Analysis and modeling of the positive degradation mechanism observed in 265 nm UV-C LEDs

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Introduction

The need for alternative solutions to mercury-based UV lamps has led to an intensification in the research of eco-friendly devices, such as ultraviolet LEDs. In this work, we analyze the positive ageing mechanism observed both on commercial- and research-grade devices, which consists in an increase in the optical power emission in the first minutes of operation. In particular, we combine experimental measurements with TCAD simulations to describe this mechanism and correlate it with the defect generation that occurs inside the device.

Experimental Procedures

The structure under test is an AlGaN-based single quantum well (SQW) LED, with a QW thickness of 6 nm [1]. To induce positive ageing, we carried out a constant current accelerated lifetime stress test (ALT) at the current level of 150 mA and at the baseplate temperature of 36 °C (junction temperature of 62 °C), during which we monitored the electrical and optical characteristics, both measured under pulsed wave conditions to avoid self-heating effects. Moreover, we also tracked defect concentration through steady-state photo-capacitance (SSPC) measurements. To conclude, we implemented the structure on an SDE tool and simulated the optical characteristics by means of the TCAD Sentaurus suite by Synopsis Inc.

Results and Discussion

During the ALT, we observed an increase in the optical power emission in the first 200 min exclusively for high measuring current levels. On the other hand, at low measuring current levels we noticed a monotonic decreasing trend for the entire duration of the experiment. We hypothesized the presence of two simultaneous effects that describe the optical power trend: a defect generation at the interface between the last QW barrier and the EBL, which results in a better hole injection to the active region and therefore to the increase in the OP, and a defect generation in the QW, which correlates with the increase in non-radiative recombination and therefore to the decrease in OP [2]. By combining the SSPC measurements (used to determine the defect concentration in the QW) with TCAD simulations, and by adjusting the defect concentrations in the two regions during the ageing, we were able to perfectly fit the OP trends both at high and low current levels.

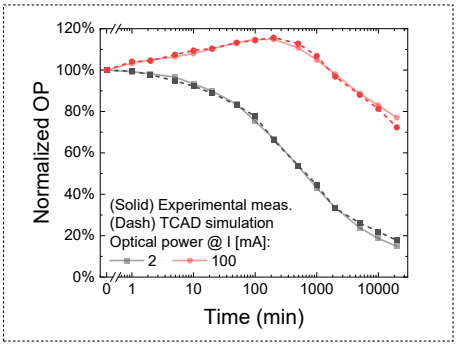

Figure 1 – TCAD simulation of the optical power

Acknowledgement

Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4, Component C2, Investment 1.1, by the European Union – NextGenerationEU. PRIN Project 20225YYLEP, CUP: C53D23000350006, "Empowering UV Led technologies for high-efficiency disinfection: from semiconductor-level research to SARs-Cov-2 inactivation". The work was also partially funded by the Bundesministerium für Bildung und Forschung (03ZZ0134C, Advanced UV for Life); Deutsche Forschungsgemeinschaft (Semiconductor Nanophotonics, Collaborative Research Centre, CRC787 9315). This work was partially supported by JST as part of ASPIRE, #JPMJAP2311.

References

[1] N. Susilo, Appl Phys Lett, vol. 112, no. 4, p. 041110 (2018)

[2] S. Chichibu, Appl Phys Lett, vol. 122, no. 20, p. 201105 (2023)