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Janning

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[54] **PICTURE PRODUCING PLASMA DISPLAY DEVICE AND METHOD OF MAKING IT**

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[73] Assignee: **The National Cash Register Company**, Dayton, Ohio

[22] Filed: **Dec. 26, 1972**

[21] Appl. No.: **318,369**

[52] **U.S. Cl.** **313/220**, 313/188, 316/17

[51] **Int. Cl.** **H01j 61/30**

[58] **Field of Search** 313/188, 220; 316/17

[56] **References Cited**

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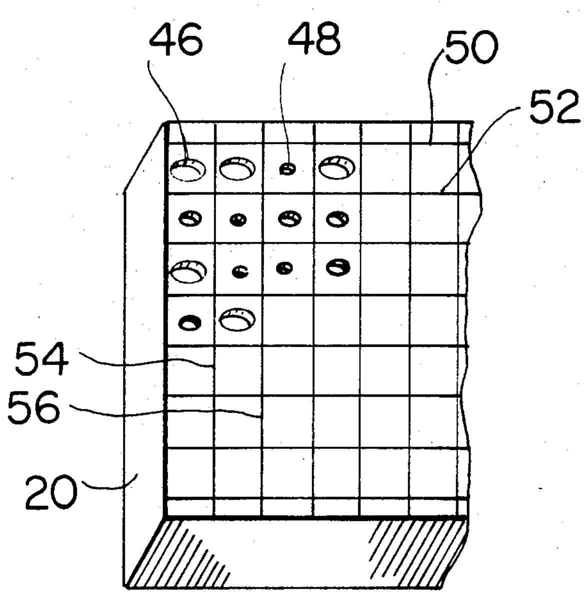
Assistant Examiner—Darwin R. Hostetter
Attorney, Agent, or Firm—J. T. Cavender; Albert L. Sessler, Jr.; Elmer Wargo

[57] **ABSTRACT**

A plasma display device capable of selectively displaying several fixed, picture-type images which may extend over the entire display area of the device. The device includes a cavity plate having cavity location areas arranged thereon in parallel rows and columns in a grid-like manner. Cavities associated with each of the fixed images are regularly located at periodically spaced rows and columns of the cavity location areas, and horizontally positioned and vertically positioned electrodes, aligned with the cavities, are used to energize the device. Each image to be displayed is produced by first making a half-tone transparency film of a picture to be displayed. The transparency film has "data dots" thereon, and these "dots" are then used in forming the cavities associated with each image.

16 Claims, 13 Drawing Figures



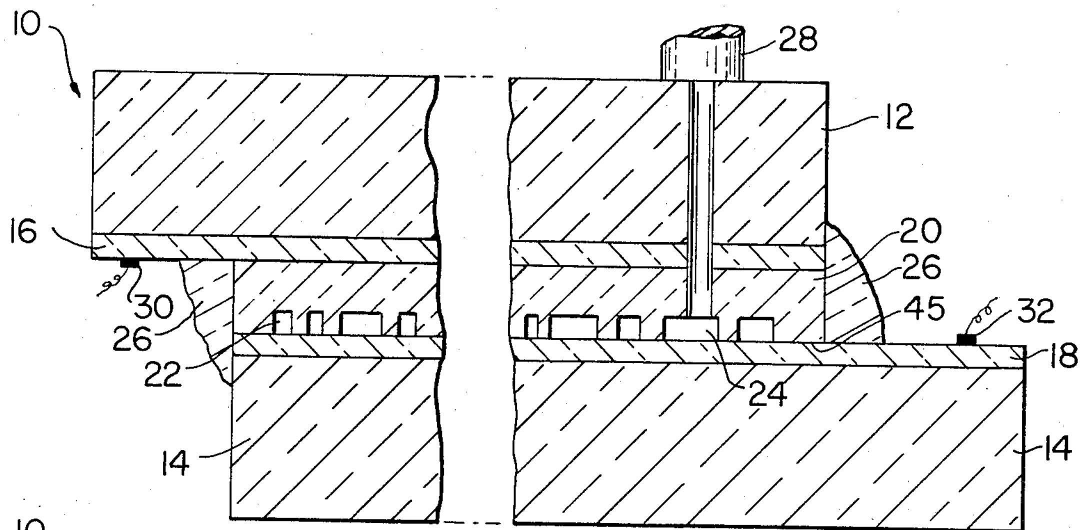


FIG. 2

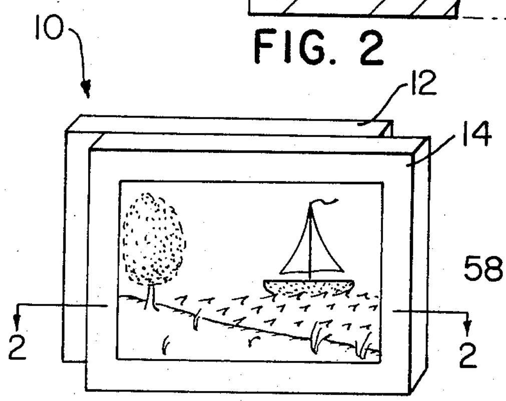


FIG. 1

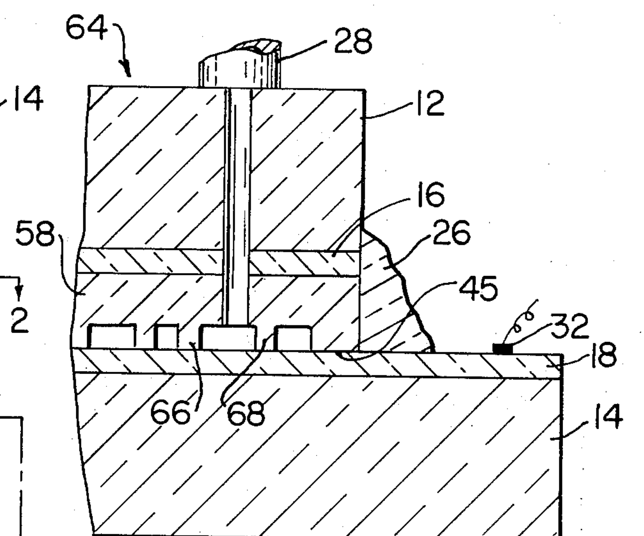


FIG. 7

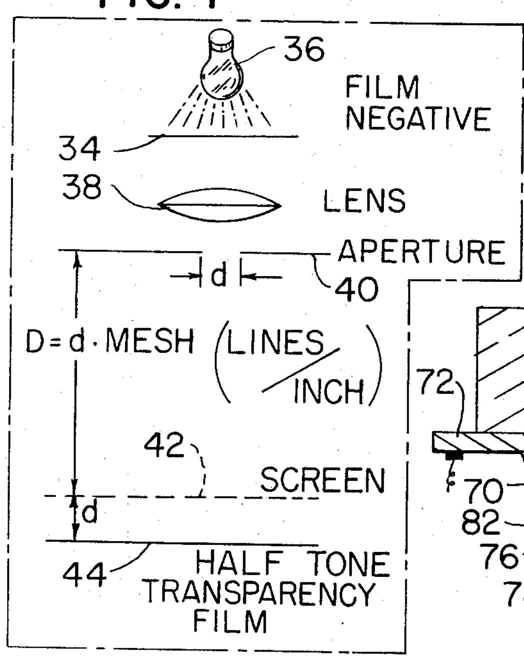


FIG. 3

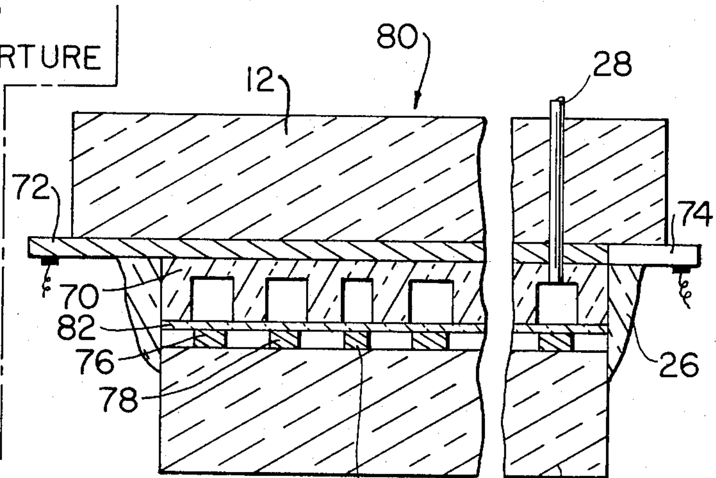


FIG. 8

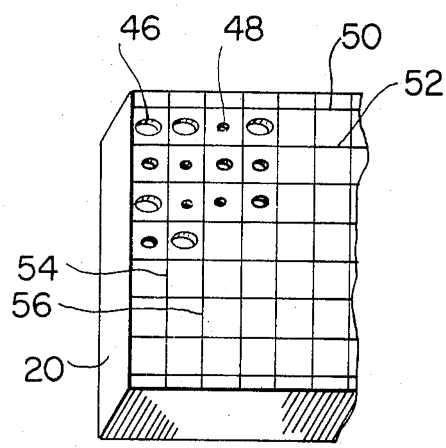


FIG. 4

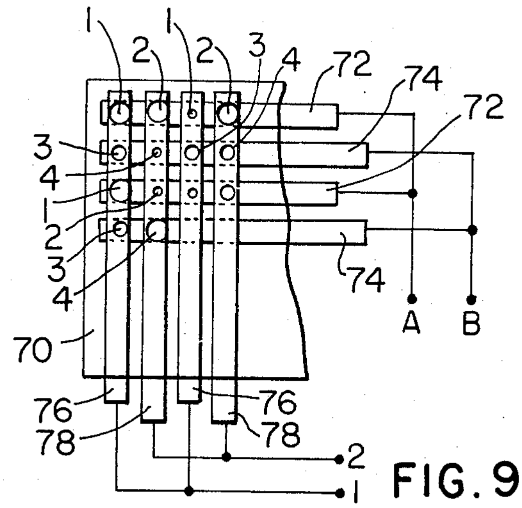


FIG. 9

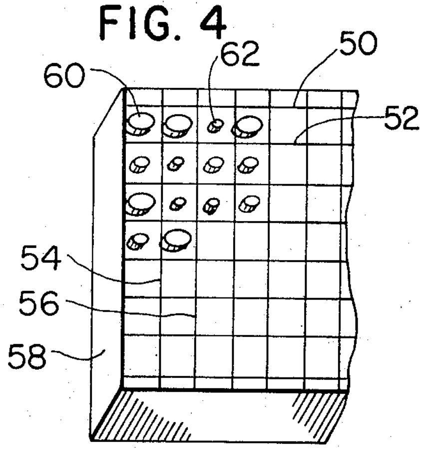


FIG. 5

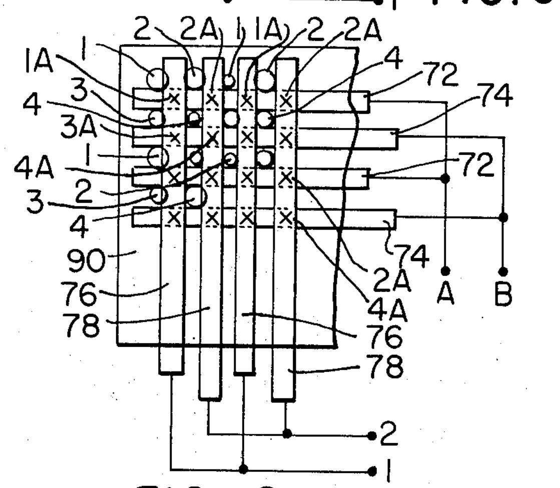


FIG. 12

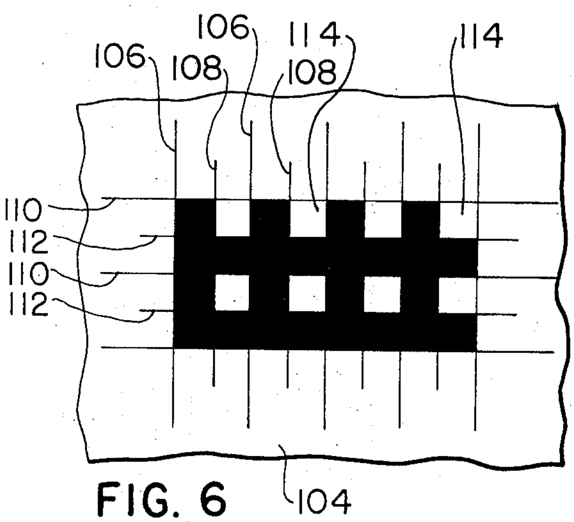


FIG. 6

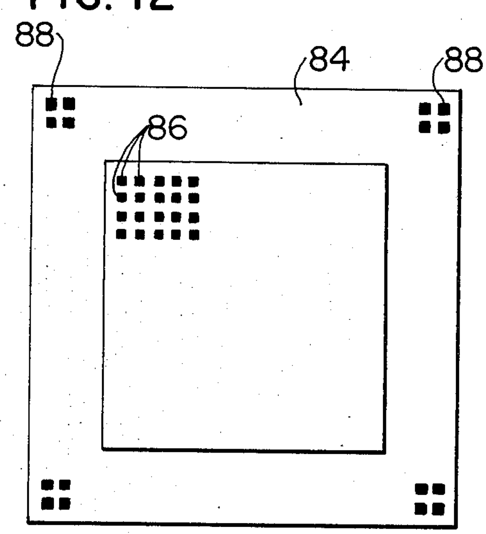


FIG. 11

FIG. 10

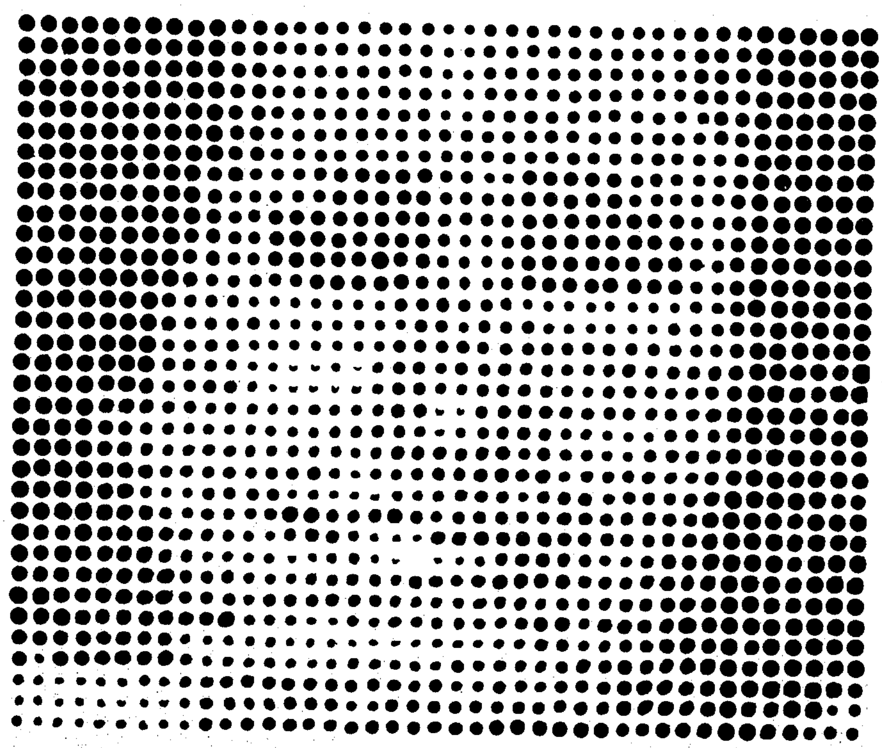
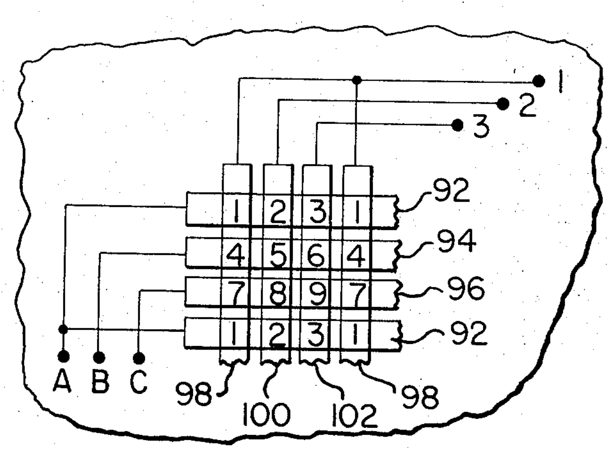


FIG. 13



PICTURE PRODUCING PLASMA DISPLAY DEVICE AND METHOD OF MAKING IT

The subject matter of this application is generally related to copending application Ser. No. 318,368 filed on Dec. 26, 1972 by John L. Janning.

BACKGROUND OF THE INVENTION

This invention relates to a picture producing plasma display device and the method of making it.

In prior art plasma display devices which display characters and graphic drawings, the dot matrix technique is generally used. This technique utilizes an array of regularly-shaped, gas-filled cells arranged in a honeycomb configuration. Conductors, arranged along x and y directions, mutually perpendicular to each other, have one of the cells of the configuration located at each crossover point of the conductors. To energize a particular cell, the appropriate x and y conductors are energized. To produce a graphic pattern, a great number of individual x and y conductors must be energized, and the resulting graphic pattern is dot-like in appearance and analogous to a line drawing.

In contrast with the above, the display device of this invention produces a picture (similar to a photograph) having a resolution of at least 65 lines per inch. Each picture produced may cover the entire area of the display device if necessitated by the design thereof, and the energizing technique for selecting a picture out of several pictures or images to be displayed is greatly simplified over the prior art devices.

SUMMARY OF THE INVENTION

This invention relates to a picture producing plasma display device and the method of making it.

The display device includes first and second substrates, each having a conductor means thereon, with the conductor means on the second substrate being transparent. A layer of glass is positioned between the first and second substrates, and the layer of glass has cavities therein, with the cavities being formed in a pattern which conforms to a half-tone transparency film which has the desired fixed image or picture thereon. Means are provided for filling and sealing the cavities with an ionizable gas, and connection terminal means are connected to each of the conductor means.

When several fixed images or pictures are to be displayed, the conductor means on the first and second substrates take the form of spaced, parallel electrodes, with the electrodes on the first substrate being positioned perpendicular to the electrodes on the second substrate to produce crossover points, with a cavity being located at each of the crossover points. The cavities associated with each said image to be displayed are located in predetermined locations, at selected crossover points, and the number of cavities associated with each said image bears a predetermined relationship to the total number of fixed images to be displayed on the device.

The general method of forming the fixed image is to first make a half-tone transparency film of the image to be displayed. The half-tone transparency film, having "data dots" thereon (like a newspaper picture), is then used to form a pattern of cavities in the display device. In one embodiment, for example, the cavities are holes having varying diameters, with the diameters of the holes corresponding to the diameters of the associated data dots of the half-tone transparency film.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a general perspective view of this invention looking at the front of a plasma display device having one fixed image thereon.

FIG. **2** is a cross-sectional view, taken along the line **2—2** of FIG. **1** to show additional details of the plasma display device.

FIG. **3** is a schematic diagram showing a method of producing a half-tone transparency film which is used in producing the pattern of cavities in the display device.

FIG. **4** is a general perspective view of a portion of a cavity plate used in an embodiment of this invention, showing a pattern of cavities which are holes having diameters which vary in accordance with a pattern of data dots on the associated half-tone transparency film.

FIG. **5** is a general perspective view, similar to FIG. **4**, showing a different embodiment of the invention in which the pattern of cavities is created by producing a pattern of posts which corresponds to the pattern of data dots on the associated half-tone transparency film, the cavities being formed in the areas around the posts.

FIG. **6** is an enlarged, modified form of a screen used in producing a half-tone transparency film for producing the desired images in a plasma display device.

FIG. **7** is a cross-sectional view, similar to FIG. **2**, showing additional details of the device when the cavities thereof are produced around posts.

FIG. **8** is a cross-sectional view, similar to FIG. **2**, showing additional details of the device for an embodiment in which several fixed images are to be displayed.

FIG. **9** is a schematic diagram showing how the cavities associated with a particular fixed image are assigned to predetermined cavity location areas.

FIG. **10** is an enlarged view of a half-tone transparency film made in accordance with the method illustrated in FIG. **3**.

FIG. **11** is a diagram of a template used in forming the cavities of the display device in predetermined cavity location areas.

FIG. **12** is a diagram showing how the cavities associated with a particular fixed image are assigned to predetermined cavity locations when the cavities are formed around posts on the cavity plate.

FIG. **13** is a diagram similar to FIG. **9** showing how the cavities are assigned to cavity location areas in a device in which up to nine fixed images are to be displayed.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a general perspective view of a first embodiment of the plasma display device of this invention which is designated generally as **10.** The device **10** includes a rear substrate **12**, a front substrate **14**, and electrode means and a cavity plate located therebetween. The rear substrate **12** is made from an insulating material like glass on which a first electrode means **16** (FIG. **2**) is positioned. The electrode means **16** is a conductor, like a thin layer of silver, which extends over at least the entire area where the cavities are located.

The front substrate 14 (FIGS. 1 and 2) is made of a transparent insulating material like glass. This substrate 14 has a second electrode means 18 secured thereto, which electrode means, in this embodiment, is a thin layer of a suitable, electrically-conductive, transparent material like tin oxide which extends over at least the entire area where the cavities are located. A thin layer of glass about 0.0005 inch thick (not shown) may be conventionally deposited over the electrode means 18 to isolate the electrode means from an ionizable gas which fills the cavities of the device 10.

The cavity plate 20, alluded to earlier, is made of a layer of glass which is positioned between the front and rear substrates 14 and 12 as shown in FIG. 2. The plate 20 is produced preferably from glass which has a black dye added thereto to produce an opaque glass. As an illustration, the glass may be made from Corning powdered glass No. 7570 manufactured by the Corning Glass Company, which glass powder is mixed with Drakenfeld powdered dye No. 1795 manufactured by Hercules, Inc., Washington, Pennsylvania. A fixed weight of the dye equal to about five percent of the weight of powdered glass makes a satisfactory opaque glass. The plate 20 has a plurality of cavities like 22, 24 formed therein as shown. The method for producing these cavities will be discussed later herein.

The device 10 (FIG. 2) is conventionally sealed by applying a layer of glass frit 26 around the edges thereof and heating the device in a furnace to fuse the frit. After the device is sealed, a tube 28, communicating with the cavities 24, 22, is used to evacuate the air therein and fill the cavities with an ionizable gas. After filling, the tube 28 is sealed. Usually, the contacting surfaces between the cavity plate 20 and the second electrode means 18 (or the layer of glass, if used, covering the electrode means 18) have minute irregularities therein to enable the gas within the cavities to equalize in pressure; however, if the pressure does not stabilize, conventional pressure equalization grooves (not shown) may be used to interconnect the cavities and thereby stabilize the gas pressure therein. A terminal 30, connected to the first electrode means 16 and a second terminal 32 connected to the second terminal means 18 are used to energize the device 10 when the terminals 30 and 32 are connected to a source of AC potential as is done conventionally.

The method of forming the cavities in the plasma display device 10 will now be discussed in relation to FIG. 3 which schematically shows a photographic enlarging process. A film negative 34, corresponding to the image to be displayed on the device 10 (FIG. 1) is positioned in an enlarger having a light source 36, lens 38, and variable aperture plate 40. In order to produce a half-tone transparency film from the negative 34, it is necessary to use a screen 42 similar to the type of screen used for producing half-tone transparencies in the newspaper printing art. The screen 42, in the embodiment shown, is composed of 65 lines to the inch, with the lines of the screen being arranged mutually perpendicular to one another as is customarily done. The diameter of the aperture in the plate 40 is equal to a distance "*d*", and the screen 42 is placed above an unexposed photographic film 44 a distance equal to "*d*." The film 44 will become the half-tone transparency film after exposure and development. The screen 42 is placed a distance "D" away from the aperture plate 40, and the distance "D" is equal to the distance

"d" multiplied by the number of lines per inch in the screen 42. For example, if the distance "*d*" is equal to ½ inch, and the screen 42 contains 65 lines per inch, the distance "D" is equal to (½ × 65) or 32.5 inches. When the negative 34 is used in the arrangement shown in FIG. 3 with the dimensions just given, a half-tone pattern is exposed on the film 44, and when this film is developed, it will contain data dots corresponding to the image contained on the negative 34. For example, FIG. 10 shows an enlarged half-tone pattern of a woman's face. The picture negative (like 34 in FIG. 3) from which the half-tone transparency film was made, has a generally clear portion for the area of the woman's hair which is actually dark in color. Because this area is clear, it shows up on the half-tone transparency film (shown in FIG. 10) as a plurality of large black data dots, and contrastly, those areas which are dark on the picture negative (like 34) for high lighted cheek areas, for example, show up as small diameter data dots on the half-tone transparency film in FIG. 10.

Using a half-tone transparency film similar to the one shown in FIG. 10, a cavity pattern in the display device 10 is produced as follows. The cavity plate 20, prior to assembly in the device shown in FIG. 2, is conventionally secured to the first electrode means 16. The surface 45, in which the cavities are to be formed, is ground to a smooth flat finish of about 9.5 to 22.5 microinch. The finished thickness of the cavity plate 20 is about 0.006 inch. The cavities in the plate 20 are produced by producing holes as shown in FIG. 4 or by producing posts with the cavities located therearound as shown in FIG. 5.

When it is desired to produce a cavity plate having holes therein (as in FIG. 4) corresponding to the image to be displayed, the following procedure is used. After the surface 45 of the cavity plate 20 is ground to a flat finish as previously described, a layer of negative photoresist is placed on the flat finish. The half-tone transparency film (like the one shown in FIG. 10) for producing the desired image is then conventionally exposed on the photoresist, and the cavity plate and photoresist are conventionally processed and chemically etched to a depth of 0.004 inch. Because of the negative photoresist, those areas of the half-tone transparency film which appeared as black dots, will appear as cavities in the cavity plate 20. For example, a large black dot on the half-tone transparency film appears as a large diameter cavity 46 in FIG. 4, while a small black dot on the half-tone transparency film appears as a small diameter cavity 48. The cavities like 46 and 48 have varying diameters corresponding to the diameters of the data dots on the associated half-tone transparency film. Obviously, the portion of the cavity plate 20 shown in FIG. 4 is not drawn to scale, and is used only to illustrate the method of forming the cavities. The horizontal lines like 50 and 52, and the vertical lines like 54 and 56 shown correspond, for alignment purposes, to the horizontal and vertical lines of the screen 42 (FIG. 3) which was used to produce the associated half-tone transparency film. After the cavities are formed in the plate 20, the plasma display device 10 is assembled as shown in FIG. 2 as previously explained. The cavities like 22 and 24 shown in FIG. 2 are analogous to the cavities shown in FIG. 4. After being assembled, the terminals 30 and 32 of FIG. 2 are conventionally energized to produce an image or display similar to that shown in FIG. 1.

When it is desired to produce a plasma display device in which the cavities thereof are developed by producing posts as shown in FIG. **5**, and as alluded to earlier, the following procedure is used. After the surface of the cavity plate **58** (similar to plate **20** in FIG. **4**) is ground to a flat finish, as previously described, a layer of positive photoresist is placed on the ground surface. The half-tone transparency film (like the one shown in FIG. **10**) for producing the desired image is then conventionally exposed on the photoresist, and the cavity plate and photoresist are conventionally processed, and chemically etched to a depth of 0.004 inch. Because of the positive photoresist, those areas of the half-tone transparency film which appeared as black dots, will appear as posts **60** and **62**, for example, with the posts having a height of 0.004 inch. Assuming that the same half-tone transparency film were used to produce the cavity plates shown in FIGS. **4** and **5**, one can see that a black, large-diameter data dot on the half-tone transparency film will produce a large-diameter cavity **46** (FIG. **4**) when using a negative photoresist, and the same data dot will produce a large diameter post **60** (FIG. **5**) when a positive photoresist is used. Similarly, a black, small-diameter data dot produces a small-diameter cavity **48** in the cavity plate **20** shown in FIG. **4**., and a small diameter post **62** on the cavity plate **58** shown in FIG. **5**. In the embodiment shown in FIG. **5**, the cavities are actually formed around and between the posts like **60** and **62**. When the cavity plate **58** is placed in the plasma display device **64** shown in FIG. **7**, the cavities around the posts **60** and **62** in FIG. **5**, and posts **66** and **68** in FIG. **7**, will glow when the device is energized. The plasma display device **64** (FIG. **7**) is identical to the plasma display device **10** shown in FIG. **2** except for the cavity plate **58** as already explained. The filling tube **28** is positioned between posts **66** and **68** (similar to the posts shown in FIG. **5**) to enable the ionizable gas inserted in the device to freely flow around the posts.

The half-tone transparency film displayed in FIG. **10** shows a portion of a woman's head, and the film is enlarged to show how the diameters of the data dots vary in accordance with the picture being represented. Notice that the data dots appear in rows and columns which are mutually perpendicular to one another. Because the data dots in the transparency film were made using a coarse screen (like **42** in FIG. **3**) the resulting face or image is not as clear as it would be if a finer screen having a resolution of 65 lines per inch had been used. The face in the transparency film can be more clearly discerned, however, by holding the film at arm's length while viewing it. It should be pointed out that when preparing the half tone transparency films, consideration should be given to the desired final form of the image as it is to appear in the plasma display device, as this may affect whether positive photoresist or negative photo-resist is used in forming the cavities in the device.

It should be noted that the two embodiments of this invention shown principally in FIGS. **2** and **7** each produce a single fixed image or picture which corresponds to its associated half-tone transparency film. This invention also contemplates producing plasma display devices in which more than one fixed image can be selectively displayed on a single plasma display device. Because the techniques already described are utilized in producing such a display device in which more than one fixed image can be selectively displayed, the explanation thereof can be simplified. Essentially, the first electrode means, the cavity plate, and the second electrode means are altered, but otherwise, the display device for displaying more than one fixed image assumes the general configuration shown in FIG. **2**, for example.

The process for forming a plasma display device for displaying a plurality of selectable fixed images can be described in relation to FIG. **9** which shows a cavity plate **70**, and first and second electrode means. The cavity plate **70** has a plurality of cavity location areas thereon, which areas are analogous to the areas bounded by the horizontal lines like **50** and **52**, and the vertical lines like **54** and **56**, shown in FIG. **4**. A cavity is located at each of these areas if necessitated by the design of the image to be displayed.

In general, if four fixed images, for example, are to be displayed on a plasma display device of this invention, then one-fourth of the cavity location areas are assigned to each of the first, second, third, and fourth fixed images to be displayed. The cavity location areas assigned for each said fixed image are regularly located in periodically spaced rows and columns of the cavity location areas.

As an illustration, the cavities marked with a "**1**" in FIG. **9** are associated with a first image, and correspondingly, the cavities marked "**2**", "**3**", and "**4**" are associated with second, third and fourth fixed images. Notice that the cavities for the first image follow the regular pattern of being located in alternate rows and alternate columns of cavity location areas which were described in relation to FIG. **4**. The cavities for the second, third, and fourth displays follow a similar pattern.

The first electrode means, alluded to earlier, includes a plurality of spaced, aligned, horizontally-positioned, parallel electrodes **72** and **74**. These electrodes are aligned with the rows of cavities shown in FIG. **9**. The second electrode means includes a plurality of spaced, aligned, vertically-positioned, parallel electrodes **76** and **78**. Notice that each of the cavities is located at a cross-over point between a horizontally-positioned electrode and a vertically-positioned one. The relationship between the first and second electrode means and the cavity plate **70** is shown in FIG. **8**.

The structure of the plasma display device shown in FIG. **8**, and designated generally as **80**, is generally similar to the display device **10** shown in FIG. **2**; therefore, where the elements of the devices **80** and **10** are the same, the same reference numerals applied to device **10** will be used in device **80**. The display device **80** includes a first glass substrate **12**, having the electrodes **72** and **74** secured thereto as shown. These electrodes may be made of a conductor material like silver which is 0.00015 inch thick. The cavity plate **70** is conventionally secured to the first substrate **12** and has cavities therein as shown. These cavities will be later discussed herein relative to FIG. **9**. The second glass substrate **14** has the vertically aligned electrodes **76** and **78** secured thereto as shown. These electrodes are made of a transparent conductor material like tin oxide and have a thickness of about 0.00001 inch. A thin layer of clear glass **82**, to be positioned over the electrodes **76**, **78**, is used to isolate them from the ionizable gas which is located in the cavities, as previously explained. Glass frit **26** is used to seal the display device **80**, and a filling tube **28** is used to evacuate the air from the cavities and fill them with an ionizable gas.

The method of assigning cavities to the various cavity location areas on the cavity plate for each fixed image to be displayed will now be discussed. Each fixed image to be displayed has its own half-tone transparency film, like **44,** produced in accordance with the technique described in relation to FIG. **3.** The half-tone transparency film, like **44,** for the first image, for example, would have all the "data dots" thereon for the associated image as shown on the half-tone transparency film in FIG. **10.** If four fixed images are to be displayed, only one-fourth of the data dots for each fixed image would be formed as cavities on the cavity plate **70.** Looking at the cavities numbered as "1", "2", "3", and "4" in FIG. **9,** the data dots associated with the first fixed image are used to form the cavities numbered with a "1." Similarly, the data dots associated with the second, third, and foruth fixed images are used to form the cavities numbered with a "2", "3", and "4" respectively. One technique for forming the cavities in the cavity plate **70** for each of the four images makes use of a template **84,** or screen or the like, shown in FIG. **11.**

The template **84** (FIG. **11**) is made of a thin opaque material and has a plurality of square holes **86** therein. Each hole **86** is located in the template to be aligned with one of the cavity location areas on the cavity plate **70.** In the template **84** shown, a hole **86** is present for every other cavity location proceeding in a horizontal direction and a vertical direction. In effect, if the cavities for four images are to be formed on the cavity plate **70,** the template **84** acts as a mask to permit only one-fourth of the data dots for each image to pass therethrough to reach alternate cavity location areas.

The template **84** is used as follows. A layer of photoresist is placed over the layer of glass which becomes the cavity plate **70** and the template **84** is placed thereover. Registration holes like **88** appear on each corner of the template and are used to align the template with the plate **70.** The holes **86** in the template are aligned with the cavity location areas which are marked with a "1" in FIG. **9,** and the half-tone transparency film for the desired image like the one shown in FIG. **10** is placed in registration with the template **84** so that the columns and rows of data dots to be recorded are aligned with the holes **86.** While the plate **70,** template **84,** and half-tone transparency film shown in FIG. **10** are shown as being different sizes in the drawings, all three naturally would have to be identical in size to obtain an accurate registration of the data dots of the half-tone transparency film with the assigned cavity location areas on the cavity plate. After the half-tone transparency film and template **84** are aligned with the cavity location areas marked with a "1" in FIG. **9,** the photoresist is exposed, and the half-tone transparency film associated with the first fixed image is removed. With the photoresist in place over the plate **70,** the template **84** is moved laterally, as viewed in FIG. **11,** so as to position the holes **86** thereof over the cavity location areas marked with a "2" in FIG. **9.** When so aligned, the data dots associated with the half-tone transparency film for the second image are aligned with the holes **86** of the template and the photoresist is again exposed using the second half-tone transparency film to form the pattern of cavities on the photoresist. The second half-tone transparency film is removed and the process just described is repeated for the third and fourth half-tone transparency films which are to be exposed on the photoresist. For exposing the photoresist for the third image, the template **84** is indexed so that the holes **86** therein are aligned with the cavity location areas marked with a "3" in FIG. **9,** and similarly, the template **84** is indexed so that the holes **86** therein are aligned with the cavity location areas marked with a "4" when the fourth half-tone transparency film is used.

After the photoresist is exposed using the four half-tone transparency films as just described, the photoresist is conventionally, chemically processed and the cavity plate like **70** in FIG. **8** is etched to produce cavities having a depth of 0.o04 inch. The cavities (like the ones shown in FIG. **9**) so produced, have diameters which correspond to the diameters of the data dots of their associated half-tone transparency films.

In order to selectively energize a particular one of four fixed images to be displayed in the plasma display device **80** shown in FIGS. **8** and **9,** the following technique is used. The electrodes **72** of the first electrode means are connected to a first common terminal marked "A," and similarly, the electrodes **74** are connected to a second common terminal marked "B." The electrodes **76** of the second electrode means are connected to a first common terminal marked "1", and similarly, the electrodes **78** are connected to a second common terminal marked "2" in FIG. **9.** As previously stated, the horizontally-positioned electrodes **72** are aligned with the cavities marked "1" in FIG. **9,** and the vertically-positioned electrodes **76** are also aligned with the cavities marked "1" so that these cavities are located at the crossover points of the electrodes **72** and **76.** In order to select the first image to be displayed, the terminal marked "A" and the terminal marked "1" (FIG. **9**) are connected to a source of AC potential. When the terminals "A" and "1" are energized conventionally, any cavity located at the crossover points marked "1" will be energized, and accordingly, the first fixed image is displayed. The following chart shows what fixed image will be displayed when an energizing potential is applied to selected terminals of the display device shown in FIGS. **8** and **9**:

When Voltage is Applied to Terminals	Image Displayed
A and 1	1
A and 2	2
B and 1	3
B and 2	4

FIG. **12** shows another embodiment of the invention which can selectively display four images; however, the cavities in this embodiment are formed around posts by the technique (with some modifications) already described in relation to FIG. **5.**

As previously stated, a half-tone transparency film would be needed for each of the images to be displayed on the device which uses cavities formed around posts. The device includes a cavity plate **90** (FIG. **12**) which has the various cavity location areas assigned thereto as previously stated. The surface of the plate **90** is ground to a smooth finish (9.5 to 22.5 micro-inch), and a layer of positive photoresist is deposited thereover. The use of a positive photoresist enables the data dots on a half-tone transparency film (like the one shown in FIG. **10**) to be formed into posts as shown in FIG. **5.**

After the photoresist is in place, the template **84** is placed thereover, with the holes **86** being aligned with the cavity location areas marked with a "1" on the cavity plate **90**. The half-tone transparency film for the first image is then placed over the template **84** with the data dots thereof in registration with the holes **86**. As previously explained, only one-fourth of the data dots of each half-tone transparency film will be printed when four images are to be displayed on the device. After conventionally exposing the photoresist using the first half-tone transparency film and removing it, the template **84** is indexed as previously explained, to align the holes **86** thereof with the cavity location areas marked with a "2" in FIG. **12**. The half-tone transparency film for the second image is then placed over the template **84** with the data dots thereof in registration with the holes **86**. After exposing the photoresist, the second half-tone transparency film is removed, and the indexing and exposing technique just described is repeated for the third and fourth half-tone transparency films with the data dots for these films being respectively exposed onto the third and fourth cavity location areas of the plate **90**.

After the photoresist is exposed using each of the half-tone transparency films for the images to be displayed, the photoresist and the cavity plate **90** are then conventionally processed and chemically etched to produce posts, like the ones shown in FIG. **5**, with the posts having a height of approximately 0.004 inch. These posts, like the ones marked **1, 2, 3,** and **4,** in FIG. **12**, have diameters which vary in accordance with the corresponding data dots of the associated half-tone transparency films. Because these posts are made of a black glass, as previously explained, the cavities for the display device are actually formed around the posts. In one embodiment, the electrodes **72, 74, 76,** and **78** may be aligned over the posts in the same manner as the electrodes were aligned over the cavities as shown in FIG. **9**.

As an alternate construction, the electrodes for the cavities may be located between the posts as shown in FIG. **12**. For example, the horizontally-positioned electrodes **72** (which are identical to the electrodes **72** in FIG. **9**) are positioned between the posts numbered **1** and **3** while the horizontally-positioned electrodes **74** are positioned between the posts marked **4** and **2**. The vertically positioned electrodes **76** are correspondingly positioned between the posts marked **1** and **2**, and the vertically-positioned electrodes **78** are positioned between the posts marked **3** and **4**. The cavities associated with the images to be displayed are located on the cavity plate **90** at the crossover points of the horizontally and vertically positioned electrodes, with each said crossover point being located by an "x." The cavities associated with the first image are referenced as "1A" while the cavities associated with the second, third, and fourth images are referenced as 2A, 3A, and 4A respectively.

The selection scheme for selecting the image to be displayed, using the embodiment shown in FIG. **12**, is identical to the scheme already described in relation to the embodiment shown in FIG. **9**. In order to select and energize the first image, for example, the connection terminals marked **1** and A are connected to a source of energizing AC potential. Notice that the alternate horizontally-positioned electrodes **72** are connected to the connection terminal marked A, and the remaining horizontally-positioned electrodes **74** are connected to the connection terminal marked B. The alternate, vertically-positioned electrodes **76** are connected to the connection terminal marked **1**, and the remaining vertically-positioned electrodes **78** are connected to the connection terminal marked **2**. The actual configuration of the completed display device using the cavity plate **90** is identical to the display device so shown in FIG. **8** already described, except for the differences pointed out with regard to FIG. **12**. The selection scheme for selecting the second, third, and fourth images to be displayed is identical to the chart already described in conjunction with FIGS. **8** and **9**.

While the display devices shown schematically in FIGS. **9** and **12** are wired to display four different fixed images, each can be wired to produce a lesser number of fixed images. For example, the horizontally-positioned electrodes, like **72** and **74** of FIG. **9** may be replaced by a single electrode, like **16** shown in FIG. **2**, and the vertically-positioned electrodes **76** and **78** may remain as they are shown in FIG. **9**. All the cavities associated with a first image would then be located in alignment with the electrodes **76**, and all the cavities associated with a second image would be located in alignment with the electrodes **78**. Energizing the common electrode and the electrodes marked **76** would then produce the first image, while energizing the common electrode and the electrodes marked **78** would then produce the second image. No drawing is shown for this embodiment as its construction is readily understood from the descriptions and drawings of the previous embodiments.

When more than four fixed images are to be selectively displayed on a display device of this invention, the wiring of the device may take the form shown in FIG. **13**. This figure is analogous to FIG. **9** and shows cavity location areas which are located at the crossover points between the horizontally-aligned electrodes and the vertically-aligned electrodes. The cavity location areas are numbered **1** through **9** inclusive in FIG. **13**, and are laid out in a repeating pattern similar to that shown in FIG. **9**, except that the repeating pattern in FIG. **13** is based on multiples of **3** whereas the repeating pattern in FIG. **9** is based on multiples of **2**. Consequently, up to nine fixed images can be displayed on a plasma display device employing the wiring pattern shown in FIG. **13**.

Only a portion of the wiring pattern is shown in FIG. **13**; however, the general wiring pattern for the entire display device can be discerned therefrom. The horizontally-positioned electrodes **92, 94,** and **96** are respectively connected to connection terminals A, B, and C. Every third horizontally-positioned electrode (like **92**) is connected to the same connection terminal, as for example, the electrodes **92** are connected to the connection terminal A. The vertically-positioned electrodes **98, 100,** and **102** are respectively connected to connection terminals marked "**1**", "**2**" and "**3**." Every third vertically-positioned electrode is connected to the same connection terminal, as for example, the electrodes **98** are connected to the connection terminal marked "**1**." All the cavities associated with producing the first image in the display device would be located at the crossover points of the horizontal and vertical electrodes which are marked with a "**1**." Similarly, the cavities associated with the ninth image, for example, would be located at the crossover points marked with a "**9**." In order to display the ninth image, for example, the connection terminals marked "**3**" and C would be connected to a source of AC potential, and similarly, in order to display the sixth image, the connection terminals marked "3" and B would be energized.

The actual structure of a plasma display device incorporating the wiring pattern shown in FIG. **13** is similar to that shown in FIG. **8**, and such a device may have the cavities therein produced by holes of varying diameters or posts as previously explained in connection with FIGS. **9** and **12** respectively. The techniques used for producing a plasma display device having the wiring pattern shown in FIG. **13** are identical to those already described; however, the template (like **84** in FIG. **11**) used in the procedure for exposing the photoresist would have the holes therein arranged to print one-ninth of the data dots of each half-tone transparency film to be displayed by the device. Naturally, when only one-ninth of the data dots of a half-tone transparency film appear as cavities for each fixed image to be displayed in the display device, the resolution of the resulting fixed image will not be as sharp as the image which is displayed on a device like the one in FIG. **9** in which one-fourth of the data dots are used.

Some comparison of the two methods (i.e., either "holes or posts") for producing cavities in the various embodiments of the display device of this invention is in order. The post method of producing cavities, as is shown in FIGS. **5** and **12** for example, permits the ionizable gas within the display device to easily flow around the posts and permits a more uniform firing voltage for firing the selected cavities than does the hole method. A plasma display device made by the post method has a picture panel which is "all lit," with black areas produced by the posts and is generally similar to a television screen. The overall contrast of the image produced by the post method is not as good as image produced by the hole method shown in FIGS. **4** and **9**, for example, wherein discrete, lighted cells are provided.

FIG. **6** shows an enlarged, modified form of a portion of a screen **104** which may be used in producing a half-tone transparency film for producing the desired images in a plasma display device of this invention. The screen **104** is composed of wires like **106** and **108** which are aligned in spaced, parallel, relationship in a vertical direction, and wires **110** and **112** which are aligned in spaced, parallel relationship in a horizontal direction to produce a mesh characteristic of screens used in producing half-tone transparency films. The screen **104** is different from the usual screen, however, in that every other "opening" of the screen (when proceeding in horizontal and vertical directions) is covered with an opaque material to prevent light from passing therethrough except in the clear areas **114**. The screen **104** may have a mesh of **65** lines per inch and when used in place of screen **42** shown in the apparatus in FIG. **3**, will produce a half-tone transparency film having one-fourth of the data dots for the image, with the light passing through clear areas **114**. The screen **104** may remain in the apparatus shown in FIG. **3**, but it is indexed in a manner similar to the indexing of template **84** of FIG. **11**, to enable the clear areas **114** of the screen **104** to become aligned with what would be the cavity location areas marked "**2**" in FIG. **9**, and the negative **34** for the second image would be exposed (in FIG. **3**) to produce a "composite" half-tone transparency film **44** which has the data dots for the first and second images in their designated places. This process of indexing the screen **104** is repeated until the data dots for the associated third and fourth images are exposed on the transparency film. Thus, the data dots for all four images to be displayed would be located in their respective positions on one composite half-tone transparency film **44**. This composite film **44** would then be used with a layer of photoresist over the cavity plate (like **70** in FIG. **9**), and the photoresist would be conventionally exposed, processed, and chemically machined to produce the cavities in the cavity plate.

The operating voltages, gas mixtures and pressures, etc., used in the various embodiments of the plasma display devices disclosed herein may be conventional. For example, in the embodiments shown, the ionizable gas used in the cavities is a mixture of 99.7 percent Neon, 0.2 percent Nitrogen, and 0.1 percent Argon, with the cavities being filled to a gas pressure of approximately 160 Torr. The energizing voltage used to energize the selected connection terminals was approximately 240 volts A.C., consisting of pulses from 2 to 6 microseconds wide and spaced approximately 50 microseconds apart.

What is claimed is:

1. A fixed image plasma display device comprising:
- first and second substrates, each having a conductor means thereon, with the conductor means on said second substrate being transparent;
- said first substrate having a layer of glass covering the conductor means thereon;
- said layer of glass having cavities formed therein in a pattern conforming to a half-tone transparency film which has the desired said fixed image thereon;
- said first and second substrates being assembled with said conductor means on said second substrate and said layer of glass having said cavity pattern therein facing each other;
- means for sealing and filling said cavities with an ionizable gas;
- an ionizable gas within said cavities; and
- connection terminals connected to each of said conductor means.

2. The panel as claimed in claim **1** in which said pattern is in the form of posts having different diameters with said cavities being located therearound.

3. The panel as claimed in claim **1** in which said cavities are in the form of holes having different diameters.

4. A plasma display device having a given area for displaying at least two fixed displays, comprising:
- a first substrate having electrode means thereon;
- a second substrate having vertically-aligned, spaced, parallel electrodes thereon;
- a layer of opaque glass desposited over the electrode means on said first substrate with said layer of glass having cavity location areas arranged thereon in parallel rows and columns in grid-like manner;
- said layer of glass having cavities positioned at said cavity location areas, each said display having a number of cavities associated only therewith, with said number bearing a predetermined relationship to the total number of fixed displays to be displayed, and in which each said display may extend substantially over said given area if necessitated by the design thereof;

said vertically-aligned, spaced, parallel electrodes being aligned with the columns of cavity location areas on said first substrate;

said cavities associated with each said display being formed in a pattern which corresponds to a half-tone transparency film which has the desired fixed image thereon for that fixed display;

connection terminal means connected to said electrode means and said parallel electrodes for energizing selected ones of said parallel electrodes and said electrode means in accordance with the display to be displayed;

means for sealing together said first and second substrates and for filling said cavities with an ionizable gas; and an ionizable gas filling said cavities.

5. The device as claimed in claim **4** in which said connection terminal means include first and second connection terminals with alternate ones of said vertically-aligned, spaced, parallel electrodes being connected to said first connection terminal and the remainder of said parallel electrodes being connected to said second connection terminal; said cavities associated with a first display being aligned with said alternate ones of said spaced parallel electrodes, and the cavities associated with a second one of said displays being aligned with the remainder of said spaced parallel electrodes.

6. The device as claimed in claim **5** in which said electrode means comprises horizontally-aligned, spaced, parallel electrodes being aligned with said rows of cavity locations; said connection terminal means further comprising third and fourth connection terminals with alternate ones of said horizontally-aligned, spaced, parallel electrodes being connected to said third connection terminal and the remainder of said horizontally-aligned parallel electrodes being connected to said fourth connection terminal; said cavities associated with a third display being aligned with said remainder of the horizontally-aligned, spaced, parallel electrodes and said alternate ones of said vertically-aligned parallel electrodes; and said cavities associated with a fourth display being aligned with said remainder of said horizontally-aligned parallel electrodes and said remainder of said vertically-aligned, spaced, parallel electrodes; said cavities associated with said first and second displays being aligned with said alternate ones of said horizontally-aligned, spaced, parallel electrodes.

7. The device as claimed in claim **6** in which the cavity location areas for each said fixed display have posts of varying diameters located thereat with said posts corresponding to the half-tone transparency film associated with the fixed display, and with the space around said posts forming the cavities for the fixed display.

8. The device as claimed in claim **6** in which the cavities for each said fixed display are holes having diameters corresponding to the pattern of the associated half-tone transparency film.

9. The device as claimed in claim **4** in which the cavity location areas for each said fixed display have posts of varying diameters located thereat with said posts corresponding to the half-tone transparency film associated with the fixed display, and with the space around said posts forming the cavities for the fixed display.

10. The device as claimed in claim **4** in which the cavities for each said fixed display are holes having diameters corresponding to the pattern of the associated half-tone transparency film.

11. The process of forming a fixed image plasma display device comprising the steps of:

a. forming an electrode on a first glass substrate;

b. covering said electrode with a layer of glass;

c. forming a half-tone transparency film of the desired fixed image;

d. forming a pattern of cavities in said layer of glass by using said half-tone transparency film as a pattern;

e. forming a transparent electrode on a second glass substrate; and

f. assembling said substrate with the sides containing said electrodes facing each other; and

g. sealing said substrates together and filling said cavities with an ionizable gas.

12. The process as claimed in claim **11** in which said forming step (d) produces posts of varying diameters with the cavities located therearound.

13. The process as claimed in claim **11** in which said forming step (d) produces cavities which are holes of varying diameters.

14. The process of forming a plasma display device for displaying a plurality of selectable fixed images, comprising the steps of:

a. forming a half-tone transparency film for each of said images, which film contains rows and columns of data dots for the corresponding image;

b. forming horizontally-aligned, spaced, parallel electrodes on a first substrate to correspond to the rows of said data dots;

c. forming vertically-aligned, spaced, parallel electrodes on a second substrate to correspond to the columns of said data dots so that when the first and second substrates are assembled, the rows and columns of data dots will correspond to the horizontally and vertically-aligned electrodes;

d. forming a layer of glass over the electrodes on the first substrate;

e. assigning cavity location areas to said layer of glass;

f. using each said transparency film, forming in said layer of glass, cavities corresponding to **1**/n of the data dots in the film being used, where n equals the number of images to be displayed;

g. each said cavity being formed being located in one of said cavity location areas so that the cavities for any one image are regularly located in periodically-spaced columns and rows of said cavity location areas;

h. connecting in parallel, selected ones of said horizontally-aligned electrodes to first connection terminal means, and connecting in parallel, selected ones of said vertically-aligned electrodes to second connection terminal means to thereby provide energization terminals for selectively displaying each of said images;

i. assembling said first and second substrates with the sides having the electrodes facing each other and with the electrodes of the first substrate being perpendicular to the electrodes of the second substrate; sealing the assembled first and second substrates; and filling said cavities with an ionizable gas.

15. The process as claimed in claim **14** in which said cavities are formed by producing posts at said cavity location areas, with said posts having varying diameters corresponding to the data dots for the associated fixed images, and with said cavities being located therearound.

16. The process as claimed in claim 14 in which said cavities are formed by producing holes at said cavity location areas, with said holes having varying diameters corresponding to the data dots for the associated fixed image.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,801,852 Dated April 2, 1974

Inventor(s) John L. Janning

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 14, line 12, delete "substrate" and substitute -- substrates --.

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents