Study of Mg doping profile in the p-cladding layer for high-brightness AlGaInP-based light emitting diodes

Hwa Sub Oh[1,2], Ho Soung Ryu[1], Hyung Joo Lee[2], Young Jin Kim[2], and Jong Hyeob Baek[1,*]

[1]Korea Photonics Technology Institute, Korea
[2] AUK Incorporation, Korea

Recently, AlGaInP-based light-emitting diodes (LEDs) have experienced an impressive evolution in both device performance and market volume. In particular, high-brightness LEDs are gaining interest for use in commercial applications such as automotive lighting, full-color displays, and general illumination. To increase their utility in these applications, improved performance such as shorter wavelengths and high-powered devices have been pursued.[1,2] However, $(Al_xGa_{1-x})_{0.5}In_{0.5}P$ heterostructures have a small conduction band offset that limits their electron confining potential. This weaker electron confinement subsequently leads to electron heterobarrier leakage in AlGaInP heterostructure LEDs, especially in short-wavelength devices, where a fraction of the electrons injected into the active region have a sufficient thermal energy to escape into the p-cladding layer. To overcome this problem, AlGaInP-based LED structures require an optimized doping profile in the p-cladding layer in order to prevent carrier overflow and to gain a higher light output power (P_{out}). In the field of AlGaInP-based LEDs that emit a short peak wavelength at around 590 nm, however, the effects of the doping profile in the p-cladding layer on LED performance has yet to be systematically studied.

In this study, we investigate the behaviors of electrical and optical characteristics according to their Mg doping profile in the p-cladding layer by analyzing device performances.

Figure 1 presents the typical current-voltage (I-V) characteristics and light output power (P_{out}) of LEDs having different Mg doping profiles in the p-cladding layer. The I-V characteristics in the "b" zone in the p-cladding layer show similar behaviors regardless of the p-doping concentration. These data indicate that the Mg doping level in the "b" zone is not significantly affected by the operating voltage, in terms of device performance.

Figure 1(b) then shows the light output-current characteristics of LEDs having different Mg doping levels in the "b" zone. In addition, the relative increase of P_{out} (RIP) of the same LEDs at a 200 mA operating current is shown in the figure inset. As the $[Cp_2Mg]/[III]$ value in the "b" zone is increased from 1.0×10^{-4} to 3.0×10^{-4}, the RIP increases from 1.0 to 1.4, though at a further increase of $[Cp_2Mg]/[III]$ to 5.0×10^{-4}, the RIP degrades to 1.3.

The improvement of internal quantum efficiency is due to the fact that the highly p-doped "b" zone increases the potential barrier in the p-cladding layer, which minimizes the electron overflow problem, and the improved hole conductivity helps to enhance the hole injection into the active region.[3] The RIP decrease in the Test 4 LED structure indicates that the excess $[Cp_2Mg]/[III]$ deteriorates the internal quantum efficiency. As such, it is important to optimize the $[Cp_2Mg]/[III]$ value in the p-cladding layer in order to improve the light output power.

Acknowledgment

This work was supported by a Korea Research Foundation Grant from the ATC project (No. 10035863) provided by the Ministry of Knowledge Economy, Korea.

References

1. J. W. Seo, H. S. Oh, J. S. Kwak, H. D. Song, K. W. Park, D. H. Park, S. W. Ryu, and Y. H. Park, J. Korean Phys. Soc. 55, 314 (2009).
2. H. S. Oh, S. M. Kim, J. H. Joo, J. H. Baek, and J. S. Kwak, J. Nanosci. Nanotechnol. 11, 1503 (2011).
3. P. Blood, Mat. Sci. Eng. B66, 174 (1999).

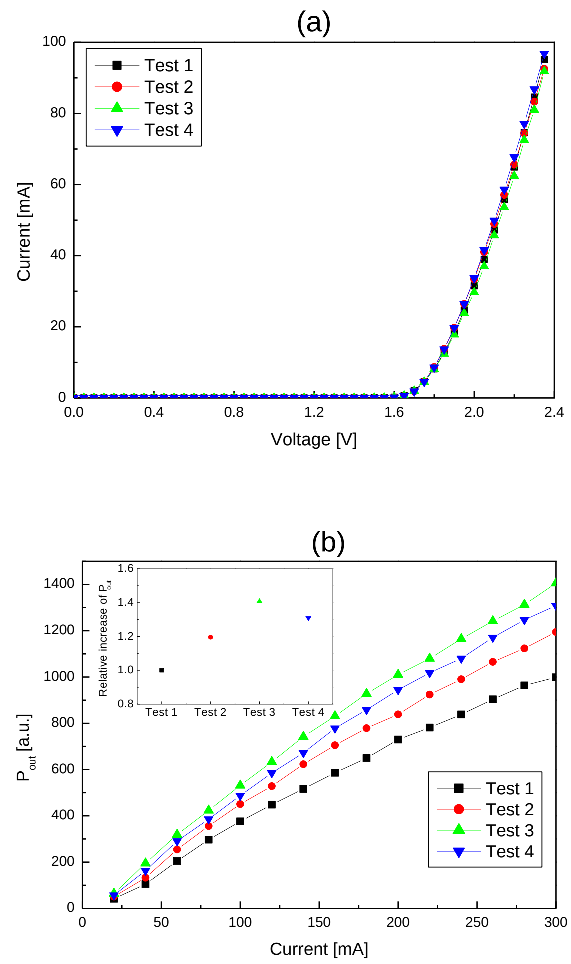

Figure 1. (a) Forward I-V characteristics and (b) light output power of LEDs having different Mg doping profiles in the p-cladding layer. The inset in (b) shows the relative increase of brightness for the same LEDs.