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Field emission display

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A **field emission display** (**FED**) is a flat panel display technology that uses large-area field electron sources to provide electrons that strike colored phosphor to produce a color image. In a general sense, a FED consists of a matrix of cathode ray tubes, each tube producing a single sub-pixel, grouped in threes to form red-green-blue (RGB) pixels.

FEDs combine the advantages of CRTs, namely their high contrast levels and very fast response times, with the packaging advantages of LCD and other flat panel technologies. They also offer the possibility of requiring less power, about half that of an LCD system. To date, however, manufacturing problems have prevented any FED system from entering commercial production.

FEDs are closely related to another developing display technology, the surface-conduction electron-emitter display, or SED.

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Description

A conventional cathode ray tube (CRT) is powered by an electron gun, essentially an open-ended vacuum tube. At one end electrons are created by "boiling" them off a metal filament, a process known technically as thermionic emission. The electrons are then accelerated and focused into a fast moving beam. The gun lies at the back of the picture tube, firing the electrons forward, towards the screen. Electromagnets surrounding the gun end of the picture tube are used to steer the beam as it travels forward, allowing it to be scanned across the screen to produce a 2D display.

An FED display replaces the single electron gun of a conventional CRT with a grid of individual nanoscopic electron guns. The emitters were originally built out of tiny molybdenum cones known as Spindt tips, but most recent FED research has focused on using carbon nanotubes instead. A high voltage-gradient field is created between the emitters and a fine metal mesh suspended just above them, which pulls electrons off the tips of the emitters. This is a highly non-linear emission process; small changes in voltage will cause the number of electrons being emitted to quickly saturate. The non-linearity of the process means that the grid of elements can be individually addressed without an active matrix – only the emitters located at the crossing points of the powered cathode and gate lines will have enough power to produce a visible spot, and any power leaked to surrounding elements will produce tiny outputs that will not be visible.[1]

This non-linearity also means that the brightness of the sub-pixel is difficult to control with a changing voltage, which is the normal method used in a CRT. Instead, the grid voltage is pulse-width modulated to control the number of electrons being produced and reaching the screen.[1] Like any screen that uses individually addressable sub-pixels, FED screens are subject to manufacturing problems that will result in some pixels being inoperable. However, the size of the emitters is so small that many "guns" can be used to power a single sub-pixel on the screen. After manufacturing the screen can be examined to find the dead emitters, and corrected by slightly increasing the pulse width sent to those pixels to make up for the loss through increased emissions from the other emitters feeding that pixel.

The grid voltage accelerates the electrons off the tip to speeds where they continue flowing past the grid into the open area between the emitters at the back of the display, and the screen at the front. In this region a second accelerating voltage is applied, greatly accelerating the electrons towards the screen and giving them enough energy to light the phosphor covering its inside face. Since the electrons from any single emitter are fired toward a single sub-pixel on the screen, there is no need for scanning and the electromagnets in a CRT are eliminated.[1]

An FED screen is built by laying down a series of metal stripes on a glass backing to form a series of cathode lines. Photolithography is used to lay down a series of rows of switching gates at right angles to the cathode lines, forming an addressable grid. At the intersection of each row and column a small patch of emitters are deposited, typically using methods developed from inkjet printers. The metal grid is laid on top of the switching gates to complete the gun structure.[1]

Since the FED display requires a vacuum to operate, like the conventional CRT, the display tube has to be sealed and mechanically robust. However, since the distance between the emitters and phosphors is quite small, generally a few millimeters, the screen can be mechanically reinforced by placing spacer strips or posts between the front and back face of the tube.[1] This forms a strong structure with little internal volume.

The efficiency of the field emitters is based on the extremely small radii of the tips. This small size renders the cathodes susceptible to damage by ion impact. The ions are produced by the high voltages interacting with residual gas molecules inside the device. FEDs require high vacuum levels which are difficult to attain: the vacuum suitable for conventional CRTs and vacuum tubes is not sufficient for long term FED operation. Intense electron bombardment of the phosphor layer will also release gas during use.[2]

This technology is much more efficient than other flat plate technologies as this has very large viewing angle and has very high brightness and resolution but it has the disadvantage that it has several manufacturing processes similar to that of OLED. so still it has not a wide application in display technologies.

Comparison

FEDs directly create light on the screen in a fashion identical to a CRT, and require acceleration energies of a similar level. However, FEDs eliminate much of the electrical complexity of a CRT, including the heated filaments in the electron gun and the electromagnets used to steer the beam. FEDs are thus much more power efficient than a CRT of similar size.

The most common flat-screen display today is the LCD. LCD displays use a bright light source at the back of the screen, filter out half of the light with a polarizer, and then filter most of the light to produce red green and blue (RGB) sources for the sub-pixels. That means that only 1/6 (or less in practice) of the light being generated at the back of the tube reaches the screen, at best. In most cases the LCD itself then filters out additional light in order to change the brightness of the sub-pixels and produce a color gamut. So in spite of using extremely efficient light sources like cold cathode fluorescent lamps or high-power white LEDs, the overall efficiency of an LCD display is not very high.

In spite of the lighting process used in the FED being less efficient than an LCD, since only lit sub-pixels require any power means that FEDs are far more efficient than LCDs in practice. Sony's 36" FED prototypes have been shown drawing only 14 W when displaying brightly lit scenes, whereas a conventional LCD screen of similar size would normally draw well over 100 W.

The removal of the lighting system and active matrix consisting of thin-film transistors also greatly reduces the complexity of the set as a whole, while also reducing its front-to-back thickness. While the FED has two sheets of glass instead of the one in an LCD, the overall weight is likely to be less than a similarly sized LCD.[3] They are also claimed to be cheaper to manufacture, as they have fewer total components and processes involved. However, they are not easy devices to manufacture in the form of a reliable commercial device, and considerable production difficulties have been encountered. This had led to a race with two other front-running technologies aiming to replace LCDs in television use, the Active-Matrix OLED and surface-conduction electron-emitter display, or SED.

OLEDs are similar to the LCD system in most ways, but replace the back lights and shutters with an OLED cell that directly emits light. They have the advantage of requiring no separate light source, and in modern examples are highly efficient in terms of light output. They also offer the same high contrast levels and fast response times that FED offers. OLEDs are a serious competitor to FEDs, but suffer from the same sorts of problems bringing them to mass production.

SEDs are very similar to FEDs, the primary difference between the two technologies is that SED uses a single emitter for each column instead of the individual spots of the FED. Whereas a FED uses electrons emitted directly toward the front of the screen, the SED uses electrons that are emitted from the vicinity of a small "gap" in a surface-conducting track laid down parallel to the plane of the panel, and extracted sideways to their original direction of motion. SED uses an emitter array based on palladium oxide laid down by an inkjet or silk-screen process.[4] SED has been considered to be the variant of FED that is feasible to mass-produce, however, even in 2008 no commercial SED display products are made available by the industry.

History

The first concentrated effort to develop FED systems started in the early 1990s using metal emitters. In practice these demonstrated erosion due to the high accelerating voltages, which eventually ruined the displays.[3] Two paths to correct for this problem were followed. The low-voltage approach used relatively low accelerating voltages that eliminated the erosion problems, and attempted to find suitable phosphors that worked at these power levels but none were found. The high-voltage approach used kV acceleration and phosphors taken from conventional CRTs, attempting to address the erosion problem through better materials, but again no suitable material was found.[3]

The first concentrated effort to develop FED systems was started by Silicon Video Corporation in 1991, later changing their name to Candescent Technologies. Candescent used metal emitters in their "ThinCRT" display. Candescent pushed ahead with development in spite of problems, breaking ground on a new production facility in Silicon Valley in 1998, partnering with Sony who were looking for new technologies that would regain them the lead the Trinitron had presented them for the past 15 years. However the technology was not ready, and the company suspended equipment purchases in early 1999, citing "contamination issues".[5] The plant was never completed, and after spending $600 million on development they filed for Chapter 11 protection in June 2004, and sold all of their assets to Canon that August.

Another attempt to address the erosion issues was introduced by Advance Nanotech, a subsidiary of SI Diamond Technology of Austin, Texas. Advance Nanotech developed a doped diamond dust, whose sharp corners appeared to be an ideal emitter. However the development never panned out, and they abandoned development in 2003. Advance Nanotech then applied their efforts to the similar SED display, licensing their technology to Canon. When Canon brought in Toshiba to help developing the display, Advance Nanotech sued, but ultimately lost in their efforts to re-negotiate the contracts based on their claim that Canon transferred the technology to Toshiba.

More recently a number of companies have attempted to use carbon nanotubes (CNTs) as emitters. "Nano-emissive display" (NED) is Motorola's term for their carbon-nanotube-based FED technology. A prototype model was demonstrated in May 2005, but Motorola has now halted all FED-related development activities. Futaba Corporation has been running a Spindt-type development program since 1990. They have produced prototypes of smaller FED systems for a number of years and demonstrated them at various trade shows, but like the Candescent efforts no large-screen production has been forthcoming. Development continues on a nanotube based version.

Sony, having abandoned their efforts with Candescent, licensed CNT technology from Carbon Nanotechnologies Inc., of Houston, Texas, who were the public licensing agent for a number of technologies developed at Rice University's Carbon Nanotechnology Laboratory. In 2007 they demonstrated a FED display at a trade show in Japan and claimed they would be introducing production models in 2009.[6] They later spun-off their FED efforts to "Field Emission Technologies", which continued to aim for a 2009 release.[7]

Their plans to start production at a former Pioneer factory in Kagoshima were delayed by financial issues in late 2008.[8] On March 26, 2009 "Field Emission Technologies" announced that it was closing down due to the inability to raise capital.[9]

See also

- Comparison of display technology
- Field emitter array
- Field electron emission
- Surface-conduction electron-emitter display (SED)

References

Notes

1. ^ [a] [b] [c] [d] [e] *Closer*

2. ^ Light emitting principle of an FED system by SHARP
3. ^ a b c *FED*
4. ^ *SED*
5. ^ *Delays*
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