

Title: Flexible AC Plasma Displays Using Plasma-spheres™

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Abstract: (35-50 words)

IST is engaged in a three year research and development effort to produce flexible monochrome and color plasma displays using Plasma-spheres™. Plasma-spheres™ are hollow microspheres encapsulating an ionizable gas. Plasmas-sphere™ displays promise advantage over standard plasma displays including low cost manufacture, ruggedness, and flexibility.

Technical Summary

Objective

IST is engaged in a three year research and development effort to produce flexible monochrome and color plasma displays using Plasma-spheres™. Plasma-spheres™ are hollow microspheres encapsulating an ionizable gas. In this paper we report findings that indicate the feasibility of a monochrome display. Key parameters of interest include operating voltage, operating margin, and brightness.

Background

Plasma-sphere™ Display vs Standard PDP Display

The Plasma-sphere™ display is a novel closed cell device that replaces the open cell structure of a standard PDP using a Plasma-sphere™. Figure 1 compares the two structures. In a standard PDP, two substrates, B, encapsulate an ionizing gas held at pressures of 0.3-0.6 atmospheres. The two substrates must be thick, flat, strong, and airtight. E is an address electrode, and F is a row electrode. The crossing of these two electrodes defines a pixel, A. C is a dielectric coat that must be applied evenly to each substrate to protect the electrodes. Other coatings such as MgO and phosphor are also applied. D is a barrier rib that must be built up or etched into the dielectric.

In contrast, the Plasma-sphere™ display is composed of a sphere, A, that contains the ionizable gas. The shell of the sphere is composed of dielectric, C, that is comparatively even due to the forming process. E and F are electrodes in the substrate, B. Because the pressurized gas is contained in a sphere, the substrate is not required to be strong or impermeable. It can be made flexible and a top substrate is not required at all. Additionally, because the sphere defines the crucial parameters of gap and dielectric thickness critical dimensions are not required over a substrate area.

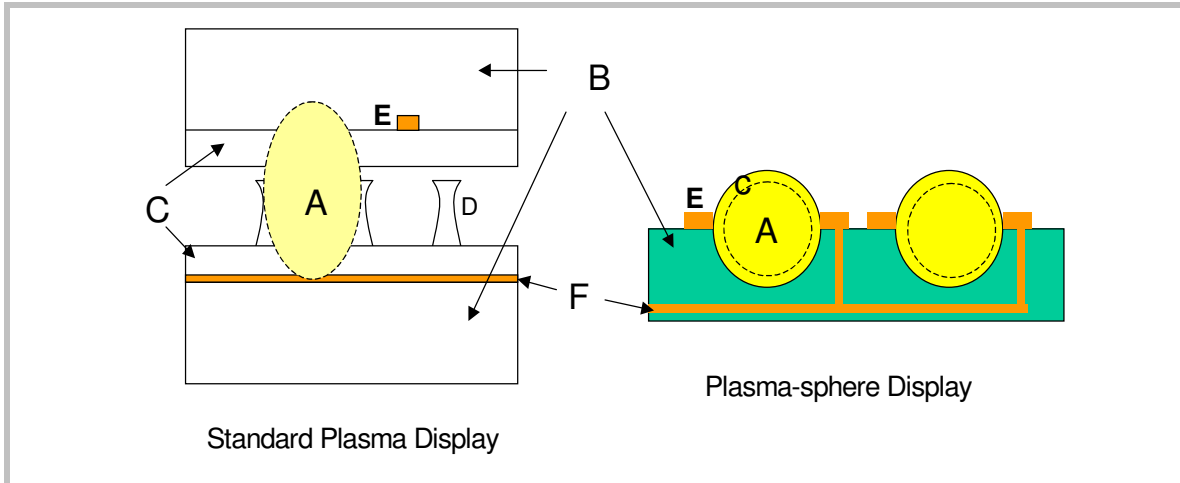


Figure 1

Manufacturing Process

The Plasma-sphere™ display manufacturing process will be significantly less costly than a standard PDP process. This new Plasma-sphere technology easily lends itself to a continuous flow process instead of a costly batch process. Additionally, some of the costly and exotic steps such as sand blasting, vacuum deposition, gas processing, and numerous screen-printing cycles are eliminated. The elimination of these various process steps, coupled with the elimination of labor intensive costs associated with batch production results in a high yield, low cost process. Furthermore, the time intensive gas-processing step is bypassed. Gas processing (filling and sealing of the panels) requires 12 to 16 hours and is the traditional bottleneck that adds to manufacturing cost. Replacing the open gas plasma structure with Plasma-spheres™ eliminates the time-consuming gas process step.

Results

IST has produced monochrome orange Plasma-spheres™ ranging in size from 0.250mm to 3mm using several methods. Most experimentation and optimization was conducted on spheres ranging in size from 1.7mm to 2mm. Two test substrates were fabricated. The first substrate was an 8X8 array fabricated from FR4 circuit board material using a structure similar to that of Figure 1. The second was made of very thin FR4 material and consists on an array of 8 X 40. Most electrical testing was done using the 8 X 8 array. The 8 X 40 array was fabricated to illustrate flexibility and scalability.

Voltage

Through various process control measures a lower operating voltage has been achieved. The first critical parameter was gas pressure. Steps were taken to modify the process to fill the spheres with gas in accordance with the Paschen curve. This accounts for the first decrease in voltage from the baseline as shown in Table 2.

| | Avg off | Avg on |
|-------------------------|---------|--------|
| Baseline | 700V | 740V |
| Control of gas pressure | 420V | 600V |
| Process purity | 280V | 330V |

After pressure was brought under control, a successful effort was made to purify the process. This included eliminating sources of contamination to the gas as well as the shell material. This resulted in another significant drop in the voltage.

Operating Margin

An increase in operating margin was obtained by decreasing shell thickness. In one exemplary experiment, two batches of spheres were produced under identical conditions including shell composition, gas composition, and gas pressure. Batch A had a shell thickness of 83 microns. Batch B had a shell thickness of 150 microns. Both batches were mounted to an 8 X 8 substrate. The ON Voltage (V_{on}) and the OFF Voltage (V_{off}) were recorded for each Plasma-sphere of matrix A and each Plasma-sphere of matrix B. The lowest V_{on} value (1st ON) was noted for each of the two matrix. The operating margin of each Plasma-sphere was calculated with the formula $1^{st} ON - V_{off}$. The results are shown in the table below.

| Operating Margin | No. Of Sphere that meet or exceed operating margin criteria | |
|------------------|---|----|
| | B | A |
| 2.5 | 29 | 58 |
| 5 | 26 | 57 |
| 7.5 | 21 | 56 |
| 10 | 19 | 56 |
| 12.5 | 18 | 55 |

It can be seen from the table that the batch of spheres B with 150 micron shell thickness has only 29 Plasma-spheres out of 64 with a V_{off} of 2.5 volts less than V_{on} , while the A batch with 83

microns has 58 that exceed the criteria. Thus it can be seen that lowering the shell thickness increases operating margin.

Brightness

Current brightness is 30 cd/m². This will be increase by increasing the pressure and increasing the electrode area.

Impact

The Plasma-sphere™ display has advantages over a standard plasma display including low manufacturing cost, seamless tiling, longer life due to the protection of phosphors, and flexible substrate. Like the standard plasma display, it has a full color pallet, wide viewing angle, video speed and ability to scale to large sizes. Additionally, the Plasma-sphere™ display is very rugged compared to a standard plasma display or any other display technologies. The Plasma-sphere™ display can tolerate temperature extremes - liquid crystal displays cannot. The Plasma-sphere™ display can withstand pressure extremes - standard plasma displays cannot. The Plasma-sphere™ can take a direct blow to the front surface and likely none of the spheres will be damaged. In the event that some of the spheres are crushed, the un-damaged areas of the display will still function. A comparison of the Plasma-sphere display with other display technologies is provided below.

| | Economical Small Size | Economical Large size | Video Speed | Full color | Pressure Extreme | Temperature Extreme | Shock and Vibration | Seamless tiling | May be Flexible | Long life |
|-----------------------|-----------------------|-----------------------|-------------|------------|------------------|---------------------|---------------------|-----------------|-----------------|-----------|
| Plasma-sphere Display | | X | X | X | X | X | X | X | X | X |
| Standard Plasma PDP | | X | X | X | | X | | | | |
| OLED | X | | X | | X | | | X | X | |
| Electrophoretic | X | X | | X | | X | | | X | X |
| LCD | X | | X | X | | | | X | X | X |

Because of it unique characteristics, the Plasma-sphere display will be useful in certain applications including very rugged applications including military, industrial, scientific exploration, and the automotive industry. Because of the large size and seamless tiling it will also be useful in large stadium and entertainment applications. The flexible substrate will allow new applications in

flight simulators, large mobile command and control shelters, and eventually futuristic video games.

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Prior Publications

None