Degradation Effects in UVC LEDs Analyzed by Single-Wavelength Photo-Capacitance Transients

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Introduction

In this work, we evaluated the degradation processes affecting an ultraviolet light-emitting diode (LED) submitted to constant-current stress for +30000 minutes. During the accelerated lifetime stress, we adopted numerous characterization techniques such as current-voltage, capacitance-voltage, optical power, and defect spectroscopy measurements. This allowed us, for the first time, to granularly follow the evolution of the characteristics in UVC LEDs and obtain meaningful correlations between defect concentration, non-radiative recombination coefficient, and injection efficiency.

Results and Discussion

Three degradation processes were observed and discussed: (i) strong optical degradation at low current measurement values in the first 1000 minutes of stress that we associated with the increase in non-radiative Shockley–Read–Hall recombination events [1]; (ii) a decrease in the diode series resistance. Through capacitance measurements we connected this result to the shrinking of the space charge region of the device. This phenomenon was ascribed to an activation of the hydrogenated Mg present in the p-contact. (iii) In the remaining stress section (> 1000 minutes), a fitting of the external quantum efficiency (EQE) revealed a reduction of the injection efficiency, which was well correlated with the reduction in optical power at high current levels (Fig.1). Defect spectroscopy and single-wavelength photo-capacitance transients at 2.81 eV allowed us to observe the increase in concentration of a pre-stress-existing defect, possibly related to the first phase and to the increase in the A coefficient. Moreover, we detected the generation and increase in concentration of another defect; this correlates with the evolution of the optical power in the second phase of the ageing test, and thus with the decrease in the injection efficiency (Fig. 2). We explain the experimental data by considering that the charged defects generated around the active region of the device reduce the carrier injection efficiency [2]. These results allowed us, for the first time, to follow the evolution of deep levels concentration and population and to correlate this process to the changes in the device optical and electrical characteristics.

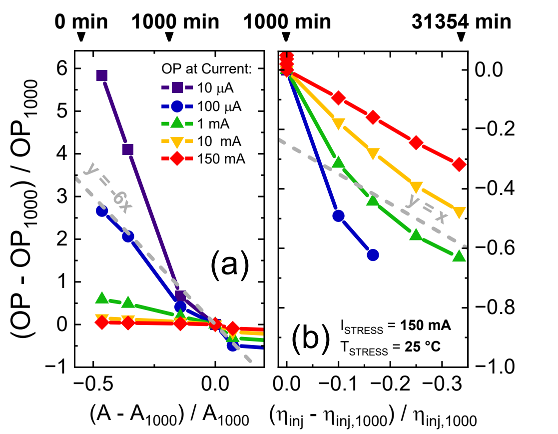

Fig. 1 – Correlation between the optical power (OP) degradation and the non-radiative recombination coefficient (A) and the injection efficiency (η_{inj}) obtained from the EQE fitting.

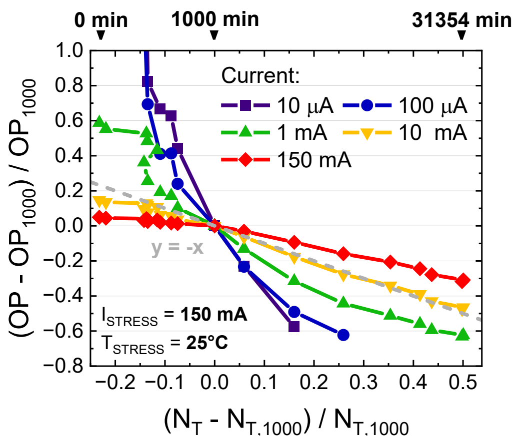

Fig. 2 – Correlation between the emitted optical power (OP) and the defect concentration (N_T) obtained from the SWPC transients.

References

[1] P. Dalapati, K. Yamamoto, T. Egawa, and M. Miyoshi, Optical Materials 2020, 10.1016/j.optmat.2020.110352

[2] F. Piva et al., Applied Physics Letters 2023, 10.1063/5.0144783.