and fabrication processing that was ensured for high carrier injection (J_{ic}) into active region. At 1.1 A of J_{ic}, the electroluminescence spectrum observed at 1.94 and 2.1 ㎛ wavelength at RT that result is a promising candidate for gas detection application.

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