Novel Electron Transporter (Elamate®246) and Hole Injector (Elamate®9363) for the Reduction of Operating Voltage and Improvement in Efficiency and Lifetime

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Abstract
The search for stable electron transporters and hole injectors has become particularly intense over the last 18 months as OLED manufacturers are poised to start production of OLED panels. We report here a proprietary electron transporter (E246), which reduces the operating voltage, increases the efficiency and the lifetime of OLEDs made of fluorescent or phosphorescent systems when compared with Alq_3 as an electron transporter. We also report a novel proprietary hole injector (buffer, E9363) which also reduces the operating voltage, increases the efficiency and doubles the lifetime compared to CuPC. These two materials are now available commercially for display manufacturers.

1 Objectives and Background
OLEDs are becoming established as an alternative technology to LCD in certain areas of application [1]. In order for the OLED technology to be widely accepted, improvement in lifetime and efficiency and reduction in operating voltages are essential and critical [2-5]. We, at ELAM-T, have been developing novel fluorescent, phosphorescent and ion fluorescent (rare earth chelates) materials (ELAMATES®) for display applications. Our current focus is in delivering competitive advantage to our customers regardless of their choice of technology, be it fluorescent, phosphorescent or ion fluorescent. It is now well recognised that the established electron transporter Alq_3 is not adequate for the growing demand of display manufacturers. Similarly, the CuPC, the hole injector used presently by some manufacturers is not suitable owing to its lack of transmittance in the red region and the high temperature required to evaporate it.

We have designed, developed and patented an electron transporter (E246), which reduces the operating voltage and increases both the lifetime and efficiency of fluorescent and phosphorescent system when compared to Alq_3 as an electron transporter. Similarly, we have developed a hole injector (E9363) which not only reduces the operating voltage, but also improves the lifetime and efficiency. Further, to sustain an evaporation rate of 2 Å/s, 390 °C is needed for E9363 whereas CuPC requires 460 °C.

2 Experimental and Results
2.1 Physical Properties
A selected physical properties of E246 is compared with Alq_3 in Table 1. A selected physical properties of E9363 is compared with CuPC and 2-TNATA in Table 2. The absorption spectrum of thin films and evaporation characteristics of 2-TNATA, CuPC and E9363 are shown in Figures 1 and 2 respectively.

2.2 Device Performance
We illustrate the superior quality of our electron transporter and hole injector by considering Alq_3 as a host and a green emitting proprietary dopant E036. E246 is compared with Alq_3. CuPC is compared with E9363. We made devices as shown in the Table 3: The thickness of CuPC and E9363 are 20nm, α-NPB (50nm), Alq_3 or E246 (host, 40nm), dopant (0.1nm), Alq_3 or E246 (etl, 20nm), LiF (0.5nm) and Al electrode (150nm) in all cases.

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Table 1

Material	T_m / °C	HOMO / eV	LUMO / eV	Photoluminescence max. / nm
E246	388	- 5.6	- 2.9	537
Alq_3	414	- 5.7	- 2.9	520

Table 2

Material	T_g / °C	T_m / °C	ϕ_{WF} / eV	Temperature required to achieve 2 Å/s
E9363	---	> 400	- 5.4	390 °C
CuPC	---	>400	- 5.3	460 °C
2-TNATA	118	254	- 5.3	370 °C

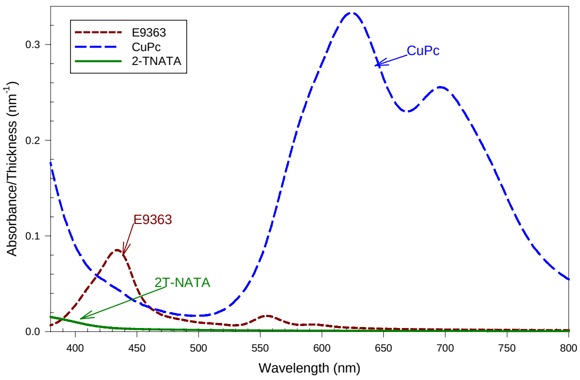

Figure 1: Absorption Spectra of Hole Injectors

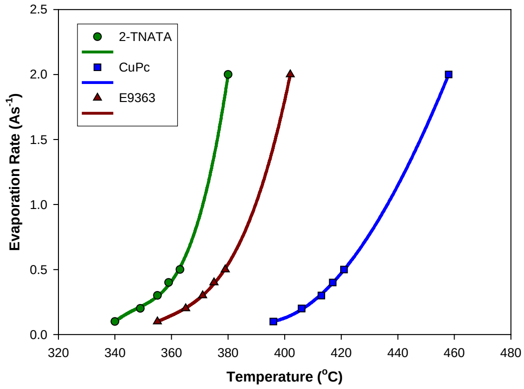

Figure 2: Evaporation Rate Vs Temperature

Table 3: Buffer, CuPC or E9363; Fluorescent Green Dopant, E036; Colour Co-ordinate, (0.30, 0.65); (a), at 100 cdm^{-2}

Device	Device Structure	Turn-on Voltage/V	Eff. / cd/A (a)	Eff. / lm/W (a)
A 1	CuPC/α-NPB/Alq_3+E036/Alq_3/LiF/Al	5.0	6.5	2.8
A 2	***CuPC/α-NPB/Alq_3+E036/E246/LiF/Al***	***3.0***	***10***	***3.4***
A 3	CuPC/α-NPB/E246+E036/E246/LiF/Al	5.0	12	4.0
A 4	CuPC/α-NPB/E246+E036/Alq_3/LiF/Al	5.0	8	2.8
A 5	E9363/α-NPB/Alq_3+E036/Alq_3/LiF/Al	2.0	8	4.6
A 6	***E9363/α-NPB/Alq_3+E036/E246/LiF/Al***	***1.5***	***10***	***5.2***
A 7	E9363/α-NPB/E246+E036/E246/LiF/Al	1.5	8	4.2
A 8	E9363/α-NPB/E246+E036/Alq_3/LiF/Al	2.0	4.2	2.2

All the devices were made under identical conditions and all the layers were deposited by vacuum deposition system (Solciet) produced by ULVAC, Japan. The device performance of Devices A1, A2, A5 and A6 are shown in Figures 3A, 3B and 3C.

3. Discussion

3.1 Device Performance

It is clear from the results that E246, when used as a host and electron transporter (A4) gives the best efficiency for CuPC as the hole injector. When Alq_3 is replaced by E246 as an etl (Compare Device A1 with A2), the turn-on voltage drops by 2V, current efficiency (cd/A) increases by 54% and the power efficiency increases by 21%. When the CuPc buffer is replaced by E9363, the efficiency of Device A1 (Alq_3 as host and Alq_3 as etl) increases by 23% and the power efficiency by 64%. When the CuPC buffer is replaced by E9363, Device A6 (Alq_3 host, E246 etl), the power efficiency increases by 53%. Thus, by using E246 as an etl and E9363 as a hole injector, an overall improvement of 54 % in current efficiency and 86% improvement in power efficiency had been achieved and compared to Alq_3/Alq_3 (A1 devices).

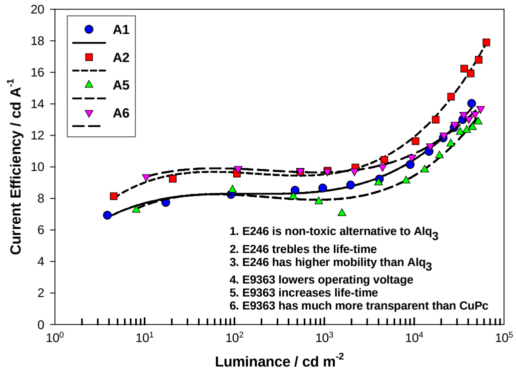

Figure 3 A

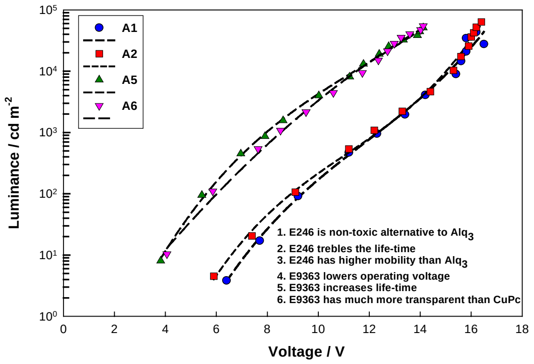

Figure 3B

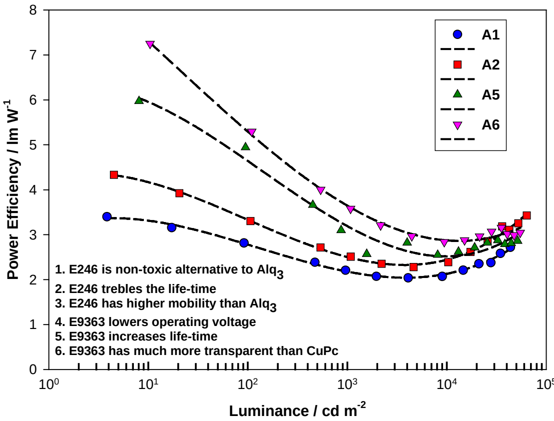

Figure 3C

When the CuPC buffer is replaced by E9363, Device A6 (Alq_3 host, E246 etl), the power efficiency increases by 53%. Thus, by using E246 as an etl and E9363 as a hole injector, an overall improvement of 54 % in current efficiency and 86% improvement in power efficiency had been achieved compared to the Alq_3/Alq_3 (A1 devices).

3.2 Lifetime Measurements

The lifetime of all the devices were measured at 1200 cdm^{-2} at constant current density. The results for devices A1, A2, A5 and A6 only are presented here for brevity. The results for devices A1 and A5 (Alq_3 as host, Alq3 as etl) are shown in Figure 4. Lifetime data for 2-TNATA as hole injector (ITO/2-TNATA (20nm)/ α-NPB (50nm)/Alq_3+E036 (40:0.1nm)/Alq_3 (20nm)/LiF/Al is also shown. It is clear that 2-TNATA based devices decay substantially faster than CuPC. E9363 based devices give longer lifetime than CuPC based devices.

Lifetime data for devices A2 and A6 (Alq_3 as host) and E246 as etl) are presented in Figure 5. It is clear the devices with E9363 as hole injector and E246 as etl perform better than CuPC/E246 system.

Table 4 summarises the lifetime data for $T_{0.75}$ (75% of initial luminance) and $T_{0.6}$ (60% of initial luminance).

4. Conclusion

We have demonstrated that our new electron transporter E246 and the hole injector E9363 reduce the operating voltage and increase the efficiency and lifetime substantially. E246 and E9363 are available in kg quantities for OLED manufacturers.

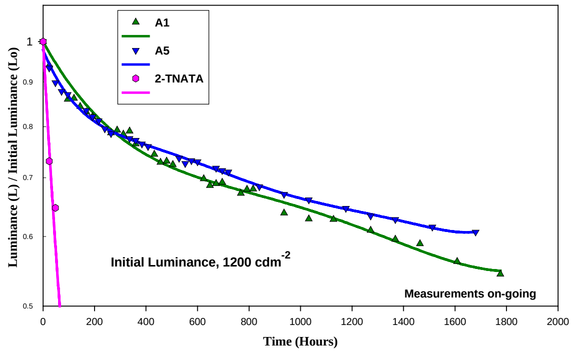

Figure 4

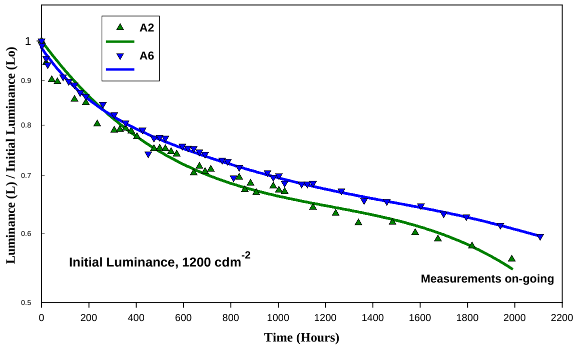

Figure 5

Table 4: Initial Luminance, 1200 cdm^{-2}

Hole Injector	**Host**	**ETL**	**$T_{0.75}$ / hours**	**$T_{0.6}$ / hours**
CuPC	Alq_3	Alq_3	380±10	1380±10
CuPC	Alq_3	E246	480±10	1750±10
E9363	Alq_3	Alq_3	490±10	2050±10
E9363	Alq_3	E246	600±10	2350±10
2-TNATA	Alq_3	Alq_3	40±5	60±5

5. Acknowledgement

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