

# Efficient Solution-Processed Dendrimer OLEDs

O. V. Salata<sup>\*a</sup>, Zugang Liu<sup>a</sup>, A. Safonov<sup>b</sup>, N. Mustapha<sup>b</sup>, Shih-Chun Lo<sup>c</sup>, Paul Burn<sup>c</sup>, Ifor Samuel<sup>d</sup>, Jonathan Markham<sup>d</sup>

<sup>a</sup>Dept. of Materials, Univ. of Oxford, UK; <sup>b</sup>Opsys Limited, UK; <sup>c</sup>The Dyson Perrins Laboratory, Univ. of Oxford, UK; <sup>d</sup>Dept. of Physics & Astronomy, Univ. of St Andrews, UK

## ABSTRACT

Light-emitting dendrimers are a new distinct class of material for OLEDs. Dendrimers consist of a light-emitting core, dendrons and surface groups. Dendrimers are designed for solution coating and have a number of advantages over conjugated polymers. We report our recent results for solution processed green dendrimer OLEDs. The OLEDs were fabricated by spin-coating a blend of first generation dendrimer/host material followed by the evaporation of a hole blocking layer and a LiF/Al cathode. Power efficiencies of 50 lm/W at practical brightness levels were achieved for these structures.

**Keywords:** dendrimers, solution processing, OLED

## 1. INTRODUCTION

Light-emitting materials have traditionally fallen into two main classes, namely small molecules<sup>1</sup> and conjugated polymers<sup>2</sup>. Conjugated polymers are solution processed whilst small molecule based organic light-emitting diodes are produced by evaporation.

Light-emitting dendrimers are a new class of material for OLEDs<sup>3</sup>. Dendrimers consist of a light-emitting core, dendrons and surface groups. Dendrimers are solution processible and have a number of advantages over conjugated polymers. These include being produced by a modular synthetic route, which gives greater flexibility over controlling the properties and independent optimisation of the processing and electronic properties. Also, the generation of the dendrimer gives molecular control over the intermolecular interactions that are vital to OLED performance<sup>4</sup>.

Finally, both fluorescent and phosphorescent dendrimers are easily accessible. Phosphorescent light-emitting materials can harness emission from singlet and triplet excited states so that it is possible to achieve OLEDs with 100% internal quantum efficiency. In contrast, in fluorescent materials, triplet formation leads to substantial loss of efficiency.

Recently reported results for a single layer spin-coated dendrimer devices demonstrated the potential of the green phosphorescent dendrimer emitter<sup>5</sup>. In another recent work we reported some preliminary results for different combinations of host and hole blocking materials<sup>6,7</sup> in double layer devices. Here we report our latest improvements in the performance of double layer OLEDs based on the combination of the first generation green emitting dendrimer with 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA)<sup>8</sup> as a host material and 1,3,5-tris(2-N-phenylbenzimidazolyl)benzene (TPBI)<sup>9</sup> as a hole blocking/electron transporting material.

\* [oleg.salata@materials.ox.ac.uk](mailto:oleg.salata@materials.ox.ac.uk); phone +44-1865-283713; fax +44-1865-847444; Unit 8, Begbroke Business and Science Park, Sandy Lane, Yarnton, Oxford OX5 1PF, UK

## 2. EXPERIMENTAL

The OLEDs were fabricated by spin-coating a blend of first generation dendrimer/host material followed by the evaporation of a hole blocking layer and a LiF/Al cathode. The dendrimer (IrppyD)<sup>5,6</sup> consists of a *fac*-tris(2-phenylpyridine)iridium core, phenylene dendrons, and 2-ethylhexyloxy surface groups, as shown in Fig.1. This dendrimer has one level of branching and hence it is a first generation dendrimer.

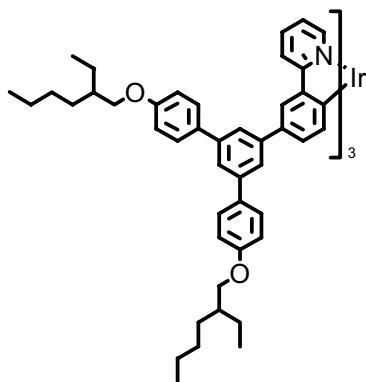


Fig.1. Structure of IrppyD

ITO coated glass substrates were cut into 1" by 1" squares and patterned using standard photolithography. After the patterning the substrates were cleaned with detergent, rinsed with deionised water, dried in the oven, and finally subjected to an oxygen plasma treatment.

The dendrimer/TCTA blends were typically spin-coated onto the substrates from 5-10 g/l solution in toluene at 100 to 4000 rpm to give a 20 to 50 nm thick films. The coated substrates were transferred to a Spectros vacuum evaporator (KJ Lesker) and a layer of a hole blocking/electron transporting material TPBI, 1.2 nm of LiF and 100 nm of Al were deposited sequentially. A typical device structure is shown in Fig.2.

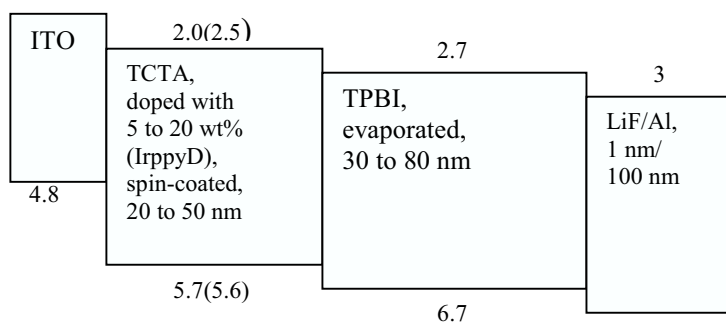


Fig.2. Typical device structure and HOMO/LUMO values for the materials used.

The completed devices were tested in air immediately after the fabrication. A PC controlled set up comprising a Keithley 4200 source-measure unit and Minolta LS100 luminance meter was used to gather electro-optical characteristics of the OLEDs. A CCD spectrograph (Oriel) was used to take EL spectra.

### 3. RESULTS AND DISCUSSION

The results of electro-optical testing are presented in Fig.3. (a) to (d).

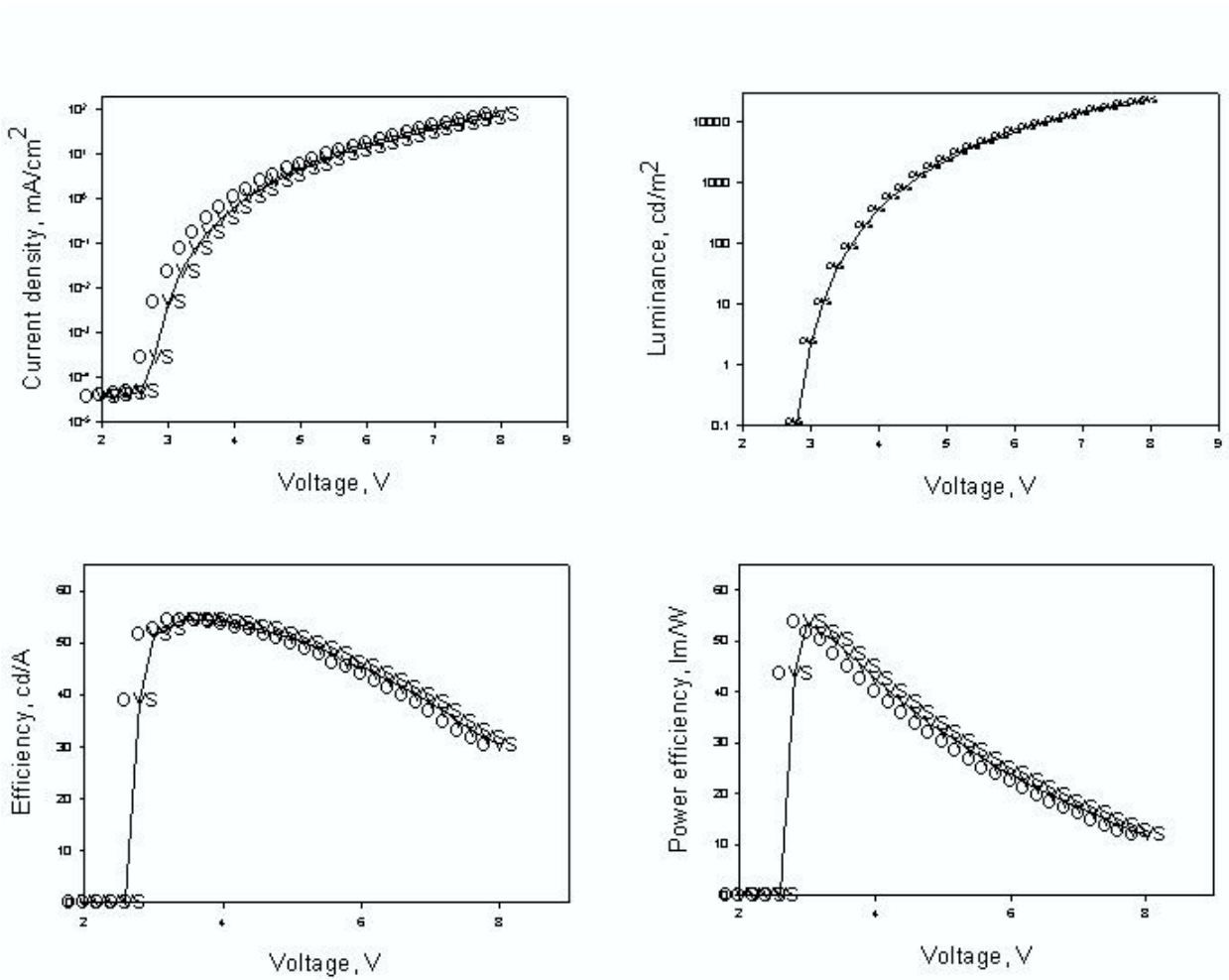


Fig.3. Electro-optical characteristics and efficiency of ITO/TCTA:IrppyD/TPBI/LiF/Al device a) current-voltage; b) luminance-voltage; c) efficiency-voltage; d) luminance efficiency-voltage

The devices turn on at 2.8 V. The CIE coordinates for the emission are  $x=0.31$   $y=0.64$  and stay virtually unchanged at high luminance. A power efficiency of 50 lm/W is achieved for these structures at 40 cd/m<sup>2</sup>, 3.4 V, and 54 cd/A. At a luminance of 10000 cd/m<sup>2</sup> the power efficiency was found to decrease but only to 20 lm/W. The performance of a typical device is summarised in Table 1.

Table 1. Summary of the typical device performance.

Voltage, V	Luminance, cd/m <sup>2</sup>	Efficiency, cd/A	Luminance efficiency, lm/W
2.8	0.1	39	44
3.4	40	54	50
3.7	100	54	46
4.5	1000	54	36
6.5	10000	42	20

The device structure and energy values of HOMOs and LUMOs are shown in Fig.2. It is likely that holes injected from the ITO are transported by hopping from one IrppyD site to another. Due to the high barrier to the hole transport at the TCTA/TPBI interface a high density of positive charge is created. This high charge density results in a strong electric field across the electron-transporting layer leading to an enhanced electron injection. Electrons crossing the TPBI/TCTA interface are recombining with holes blocked on the dendrimer sites with a very high efficiency.

#### 4. SUMMARY

These numbers are comparable with the best performance figures reported for the small molecule phosphorescent OLEDs<sup>9</sup> and surpass the best polymer devices<sup>10</sup>. We believe that these are the best results reported to date for the solution processed devices. Such high efficiency achieved for a solution processed dendrimer device paves a way to cheaper large area displays.

#### REFERENCES

1. C.W. Tang and S.A. Van Slyke, *Appl.Phys.Lett.* **51**, pp. 913-5, 1987.
2. J.H. Burroughes, D.D.C. Bradley, A.R. Brown, R.N. Marks, K.D. Mackay, R.H. Friend, P.L. Burn, A.B. Holmes, *Nature*, **347**, p. 539, 1990.
3. Wang, P. W., Liu, Y. J., Devadoss, C., Bharathi, P., and Moore, J. S., *Advanced Materials* **8**(3), p.237, 1996. Halim, M., Samuel, I. D. W., Pillow, J. N. G., Monkman, A. P., and Burn, P. L., *Synthetic Metals* **102**(1-3), p.1571, 1999. Freeman, A., Frechet, J., Koene, S., and Thompson, M., *Macromolecular Symposia* **154**, p. 163, 2000. Lupton, J. M., Hemingway, L. R., Samuel, I. D. W., and Burn, P. L., *Journal of Materials Chemistry* **10**(4), p. 867, 2000. Lupton, J. M., Samuel, I. D. W., Frampton, M. J., Beavington, R., and Burn, P. L., *Advanced Functional Materials* **11**(4), p. 287, 2001.
4. Lupton, J. M., Samuel, I. D. W., Beavington, R., Burn, P. L., and Bässler, H., *Advanced Materials* **13**(4), p. 258 2001.
5. Markham, J. P. J., Lo, S. C., Magennis, S. W., Burn, P. L., and Samuel, I. D. W., *Appl. Phys .Lett.* **80**(15), p. 2645, 2002.

6. Lo, S-C., Male, N. A. H., Markham, J. P. J., Magennis, S. W., Burn, P. L., Salata, O. V., and Samuel, I. D. W. *Advanced Materials* ,**14** (13-14), p. 975, 2002.
- 7 Markham, J. P. J., Anthopoulos, T., Magennis, S. W., Samuel, I. D. W., Male, N. A. H., Salata, O.V., Lo, S. -C., Burn, P.L. L., SID Int. Symposium Digest vol. **XXXIII**, no. II, p.1032 ,2002.
8. Ikai, M., Tokito, S., Sakamoto, Y., Suzuki, T., and Taga, Y., *Appl. Phys. Lett.* **79**(2), p. 156, 2001.
9. Gao, Z., Lee, C. S., Bello, I., Lee, S. T., Chen, R.-M., Luh, T.-Y., Shi, J., and Tang, C. W., *Appl. Phys. Lett.* **74**, p. 865, 1999.
10. Friend, R.H., *Pure and Applied Chemistry* **73** (3), p. 425, 2001.