Development of Reclaiming Pattern Sapphire Substrates Technologies for GaN-Based LEDs

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1. Introduction

The high-brightness GaN-based light-emitting diodes (LEDs) have developed quite maturity in the group III-nitrides. It's mainly application for the illumination markets in the future. However, the LED bulb is still too high a price. Reduction of manufacture costs is one of the essential factors. The sapphire substrate prices possess a 50 % of the epitaxy production costs. For these reasons, it's important for reclaiming substrates from a wafer-scrap of the LED epitaxial procedures. The chemical mechanical polishing (CMP) is most common methods for reclaiming substrates. However, its disadvantage includes the workmanship complication, the surface scrape and thickness variations of a substrate-reclaimed. Therefore, we study a thermal dissociation technique to avoid the above disadvantage. In this paper, the performance and characterization of a re-growth GaN-based LED on reclaimed-pattern sapphire substrate (PSS) will be discussed.

2. Experimental

The sample in this research used the InGaN-based LEDs structure on PSS by metalorganic chemical vapor deposition system. The growth conditions of the LED epitaxial structures were the standard method for producing InGaN-based epilayers. The sample was then annealed from 800 to 1200 °C in a furnace under hydrogen ambient at 90 minutes. Residual substances of a sample surface were removed using the wet etching procedure in order to obtain the clean surface of a reclaimed-PSS. The next step, the GaN epilayers was re-grew on this reclaimed-PSS. A re-growth GaN-based LED with a chip size of 10×24 mil^2 on reclaimed-PSS and original-PSS was finished by the standard chip processes.

3. Results and discussion

Scanning electron microscope (SEM) photographs of the original epilayers with and without annealed at 90 min for the different temperatures from 800 to 1200 °C were shown in Fig. 1. A chasmy surface morphology of the original epilayers is shown in Fig. 1 (a). This is due to that the sample is a wafer-scrap from the LED epitaxial processes. The surface shapes from Fig. 1(a) to (d) reveal the GaN film morphologies depend on the annealed temperature. For the original epilayers annealed in temperature up to 800 °C at hydrogen ambient, the GaN film was began to change surface morphology as Fig. 1 (b). The original epilayers annealed at 1000 °C (Fig. 1c) shows partial sublimation of a GaN (white areas) film and a surface of an exposed PSS. Relative to Fig. 1(c), a GaN film of Fig. 1 (d) is nearly complete sublimation with only the PSS (black area) remaining. These results indicated that the sublimation rate rises with the annealed temperature increases. The phenomenon corresponds with the demonstration as in [1]. X-ray diffraction (XRD) spectra of the original epilayers with and without annealed at 800 °C, 1000 °C, and 1200 °C are also shown in Fig. 2. The original epilayers shows a GaN (002) peak located at around 34.6 degree, and a sapphire (001) phase at around 41.6 degree is also appear in this inset. The XRD spectra of the original epilayers with annealed have not GaN (002) phase compare with the original epilayers without annealed. This exhibits the GaN film is not already single crystal structure after high temperature procedure. Furthermore, the XRD spectrum of the original epilayers with annealed at 800 °C have the sharp GaN (103) peak located at around 63.6 degree. The GaN (103) peak is disappearance when the annealed temperature up to 1200 °C. This result could be attributed to the GaN film is nearly complete sublimation. Under an injection current of 20 mA, the GaN on reclaimed-PSS and original-PSS were determined 3.18 and 3.16 V, respectively. The output power of the both kinds of LEDs is similar as the injection current from 10 to 100 mA.

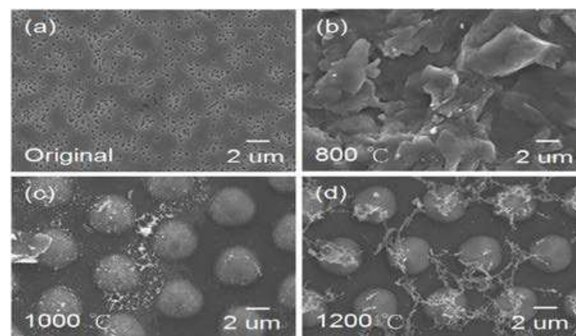

Fig. 1. Plane-view SEM micrographs of the original epilayers with and without annealed at 800 °C, 1000 °C, and 1200 °C.

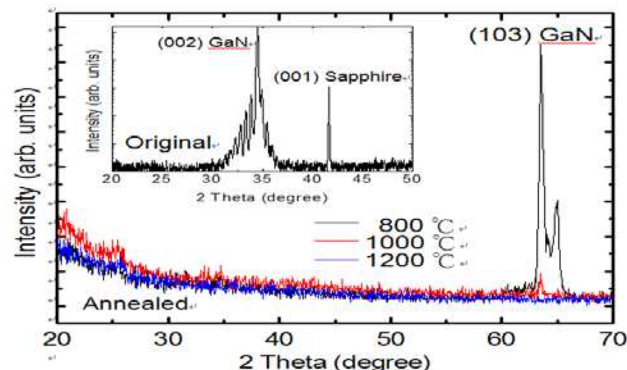

Fig. 2. XRD spectra of the original epilayers with and without annealed at different annealing temperatures from 800 to 1200 °C.

4. Conclusion

A method of reclaiming PSS from a GaN-based LED wafer is provided by thermal decomposition techniques. The composition and morphology of a GaN film for 1200 °C annealed under hydrogen ambient at 90 minutes indicate that the GaN film is nearly complete sublimation. The optical and electrical properties for both kinds of LEDs were correspondence for each other. These uniform performances demonstrated that the reclaiming procedures have not degraded the quality of the re-growth GaN-based LEDs. The results confirmed that the reclaiming techniques are excellent in reclaiming substrates applications.

Acknowledgment

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References

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