Investigation of hybrid white inorganic/organic LEDs using a novel organic compound for colour conversion

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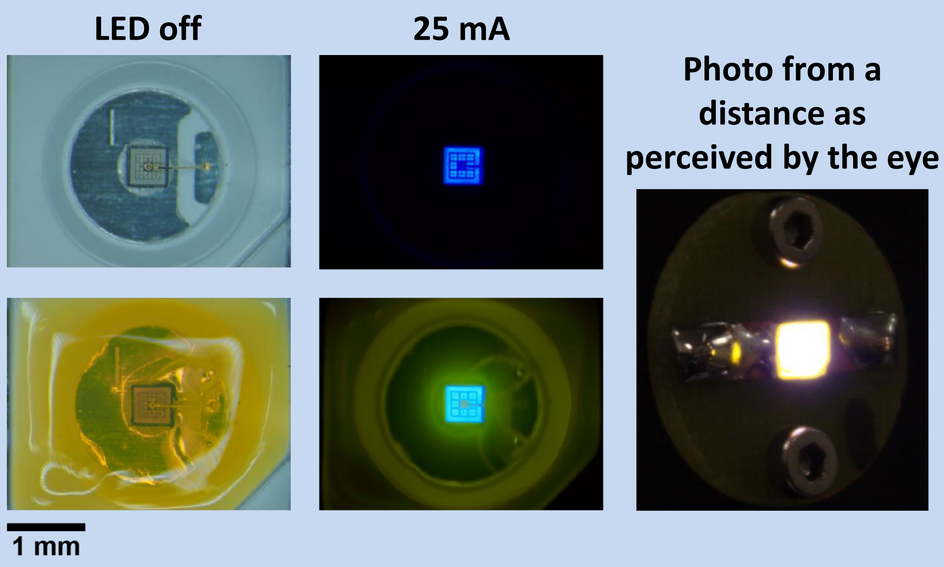
Introduction and motivation

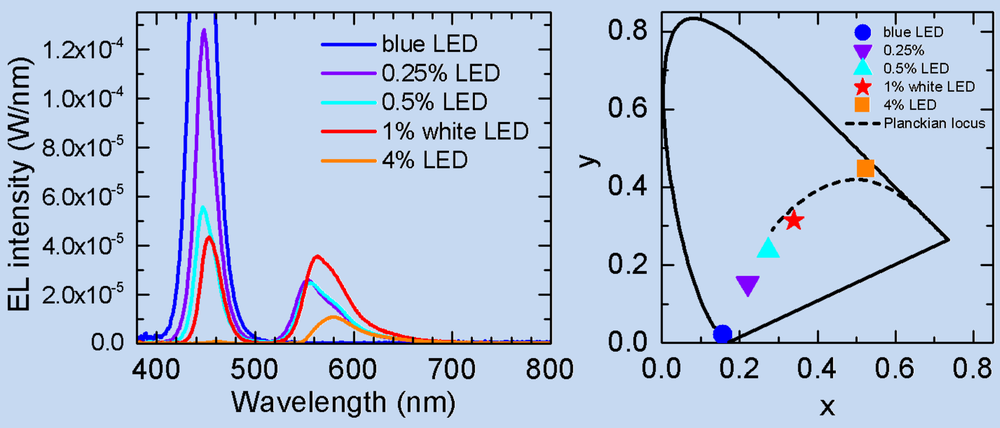
- White light-emitting diodes (LEDs) are an integral part of solid-state lighting to replace conventional light sources
- Commonly, a white LED consists of an *inorganic* blue LED pumping a yellow-emitting phosphor to produce white light
- However, there is still scope for improved wavelength converters for optimising the quality of the white light
- In this work, white LEDs are fabricated by combining novel *organic* colour converters based on the BODIPY unit with a commercial, *inorganic* blue LED
- These organic compounds offer low-cost manufacturing, solution processability, tuneable emission and absorption properties by manipulation of the chemical structure and high speed of response (light communication)

Colour conversion

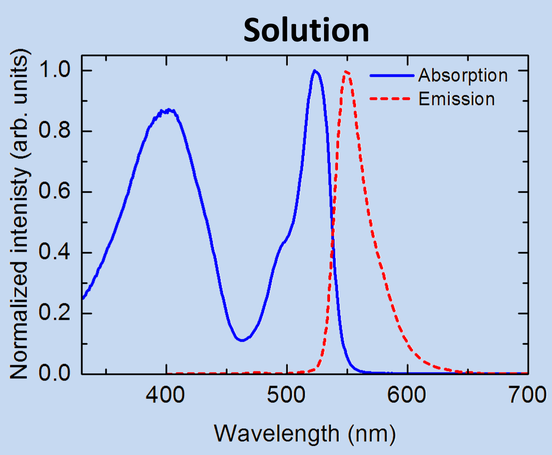
- Different concentrations of the organic material, which was incorporated into the transparent matrix, was deposited on a fully-processed blue LED chip from Plessey (InGaN/GaN MQW structure emitting at 445 nm)

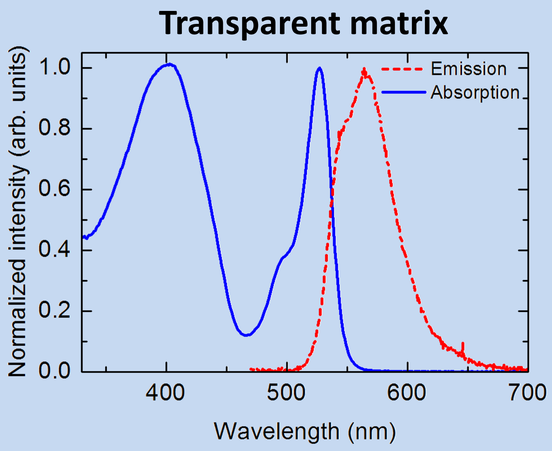


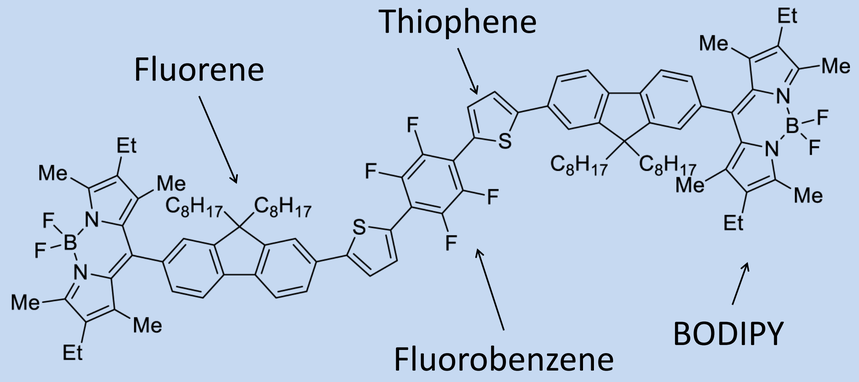
- Electroluminescence (EL) was measured in an integrating sphere, which measures the absolute intensity in units of W/nm
- This makes it possible to determine parameters such as the colour rendering index (CRI), correlated colour temperature (CCT) and chromaticity coordinates (x, y) characterising the quality of the white light emission
- With increasing concentration of the organic converter the chromaticity coordinates shift towards the lower left corner of the diagram where monochromatic blue light is located
- White light was achieved with a concentration of 1% giving chromaticity coordinates of (0.34, 0.31) and a CCT of 5137 K
- The colour rendering is not ideal, which is due to the missing green creating a gap between the blue and yellow peaks
- A fourfold increase in luminous efficacy was observed after the organic converter was combined with the blue LED



Synthesis and physical properties of the organic colour converter



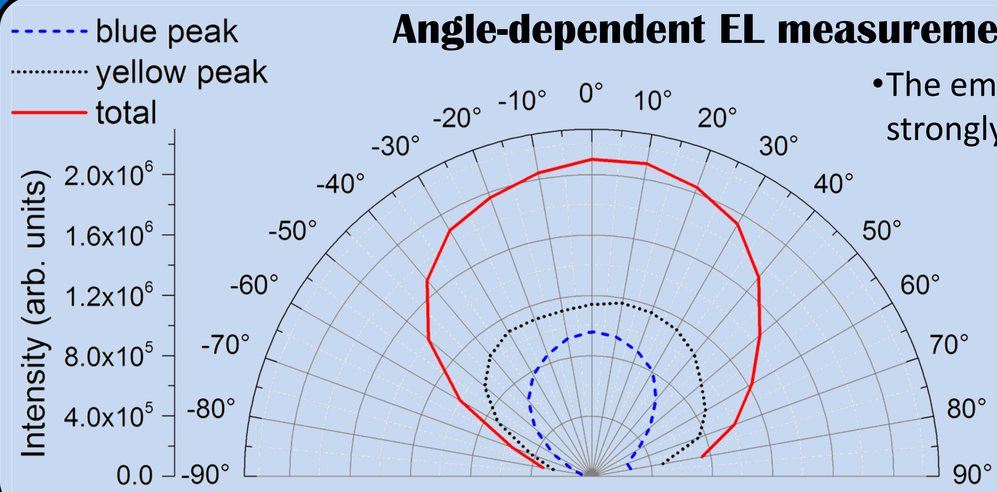




- The organic converter consists of an absorbing core unit (fluorobenzene with a thiophene and fluorene unit on either side) and a BODIPY emitter unit on both ends
- Absorption in solution identifies a peaks around 403 nm from the core and a second peak at 525 nm from the BODIPY unit
- Exciting the molecule at 440 nm results in emission from the BODIPY at 550 nm
- For easy deposition on LEDs, prevention of aggregation and use of low concentration the molecule was incorporated into a transparent matrix, which also retains the optical properties of the solution state

N. J. Findlay, C. Orofino-Peña, J. Bruckbauer et al., *J. Mater. Chem. C* **1**, 2249 (2013)
A. J. C. Kuehne et al., *Adv. Mater.* **21**, 781 (2009)

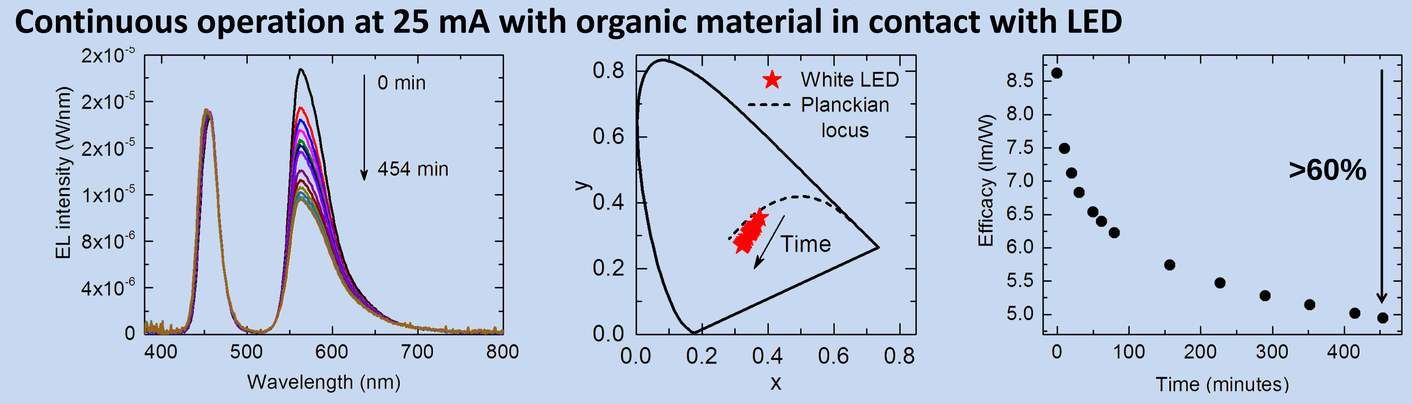
Angle-dependent EL measurements



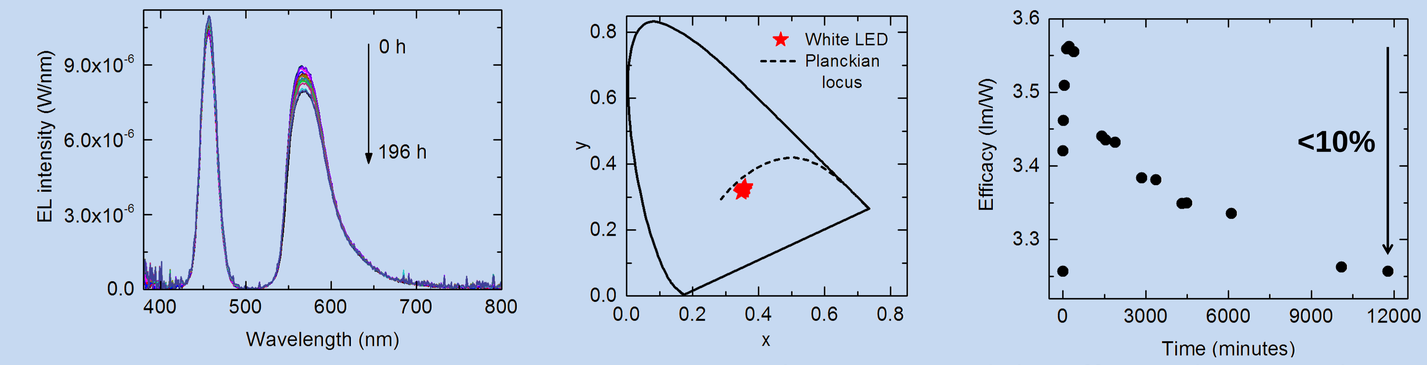
- The emission from the blue LED is strongly directional
- Yellow emission from the organic converter is more intense in general and also higher at larger angles compared with the blue emission
- Conversion strongly depends on film thickness

Lifetime testing

Continuous operation at 25 mA with organic material in contact with LED



Continuous operation at 25 mA with organic material separated from LED with an air gap



- When in close contact the luminous efficacy decreases rapidly and the chromaticity coordinates shift towards the blue corner in the chromaticity diagram
- When separated the efficacy decreases by less than 10% after 200 hours
- Heat from the LED might cause degradation of the organic material or transparent matrix

Summary

- White light was achieved using a novel *organic* colour converter in combination with an *inorganic* blue LED
- Chromaticity coordinates are located close to the centre of the diagram and a fourfold increase in efficacy is observed

N. J. Findlay, J. Bruckbauer et al., *Adv. Mater.* (accepted)

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