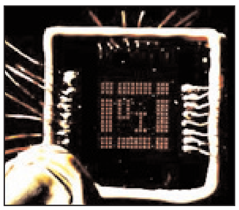
about Plasmas
from the Coalition for Plasma Science

Plasma Display Panels

PLASMA SALE: We see this more and more on store signs and in ads promoting large-screen, flat-panel plasma TVs. The flat plasma display is a major competitor among several flat panel display technologies – all vying for the potentially enormous High Definition TV market.



For many people, the word "Plasma" has come to mean only display screens. As impressive as those displays are, the word refers much more generally to a special state of matter that resides not only inside those display panels, producing their light and images, but also in many other devices we use every day. In some cases plasma is part of a product's manufacturing process. In addition, plasmas fill much of our surrounding universe. A plasma is a gas containing a large number of electrically charged particles, both negatively-charged electrons and positively-charged atoms, called ions. In most plasmas, including those in the plasma display panel, there also remains a large number of uncharged particles (called the "background gas"). The plasma in a display panel is much like the plasma in another familiar device, the fluorescent lamp.

Page Left: An early 16x16 cell monochrome PDP (one-half inch on a side) from the University of Illinois in 1967. Above: Today's PDP with up to 80" diagonal screens and millions of individual color elements.

A plasma display panel (PDP) is essentially a collection of very small fluorescent-type lamps, each a few tenths of a millimeter in size. If we look closely, it is easy to distinguish the individual PDP cells – the tiny color elements of red, green and blue light that together form what is called a pixel. As in a fluorescent lamp, the light we see does not come from the plasma directly, but rather from the phosphor coatings on the inside walls of the cells when they are exposed to ultraviolet (UV) radiation emitted by the plasma. Because each cell emits its own light, a plasma display panel is called an "emissive display." This contrasts with the familiar liquid crystal display (LCD), a type of flat display in which the light comes from a lamp (actually a plasma lamp!) behind the liquid crystal, which has arrays of small switches controlling where light is allowed to pass through.

All plasmas require a source of energy. As in fluorescent lamps, the plasma in a PDP is produced by applying a voltage across a gap that contains gas. The plasmas used in PDPs are considered "cold" plasmas in the sense that the background gas stays relatively cold while the electrons (and ions) in the plasma are heated by the applied voltage. When the hot electrons collide with the background gas atoms and transfer energy to them, many of those atoms respond by emitting UV radiation. The operating conditions of the display (gas composition, pressure, voltage, geometry, etc.) represent a compromise, taking into account performance requirements such as low voltage operation, long life, high brightness and high contrast.

The plasma display itself is a simple device consisting of two parallel glass plates separated by a precise spacing of some tenths of a millimeter and sealed around the edges. The space between the plates is filled with a mixture of rare gases at a pressure somewhat less than one atmosphere. Parallel stripes of transparent conducting material with a width of about a tenth of a millimeter are deposited on each plate, with the stripes on one plate perpendicular to those on the other. These stripes are the "electrodes" to which voltages are applied. The intersections of the rows of electrodes on one side and the columns of electrodes on the opposite glass plate define the individual color elements – or cells – of a PDP. For

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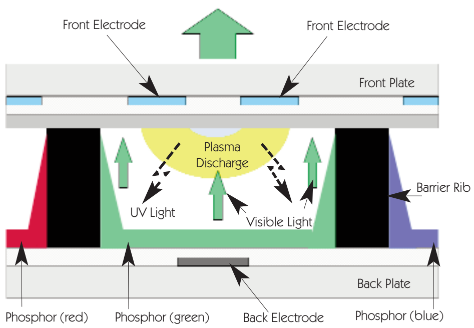
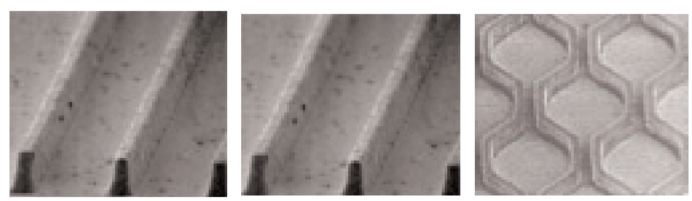


Schematic of a plasma display pixel. In reality the front and back electrodes run perpendicular to each other rather than parallel.

high quality color images it is important to keep the UV radiation from passing between cells. To isolate the individual cells barriers are created on the inside surface of one of the plates before sealing. Troughs, honeycomb-like structures and other shapes have been used. The red, green and blue phosphors are deposited inside these structures.

An important feature of PDPs is that the plasma in each individual cell can be turned on and off rapidly enough to produce a high quality moving picture. (To help turn the individual cells on and off, there are actually two electrodes on one side and a third electrode on the opposite side of each cell.) Switching the cells on and off cheaply and efficiently is now possible because of advances over the past 20 years in the miniaturization and efficiency of electronics.

A commercial panel consists of several million cells which have to be switched at a rate that will create 60 TV picture frames per second. A computer translates an image into a sequence of On and Off voltage pulses which are applied to the electrode arrays line by line and row by row to select individual cells. Such control is possible because the plasma is fast and can respond to the voltage pulses in a millionth of a second. The complexity increases significantly when we consider that each small picture element, or pixel, consists of three color cells, and each color cell can display 256 intensity levels. Thus each pixel can display over 16.7 million (or, more exactly, 256x256x256) colors. Variation in light intensity from a particular cell is not accomplished by changing the voltage or the current through the cell. Rather, it is achieved by changing the length of time that the cell is ON during one TV frame. Since the eye response is slower than the TV picture frequency, it perceives different colors depending on how long each cell is ON. Each company has made its own contribution to the switching systems to improve efficiency, speed and performance.



Examples of the barriers that isolate each cell. The distance between the walls of each cell is a couple hundred micrometers – or about ten times the diameter of a human hair.

Many years of research and development as well as major advances in electronics and manufacturing techniques have led to the plasma display panels we see on the market today. The plasma display panel itself was invented in 1964 by researchers at the University of Illinois, with the first PDPs being single-color (or “monochrome”) displays. Research on multi-color PDPs was going strong in the 1980's, and the first commercially available color displays appeared in the late 1990’s. It is now possible to manufacture PDPs with diagonals as large as 80 inches and with a thickness of only 3 to 4 inches. Considerable progress has also been made recently to reduce the power consumption and increase the efficiency and life-time of PDPs.

Large screens, excellent image quality and brightness, and greater than 160° viewing angle characterize today's plasma panels, which are perfectly flat and perform well even in bright environments. Long-term commercial success of the PDP now lies in the manufacturers' ability to produce low cost displays. Significant reductions in costs have been realized over the last few years, and new PDP designs and processes are being introduced all the time, continuing to reduce production costs. The PDP is sure to be one of the predominant large-format displays of the future.

References and Suggested Reading:
There are many good articles on plasma TVs in popular magazines. For a more technical description of some the physics issues, see Weber, L. F., “Color Plasma Displays,” in The Electrical Engineering Handbook, edited by Richard C. Dorf, (CRC Press, Boca Raton, Florida, 1997), pp. 1939-1950; and the review article "Plasma display panels: physics, recent developments and key issues", by J.-P. Boeuf in Journal of Physics D: Applied Physics 36 (2003) R53-R79.

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Images: Used with permission. University of Illinois at Urbana-Champaign/monochrome pixel array built by R.L. Johnson; Plasmaco/Matsushita; Larry Weber; Society for Information Display [Sato, Amemiya and Uchidoi, Journal of the SID, vol 10, p 17 (2002).]