Novel Electron-Transport Materials for OLED TVs and OLED Mobile Displays

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Abstract

With the market for mobile AMOLED displays still increasing, both Samsung Mobile Display and LG Display have announced that OLED TVs will be commercially available in 2012. OLED TVs have different requirements compared to mobile devices and especially the lifetime has to be significantly longer in TVs. Therefore, Novaled has developed new ETL materials that lead to much longer lifetime in monochrome OLEDs. Furthermore, these ETLs can also be used to reduce the voltage in monochrome OLEDs and stacked white OLEDs.

1. Introduction

AMOLED displays have now been on the market for several years with good customer feedback, which leads to more and more mobile products with such displays. Especially the Galaxy series by Samsung has made the OLED displays known worldwide. In 2012, we now expect the first OLED TVs to appear on the market. With their greatly improved picture quality, these TVs may revolutionize the TV market because their contrast ratio and color saturation are stunning. Nevertheless, some issues still have to be resolved. The main issue is definitely the production costs that have to come down for OLED TVs to become mainstream, but also the performance needs to be improved. TVs require a much longer lifetime than mobile devices, but the power consumption will have to be reduced for both applications still.

Novaled recognized a while ago that the currently limiting factor for the OLED performance is the electron-transporting side of the device. Therefore, we have developed new electron-transporting materials and n-dopants that can be used in electron-transport layers (ETLs) of monochrome OLEDs with extremely long lifetime, but also in stacked white OLEDs with low voltage. Here, we present our newest materials that can be used in mobile displays as well as in TVs. Furthermore, by choosing a specific blue emissive layer we were able to achieve low-voltage monochrome OLEDs with long lifetimes.

2. Air-stable ETL materials for very long lifetime

Using the Novaled PIN OLED® Technology,[1] Novaled has continuously presented high-efficiency and long-lifetime OLEDs with proprietary transport layers at the anode and the cathode.[2] It has been shown that our dopant products NDP-9 and NDN-26 are very good injection solutions from most electrode materials leading to a high OLED performance. However, to suit the display industry's focus on highest lifetime and ease of manufacturing better, we have developed a completely new class of ETL systems that are completely air-stable.

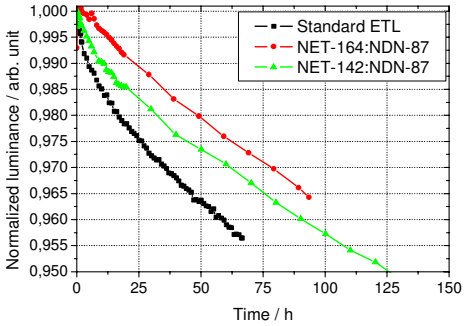

Fig. 1. Normalized luminance at 15 mA/cm² as a function of the time for devices with the new Novaled ETLs in comparison to a standard ETL.

Currently, our best-performing ETL host materials are NET-142 and NET-164. These materials can replace standard ETL hosts in monochrome displays without too much further optimization for a performance improvement. In combination with the new air-stable dopant NDN-87, these ETLs show higher efficiency and much longer lifetime than current ETLs (Figure 1). Table 1 shows an overview of the performance of top-emission blue OLED devices with the structure Ag/NHT-49:NDP-9/NHT-49/blue EML/ETL/Mg:Ag. A blue emitter system by Sun Fine Chemicals (SFC Co. Ltd., Korea) was used for these tests since we have achieved good results with such emitters before.[3] A similar performance improvement has been

observed for red and green monochrome OLEDs.

Table 1. Performance of blue monochrome OLEDs at 15mA/cm² with different ETLs. LT95 denotes the lifetime to 95% of the initial luminance.

	Voltage / V	Current Efficiency / cd/A	CIE 1931 y-coordinate	Lifetime LT95 / h
Reference OLED	4.4	4.4	0.046	85
NET-164: NDN-87	4.8	4.7	0.040	140
NET-142: NDN-87	5.3	4.3	0.048	125

Further development based on NET-142 and NET-164 is still ongoing. LT95 up to 1500h at 15 mA/cm² have already been measured with a different deep-blue emitter system.

3. Air-stable ETL material for low voltage and long lifetime

While lifetime improvement currently has highest priority in the development of OLEDs, ultimately the voltage also has to come down to reduce the power consumption of the OLED display. However, especially for the blue pixel, state-of-the-art emissive layers do not allow a reduction of the voltage without sacrificing lifetime. Almost all blue emissive layers nowadays feature poor hole transport. Therefore, improvement of electron injection, which is a prerequisite to reduce the OLED voltage, usually results in an electron oversupply at the interface between the hole-transport and the emissive layer (EML), and the resulting stress leads to a short OLED lifetime.

Therefore, low-voltage monochrome OLEDs with a long lifetime require more balanced charge transport in the EML. By using a more ambipolar EML, Novaled has achieved low-voltage OLEDs with even longer lifetime than the reference OLED from above. For best electron injection, we used our new air-stable n-dopant NDN-77. Like NDN-87, this dopant was optimized for our newest host materials NET-142 and NET-164. The performance for such a device is shown in Table 2.

Table 2 Performance of blue monochrome OLEDs at 15mA/cm² with different ETLs.

	Voltage / V	Current Efficiency / cd/A	CIE 1931 y-coordinate	Lifetime LT95 / h
Reference OLED	4.4	4.4	0.046	85
Novaled low-voltage OLED	3.6	5.1	0.053	130

4. New ETL material for tandem white OLEDs

For TV application, some display manufacturers also consider the use of white OLED pixels with color filters. In this case, tandem white OLEDs are typically used for longer lifetime and improved reproducibility. Low voltage and good electron injection are also of high importance in such devices. NET-164:NDN-77 and NET-142:NDN-77 are suitable as ETL for such applications (see device architecture in Figure 2). In fact, compared to thin electron-injection layers like LiF, they also have the advantage that they are easier to process since the performance does not vary much with a fluctuation of the doping concentration and of the thickness of the ETL. With Novaled´s doped transport layers and the Novaled pn-junction, a voltage of 6.9 V at 10 mA/cm² has been achieved in a tandem white OLED without any negative influence on the efficiency or the lifetime.

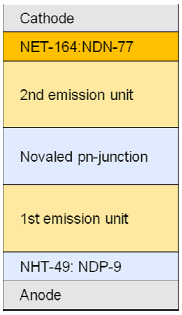

Fig. 2. Typical tandem white OLED stack architecture with Novaled p-HTL, pn-junction, and the new ETL for low voltage with high efficiency and long lifetime.

5. Summary

Novaled has recently developed new air-stable electron-transport host and dopant materials that can be used for monochrome and white display applications. For monochrome OLEDs, very long lifetime can be achieved with such ETLs, which is crucial for TV applications. Furthermore, by using more ambipolar blue EMLs in monochrome blue OLEDs as well as in white tandem stacks in general, low voltages and long lifetimes can be achieved with these ETLs.

Acknowledgment

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References

1. K. Walzer et al., *Chemical Reviews,* vol. 107, p. 1233 (2007).
2. T.W. Canzler et al., *IDMC 07 Proceedings*, vol. S17-03, p. 332 (2007).
3. Ulrich Denker et al., *IMID/IDMC/ASIA Display 2010 Digest*, 253 (2010)