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Stability improvement of PMMA and Lumogen® coatings for hybrid white LEDs

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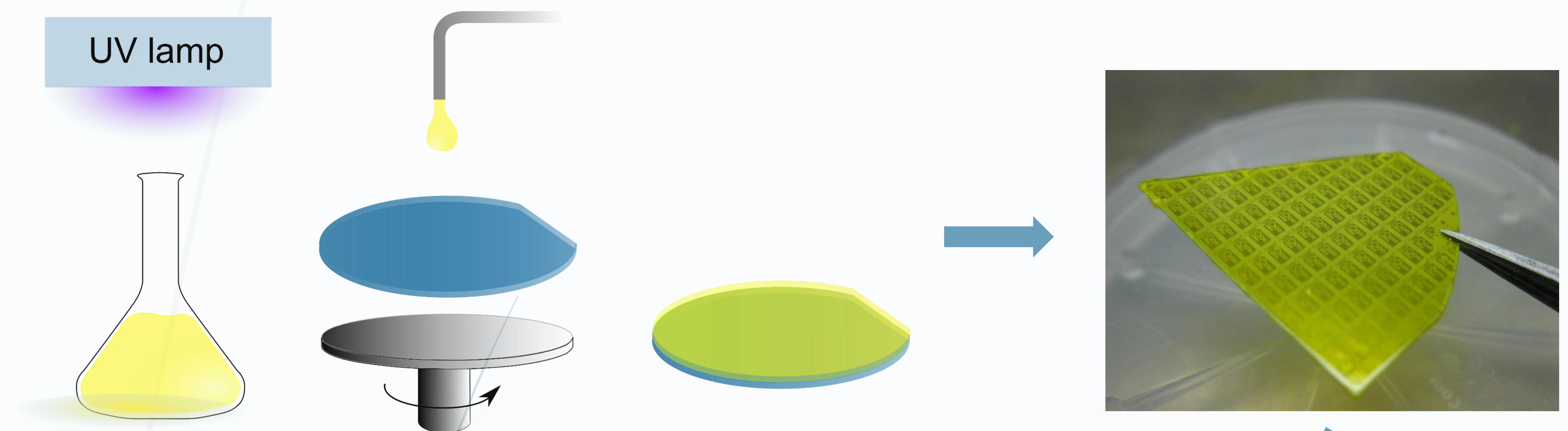
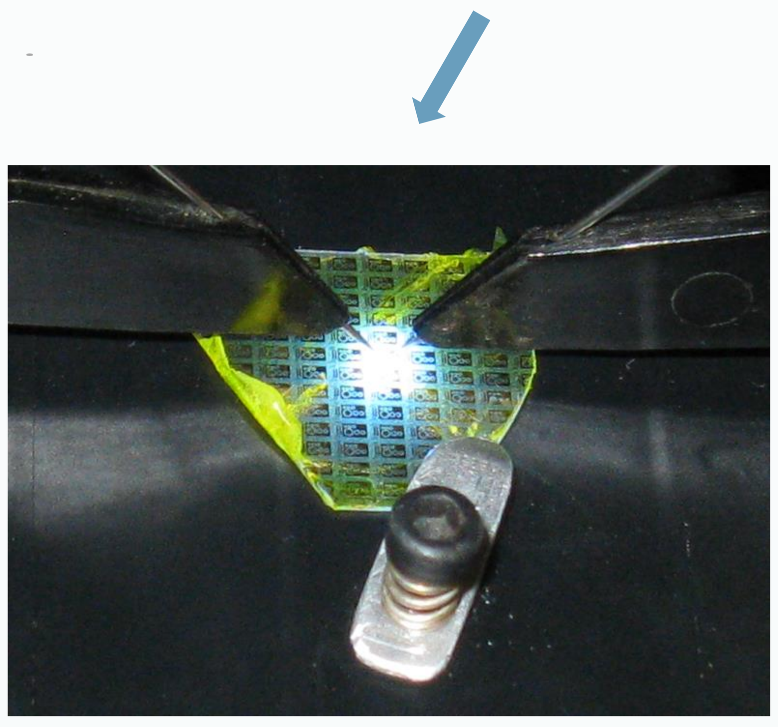
Introduction

Hybrid white LEDs employing perylene-based dyes for the frequency down-conversion of blue light, generated by a standard inorganic source, suffer from colour rendering variations due to the degradation of the organic molecule under prolonged irradiation [1, 2]. To avoid such inconvenient, proper encapsulation of the dyes in resins or other polymer matrices can prevent their accelerated ageing [3]; nevertheless, embedding polymers can also exhibit significant bleaching caused by chemico-physical agents. Among all, polymethyl methacrilate (PMMA) is one of the most used materials for the fabrication of hybrid LEDs' colour conversion coatings, therefore its stability needs to be investigated.

Typical Process

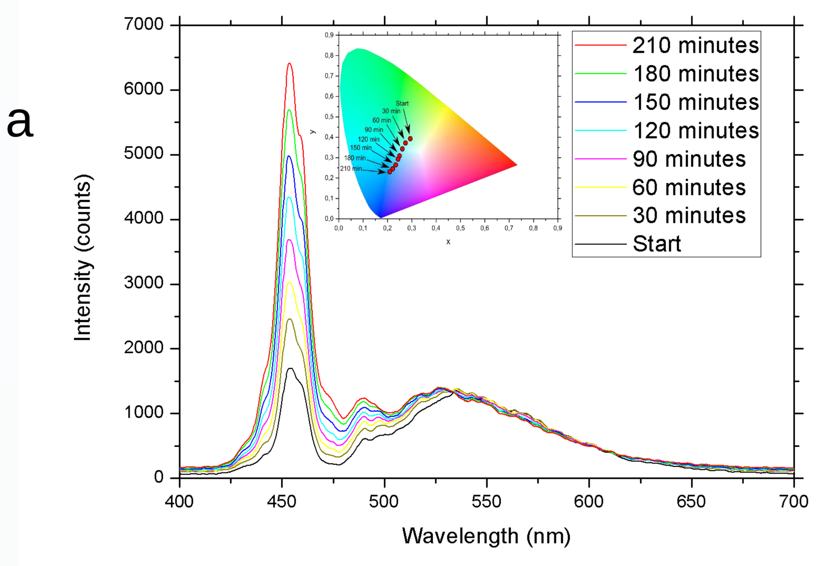


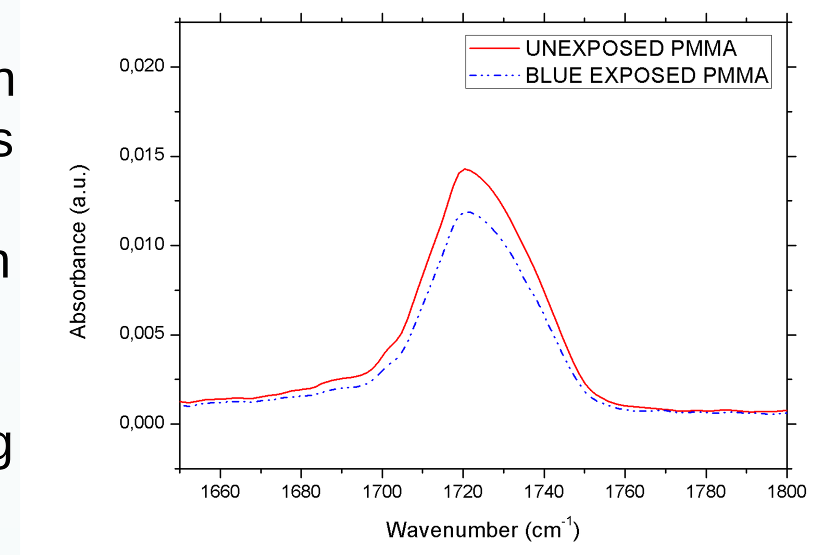


The process that is used begins with the preparation of the solution containing PMMA and Lumogen ® Yellow F083 (a perylene-based dye). The mixture is then cured under a UV lamp for 1 hour. The unprocessed side of a blue GaN/InGaN LED wafer is spin-coated with the solution and the wafer is flipped over for the metal contacts to be probed with a micromanipulator. A constant current is fed to the LED and the spectral emission is recorded with a spectrometer via an optical fiber which is positioned under the sample.

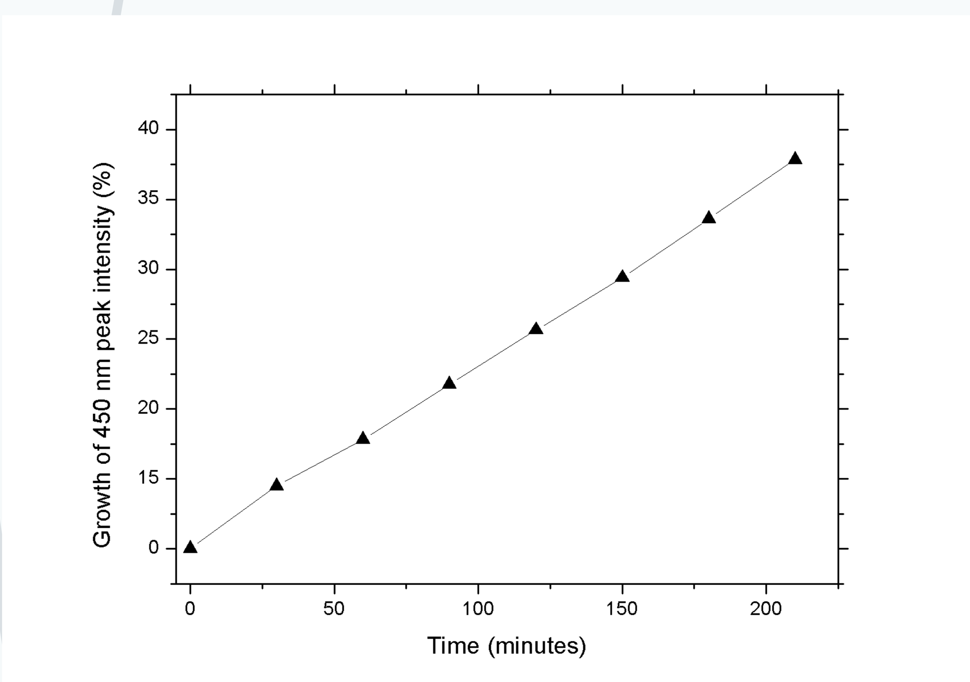
Color Shift

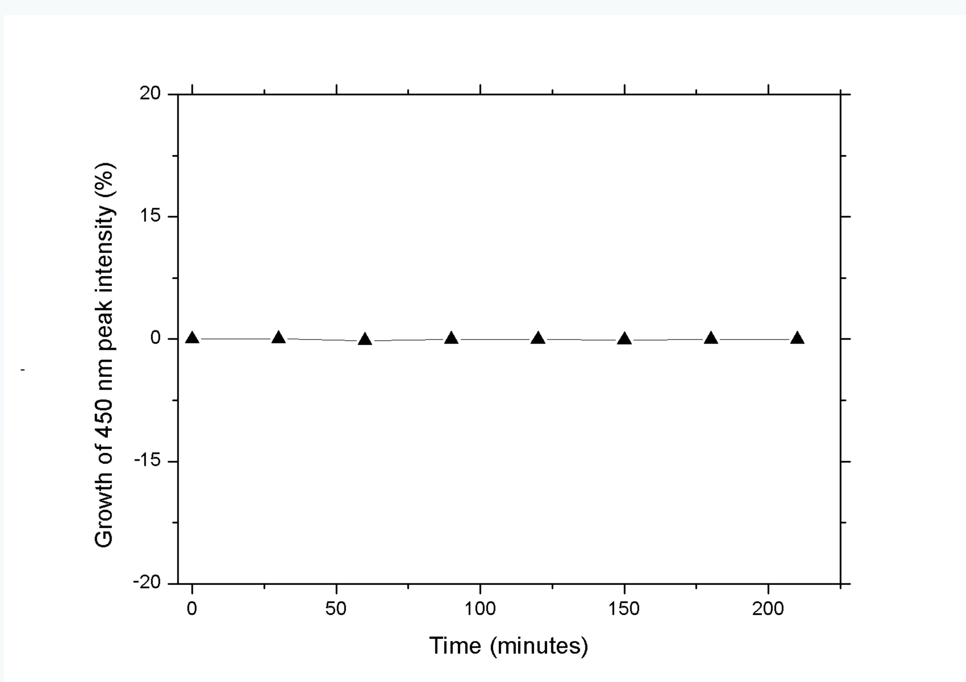
Under continuous DC biasing of the device, the non-cured mixture, which acts as a conversion coating, exhibits a significant loss in the absorption of the blue wavelength region of the visible spectrum.
In over 3 hours of operation the colour of the LED gradually turns back to the emission of the source.
Though the optical power of the pump is not very high, an FT-IR spectroscopic analysis have shown that the blue irradiation causes a variation in the carboxyl bond of the non-cured polymethyl methacrilate, thus confirming that the photo stability of the polymer is compromised.

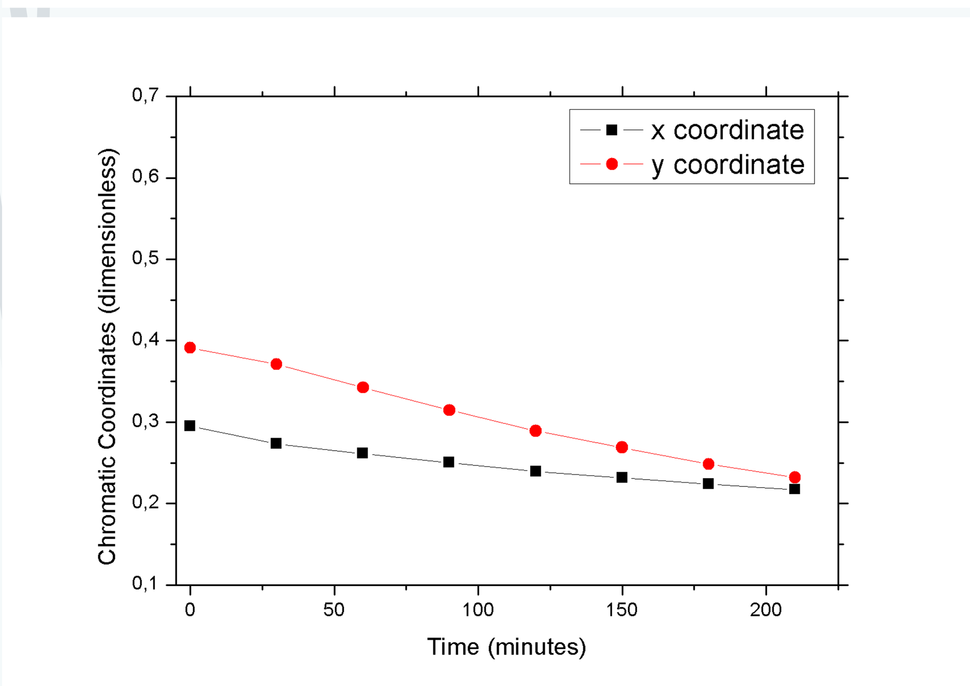


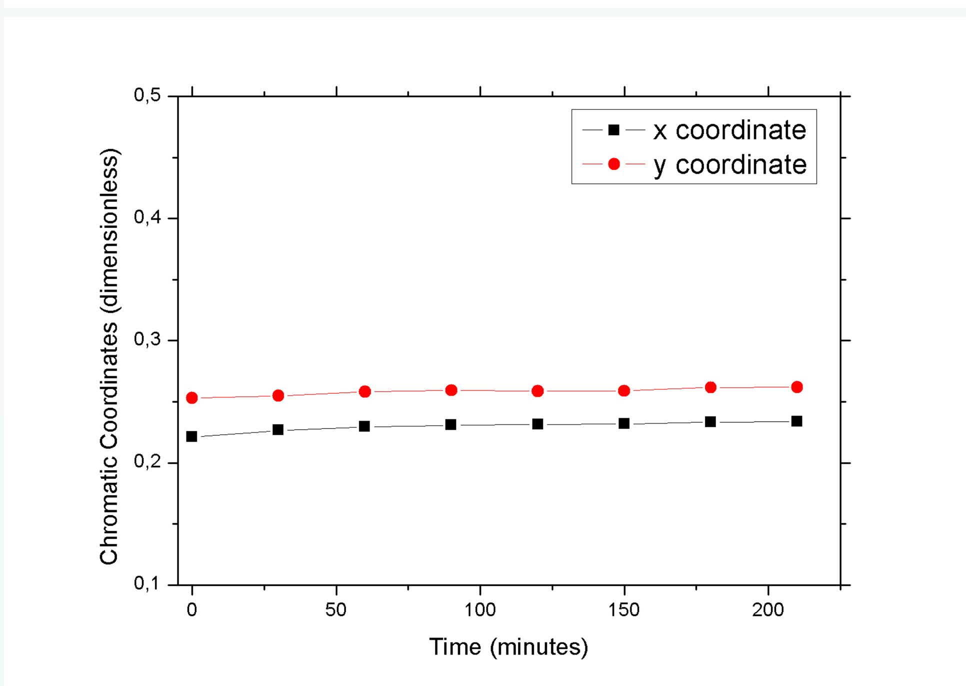


Results









No Curing **With Curing**

Several tests show that there is a clear difference between a non-cured and a cured mixture. In both cases the spin-coated layer of PMMA and Lumogen ® has been irradiated for 210 minutes with a blue LED: during the experiment the percentage growth of the blue emission peak has been recorded, together with the chromatic coordinates according to CIE standards. A white LED with a UV-cured coating does not suffer any spectral variation or color shift.

During the tests the temperature of the unprocessed side of the wafer never exceeded 30 °C: this excludes any possible degradation of the polymer due to the rise of the junction temperature of the LED.

Operating conditions of the LEDs:

I_f = 20 mA (constant)
V_f = 3.4 V
T_{amb} ≈ 25 °C

References:

[1] Caruso, F. et al., "Generation of white LED light by frequency down-conversion using a perylene-based dye", Electronics Letters, vol. 48, n. 22, 2012, 1417-1419.

[2] Sessolo, M. and Bolink, H. J., "Hybrid Organic–Inorganic Light-Emitting Diodes", Advanced Materials, vol. 23, 2011, 1829-1845.

[3] Schubert, E. F., "Light-Emitting Diodes", Cambridge University Press, Cambridge, 2006, 350-351.