ISETC2025

UNIVERSITI TEKNOLOGI MARA

ISETC2025

2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM



THE POWER OF SCIENTIFIC INNOVATION

INTELLIGENT SOLUTIONS FOR A SUSTAINABLE WORLD

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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
Ms. Rozaina Saleh

ISETC 2025 Proceedings Editors

THERMAL INFLUENCE ON QUANTUM EFFICIENCIES AND DROOP BEHAVIOR OF AlGaN-BASED DUV-LED

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Abstract: This study investigates the temperature-dependent performance of AlGaN-based deep-ultraviolet light-emitting diodes (DUV-LEDs) emitting at 242 nm, using one-dimensional drift-diffusion simulations. Five device structures were analyzed across a temperature range of 0 °C to 200 °C to evaluate carrier distribution, radiative recombination rates, and efficiency characteristics. Results show that increasing temperature enhances carrier injection and radiative recombination, leading to higher internal and external quantum efficiencies (IQE and EQE), along with a significant reduction in efficiency droop. However, a trade-off is observed, as the maximum IQE and EQE slightly decline at elevated temperatures. These findings highlight the critical role of thermal effects in optimizing the efficiency and stability of DUV-LEDs under high-current operation.

Keywords**:** *Thermal effect, deep-ultraviolet light-emitting diode, AlGaN, carrier distribution, internal quantum efficiency*

INTRODUCTION

Deep-ultraviolet light-emitting diodes (DUV-LEDs), typically based on AlGaN semiconductor materials, have gained considerable attention for applications in sterilization, water purification, and optical communication due to their compact size, energy efficiency, and environmental safety compared to mercury-based sources (Kneissl et al., 2019). Despite significant advancements, studies investigating the relationship between efficiency droop and temperature in DUV-LEDs, particularly those emitting at wavelengths below 250 nm, remain scarce, limiting the understanding needed to optimize performance under thermal stress. In this study, five DUV-LED structures were simulated with operating temperatures ranging from 0 °C to 200 °C. Carrier concentrations and radiative recombination rates were analyzed, and the corresponding device internal (IQE) and external (EQE) quantum efficiencies were computed to investigate the effects of temperature on DUV-LED performance.

THEORY AND CONFIGURATION PARAMETERS

The simulations were performed using the one-dimensional drift-diffusion carrier concentration (1D-DDCC) software developed by Prof. Yuh-Renn Wu. This tool employs the drift-diffusion model (DDM), which self-consistently solves the coupled current density, carrier continuity, and Poisson's equations to obtain the spatial distributions of carrier concentrations and Fermi potential. Carrier mobility in the AlGaN-based semiconductor layers was calculated using the Caughey–Thomas empirical model. For the computation of EQE, the light extraction efficiency at UVC wavelengths below 250 nm was assumed to be 3% (Guttmann et al., 2019).

The DUV-LED structures were simulated on an AlN substrate, followed by a 2.5 μm AlGaN buffer layer and a 1 μm n-$Al_{0.80}Ga_{0.20}N$ electron injection layer (EIL) doped with 5×10^{18} cm^{-3} Si. The active region consists of a single 4 nm $Al_{0.70}Ga_{0.30}N$ quantum well (QW) sandwiched between two 12 nm $Al_{0.75}Ga_{0.25}N$ quantum barrier (QB). A 20 nm p-$Al_{0.85}Ga_{0.15}N$ electron blocking layer (EBL), doped with 1×10^{19} cm^{-3} Mg, is implemented to suppress electron leakage (Aman et al., 2024). The hole injection layer (HIL) comprises 40 nm of p-$Al_{0.75}Ga_{0.25}N$ (3×10^{19} cm^{-3} Mg-doped) and 40 nm of p-GaN (1×10^{20} cm^{-3} Mg-doped).

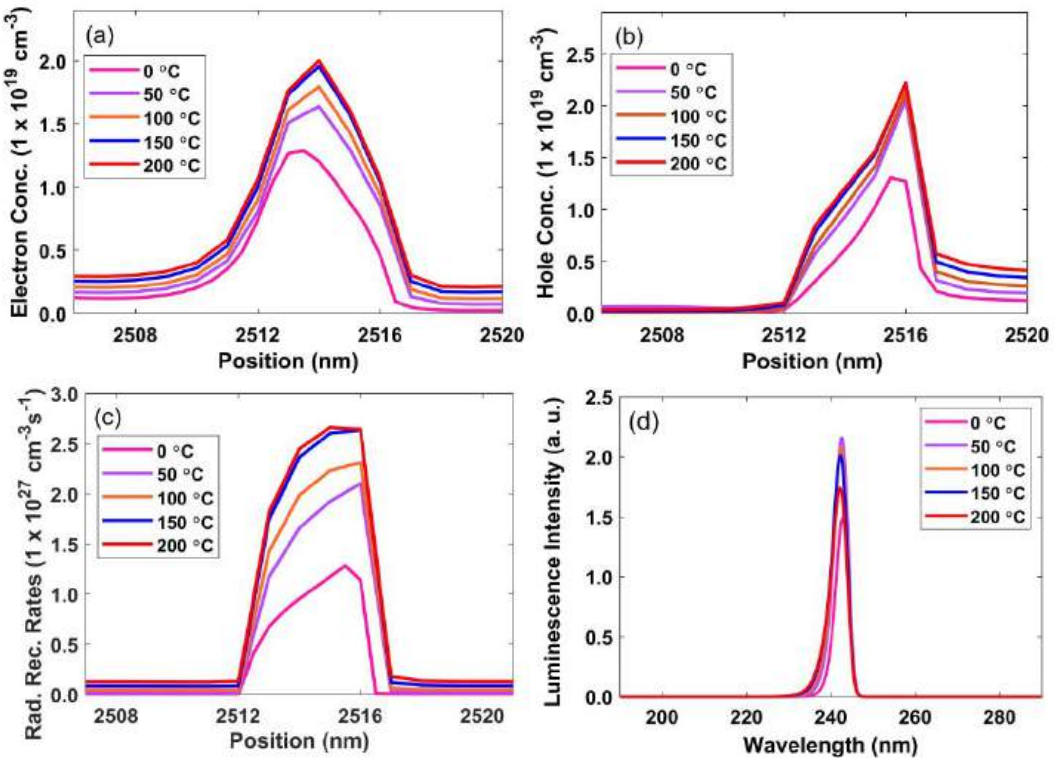


Figure 1. The (a) electron concentration, (b) hole concentration, (c) radiative recombination rates and (d) wavelength emissions of the DUV-LEDs

RESULTS AND DISCUSSION

As shown in Figure 1(a), the electron concentration within the quantum well increases steadily with temperature. This behavior is attributed to enhanced carrier injection and dopant activation at elevated temperatures, resulting in a greater population of free electrons in the active region. Similarly, Figure 1(b) demonstrates a rise in hole concentration with temperature, though the magnitude of increase is comparatively lower. This is due to the limited p-type conductivity of AlGaN, but higher temperatures facilitate acceptor ionization and improve hole mobility, leading to better hole injection efficiency.

The combined increase in both electron and hole concentrations contributes to a noticeable enhancement in radiative recombination rates, as shown in Figure 1(c). Radiative recombination is directly proportional to the product of electron and hole densities; thus, the improved carrier injection at higher temperatures results in stronger recombination activity within the quantum well. However, it is important to note that while radiative recombination is enhanced, high temperatures also activate non-radiative pathways such as Shockley–Read–Hall and Auger recombination, deteriorating the overall efficiency of the device (Ishii et al., 2020). The resulting luminescence spectra, presented in Figure 2(d), shows a slight redshift (Lin et al., 2022). This is due to temperature-induced bandgap narrowing of AlGaN materials, however, the change in emission wavelength is minor where peak wavelength emission consistently observed at 242 nm.

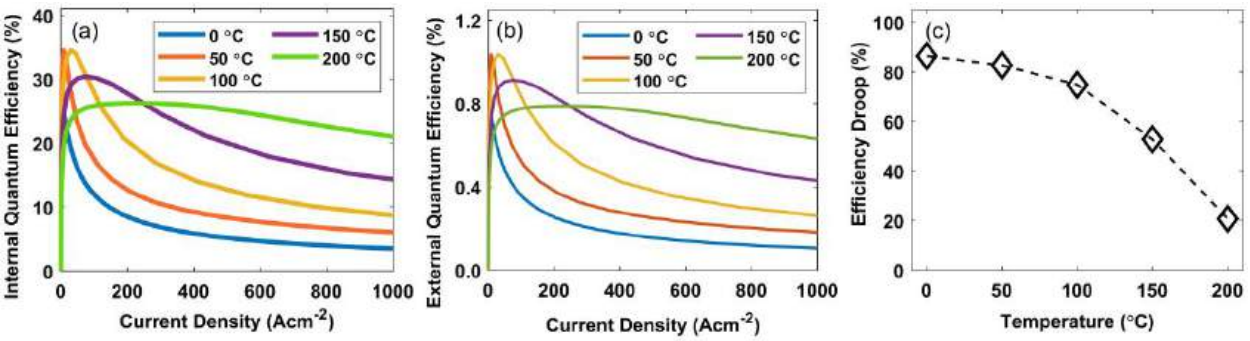


Figure 2. The (a) internal quantum efficiency, (b) external quantum efficiency and (c) efficiency droop of the DUV-LED with varying temperature

Figure 2 illustrates the impact of temperature on the IQE, EQE, and efficiency droop of the DUV-LEDs. As shown in Figures 2(a) and 3(b), both IQE and EQE increase with temperature, with peak values shifting to higher current densities. This improvement is attributed to enhanced carrier injection, increased acceptor activation, and more balanced carrier distribution at elevated temperatures. Although efficiency droop remains present at high current densities, it becomes less severe with temperature. Figure 2(c) shows a significant reduction in droop from over 80% at 0 °C to below 40% at 200 °C, highlighting the beneficial role of thermal energy in mitigating non-radiative losses and carrier leakage.

CONCLUSIONS

The simulation shows that higher temperatures enhance carrier injection and balance, leading to improved IQE, EQE, and reduced efficiency droop in DUV-LEDs. However, there is a trade-off, as the maximum IQE and EQE slightly decrease at elevated temperatures. This shows the need to balance peak efficiency and droop mitigation when optimizing thermal performance.

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Sekian, terima kasih.

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Setuju.

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