Colour, Colour Stability, and Lifetime of Solution-Processable White PLED Materials for Lighting

Torsten W. Bünnagel, Richard J. Wilson,
Thomas J. Pounds, and Ilaria Grizzi

Project TOPLESS

Project Topless

- **T**hin
- **O**rganic
- **P**olymeric
- **L**ight
- **E**mitting
- **S**emiconductor
- **S**urfaces

- **UK consortium**
  - Thorn Lighting Ltd (Lead Partner)
  - Sumation UK (Industrial Partner)
  - University of Durham (Academic Partner)
- Sponsored by UK government grant from the Technical Strategy Board, Department of Innovation, Universities and Skills
- **Objective**
  - Efficient single white light emitting polymer devices
  - 40 lm/W @ 1000cd/m^2 and >10k hrs lifetime
  - Determined manufacturing philosophy for large area emissive panels

SUMATION

Why a new type of lighting?

- 2650 TWh of electricity consumption used for lighting per annum
  → ~19% of global electricity
  → Equivalent to the output from 1265 power stations

Source: OECD/IEA 2007 – Paul Waide

- ~50% lamp sales by volume are inefficient tungsten light bulbs
  → ~5% of electricity converted to light@ 11-15 lm/W

- In September 2007 UK Government announced shops would stop selling the following tungsten bulbs
  → 150W by Jan 2008
  → 100W by Jan 2009
  → 60W by Jan 2010
  → 40W by Dec 2011

- Similar program is currently discussed for the EU.

SUMATION™

Some Issues with Fluorescents

- Slow turn-on time (improving)
- Poor colour rendering (improving)
- Noise (improving)

- Lifetime – can be shorter than advertised if frequently switched on/off
  → For example, 6000-15000 hours continuous use vs.1000 hours if turned on and off every 5 minutes
- Lamp contain Mercury (up to 5 mg of Mercury in a CFL)
  → Potential for widespread Hg contamination in incinerators and landfill

- While tube efficiencies are high, up to ~60-100 lm/W
  → Practical efficiencies only around 50% of this due to fixture losses (drivers, reflectors etc)
  → Installed luminaire efficiencies around 30-60 lm/W

SUMATION

Solid-State Lighting

- Solid State Lighting offers potential for:
  → high efficiencies
  → long lifetimes
  …and are mercury-free

- Inorganic vs OLED
  - Inorganic LEDs
    → best suited to applications requiring point source of light
    →not a good match for uniform, diffuse large area emission
    → requires diffuser materials, arrays of LEDs, costly assembly and integration
  - OLEDs
    → best suited to applications requiring uniform, diffuse large area emission
    → not a good match for point source or highly directional applications

- OLEDs would be the Luminaire
  → no additional efficiency losses
  → attractive mirror finish in off state

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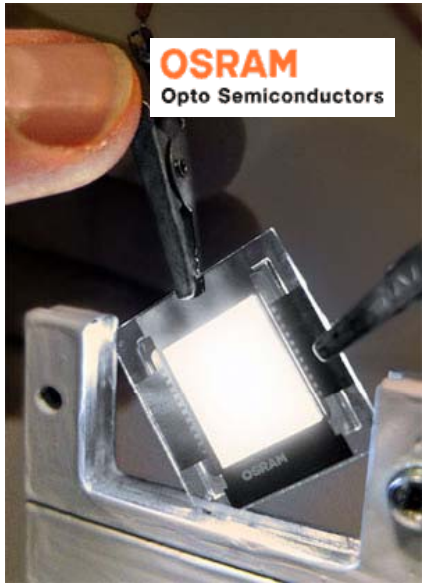
smOLED

- Many layers required for optimum performance
- Each layer requires precise thickness control
- Yield remains an issue
- Materials deposited by evaporation under vacuum
- Poor material utilisation
- Cost of vacuum equipment scales as ~dimension^3

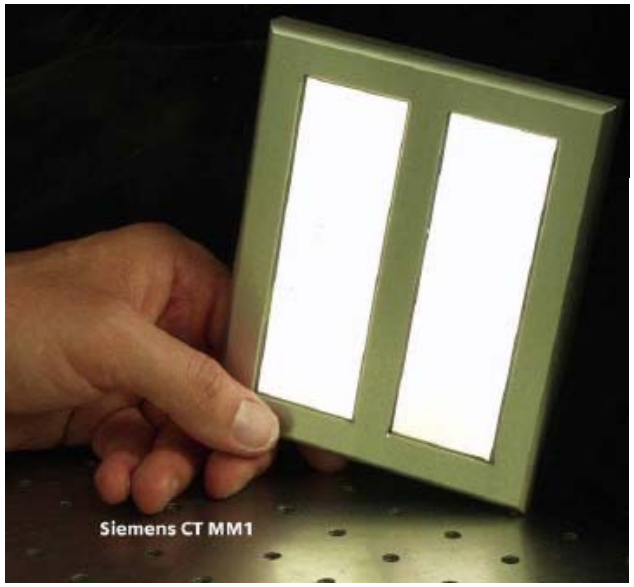
Osram (March 08)

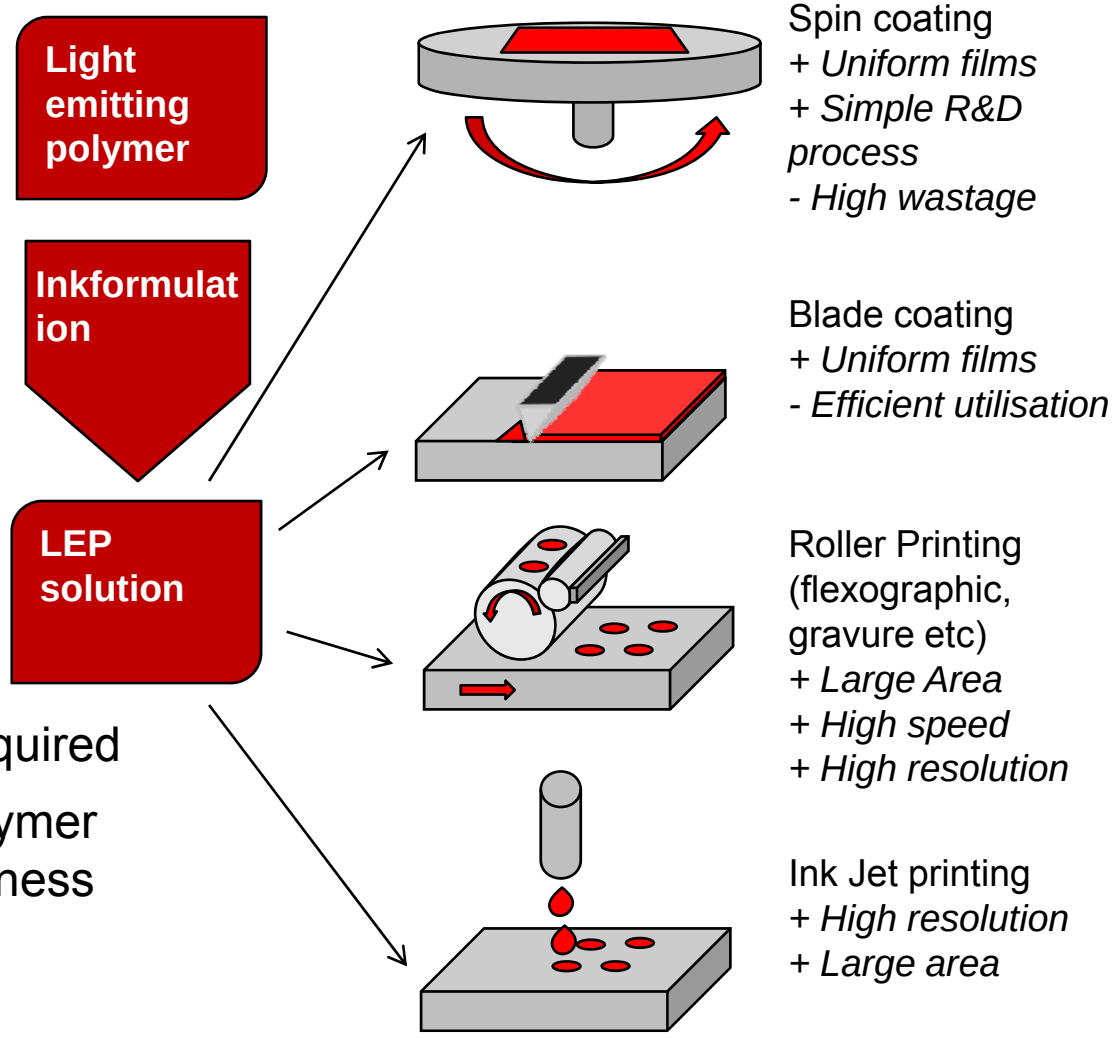
- 46 lm/W achieved with warm white OLED
- 5000 hours from 1000cd/m^2 lifetime
- Colour rendering factor 80



SUMATION

P-OLED

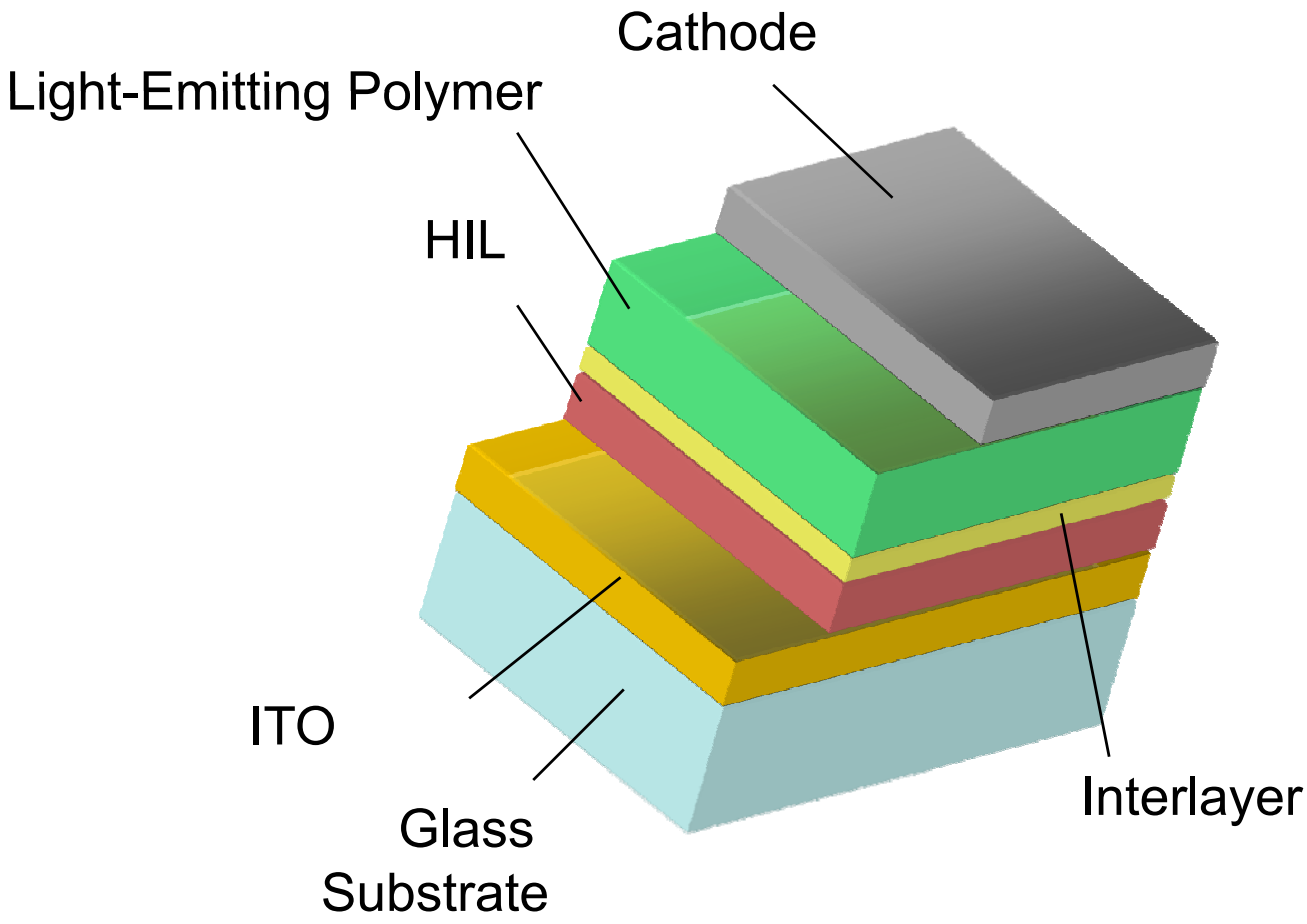




- Significantly fewer layers required
- Colour controlled during polymer manufacture and layer thickness
- Solution processing
  → **Low cost**
  → **higher lm/$**

SUMATION

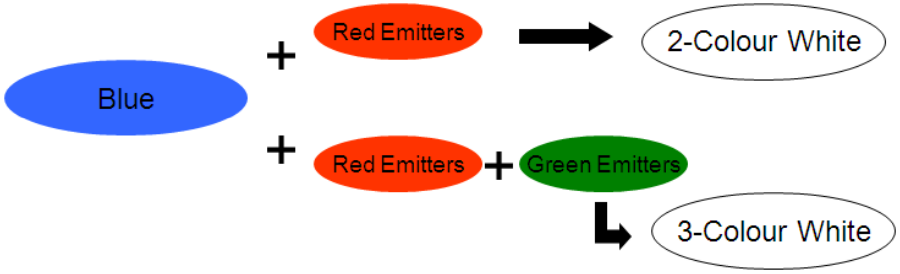
Device structure



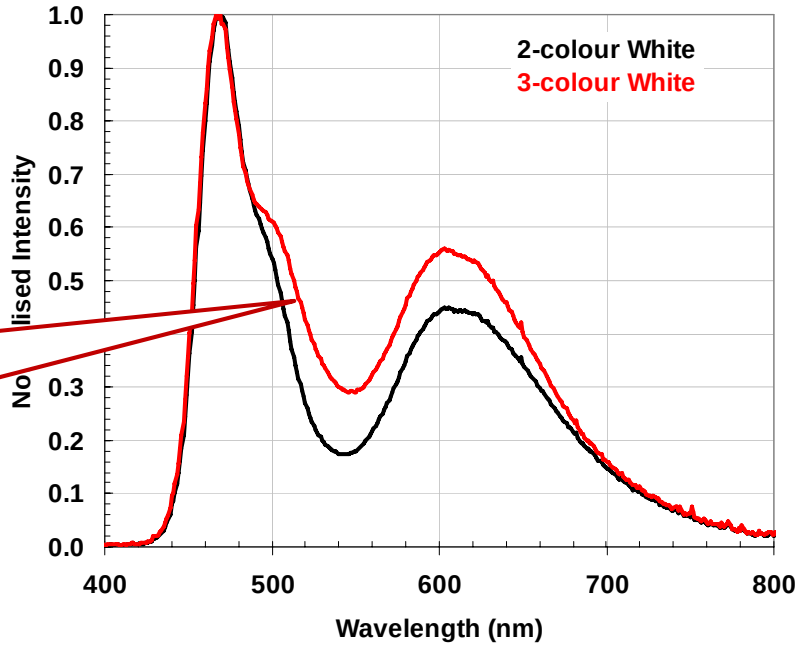
SUMATION

White P-OLED Approach

- Different coloured components combined to give white P-OLED emission
- Colour fixed during polymerisation of components gives good colour reproducibility
- Ratio of R,B or R,G,B emitters can be controlled to give the desired colour point



3-Colour approach gives higher efficiency as emission is enhanced in 480-560 nm region (eye sensitive area).



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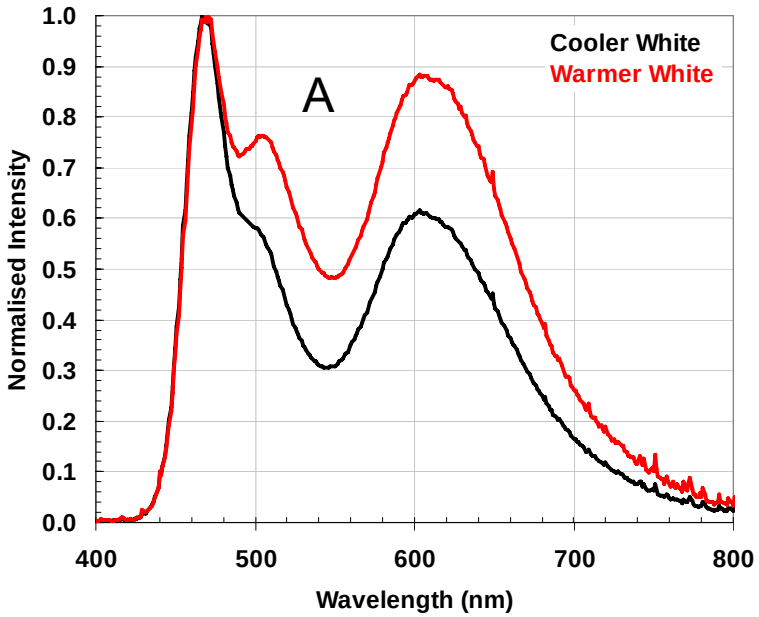
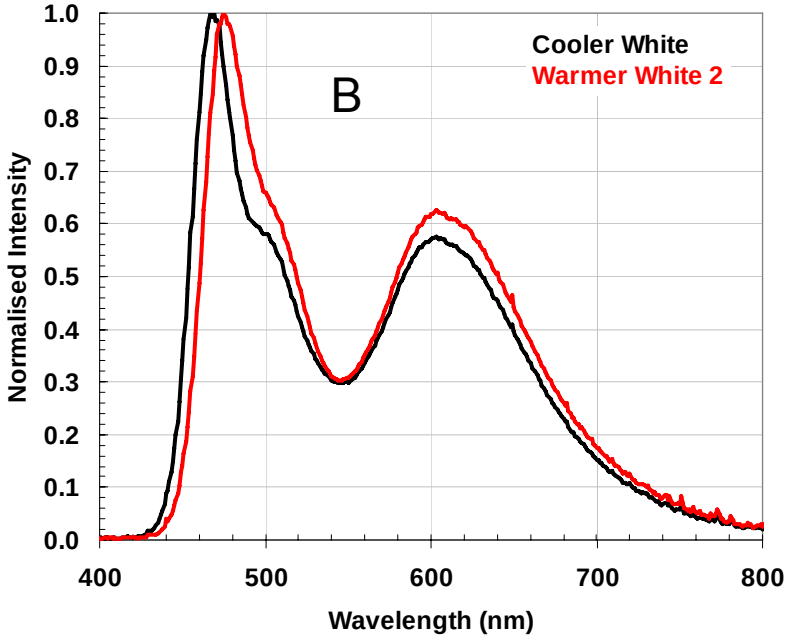
Warmer Whites for Lighting

- White polymers with warmer white colour have been prepared by:
  A) Controlling R, G, B ratios during polymerisation.
  B) Replace blue chromophore with green-blue or cyan emitter.



CIE x, y = 0.313, 0.326 @ 2400 cd/m^2



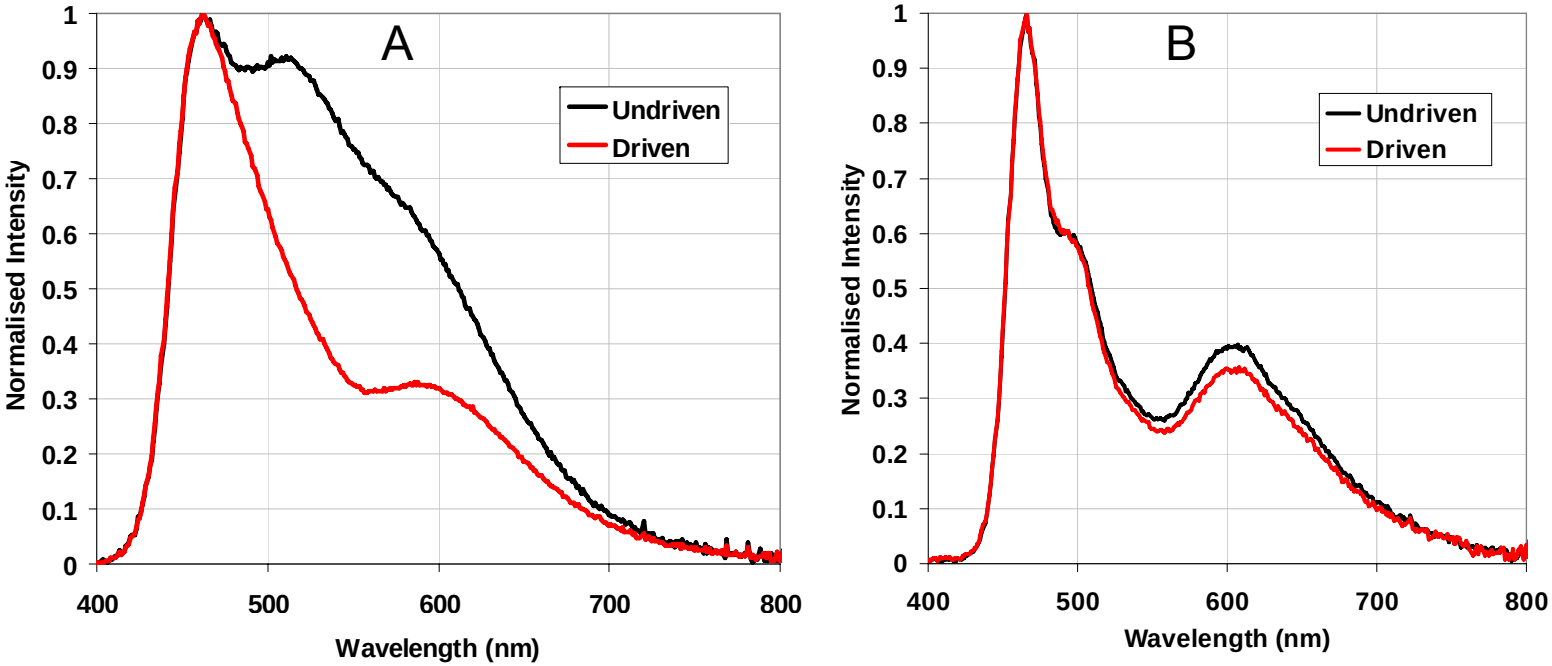
CIE x, y = 0.330, 0.365 @ 2400cd/m^2

SUMATION

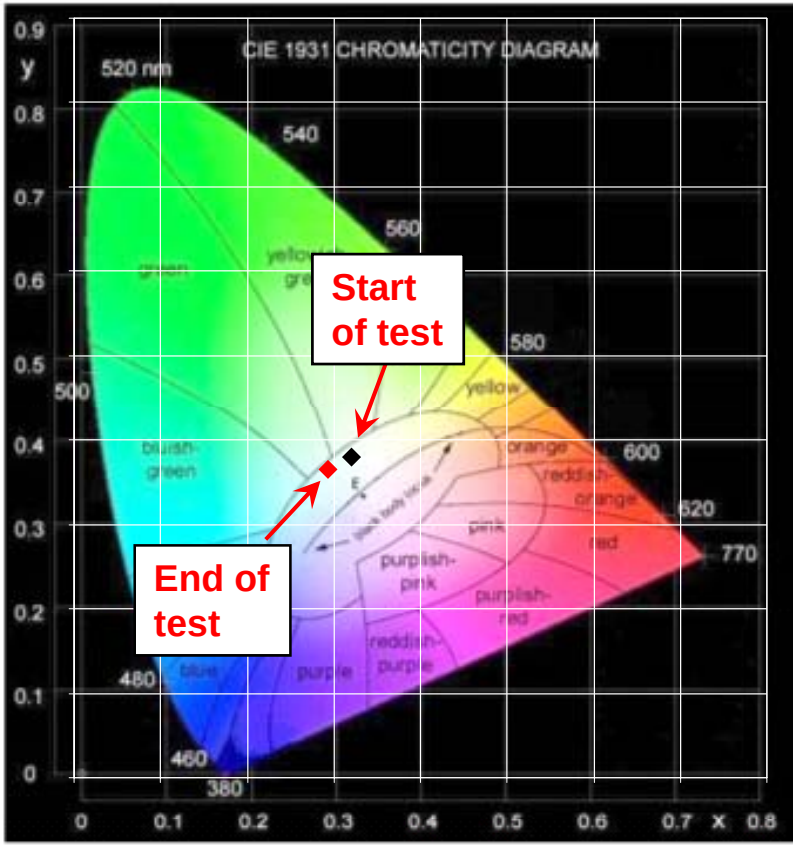
Colour Stability

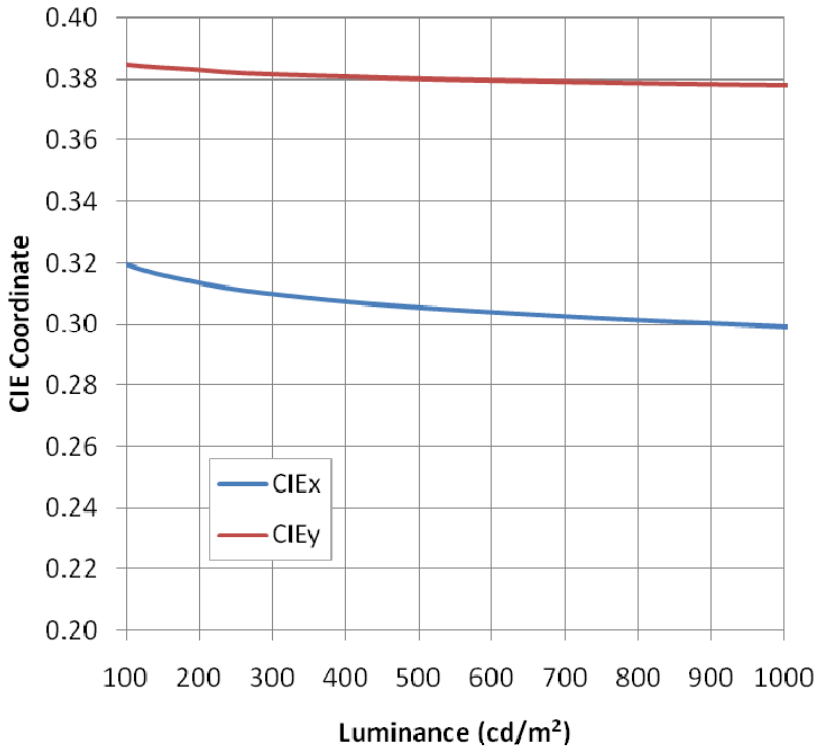
- EL spectra before and after driving to T_{50} (constant current driving).

A) Early 3-colour whites showed decay of the green emitter.
ΔCIE x = 0.037, y = -0.086
B) Material with more stable green emitter shows good colour stability.
ΔCIE x = -0.011, y = -0.009



Colour Stability

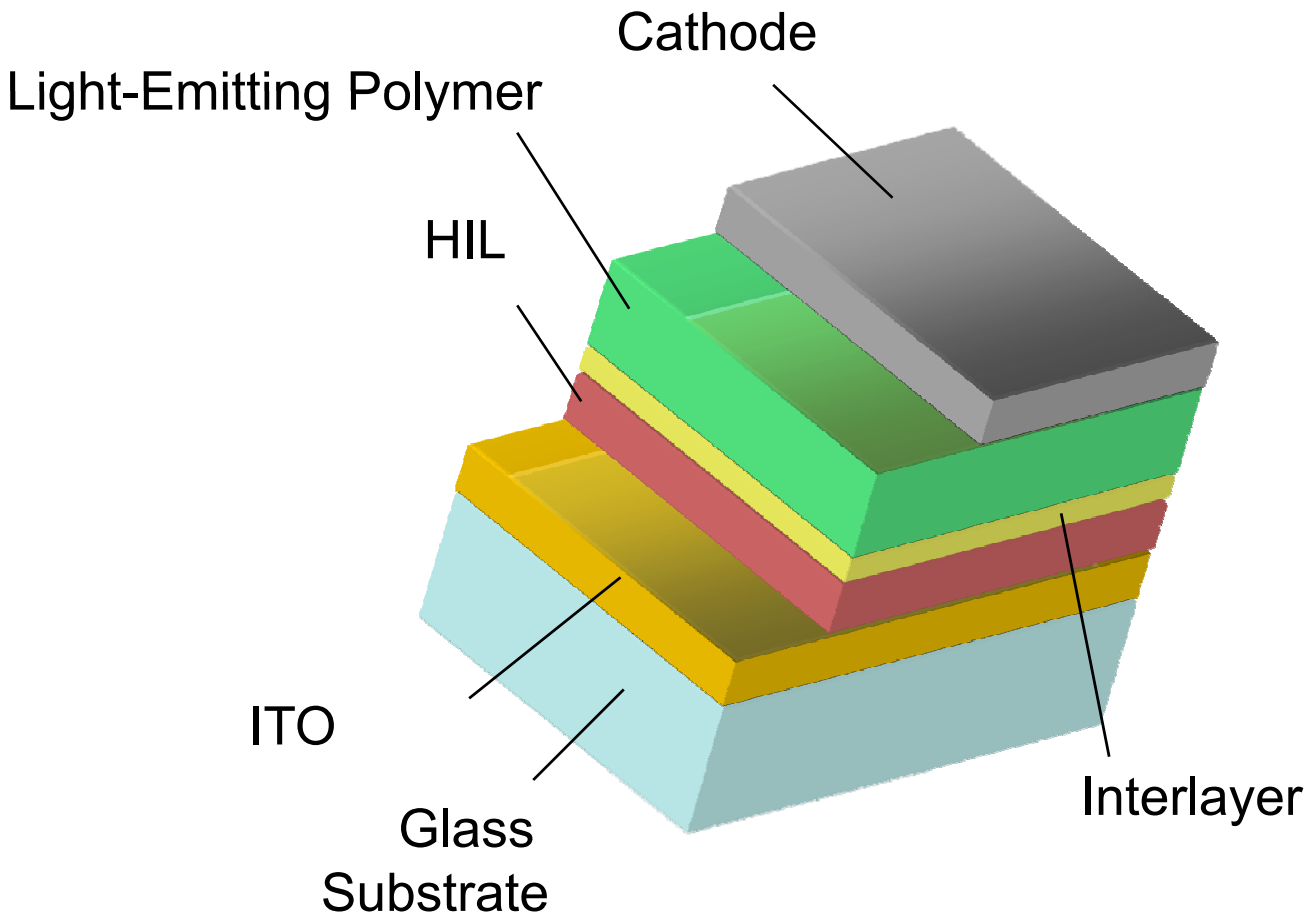




- Colour change upon driving.
- Colour change with increasing luminance.

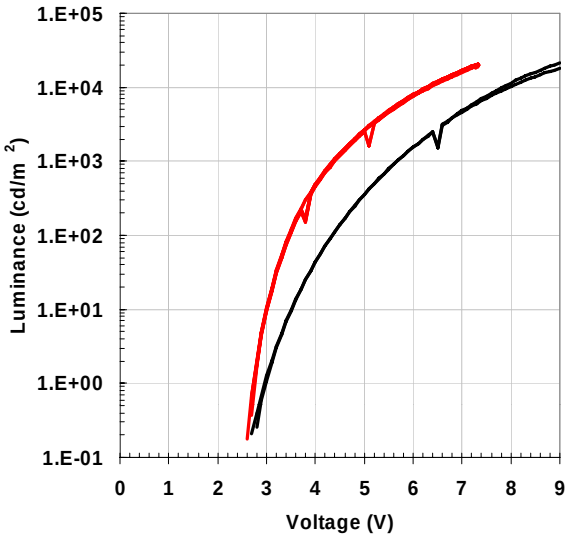
SUMATION

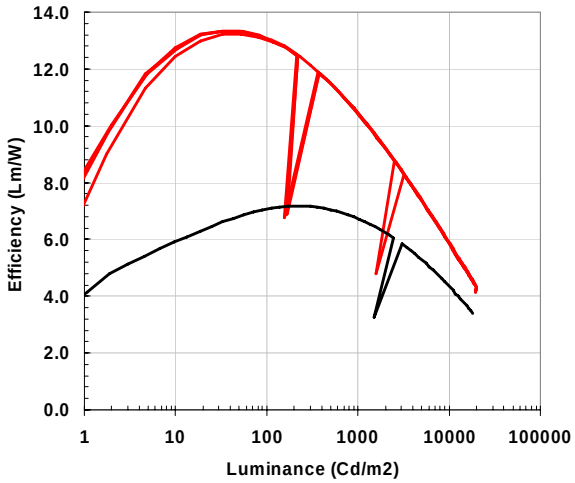
Device structure



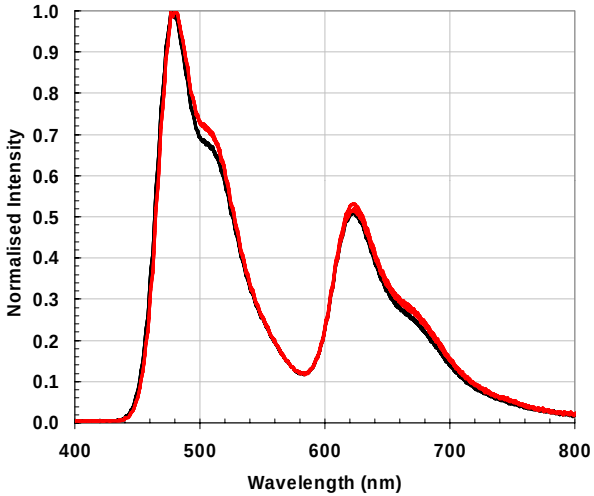
SUMATION

White Material with Low Voltage Cathode





Standard Cathode vs. Low Voltage Cathode



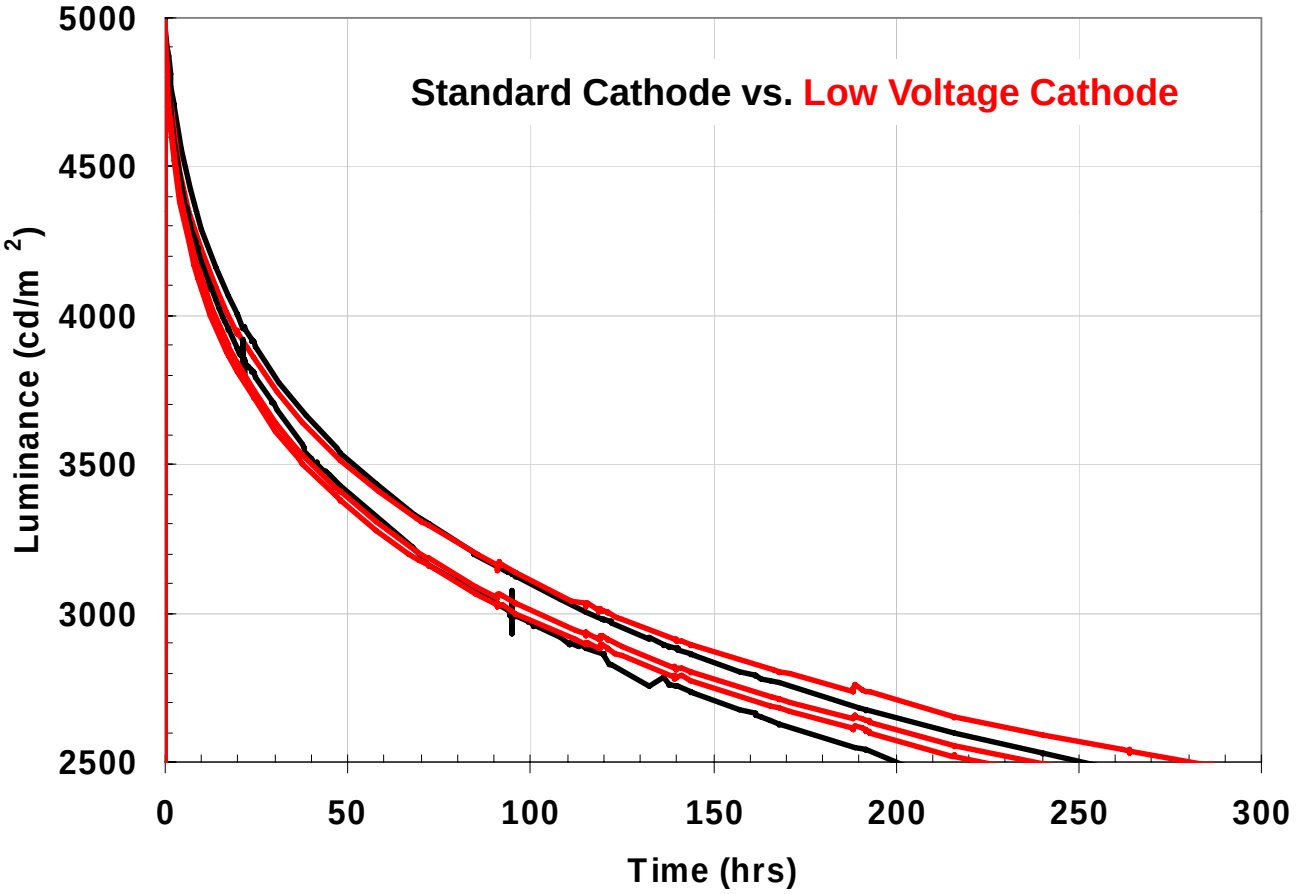
CIE x	CIE y
0.308	0.376
0.310	0.384

- Significantly lower drive voltage with new cathode
  → Better electron injection
- Improved lm/W at all luminances

SUMATION

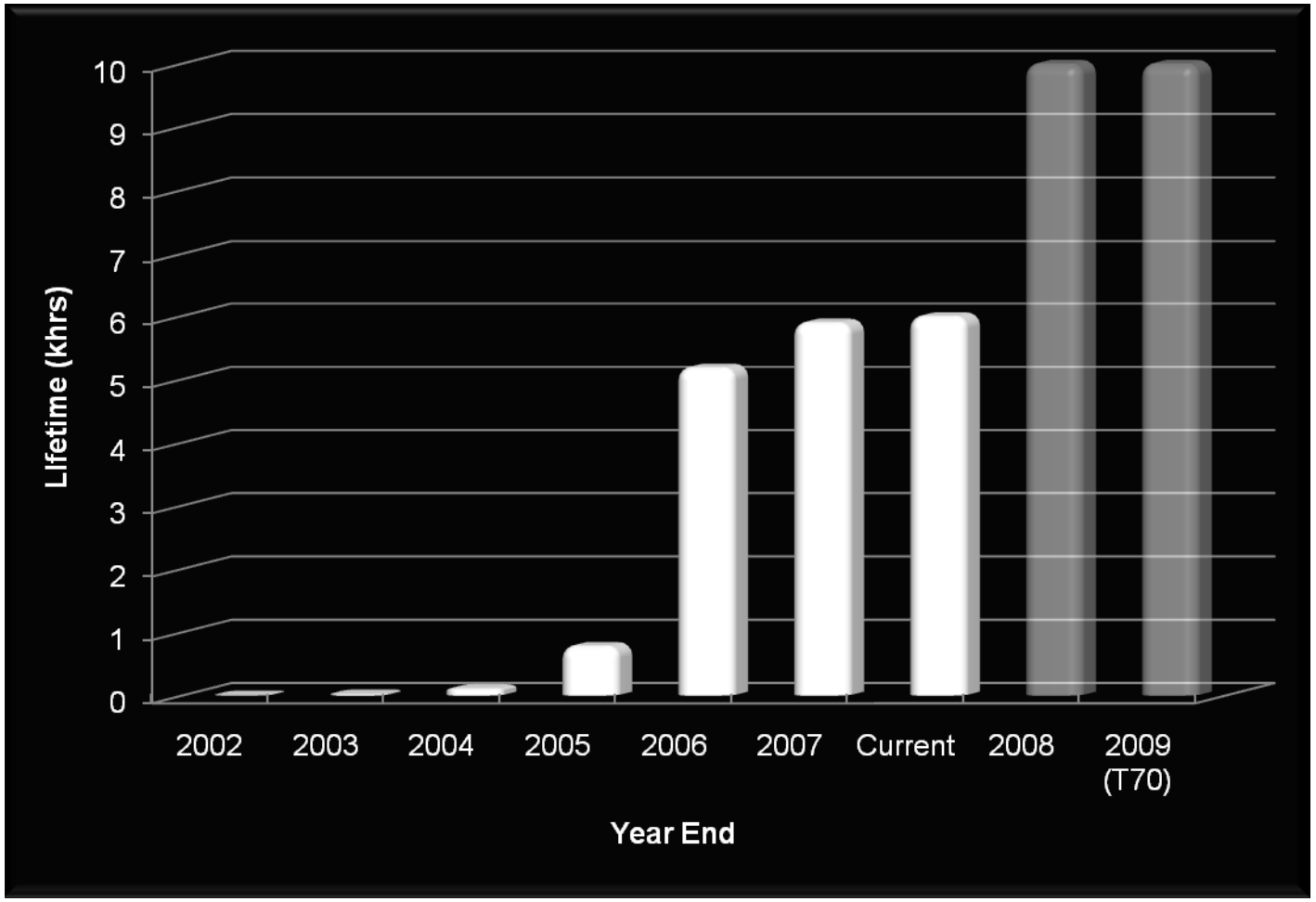
White Materialwith Low Voltage Cathode

- Lifetime similar with low voltage cathode
- measured under accelerated conditions



Current Lifetime Status

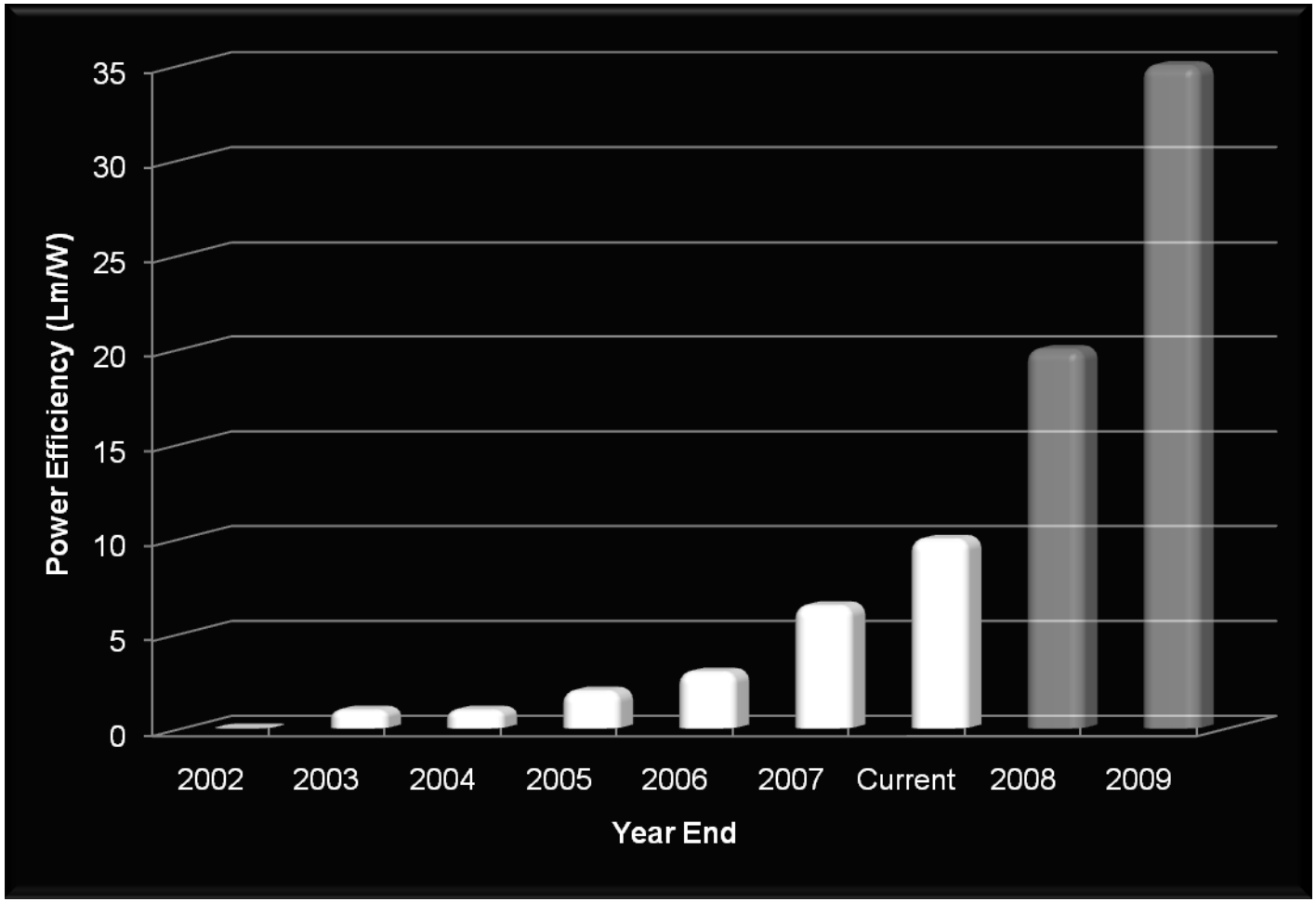
- CDT Test Cells ~ 6000 hrs from 1000 cd/m^2



SUMATION

Current Efficiency Status

- CDT Test Cells 10-11 lm/W at 1000 cd/m^2



SUMATION

Osram P-OLED Lighting

- P-OLED Ceiling Lighting Fixture Demo – Flying Future™

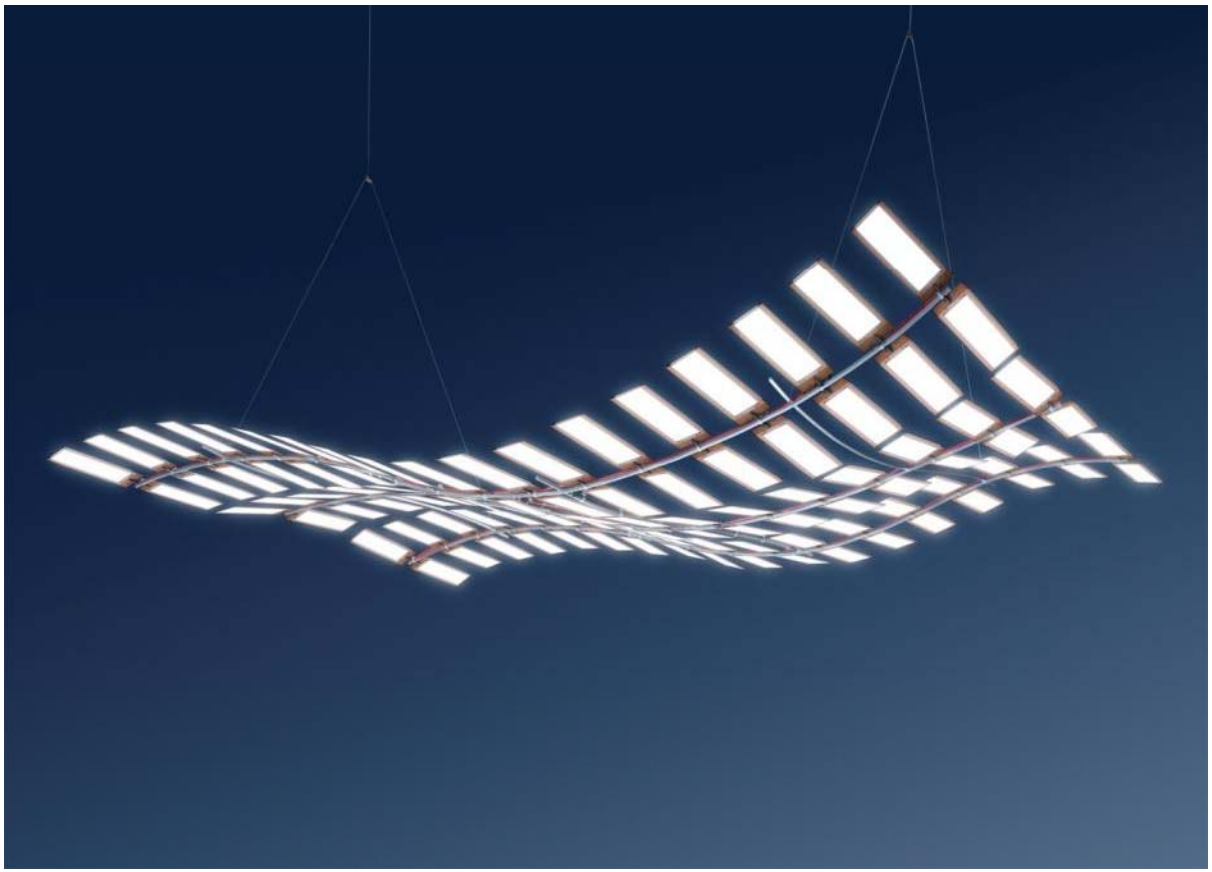


image courtesy of Osram and Ingo Maurer

- 108 Sumation polymer OLED cells

SUMATION

Summary

- White P-OLEDs show high potential for SSL applications.
  - Large area deposition for low cost devices
  - Diffuse light emission from large areas for general lighting
  - Colour tuning via emissive material
- Improved colour stability
  - over operation time
  - at different luminances
- Improved power efficiency without effecting the lifetime
- Part of Project TOPLESS sponsored by the Technical Strategy Board, Department of Innovation, Universities and Skills

SUMATION

http://www.cdtltd.co.uk

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