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High Brightness and Crack-free InGaN/GaN Light Emitting Diode With AlGaN Buffer Layer On Si (111)

Y. P. Hsu[1], S. J. Chang[1], Y. K. Su[1], W. S. Chen[1], J. K. Sheu[2], J. Y. Chu[2], and C. T. Kuo[3]

[1]Institute of Microelectronics & Department of Electrical Engineering
National Cheng Kung University, No. 1, University Road Tainan, 70101, Taiwan.
Phone: +886-6-2757575 E-mail:changsj@mail.ncku.edu.tw
[2]Institute of Electro-Optical Science and Engineering
National Cheng Kung University, No. 1, University Road Tainan, 70101, Taiwan.
[3]Epitech Technology Corporation, Hsin-Shi 744, Taiwan

1. Introduction

With a wide bandgap energy varying from 0.7eV for InN to 6.3eV for AlN, group III-nitrides are highly promising for the light-emitting diode (LED) applications in the wavelength range from green to ultraviolet [1-2]. Commercially available devices such as light emitting diodes (LEDs) are usually grown by metalorganic chemical vapor deposition (MOCVD) on sapphire or SiC substrates due to the lack of large and expensive GaN substrates. Compared to these substrates, Si offers the advantage of a lower cost, good electrical and thermal conductivity, and availability up to 12" in diameter, but with the disadvantage of large thermal mismatch (56%) and lattice mismatch (17%) between Si and GaN lead to the formation of cracks when the thickness of GaN epilayer exceeds a critical value. Thus, it is difficult to fabricate heterostructure devices on thick GaN films grown on Si substrate. In this paper, we have successfully fabricated high brightness and crack-free light emitting diode (LED). Room temperature electroluminescence (EL) characteristics were the measured by injecting different amount of DC currents into the fabricated LEDs on wafer with polishing and package. The current-voltage (I-V) measurements were also performed at room temperature by an HP4156 semiconductor parameter analyzer. The output powers were measured with the integrated sphere detector.

2. Experiment

The samples used in this study were all grown on Si (111) substrate in a vertical D180 MOCVD system. During the growth, trimethylalummum (TMAl), trimethylgallium (TMGa), Trimethyindium (TMIn) and ammonia (NH3) were used as aluminum, gallium, indium, and nitrogen sources, respectively. Biscyclopentadienyl magnesium (CP2Mg) and disilane (Si2H6) were used as the p- and n-type doping sources, respectively. After process, these chips were then encapsulated with epoxy and packaged into LED lamps.

3. Results and discussion

Figure 1. shows that the total GaN on Si substrate LED structure. Amano et al.[3] have demonstrated that the insertion of low-temperature (LT) AlN interlayers between high-temperature (HT) GaN layers reduces the stress, improves the layer quality and allows for the growth of thick, strained AlGaN layers onGaN/sapphire. As has been shown by Dadgar et al.[4] these benefits of the insertion of LT-AlN interlayers are also valid for the growth of GaN on Si. We also used two LT-AlN interlayers to grow crack-free GaN LED. According to the cross-section view of TEM, the thickness of total GaN on Si LED is about 1.4 μ m.

Figure 2 shows the spectra measured with varied DC current injection for the horizontal GaN LED on Si substrate. The spectra intensity of LED increased with the increasing injection current.

Figure 3 shows I-V characteristics of InGaN/GaN LEDs on Si substrate with vertical and horizontal LEDs. With a 20mA current injection, it can be seen that the LED forward voltage was 3.5V and 4.8V for horizontal and vertical LEDs, respectively. Such a result suggests that high series resistance of vertical LED device was due to difficult Si-doped in HT-AlN layer.

Figure 4 shows intensity-current (L-I) characteristics of GaN LED on Si substrate with horizontal LED. It was found that the output power of GaN LED on Si substrate increase as a function of injection current. It was also found that the 20mA output power was about 1.5mW for horizontal GaN on Si LED.

4. Summary

In summary, low cost, high brightness and crack-free GaN light emitting diodes on Si substrate were demonstrated with forward voltage 3.5V and output power of 1.5mW for horizontal LED device. We also showed that forward voltage of vertical LED on Si substrate was about 4.8V.

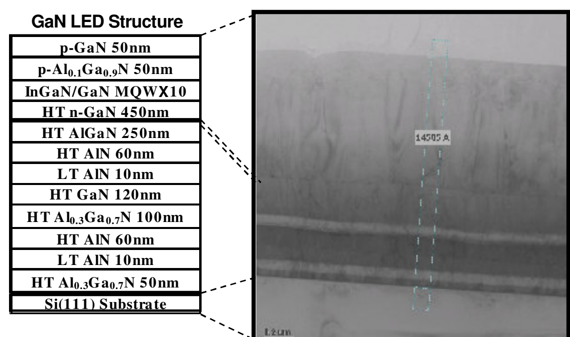

Figure 1

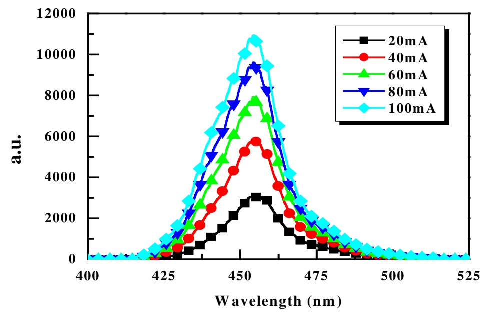

Figure 2

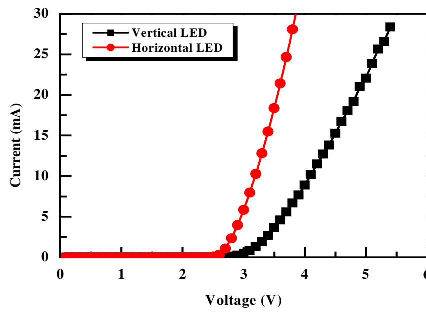

Figure 3

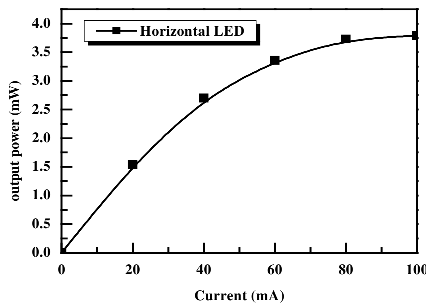

Figure 4

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