

Comparative Evaluation of Inorganic and Organic Light-Emitting Diodes for Signage Application

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ABSTRACT

Solid-state lighting using light-emitting diodes has been effectively utilized for commercial signage. With the availability of high brightness inorganic LEDs, it was possible to develop standard signs with strips of LEDs placed on the edges of a non-engraved acrylic panel, commercially. The experiment indicated that these signs based on edgelighting technology possessed an efficacy of 18 lm/W. These displays, although proven to be more efficient than the conventional signage technologies, suffered from several limitations. Homogeneity of displays, which is a prime requirement for illuminated signs, was not achieved. If the display size increases further, then the center part of the display would become darker and the purpose of illumination would be lost. Reflective diamond gratings, used for spreading light, reduced the problem but did not eliminate it. This problem could be overcome with the use of a diffused source of light and the organic-LED technology could be a possible contender. We selected a commercially available full-colored, 0.95" diagonal, passive matrix OLED module and determined its opto-electrical parameters. We scaled it to the reference display size. The evaluation suggested that a more uniform display than the inorganic LEDs was possible with OLEDs. The efficacy of the commercially available full-color module was 0.3 lm/W at 40cd/m². The comparative results indicated that current OLED-based signs could not compete with conventional LED-based signs in terms of energy efficiency. However, being lightweight, diffused sources with the potential of being built on flexible substrates, OLEDs are very suitable for distributed, large area applications such as signage.

Keywords: Organic light-emitting diodes, illuminated, signage, large displays, light-emitting diodes

1. INTRODUCTION

Signage is used to convey information, in the form of a display, to the viewer. It may be in the form of a stop sign, an arrow sign, or an address sign, which we may come across in our daily lives. Its main objective is to provide information in an easily readable and distinct manner without stressing the eyes of the viewer. The signs used for nighttime are generally illuminated. There are various techniques used for illuminating signage, such as the signage using incandescent bulbs, compact fluorescent lamps, tritium gas, photoluminescence and light-emitting diodes. Incandescent lamps have been proved to be highly inefficient wasting almost 95% of the energy as heat.¹ Compact fluorescent lamps are more efficient than incandescent bulbs but are composed of toxic materials, highly difficult to dispose off.² Tritium gas signs also pose the same danger. Photoluminescent signs require more maintenance and have lower luminance values than the other signs. The limitations of the various techniques available and the possible energy savings associated with LEDs have encouraged the lighting industry to manufacture LED-based illuminated signs.

Solid-state lighting using inorganic light-emitting diodes (LEDs) has progressed quickly with output doubling every 18-24 months for the past 34 years (Haiz law).³ New materials and technologies have enabled the use of LEDs in areas other than indicator lighting. They have verified efficiencies better than the incandescent lamps and have been successfully employed for signage application. LEDs are now available in various colors and specifications including white. This has opened new vistas of applications for LEDs from indication to illumination.⁴ The interest in solid-state lighting sources has further been fueled by the development of small-molecule and polymer-based organic light-emitting diodes (OLEDs). OLEDs have validated their potential in microdisplays such as the cell-phone display and the PDA screens. They have invoked considerable interest in the flat panel display industry.⁵ OLEDs have successfully challenged their counterpart, the liquid crystal display, in this application. However, their potential application in large displays for signage has not been ascertained. In this paper, we evaluated and compared the performance of inorganic LED-based signage with organic LED-based signage.

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2.INORGANIC LED-BASED SIGNS

LEDs based on inorganic materials stand for the most efficient source of lighting available today. They are the most widespread solid-state lamps possessing long-life and good compatibility with integrated circuits, which broadens their area of application. LED-based signs can be based on edge lighting or may be element lit. Element lit signs are usually used for alphanumeric displays and the edge-lighting technology is often used for large area displays. More advanced edgelit LED signs with engravings are also available which are used for advertising. Our primary focus was on the signs, which used edgelighting techniques to backlight a display panel.

2.1 Structure

Inorganic LEDs are commercially available in various colors and specifications. For large displays, many companies are using edgelit technology with LEDs. For this project, we selected a standard backlit display that used LED edgelighting. These signs consisted of the high-brightness white LEDs placed on the edges of an acrylic sheet. These LEDs were driven by specific driver circuits designed to optimize the current flowing through them. The display size was standardized to (600mm x 600mm) size according to industrial usage. Figure 1 depicts a 600mm sign with an arrow pattern on an acrylic panel.



Figure 1: Arrow Sign

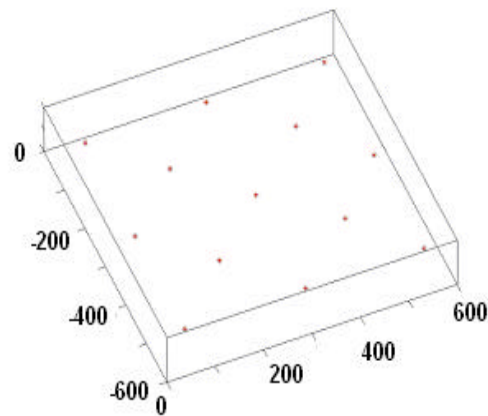


Figure 2: Position of points of measurement on the display

2.1 Measurements

In order to evaluate the sign, we performed the photometric measurements at specific points. These measurement points were equally distributed on the display (Figure 2). We used S370 optometer from UDT instruments along with Agilent 6612C system DC power supply to perform the photometric measurements.

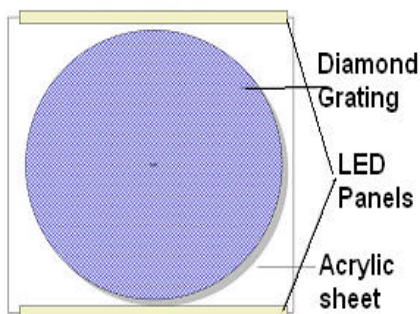
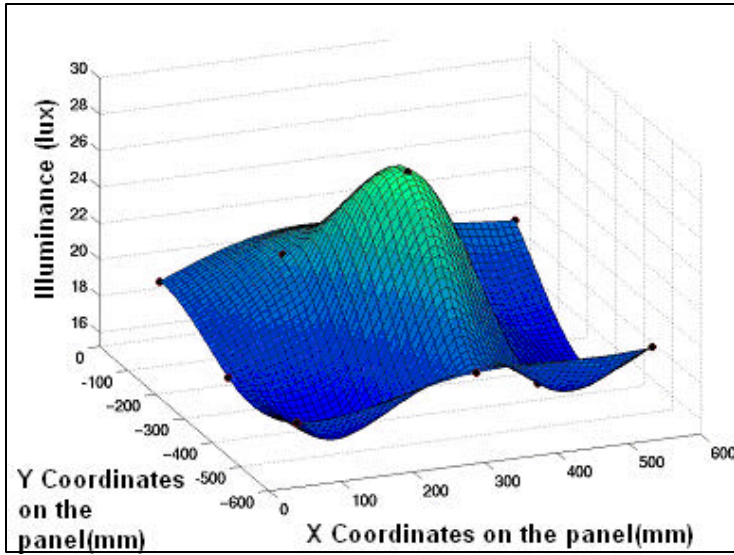


Figure 3: LED-based sign with the diamond grating

The measurements were made in a dark room with black-colored walls to avoid any unwanted light input to the photometer. The photometric measurements were made after proper calibration of the instruments.

In addition to the standard signs without the pattern, we measured a sign with a diamond grating in the central part. This diamond grating is used to scatter and spread light in the required areas. It also reflects the light, which may have been absorbed by the acrylic sheet. Figure 3 depicts the diamond grating in the center of the display.

The LEDs are placed on the edges of the display and are powered up with the help of a simple driver circuit.



generated (Figure 5).

Figure 4: Surface plot of illuminance for a standard 600mm-sign

The display was powered up with different voltages and current values. Brightness of the display was controlled by varying the input current. All the values were measured in terms of the illuminance value (lux) as the light average light output for these displays has been standardized as 20 lux according to commercial usage. The voltage and current given to the display was set-up to give an average output of 20 lux.

The photometric measurements were taken with various samples available and surface plot for the standard 600mm display was generated. Figure 4 depicts such a plot without the diamond grating and the pattern.

Displays with circular diamond gratings in the center of the acrylic were also analyzed. Photometric measurements were taken and the surface plot was

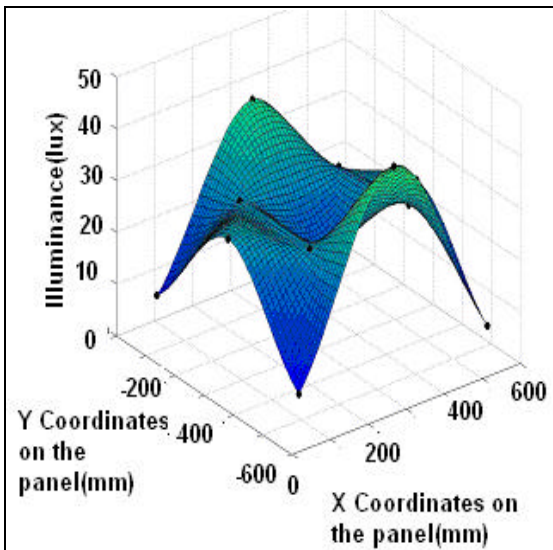


Figure 5: Surface plot with the diamond-grating

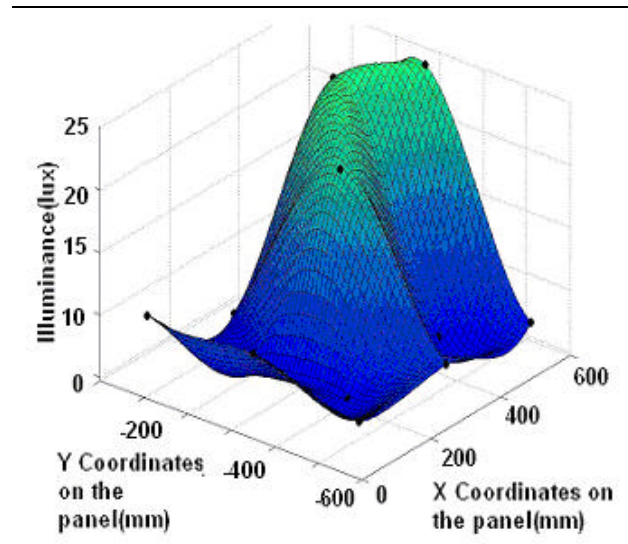


Figure 6: Surface plot with the pattern (arrow in this case).

These LED-based signs were first designed for a generic display. The final display pattern on the top actually determined the light output of the sign. We chose an arrow pattern for our evaluation, which is a common highway sign, used in North America. Figure 6 shows the values obtained with the display pattern on top of the reference sign. The measurements indicated an efficacy of 18lm/W for a 20 lux average illuminance with a 600mm sign.

3. ORGANIC LED-BASED DISPLAYS

Research and development in the area of organic light-emitting diodes has gained considerable momentum in the last decade. In 1987, Tang and VanSlyke from Kodak⁶ vitalized the OLED industry by demonstrating a green electroluminescent device based on small-molecule based organic materials. This was followed by the demonstration of conjugate polymer⁷ based organic light-emitting device by a Cambridge group. Since then, there has been an increasing interest in these devices that possess a robust design, high resolution and uniform operation without flicker.⁸ Research is still underway to determine the potential of OLEDs for different applications.

Through this paper, we intended to assess the feasibility of using OLEDs for signage application.

3.1 Normalization and Standardization

The comparison of the organic LED displays and the conventional LED displays could only be made if the devices were normalized for a common parameter. In this case we normalized the displays on the basis of their light output. The average illuminance from a 600 mm sign display is assumed to be 20 lux. The area of the panel is (0.6 x 0.6) m². So the net light output falling on a surface would be 7.2 lumen. Therefore, 7.2 lumen was the targeted output from the display.

3.2 OLEDs for signage

Different kinds of OLED modules are available commercially nowadays. The choice of the OLED module has a great bearing on its performance. This choice was made, keeping in mind, the specific requirements for the signage application. Signage is a very low-resolution application and large display signs are usually viewed from a distance and so the number of pixels and the display resolution is not of larger concern. Hence, it was evident that a passive matrix OLED display would be suitable.

In addition, small-molecule OLEDs under mass-production, were available commercially in different sizes in full-color unlike polymer OLEDs. Polymer OLEDs were only available as monochrome microdisplays or research samples having large areas. So, the choice of small-molecule based OLEDs was more feasible. The signage display could have a multicolored pattern on the top, so a full-colored or white colored OLED module was more suitable. On the basis of these requirements, we obtained 0.95" diagonal, 65K colored OLEDs available commercially.

3.3 OLED Display measurement

In order to power-up these displays, we required additional circuitry and programming. The circuitry was designed and the printed circuit board was laid out for supplying the voltage to these modules. These devices required an additional microprocessor/microcontroller to turn the display ON and to tune it to different colors. MSP-430 is a low power microcontroller popularly used for LED-based systems. Based on the competence of these microcontrollers, we used it for this project as well. MSP-430 provided a user-friendly environment with the option of using C language to program it. A program for giving instructions the OLED driver chip through the PCB was written in C language. Individual OLED module was attached to the populated PCB and the commands and data instructions were programmed in.

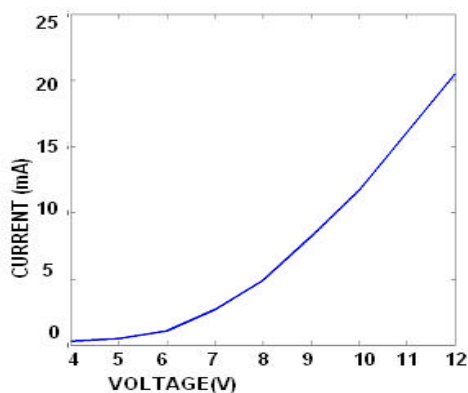


Figure 7: I-V characteristics for an OLED display.

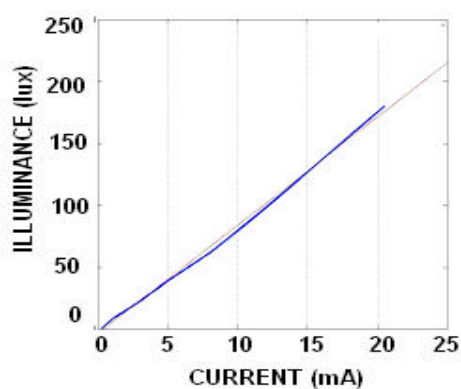


Figure 8: L-I characteristics of the OLED display.

The OLED display was tested and the IV characteristics were obtained using the same apparatus as for the LED-based display. The display was tuned to white color. The measurements were made in the same environment as an LED. Figure 7 depicts the IV characteristics of the OLED. For signage application, if a pattern has to be employed then the displays could also be built in a tiled manner. Small displays with less resolution could be used for this application with could reduce the cost of the display.

So, a display consisting of OLEDs lined together was formed. This display was scaled for 600mm sign with 20" diagonal. The LI characteristics were measured (figure 8) and the display values were scaled for a 600mm sign size. The display promised uniformity if the same kind of devices with the same inputs were used to obtain a 20" diagonal size. The power consumption was approximated to 20 W for a uniform 20 lux output. This implied an efficacy of 0.3 lm/W at 40cd/m² for this signage.

4. RESULTS AND DISCUSSION

On the basis of the measurements carried out with the backlit LED displays that use edgelighting technology, it could be inferred that the LED - based signs were not power hungry and could be easily designed and manufactured commercially. High-brightness LEDs proved very useful in the signage application. The comparison of the display with and without the diamond grating clearly indicated a marked change in illuminance values. Diamond gratings tend to spread out the light in the desired area. The light output visible to the viewer was also dependent on the pattern, which was placed on top of the acrylic. The displays did not require a complicated circuitry and could be modulated and controlled easily by varying current through them. However, the photometric measurements suggested a non-uniform display. Homogeneity of displays, which is a prime requirement for illuminated signs,⁹ was not achieved. Exceptionally dark and light areas were visible. It could also be inferred that if the display size were made to increase further on, the display would become darker at the center in the absence of any grating or customized wave-guide. After the pattern was put on, there was a clear change in the illuminance values and the light output was wasted in some areas of the display. It could be inferred that although, the LEDs were suitable for displays, the display quality was not as desired.

The experiment with organic LEDs, which are diffused sources, suggested that the light output from a module does not change from different positions in a display i.e. it was possible to obtain a uniform light output with OLED displays. The efficacy of OLED based signs was 0.3 lm/W, which is much less than the already existing inorganic LED technology. However, research samples indicate an efficacy¹⁰ of approximately 6 lm/W at a maximum brightness of the order of 30000 cd/m². The I-V characteristics of the OLED were similar to the conventional LED device. Hence, even though the OLED technology is novel, it was not difficult to understand its operation on the basis of the I-V curves. The L-I curves were linear indicating that in an OLED the brightness could easily be controlled by increasing the amount of current to the display. Studies indicate that OLED displays can also be obtained on a flexible substrate¹¹ and can be made ultra-light. This property of OLEDs makes them economically feasible potentially reducing the cost of installation.

5. CONCLUSION

On the basis of the results obtained, it can be concluded that the current OLED technology has not matured fully to be used for signage. The comparative results indicated that the present OLED-based signs couldn't compete with the conventional LED-based signs in terms of energy efficiency. The conventional LED technology and the OLED technology offer two different sources of light for signage. OLEDs surely promise better illumination for large signs. The major point of differentiation of the conventional LED with the OLED was that the conventional light-emitting diodes are point sources whereas OLEDs are diffused light sources. This characteristic of OLEDs makes them an ideal for a distributed area application such as signage. It is also possible to achieve uniformity of display with OLEDs. Being programmable, it is clearly evident that any kind of signage pattern can be obtained by using addressable OLED displays. This makes them less wasteful of energy unlike the LED displays in which the pattern has to be placed on top of the display leading to wastage of the light output. However, OLEDs have to attain an approximate efficacy of 18lm/Watt to prove themselves more power efficient than conventional LEDs. The commercial unavailability of large OLED modules has limited the scope of our work.

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