

# The Latest Progress of Nitride-based Visible LEDs and Laser Diodes: Nonpolar and Semipolar Devices vs. Polar (C-plane) Devices

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## INTRODUCTION

Maruska and Tietjen did the first GaN growth by using hydride vapor phase epitaxy in 1969. Since their first GaN growth, a lot of technical breakthroughs have been achieved for the crystal growth of GaN and InGaN, conductivity control of p-type GaN, and the structures of LED and laser diodes. Then finally, high-brightness blue LEDs were developed in 1993.

Since first high-brightness blue c-plane LEDs grown on sapphire were developed in 1993, these LEDs have been used for all kinds of applications, such as display, lighting and others. We name these c-plane LEDs grown on sapphire and SiC substrate as 1st generation LEDs. These c-plane LEDs have been operated at a low current density due to an efficiency droop problem. Recently, nonpolar and semipolar LEDs have been developed using GaN substrates. We like to name these LEDs grown on GaN substrates as 2nd generation LEDs because these LEDs have superior characteristics in the view of the wavelength stability, efficiency droop and others.

First c-plane violet laser diodes (LDs) were developed in 1995. Then, those violet LDs have been used for the Blue-Ray DVDs. Blue and green LDs were developed using c-plane GaN substrates later. We like to name these c-plane LDs as the 1st generation LDs. Recently, violet, blue and green semipolar LDs were developed. In 2012, Sumitomo Electric Inc., and Sony Corporation announced high power and high wall plug efficiency semipolar (20-21) pure green LDs at a wavelength of 525 nm, which value of the output power and the wall plug efficiency were more than two times higher than those of conventional c-plane green LDs. First nonpolar vertical cavity surface emitting laser (VCSEL) diodes which polarization locked along a-axis were developed by our group as shown in figures. We like to name these nonpolar and semipolar LDs as 2nd generation LDs.

## ACRONYMS

- LD: Laser diode
- LED: Light emitting diode
- VCSEL: vertical cavity surface emitting laser



