Light Emitting Polymer Displays

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Abstract

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We will report the latest developments in light emitting polymer (LEP) systems developed at CDT. Device performance for spin coated and ink jet printed systems will be described which are state-of-the-art. We will also report on novel driving schemes for both active and passive addressed LEP displays. These drive schemes extend system lifetime as well as lowering power consumption.

Technical Summary

Objectives and Background

The last few years have seen dramatic progress in OLED technology for flat panel displays. Of particular importance have been developments in device performance and fabrication techniques. OLED displays are very attractive for commercial exploitation as a flat panel display technology due to their low power consumption, wide viewing angle, fast response time and the compact and lightweight nature of their construction. Small molecule displays based on Eastman Kodak's technology [1] are now in the marketplace, as Pioneers in-car stereo display and the Motorola 'Timeport' branded clamshell-type phones. LEPs based on CDT's proprietary technology [2] offer several advantages over small molecules associated with their intrinsic characteristics of thermal stability, solution processability and simple device architectures. These characteristics which offer the potential for cheaper manufacturing routes. At CDT we have concentrated on developing polyarylene systems that have been prepared by Suzuki cross coupling. The performance of these systems is excellent in terms of colour, efficiency and lifetime. In this paper we will report our latest device results for blue, green and red systems. These are particularly significant as, in key respects such as efficiencies and lifetime, the results represent the state-of-the art. In particular the stability of our red system is suitable for the most demanding applications and recent improvements in blue are now approaching the level required for many products. Finally we will describe how the polymer materials have been modified for direct patterning by ink jet printing. This pioneering work, which has been developed with Seiko Epson Laboratories, has lead to the successful development of a 16 greylevel, full colour, active matrix LEP video display.

Results

Active matrix driving scheme

We have developed a simplified active matrix structure, wherein the pixel is driven to a achieve a given brightness rather than the more usual voltage or current requirement. This means that the cell automatically compensatites for; non-uniformities and aging of each individual pixel. This driving scheme has the additional benefit of detecting failed pixels, both open and short.

Passive matrix scheme

We have also developed and tested a passive matrix driving scheme that delevers lower power consuption and extends system lifetime. The ecence of the scheme is to be content sensitive, i.e. it adjusts the driving parameters, in real time, dependent on information to be displayed.

Red

The red emitter is currently the most highly developed of CDT's emissive materials. As might be expected for a system with the smallest band gap and consequently the lowest likelihood of non-emissive degenerate states arising the stability is high. Work has concentrated on reproducibility and an understanding of the key materials factors to produce an efficient, long lived device, without sacrificing colour (CIE co-ordinates of (0.69,0.31) which already exceed the PAL specification) or the rheological properties required for ink jet printing. Our current standard red system gives efficiencies of around 2 Lm/W at 100Cdm^{-2} and extrapolated lifetime* of approximately 50,000hrs while more recent research materials have demonstrated projected lifetimes of approximately 300,000hrs at room temperature (20^{o}C) from 100Cdm^{-2}.

Green

The green system we have been developing has a luminous efficiency of up to 24 Lm/W and lifetime for green devices is up to 10,000hrs, meeting the target for most device applications. Although the colour with CIE co-ordinates of (0.39,0.59) lies outside the PAL region recent advances have made some progress in chromaticity.

Blue

We have developed a blue polymer system based, again, on polyarelenes and comprising a hole transporter, an electron transporter and the emitter. New cathodes have also been a key development within an optimised device architecture This has minimised the barrier for electron injection and optimises the charge carrier (hole/electron) balance. This cathode comprises a first layer of LiF, a thin layer of a low work function material such as calcium and an aluminium cap from which contacts are made which reduce the resistance. Peak luminous efficiencies of up to 4 Lm/W have been achieved and predicted lifetimes in the region of 3-5,000 hours have been achieved. It is anticipated that further material and device optimisations will further increase the stability of these systems.

In order to make a full colour LEP display there is a requirement to form an array of patterned RGB LEPs emitters, which define the device pixels. Workers at Seiko Epson and CDT have co-developed an ink jet printing process that enables the direct patterning of both the charge conducting and emissive polymer layers on large area substrates with high resolution and at low cost. The LEP inks were developed at CDT, and will be described, are based on poly(dialkylfluorene). Using these LEP inks and patterning technique workers from Epson and CDT have demonstrated a 2.5 inch full colour 16 greylevel active matrix display. The display is 200 x 150 pixels with each pixel comprising 9 sub-pixels, 3 per colour. This display [3] is based on low temperature; polysilicon active matrix technology, which uses a digital drive scheme, based on temporal and spatial dither to achieve the 16 greylevels (per colour).

Impact

The results we publish at SID will be our latest and, we believe, represent the state of the art in this rapidly developing technology. Particularly significant is the performance of the red where stabilities are now reaching levels of inorganic LEDs. The modifications to the LEP material, which will be described, to enable ink jet printing is also original.

These results will be of great interest to the flat panel display community. Small molecule OLED displays are now in the market place and the visual appearance and overall device performance has been extremely well received. PLED displays represent the next generation display technology which is now poised to enter the market place.

The area of novel driving schemes is is veryu important from an enabling perpective. V. important as stability of systems (blue) is a key technology challenges, power consumption.

References

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[2] J H Burroughes et al., Nature, 347, 539 (1990).

[3] Shimoda et al., IDW Kobe, Japan 2,000

- Device stability data is measured under accelerated conditions at 80°C and at 400 Cd/m^2 and calculated back to approximate 20°C at 100 Cd/m^2.