Developing Organic Light-emitting Diodes for Photodynamic Therapy

University of St Andrews

SUPA

Mina Riahi, Hassan Hafeez, Kou Yoshida, Cheng Lian, Saydulla Persheyev and Ifor D. W. Samuel

Organic Semiconductor Centre, School of Physics and Astronomy, University of St Andrews, UK

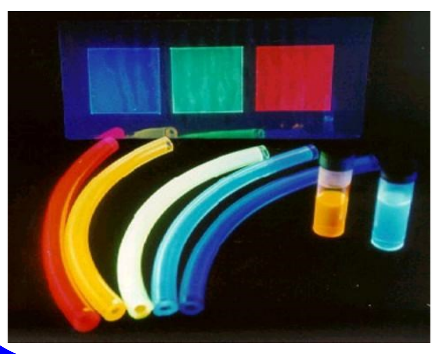
POLYTHEA

Motivation

Photodynamic therapy (PDT) is an effective light-based treatment for a range of diseases. The desired features of a light source for PDT are suitable wavelength, large emission area, uniform and bright. However, increasing the size can cause the problem of non-uniform light output due to the sheet resistance of electrodes. In this study, we show the characteristics of large area OLEDs with two different sizes and investigate the effect of contact design on larger organic light emitting diode. Results show improvements in contact design can give larger OLEDs with good uniformity.

Organic Semiconductors

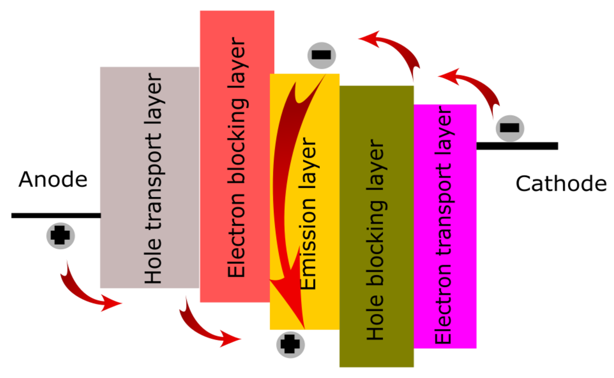
Organic semiconductors are carbon-based materials that exhibit semiconducting properties, which include single molecules, short chain (oligomers) and conjugated polymers. These materials are promising for optoelectronic devices such as organic light-emitting diodes (OLEDs), organic photovoltaic cells (OPV) and field-effect transistors due to their electrical and optical properties.



- Novel class of semiconductors
- Simple fabrication
- Tuning of properties
- Flexible
- Light-emitting

OLEDs

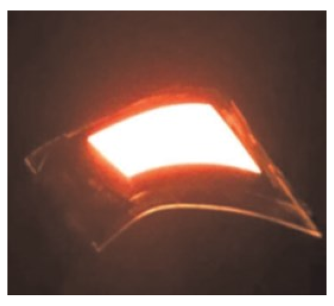
Electric field causes electrons and holes to be injected into the device. These electrons and holes combine to form excitons in the emissive layer, leading to light emission.



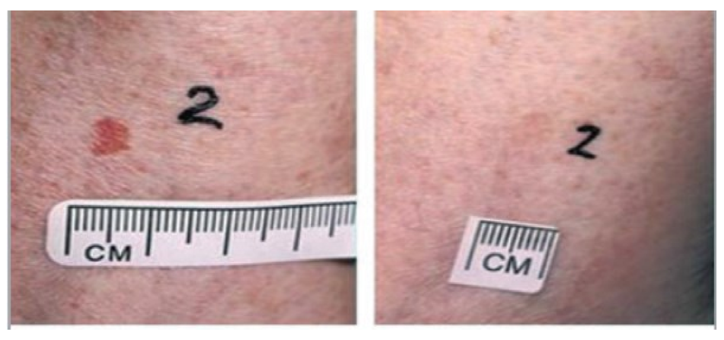
Ambulatory PDT using OLED

Advantages of OLED

- Lightweight - can be worn
- Has the potential to increase the size
- Allows low intensity/long treatment
- Reduced pain, increased effectiveness
- Low cost
- Widens access to PDT
- Simple wearable power supply



OLED-PDT



OLEDs have been successfully used for treating Bowen's disease (an early form of skin cancer). Small size lesion (diameter lower than 1.5 cm) completely cleared by using OLEDs with diameter of 2cm. For treating larger lesions increasing the emission area of OLED is required.

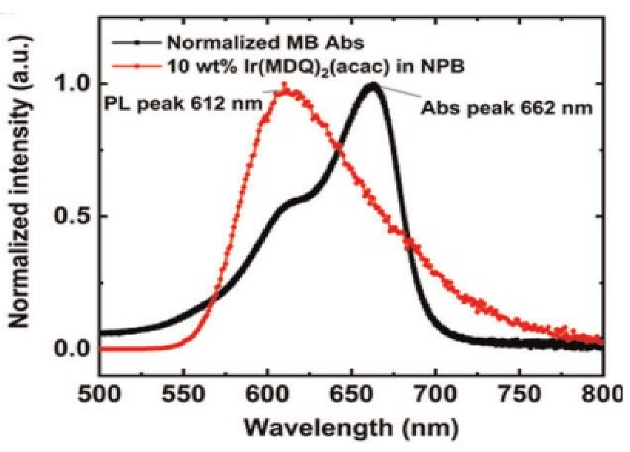
Score of pain (1-10)

Light source	Score
OLED-PDT	1
Conventional PDT	6

- OLEDs on glass substrates

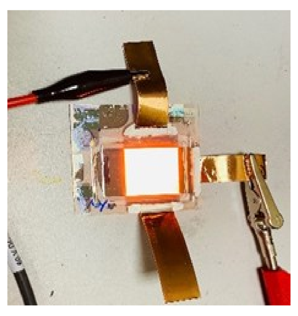
  Irradiance = 5 mw/cm^2

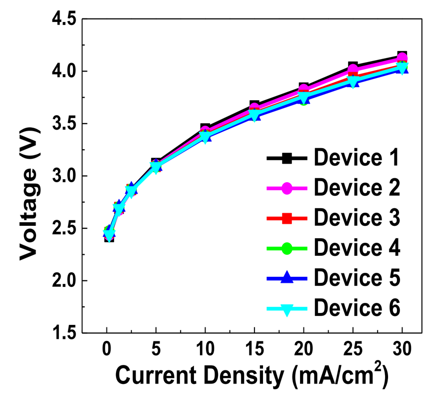
  Irradiation time: 3 hours
- Conventional PDT use ~ 80 mw/cm^2 for 20 min)

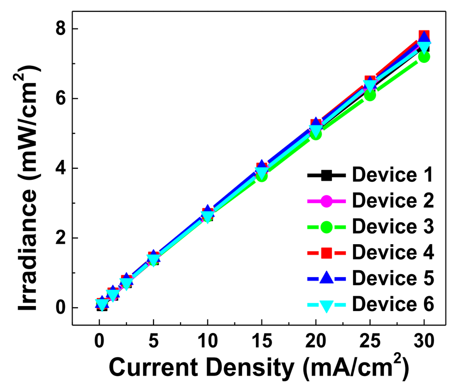


- Phosphorescent red emitter is used in emission layer for higher efficiency.
- For effective photoexcitation of the photosensitizer the emission spectrum of red emitter and absorption spectrum of MB should be overlapped.

Towards Large Area OLEDs



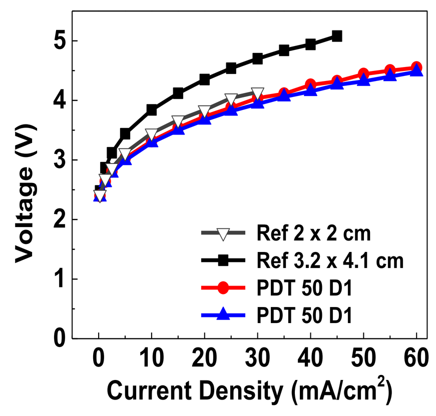


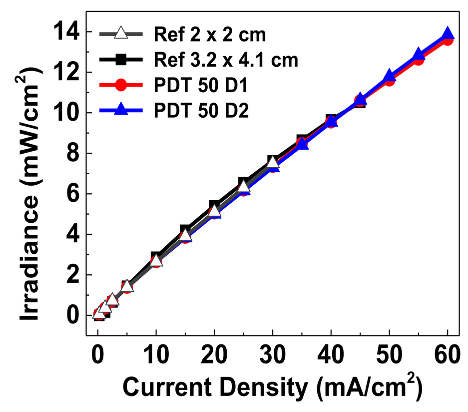


OLEDs with 20 mm by 20 mm emission area:

- At 100 mA (25 mA/cm^2), OLED delivers irradiance of 6.5 mw/cm^2 with 4 V driving voltage.
- Less than 10% intensity decay after 7000 minutes operation at irradiance of 6.5 mw/cm^2.

OLEDs with 28 mm by 50 mm emission area:

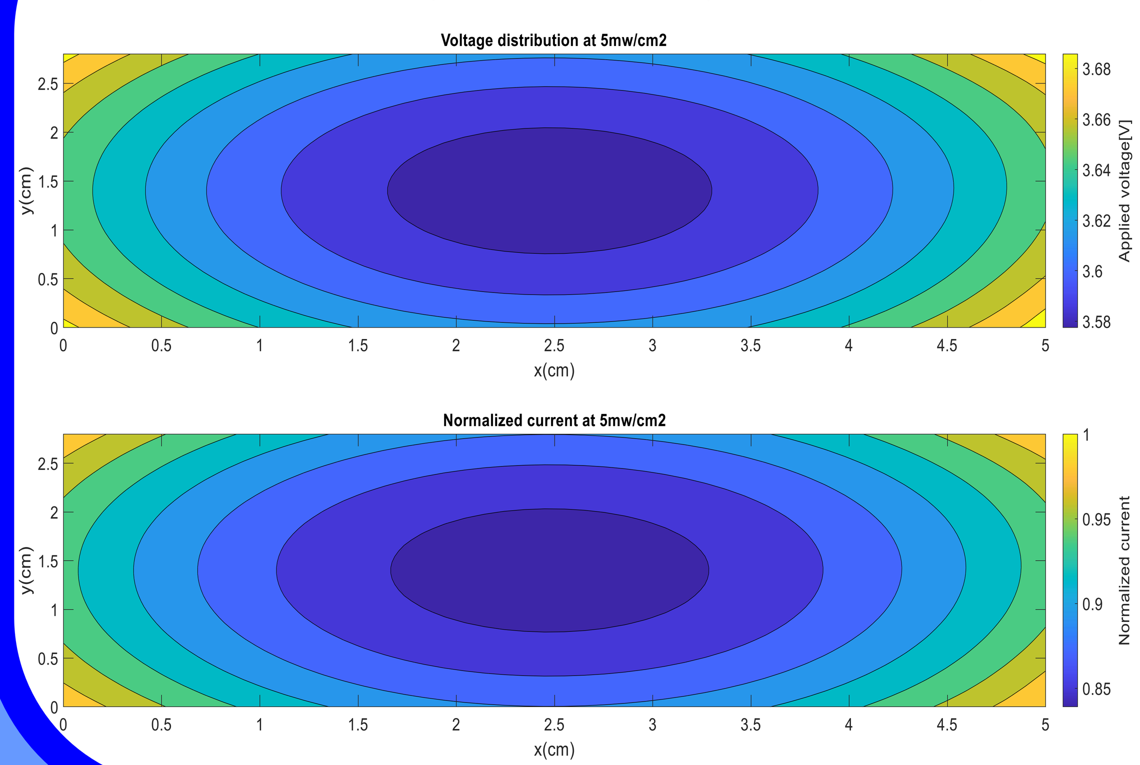




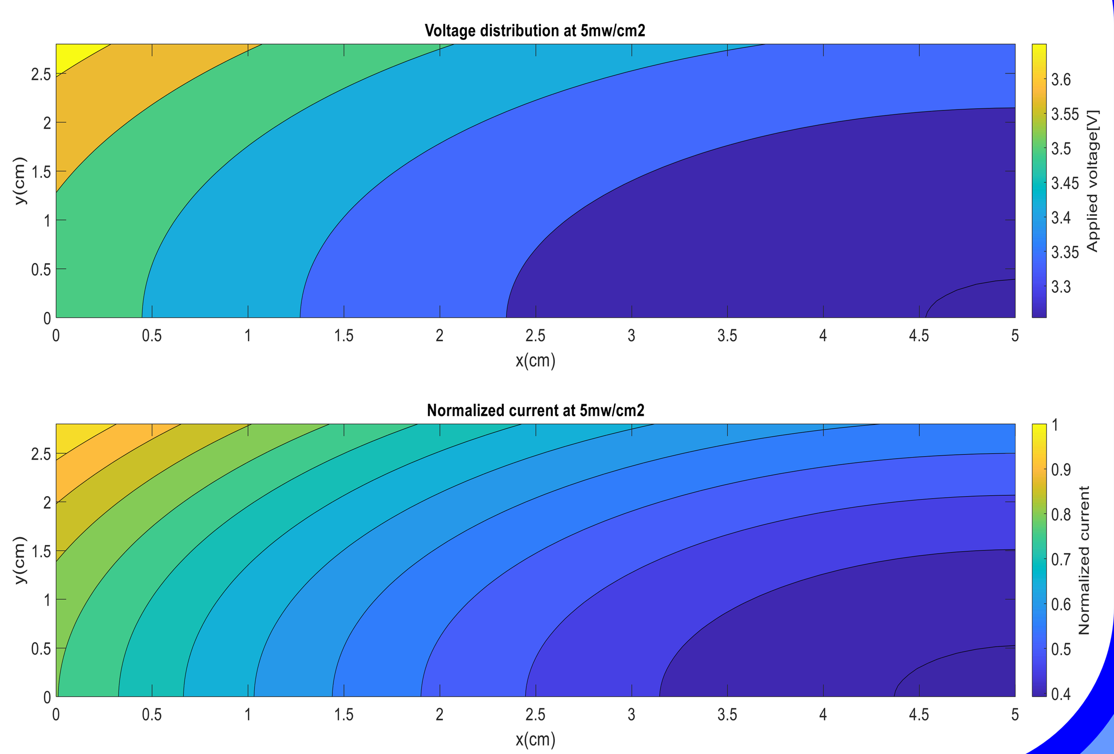
- OLEDs have the potential to expand the emission area for treating different sizes of wounds.
- Increasing the size causes luminance non-uniformity.
- Due to the sheet resistance of the electrodes, the injected current decreases and the light emission distribution becomes non-uniform.
- Electrical modelling of the OLED to calculate voltage drops and normalized current.
- Using double contacts reduces voltage drop leading to more homogenous light output.

Simulation Results

28 mm by 50 mm OLED (double contacts)



28 mm by 50 mm OLED (single contacts)



Conclusion

- OLEDs are promising light sources for photodynamic therapy.
- For treating large size wounds the emission area of OLEDs should be increased.
- Increasing the size of OLEDs leads to inhomogeneous light output.
- Large area OLEDs with uniform light were developed by improvement in contact design.

References

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- Lian, C. et al. Flexible organic light-emitting diodes for antimicrobial photodynamic therapy. npj Flex. Electron. 3, 0–6 (2019).