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Enhancement Performance of GaN-based Light-emitting Diodes by Modified Patterned Sapphire Surface

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The PSSs were fabricated by wet etching. Compared with the platform-PSS, the modified-PSS was still capped with a layer on the top platform after wet etching. The output power of the platform-PSS LED and modified-PSS are 27.3 mW and 29 mW, respectively, at an injection current of 20 mA. The output power of the modified-PSS LED is enhanced 6% compared with the platform-PSS. The results reveal that both electrical properties and optical properties of modified-PSS LED were improved.

Introduction

GaN-based light-emitting diodes (LEDs) have been wildly developed for improving the internal quantum efficiency (IQE) and the light extraction efficiency (LEE) and wide range application for traffic lights, outdoor displays, and so on. Currently, the patterned sapphire substrate (PSS)[1-4] has attracted much attention for advanced LED. Because of PSS technique can improve both IQE and LEE.

In this study, a Platform-PSS (PPSS) and a Modified-PSS (MPSS) were prepared by wet etching and growing GaN-based LEDs on top of them. The pattern morphologic and epilayers quality of the InGaN/GaN-LED were systematically investigated. To verify the **GaN-based LED performance effects of the PPSS and MPSS.**

Experimental

Sapphire substrates (2-inch in diameter and 430μm in thickness) were used in this study. A thin film was deposited on sapphire substrates. Then, the circular photoresist array with a 2μm diameter and 2.5μm spacing was defined by the standard photolithography on thin film. The thin film was etched to form pattern as the wet-etching hard mask. The samples were etched in hot H_3PO_4-based solutions[5-6]. Compared with the platform-PSS (PPSS), the modified-PSS (MPSS) was still capped with a thin film on the top platform, as shown in Fig. 1. Scanning electron microscopy (SEM) was used to determine the etching depths of patterned sapphire substrates. After the cleaning process, the LED structure was grown on the PSS by metal-organic chemical vapor deposition. The LED structures contained a buffer layer, a undoped-GaN layer, a *n*-GaN layer, a Si-doped AlGaN cladding layer, an InGaN-GaN multiple quantum well (MQW) with emission wavelength in the blue region (440 nm), a Mg-doped AlGaN cladding layer and a *p*-GaN layer.

The device mesa with chip size of 300 × 300 μ m^2 was defined by a standard photolithographic process and was partially etched until the n-GaN was exposure. After annealed at 600 °C for 10 min, the indium tin oxide (ITO) layer was deposited to form a

p-side contact layer and a current spreading layer. The Cr/Au layer was deposited onto the ITO layer to form the *p*-side and *n*-side electrodes.

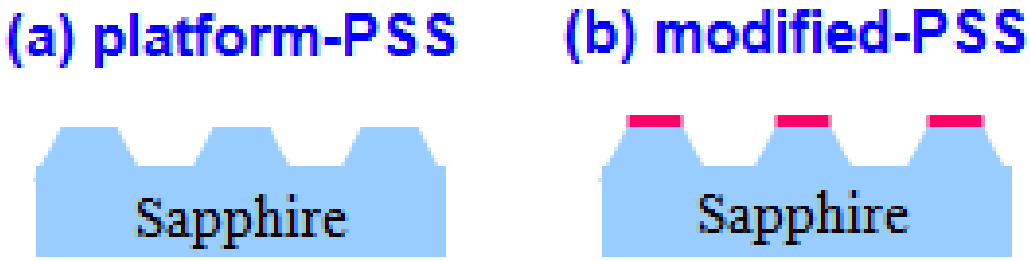

Figure 1. Diagrams of the various PSSs: (a) PPSS and (b) MPSS.

Results and Discussion

The XRD FWHM results that (002) and (102) of the MPSS were 279.5 arsec and 314.9 arsec, respectively. The XRD results revealed that both of GaN (002) and GaN (102) were improved for the crystal quality of MPSS, as shown in table I. The PL results show that FWHM of the MPSS and the PPSS are 24.1nm and 27.3nm, respectively. Moreover, the peak height of the MPSS was 1.13 times higher than that of PPSS, as shown in table I. Crystal quality and optical properties were both improved for the MPSS. We found top platform of MPSS didn't grow GaN, but top platform of PPSS did. The top platform area of the MPSS was grown by ELOG mechanism. In other words, ELOG area of MPSS was larger than PPSS. As a result, the crystal quality of MPSS was improved. Finally, the output power of the MPSS LED was enhanced 6% compared with the PPSS. The LED output power of the PPSS and MPSS were 27.3 mW and 29 mW, respectively, at an injection current of 20 mA, as displayed in table I.

TABLE I. The PSS-LEDs performances.

	XRD FWHM (arcsec)		PL		LED
	(002)	(102)	Height (a.u.)	FWHM (nm)	Output power(mW)
PPSS	295.0	333.0	64030.8	27.3	27.3
MPSS	279.5	314.9	72535.7	24.1	29.0

Conclusion

Both of electrical properties and optical properties were improved for the MPSS LED. The XRD FWHM show that GaN (002) and GaN (102) were both lower than those of PPSS. The FWHM and height of PL of the MPSS LED were improved. Furthermore, electrical properties and optical properties were both improved for the MPSS LED. The output power of the modified-PSS LED is enhanced 6% compared with the PPSS. The LED output power of the platform-PSS and modified-PSS are 27.3 mW and 29 mW, respectively, at an injection current of 20 mA.

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