ANALYSIS OF HIGH DEFINITION TELEVISION DISPLAY TECHNOLOGIES

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ABSTRACT

This paper presents an overview of various display technologies likely to contend for the High Definition Television (HDTV) market. These include Surface and Columnar Discharge AC Plasma, Plasma Addressed Liquid Crystal (PALC), and Projection Displays. There is also a discussion of the history of HDTV, HDTV definitions and standards (subset of DTV), and the significance to the consumer market.

HISTORY

The concept of High Definition Television (HDTV) started around 1984. Several factors have contributed to the advent of the high definition concept. These factors include the advancement of satellite broadcasts, particularly in Japan; breakthroughs in efficient use of the broadcast spectrum; and the development of digital broadcasting. These factors are all interrelated. When taken together, they make it possible to send a higher quality video signal with greater information content on a smaller bandwidth thereby setting the stage for HDTV.

DEFINITION AND STANDARDS

The basic concept behind HDTV is actually not to increase the definition per unit area, but to increase the percentage of the visual field contained by the image. In general, a HDTV display is defined as a display with an aspect ratio of 16:9. Most television used by consumers today has an aspect ratio of 4:3. The HDTV format provides a longer more rectangular image, similar to the screens at a movie theater. Beyond the 16:9 aspect ratio, there is little or no agreement on other HDTV standards, including resolution and signal standards.

Committees throughout the world have been formed to define HDTV standards. In Japan the NHK Muse system has achieved wide acceptance. This system provides for digital signals to be transmitted in an analog format. Programs are already being transmitted to this standard. It is called “Hi Vision.” The European standard started with an analog signal using MAC compression. This was later abandoned because it did not provide enough compression. In the U.S. a committee called the Grand Alliance was formed to establish HDTV broadcasting standards. Although Europe and Japan have been diligently working on standards, the display manufacturers are waiting to see what the U.S. will adopt because the U.S. represents a very large market and may dictate the direction of HDTV.

FOR THE CONSUMER

Although HDTV has received a great amount of support from government and industry, the ultimate success of HDTV rests with the consumer. For HDTV to receive wide acceptance in the commercial arena, it must provide noticeably better performance at an acceptable price. Presently, many display manufacturers are investing heavily to achieve this goal. It is generally accepted that high definition television should provide a theater like experience. This is part of the rational for the 16:9 ratio. Studies show that for optimum viewing, a person should be a distance of 3 times the *height* from the viewing screen. By comparing standard TV (aspect ratio 4:3) with a given height, to an HDTV format with the same height, it can be seen that a viewer optimally seated will get 33 percent more viewing area with the HDTV format. Because the HDTV format provides a more panoramic view, the viewer is more engulfed in the image.

OVERVIEW OF DISPLAY TECHNOLOGIES

Manufacturers are concentrating on large area displays for HDTV. The performance issues that must be addressed for full color HDTV include display luminance, contrast, life, power, luminous efficiency, weight, and size. All these issues must be satisfactorily addressed before a consumer product is realized. A list has been compiled in Table I of the primary manufacturers investing in large area high definition display systems which use the following three display technologies: Projection, AC plasma, and PALC. Table II presents an overview of these three display technologies. Each display technology has its advantages and disadvantages, but no single technology can presently claim dominance in the emerging large area HDTV market.

Table I

Large Area High Definition Display Systems

Selected Manufacturers

Company	Diagonal	Technology	Resolution*	Format Standard
Toshiba	40-60 in	Projection	480P-1080I	NTSC SDTV HDTV
Thompson	40-60-in	Projection	480P-1080I	NTSC SDTV HDTV
Sony	40-50-in	Projection	480P-1080I	
Sony	42, 50 in	PALC		NTSC SDTV HDTV
Pioneer	40-50-in	Projection	480P-1080I	NTSC SDTV HDTV
Pioneer	40 in	AC Plasma	480P-640P	NTSC SDTV
Fujitsu	42 in	AC Plasma	480P-852P	NTSC SDTV hi-vision
NEC	42 in	AC Plasma	480P-853P	
Philips	42 in	AC Plasma	480P-853P	NTSC SDTV
Philips	50-60 in	Projection	480P-1080I	NTSC SCTV HDTV
Hitachi	50-60 in	Projection	480P-1080I	
Zenith	50-60 in	Projection	480P-1080I	NTSC SDTV HDTV
Samsung	50 in	Projection	480P-1080I	NTSC SDTV HDTV
Mitsubishi	40-60 in	Projection	480P-1080I	NTSC SDTV HDTV

* P = Progressive display, I = Interlaced display

As presented in Table I and Table II, major corporations are pursuing the HDTV market, each with very different approaches. Although no one display technology is currently the leader for this market, many experts believe AC plasma has a good chance of dominating this market.

Table II

Overview

Primary HDTV Display Technologies

	AC Plasma Surface Discharge	PALC	Projection CRT/LCD
Size	40-50 inch	42 & 52 in.	40-70 inch
Display Type	Emissive	Non-emissive	Non-emissive
Scan Resolution	480P-720P	480P-720P	480P-10801
Contrast	Good	Good	Good
Portability	Yes	Yes	Yes
TV on Wall	Yes	Yes	No
Luminance	60-120 Ft/Lamberts	60-120 Ft/Lamberts	60-2000 Ft/Lamberts
Cost	High	High	Medium-High
Depth	4-7 inches	4-6 inches	1-2 ft. for rear
Life	>10,000 hrs.	>10,000 hrs.	>10,000 hrs.

AC PLASMA

Japanese and Korean firms have invested heavily in the development of large area AC plasma color displays. Investments have also been made in Taiwan and The Peoples Republic of China. All of the Asian companies are using an AC plasma display panel with a surface discharge structure, which is superior to the columnar discharge structure used in France and the United States.

The columnar discharge structure is also referred to as opposing electrode discharge or twin substrate discharge. In a columnar discharge AC plasma display structure, the sustaining voltage is continuously applied between an electrode on the rear substrate and an electrode on the front substrate.

In a surface discharge AC plasma display, the sustaining voltage is applied between a pair of electrodes on the front substrate. The electrodes on the rear substrate are used only to periodically address one or both electrodes on the front substrate.

Table III presents a comparison of the columnar discharge AC plasma structure versus the surface discharge AC plasma structure at a sustain frequency of 30 kHz and a gas mixture containing less than 6% xenon.

TABLE III
AC PLASMA DISPLAY STRUCTURES
COLUMNAR DISCHARGE vs SURFACE DISCHARGE

Attribute	Columnar Discharge	Surface Discharge
Phosphor Deposition	Unforgiving: Phosphor cannot cover electrode at discharge sites on the bottom substrate. Will decrease life of phosphor and panel	Forgiving: Phosphor entirely covers the electrode on the bottom substrate. Will not decrease life of phosphor and panel
Number of Bits per Color @ 640 x 480 resolution @ 1280 x 1024 pixels	 8 bits 4 to 6 bits	 8 bits 6 bits
Display Colors @ 1280x1024 pixels	262,144	262,144
Luminance, FL @ 30 kHz sustain	< 30	> 60
Power, Watts @ 30 kHz sustain: 19-21" diagonal 640 x 480 pixels 19-21" diagonal 1280 x 1024 pixels 24-25" diagonal 1280 x 1024 pixels 30" diagonal 1024 x 768 pixels 42" diagonal 852 x 480 pixels	 150-200 W 200 W 220 W 350-400 W -	 110 W - 200 W - 350 W
Luminous Efficiency, Lumens per Watt, at 30 kHz sustain	< 0.4	0.5 to 1.2
Operating Life in Hours @ 30 kHz sustain and 20% fill factor	<2000	>10,000
Contrast Ratio	<100:1	>100:1
Peak Discharge Current	4 times Surface Discharge Peak Current	
EMI	Much higher because of high peak discharge current	

As summarized in Table III, surface discharge superiority over columnar discharge includes lower power, longer life, greater contrast, lower peak discharge current, and higher luminous efficiency. The high peak discharge current of columnar discharge greatly adds to the costs of the electronic circuitry particularly the drivers.

Surface discharge also has manufacturing advantages over columnar discharge. One of these (phosphor deposition) is listed in Table III. The deposition of phosphor in the manufacture of surface discharge is very forgiving because the phosphor covers the electrodes on the back (bottom) substrate without decreasing panel life.

In columnar discharge the phosphor must be precisely deposited and can not cover electrode discharge sites on the back substrate without decreasing phosphor life. There is little or no forgiveness. It may also be necessary to use an overcoat such as magnesium oxide to protect the phosphor from the discharge. However, a protective overcoat decreases light output from the phosphor. A protective phosphor overcoat is not used or required in the manufacture of surface discharge displays.

Surface discharge is also much less sensitive than columnar discharge to variations in the gas discharge gap between the back and front substrates. In columnar discharge the gap must be precisely controlled to avoid variations and distortions in luminance and chromaticity.

There are currently over 15 companies developing or manufacturing color AC plasma displays with a surface discharge structure, but only two companies have attempted to produce AC plasma displays with a columnar discharge structure. Almost all of the surface discharge firms are in Asia. Based on Fujitsu's reported production rates, the total number of manufactured 42-inch and 50-inch surface

Table IV

Census

AC Plasma Display Manufacturers at INFOCOMM 98 Dallas

MANUFACTURER	QUANTITY	SIZE	PRODUCT LITERATURE AND QUOTED PRICE
Fujitsu General	27 1	42" 21"	Product literature for 42". Price $7,000 No product literature for 21".
Pioneer	24 2	40" 50"	Product literature for 40". No price quote. No product literature for 50". No price quote.
Mitsubishi	10 1	40" 50"	Product literature for 40". Price $11,500 No product literature for 50". No price quote.
NEC	12	33"	Product literature for 33" and 42". No price quote.
Hitachi	1	41"	Product data sheet for 41". No price quote.
Panasonic	2 1	42" 50"	No product literature for 42". No price quote. No product literature for 50". No price quote.
Sony	3	42"	Repackaged Fujitsu. Price $8,500.
Philips	1	42"	Repackaged Fujitsu. No price quote.
Sharp	0	-	No plasma display or product literature. No price quote.

discharge displays is estimated at over 20,000. No columnar discharge displays have been produced in these sizes. It is estimated that only about 15 30-inch columnar discharge panels have been produced and about 50 in the size range of 19-inch to 24-inch.

Fujitsu, the leading producer of AC plasma displays, has manufactured thousands of 21-inch 640 x 480 color surface discharge displays. One 25-inch 1280 x 1024 color surface discharge panel has been demonstrated by Fujitsu during 1998 at electronic and display conventions in Japan.

At the June 1998 INFOCOMM 98 Convention and Exhibition in Dallas, Texas, six Japanese manufacturers exhibited over 85 surface discharge AC plasma color displays. In addition, Sony and Philips repackaged and exhibited 42-inch Fujitsu displays. Sharp had a booth at INFOCOMM 98, but did not exhibit any AC plasma displays. There were no columnar discharge AC Plasma color displays exhibited at INFOCOMM 98. A census of the INFOCOMM 98 AC plasma display manufacturers is presented in Table IV. A summary of the AC plasma product literature distributed at INFOCOMM 98 is presented in Table V.

On the basis of the technology and market activity, it is obvious that surface discharge AC plasma is technically superior and is the manufacturing and market choice over columnar discharge AC plasma for all applications including HDTV.

However, surface discharge AC plasma has problems relative to other display technologies, particularly low luminous efficiency and high power input. The display industry has a de facto standard for luminous efficiency of 5 lumens per watt. Some display technologies including FED, CRT, and projection are reportedly above this minimum. Surface discharge AC plasma at 1.2 lumens per watt is less than 25% of the minimum.

Surface discharge also has high manufacturing costs as evidenced by Fujitsu's present selling price of $7,000 for its 42-inch 852 x 480 AC plasma display products. Large plasma displays are now being sold for industrial or business applications that are less price sensitive. At larger HDTV sizes and higher HDTV resolutions, it will be a challenge to reduce the costs of AC plasma panel manufacturing and drive electronics. Plasma displays will probably not be used in the home until the price is below $3,000.

In higher HDTV resolutions up to 1920 x 1080, AC plasma manufacturers will be additionally challenged to obtain full color of 8 bits per primary color (16.7 million colors.). Some early low-resolution AC plasma displays were able to demonstrate full color. The highest resolution publicly demonstrated has been 1280 x 1024 by Thomson, Fujitsu, and Photonics. All of these were limited to 6 bits or less. Although NEC has demonstrated a resolution of 1365 x 768, the level of gray scale is not known.

Table V

Summary of Product Literature for AC Plasma Display Manufacturers at INFOCOMM 98 Dallas

Manufacturer (OEM)	**Screen Size** (Diagonal)	**Aspect Ratio**	**Resolution**	**Luminance** (cd/m^2)	**Contrast Ratio**	**Power** (watts)
Fujitsu Plasmavision 42	42"	16:9	852 x 480	-	400:1	350 max.
Pioneer PDP-V401	40"	4:3	640 x 480	400 without filter	-	350 max.
Mitsubishi Leonardo	40"	4:3	640 x 480	>140 analog RGB	100:1 analog RGB	400 max.
Mitsubishi Leonardo	40"	4:3	640 x 480	210 NTSC	150:1 NTSC	400 max.
NEC 3300 Plasma Sync	33"	4:3	640 x 480	120	150:1	400 max.
NEC 4200W Plasma Sync	41.7"	16:9	853 x 480	-	-	600 max.
Hitachi	41"	4:3	1024 x 768	250	>300:1	-
Sony PFM-500A1WU	42"	16:9	852 x 480	-	-	450 max.
Philips PW 9962 42 Flat TV	42"	16:9	852 x 480	250	350:1	450 max.

Notes: 1. Life data was specified only in the Fujitsu literature. Fujitsu specified life as 30,000 hours, which is the elapse time to 50% of initial luminance.
2. Sony and Philips presented repackaged 42" Fujitsu panels
3. Panasonic exhibited two 42" and one 50" but did not handout product literature.
4. Sharp did not exhibit any plasma displays and distributed no product literature.

New DC and AC plasma display structures have been and are being developed by several firms in Asia including a structure invented by Dr. Amano of Technology Trade and Transfer Corporation. A new structure may provide increased luminous efficiency, full color at HDTV resolution, and low manufacturing costs.

Historically, there have been many US companies, which have exited the manufacture of monochrome AC plasma. These include IBM (twice), AT&T, Owens-Illinois, Texas Instruments, Control Data Corporation, and NCR. The AT&T efforts also included color surface discharge AC plasma. In Japan NEC also dropped monochrome AC plasma. Most of these firms exited because of high manufacturing costs and the inability of plasma to compete in the commercial market with other display technologies, notably LCD and CRT. This history could be repeated if performance and price goals are not achieved.

Plasma Addressed Liquid Crystal (PALC)

This technology uses a plasma panel to address an LCD. This concept originated at Tektronix in 1990 and was licensed to Sony in 1992. In 1996 Sharp teamed with Sony and in 1997 Philips teamed with Sony and Sharp. Although Sony exhibited its PALC (Plasmation 42") at SID San Diego in May 1996, Sony did not exhibit a PALC display at INFOCOMM 98. Instead, Sony demonstrated three repackaged 42-inch Fujitsu surface discharge AC plasma color displays, two in landscape mode, and one in portrait mode. Sony also featured its own video interfaces with the Fujitsu 42-inch surface discharge AC plasma displays, quoting a price of $8500 for small quantities. In addition, Philips also demonstrated a repackaged Fujitsu 42-inch AC plasma display at INFOCOMM 98, but did not exhibit any PALC. Sharp did not exhibit either PALC or AC plasma at INFOCOMM 98. During 1997, Sony, Philips, and Sharp announced that PALC HDTV would be available in December 1998. With Sony and Philips now offering a repackaged Fujitsu 42-inch, the future of PALC may be in question.

PROJECTION DISPLAYS

Projection displays have made substantial progress over the past five years. The two kinds of projection, Front or Rear Projection displays, typically use CRT or LCD projection systems. The price of projection displays increases with higher luminance, the price ranging from about $2000 to $100,000 with luminance ranging from about 200 to 7000 lumens. Contrast is about 100:1 to 350:1. The power input is about 120 to 2000 watts.

The projection display screen for HDTV ranges from 18 to 500 inches. Resolution ranges from 640 x 480 to 1280 x 1024. Higher resolutions are available with a substantial increase in cost.

Projection displays have benefited from improvements in LCD technology, particularly polysilicon thin film LCD. In addition, there have been improvements in electronics and compact packaging which have made rear projection more viable.

Many of the producers or sellers of surface discharge AC plasma are also offering projection displays. At INFOCOMM 98, there were over 600 exhibitors. Surface discharge AC plasma displays were in about 30 booths and projection displays were in over 570 booths. In some booths, both AC plasma and projection displays were exhibited. Among the manufacturers exhibiting both technologies, projection displays were dominant. These included Pioneer, Mitsubishi, NEC, Hitachi, Panasonic, Sony, and Philips.

In order to meet the anticipated consumer demands for HDTV, projection displays will have to meet the same goals stated above for AC plasma including low cost, full-color, luminous efficiency, and HDTV resolution.

Projection displays are already available with full-color at prices below $3,000. During the last five years, the luminous efficiencies for projection displays have increased to above 5 lumens per watt.

Resolutions up to HDTV are available, but are presently too costly. An alternative approach is to compress a high resolution input signal and project a lower resolution display. Thus a 1280 x 1024 input signal might be compressed to 1024 x 768. However this is only an interim approach. Ultimately the higher HDTV resolutions must be provided at low cost.

OTHER DISPLAY TECHNOLOGIES

Other display technologies including CRT and LCD could play a role in HDTV. Philips has introduced a 33-inch CRT for HDTV. Samsung has demonstrated a prototype 30-inch LCD monitor at a resolution of 1600x 1200. Sharp has demonstrated a 40-inch 800 x 600 LCD monitor.

The HDTV display could also come from dark horse displays such as Field Emission Displays (FED). The FED firms have reported luminous efficiencies above 5 with at least one firm reporting 10 lumens per watt.

Within the last two years TI has introduced a new projection technology marketed as Digital Micromirror Device (DMD). Digital Projection of Dallas, Texas offers a family of DMD projection display systems using 1, 2, or 3 DMD chip systems. The performance of 2 and 3 chip systems compares favorably with the performance of polysilicon LCD projection systems.

Digital Projection offers its latest DMD system, Model Power 7 GV, with a luminance of 6500 ANSI lumens. The system receives an input of 1280 x 1024 which is compressed to a display resolution of 1024 x 768. The bulb life is 500 hours and the luminous efficiency is over 2 lumens per watt. This technology is expensive, the Power 7 GV being priced at about $100,000 plus a lens systems of $3000 to $10,000.

SUMMARY

Surface discharge AC plasma displays appear to be a favorite for HDTV. However, this display technology has significant problems that may delay its use for HDTV. These problems include very low luminous efficiency, high power, high manufacturing costs, high electronics costs, and insufficient gray scale (and color) at the proposed HDTV size and resolution. It is possible that a new plasma structure will provide solutions for the technical and cost problems. If AC plasma displays do not overcome technical and cost problems and stumble on the road to HDTV, projection displays may be available to meet the demand. High quality projection displays are already being offered at prices 50 to 70% below AC plasma display prices. Whatever display technology is accepted for HDTV, it will be decided by price and performance.

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