Compare/Contrast of Thin Film EL (TFEL) to EL Backlighting, LED, and OLED Technologies

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Abstract

Although Planar's thin film EL (TFEL), EL backlighting for LCDs, LEDs, and Organic Light Emitting Diodes (OLED) are all electroluminescent materials, their properties are very different and lend themselves to specific applications. This short primer is meant to assist you with a general understanding of how these electroluminescent devices are differentiated.

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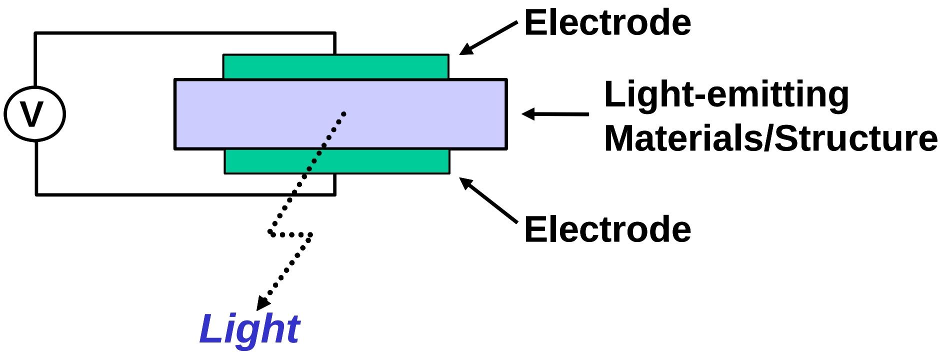
Electroluminescence describes the phenomenon which occurs when one energizes a material with an applied voltage and the material subsequently emits light.



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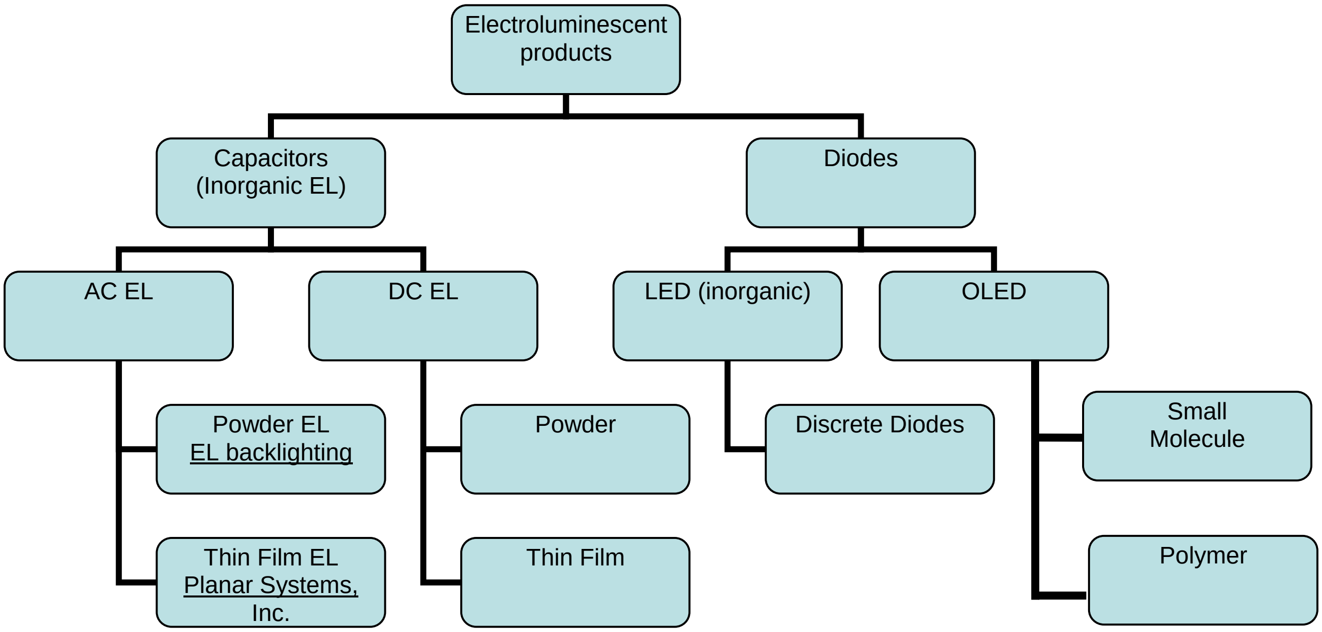


Electroluminescent display materials come in many forms

Inorganic EL vs Diodes

The principal difference between these two types of light emitting materials is that Inorganic EL can have a bi-directional current pathway from the AC drive, while diodes have unidirectional current paths. Additionally, all commercially available EL displays use inorganic phosphors whereas light emitting diodes may be either organic or inorganic materials. In this case, “organic” means the materials used to fabricate the device are largely carbon-based, not to be confused with the growing interest in foods that are labeled “organic.”

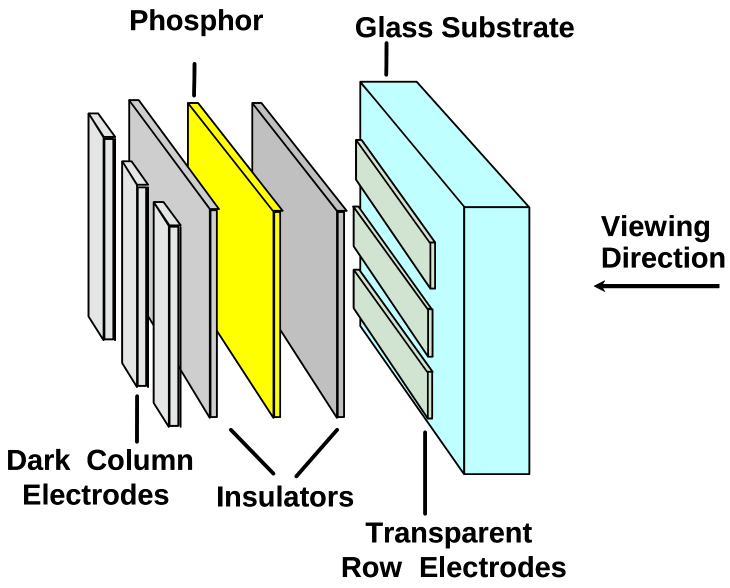
AC EL vs. DC EL

The difference between the two electroluminescent approaches is obvious by their titles: alternating vs. direct current. AC displays use alternating polarity voltage to create light emission from a phosphor layer usually comprised of zinc sulfide (ZnS) doped with a small amount of manganese. DC displays use pulsed current to create light emission from a phosphor layer comprised of ZnS. AC EL has been widely used for addressable matrix displays from Planar Systems, Inc and other companies. DC EL has experienced limited success due to reliability issues and inferior half-life when compared to AC EL products. Despite considerable previous development, there are no DC EL products presently marketed due to these limitations, so no further explanation will be undertaken concerning DC EL in this paper.

Thin Film EL vs. Powder EL

As stated earlier, AC EL products generally use ZnS based phosphors. In Thin Film EL (TFEL), a ~0.5 µm (micron) phosphor layer is insulated between two ~0.3µm dielectric layers that limit current to a level which only allows capacitive charging and discharging. The entire thin film structure is approximately one micron thick, requiring great precision in the deposition processes. For reference, standard notebook paper has a thickness of about 100 microns. Sandwiching the thin film structure are opposed, perpendicular electrodes, as shown in the figure below. At least one of these electrodes must be transparent. When drive is applied (±200 VAC) to the intersection of the perpendicular electrodes, high-energy electrons are injected into the phosphor, resulting in illumination of the phosphor between the intersecting electrodes. Light is passed through the transparent electrode towards the viewer. *(Planar’s transparent TFEL, called TASEL, has two transparent layers on both sides of the thin film structure. Planar’s typical electroluminescent displays have one transparent layer and one typically black rear electrode layer which create increased contrast).*

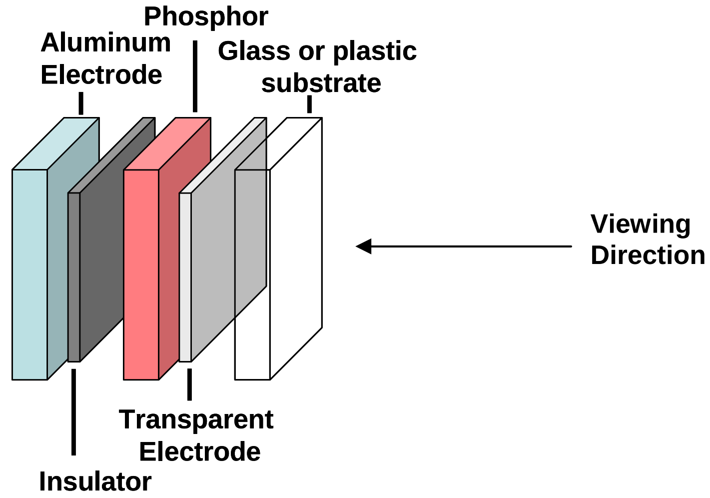
As the human eye can detect brightness differences in illuminated pixels as small as 2-5%, the pixels of a display must emit light uniformly. Thin film deposition processes are extremely precise and create very finely packed, uniform layers of phosphor and dielectric. The engineering that went into the materials selection and device design, in addition to the density and uniformity achieved in Planar's deposition process, are the principal reasons that TFEL displays have such high brightness uniformity, stable brightness, and long lifetime to half-brightness (one hundred thousand+ hours).



An AC-TFEL Display Structure

Unlike TFEL, Powder EL is applied with simple deposition techniques, such as silk screening. Phosphor powder is combined with a liquid agent to create slurry. The slurry is applied to a substrate and dried into a 50-100.0µm thick film. The phosphor layer is insulated and two electrodes are added, one of which must be transparent. When voltage is applied, the phosphor emits light through the transparent electrode just as TFEL does. This deposition technique, compared to the precision required for TFEL applications, is lower in cost; but again, despite extensive development efforts, AC powder EL has not proven to be suitable for high information content displays because of inferior reliability in the phosphor materials and device structure compared to TFEL.

The human eye is much less precise at detecting brightness degradation in stand-alone light sources, making powder EL an acceptable light source for wall plug night lights, automotive indicator lights, stage lighting and for backlighting small LCDs like those found in wrist watches. Powder EL, like TFEL, generally uses ZnS-based phosphors; however, they are usually doped to create the colors we associate with EL lighting (blue, green, and red).



An AC Powder EL backlight

LED (Inorganic) vs. Organic LED (OLED)

LEDs fabricated from inorganic materials, such as indium, aluminum, gallium, arsenic and/or nitrogen, have been commercially available since the 1960's. In the last decade or so the efficiency has reached a level where LEDs now compete with incandescent and even fluorescent light sources. All inorganic LED devices are manufactured by precise deposition of the LED film stack on specially prepared wafers. The fabrication processes are common to the semiconductor industry. After the film stack is deposited, the wafers are cut into die, usually ~1mm or less on a side, and incorporated into packages of varying design for use.

Creating inorganic LED wafers large enough to fabricate single-substrate displays is problematical at this time. As a result, inorganic LEDs have been implemented for commercial use only in these small, discreet packages.

Products with LEDs fabricated from organic materials were made commercially available for the first time in 1997. These displays can be referred to either as OLEDs or organic EL. The technology has the advantage over its inorganic counterpart in that a matrix display can be fabricated relatively easily with OLED materials. Two types of OLED devices have been developed: small molecule and polymer, invented by Eastman Kodak and

Cambridge University, respectively. To date, most OLED products have been the small molecule type, but there is much interest in the polymer approach due the possibility of using ink-jet printing as a low cost and simple manufacturing technique. OLEDs, packaged as single pixel panels, are likely to find use in the general lighting market in the future, as well.

The diode film stack, either inorganic or organic, consists of two adjacent semi-conductors (n-type and p-type) with differing numbers of free electrons. Current only flows one way in a diode, so when voltage is applied to the n-type material, electrons flow towards the p-type in a light emitting diode and light is created.

TFEL vs. OLED (2008-2009)

While OLED products have been available for over a decade, these devices have only been suitable for applications such as cell phones, car stereos, cameras, MP3 players and other uses where the display is never used for an extended period and/or the product lifetime is relatively short. Because of differential aging, there are no OLED displays used in laptop computers, PDAs or professional instruments where static screen content would be burned-in.

TFEL Key Quality Issue: Differential Aging, Half-Life, and Temperature

OLED vendors typically characterize luminous life as the time to 50% of original brightness. This is a common metric in describing the life of lamps and other non-display light emitters, but it has little meaning for high information content displays. As stated previously, the human eye can see non-uniformity as small as 2-5% in brightness on a display. Thus a 5 to 10% loss of local luminous efficiency can result in a very visible burned-in image. A display with a claimed 20,000 hours of life to 50% brightness might only have several hundred hours to 10% where burn-in would be a problem.

Because of the aging issue with OLED displays, they are not suitable for use in products whose displays require extended illumination. Additionally, heat accelerates aging in OLEDs, further shortening its useful lifespan. Above 70ºC, OLEDs can fail catastrophically; consequently, they should not be employed in applications where high temperature use is a requirement.

Perhaps the most compelling data we have regarding the robustness of Planar’s EL vs. OLED technology is the fact that TFEL displays have been implemented in hundreds (or thousands) of military vehicles and other military equipment, but no OLED display has been qualified for field use by the US Army to date.

As a result, OLEDs are recommended only for consumer applications, such as cell phones and car stereos, with very limited illuminated duty cycles and small diagonal dimensions. TFEL, whose properties exhibit a half-life greater than 100,000 hours without visible differential aging of pixels, and can be designed for use at temperatures over 70°C, is the most dependable emissive display technology that is commercially available.

Summary

Thin film electroluminescent (TFEL) is a proven display technology whose resistance to differential aging and long brightness lifespan has been demonstrated in 25 years of manufacturability. It is well-suited for capital equipment requiring graphic and alphanumeric displays of information, durability, and reliability. It is the proven, low-risk choice for product designers.