

[54] **ALPHA-NUMERIC DISPLAY DEVICE
UTILIZING LIGHT EMITTING DIODES**

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Apr. 28, 1972 Japan..... 47-42886

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[51] **Int. Cl.**..... **H01j 1/54**
[58] **Field of Search**..... 313/108 D, 109.5;
315/169 R, 169 TV; 340/336

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Attorney, Agent, or Firm—Hill, Gross, Simpson, Van
Santen, Steadman, Chiara & Simpson

[57] **ABSTRACT**

An alpha-numeric character display device is formed on a transparent plate having a plurality of coplanar opaque layers covering the plate. The opaque layers have windows therethrough which are located so as to display an alpha-numeric character. A plurality of light emitting diodes are mounted on the opaque layer. Layers of light transmitting material extend from the diodes above the opaque layer up to and through the windows. Each diode has a PN junction lying parallel to the transparent plate. A novel method of forming this diode is also disclosed.

8 Claims, 24 Drawing Figures

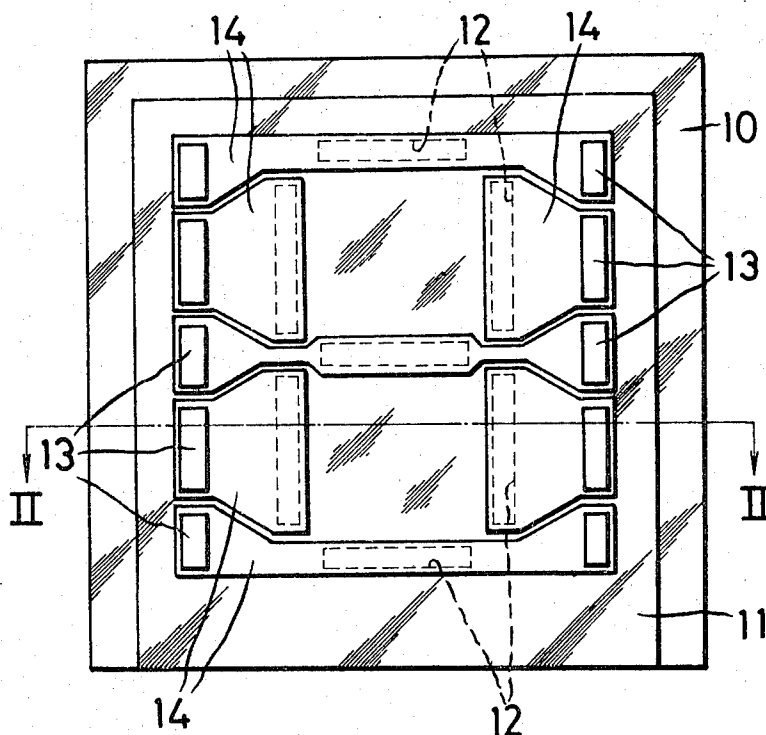


FIG.1

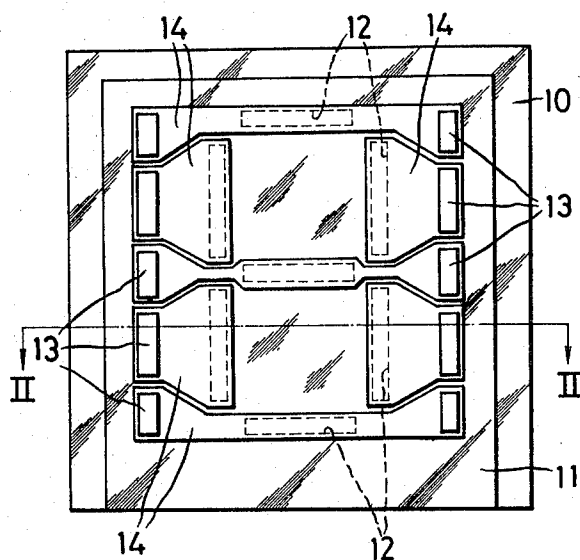


FIG.2

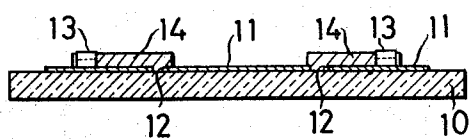


FIG.6

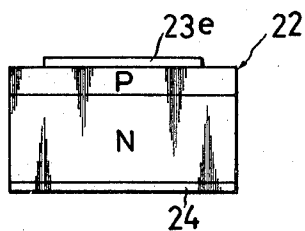


FIG.5

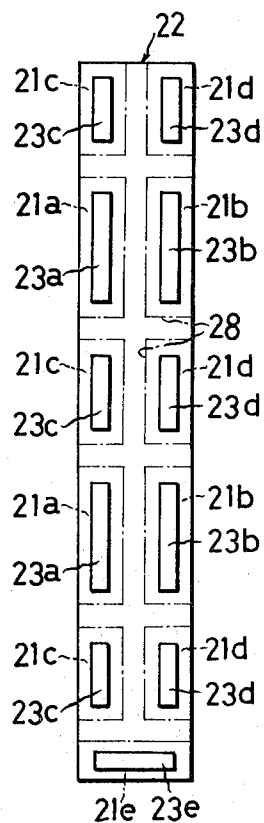


FIG.3

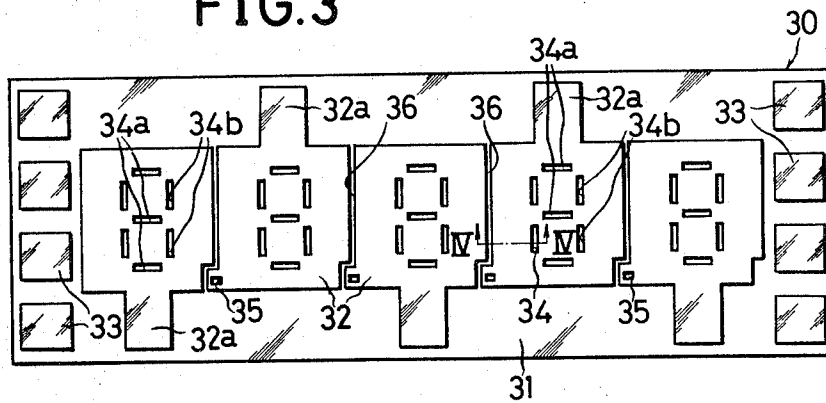


FIG.10

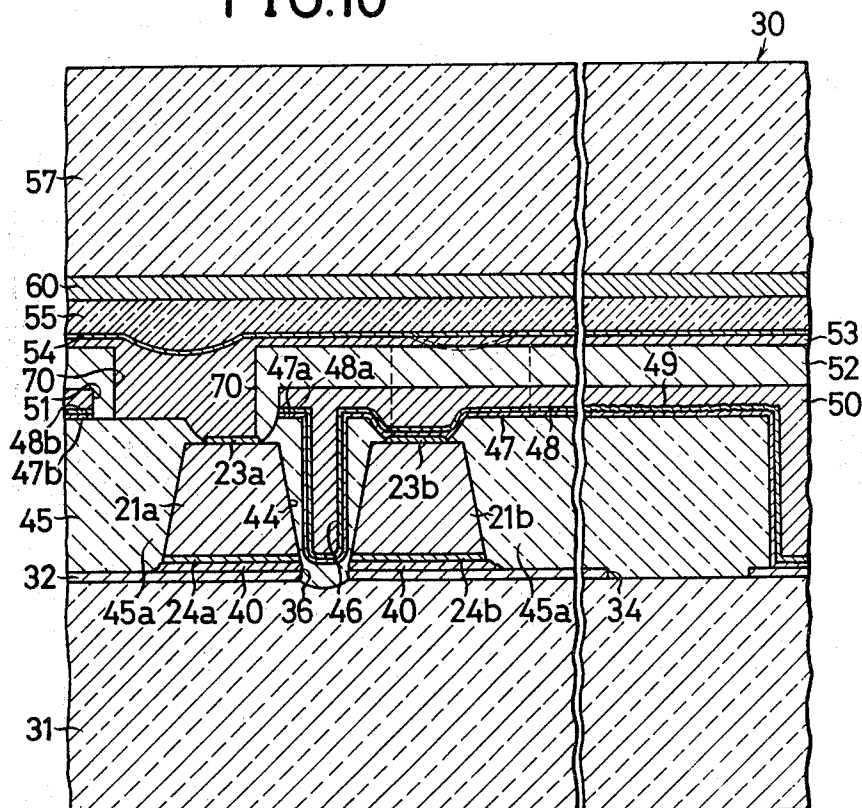


FIG.4A

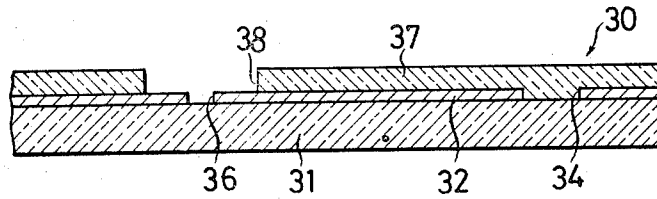


FIG.4B

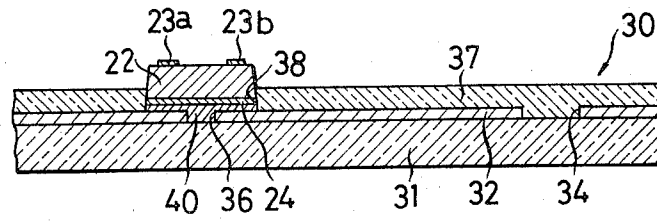


FIG.4C

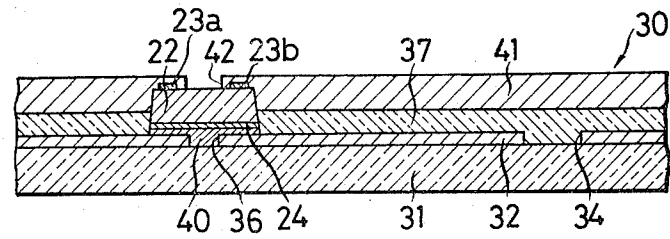


FIG.4D

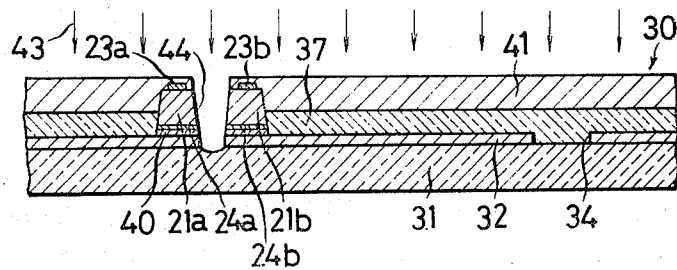


FIG.4E

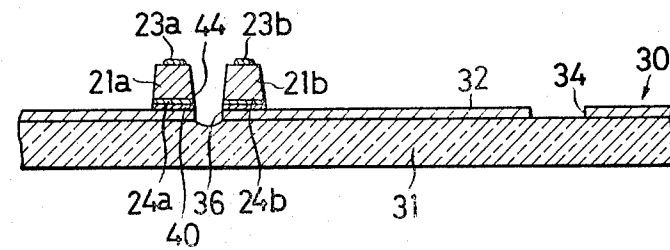


FIG. 4F

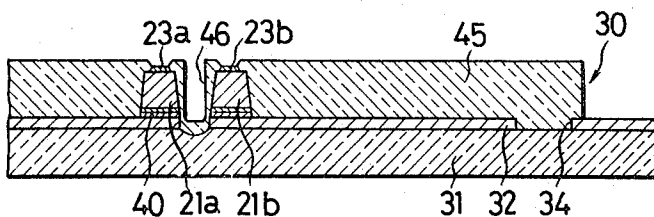


FIG. 4G

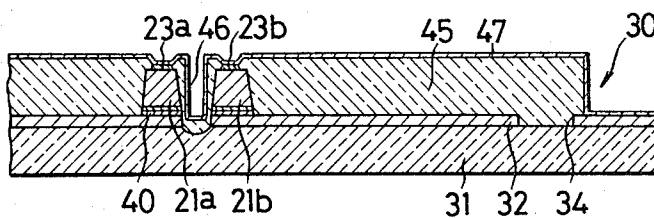


FIG. 4H

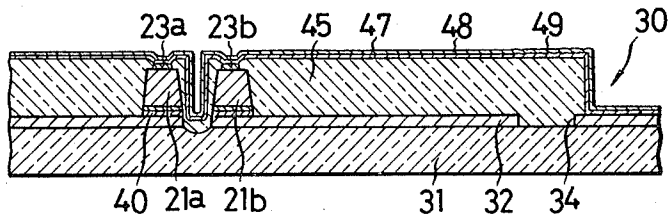


FIG. 4I

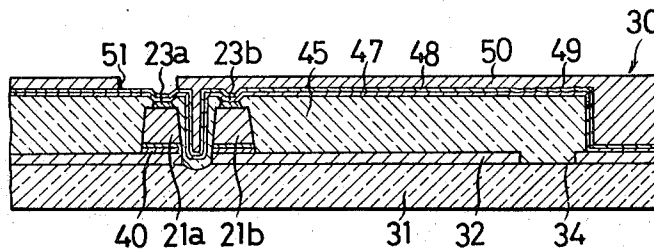


FIG. 4J

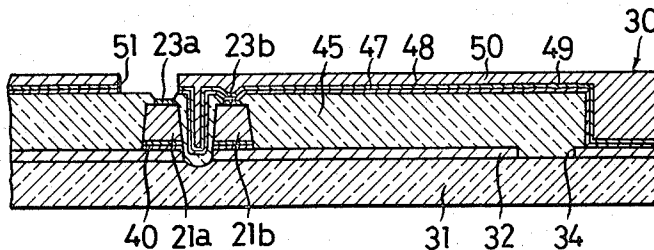


FIG.4K

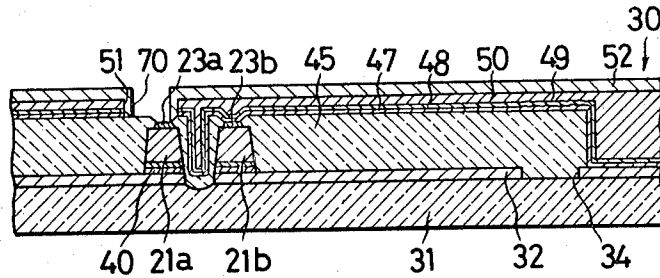


FIG.4L

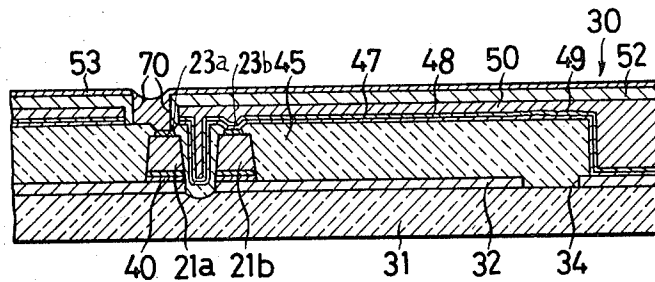


FIG.4M

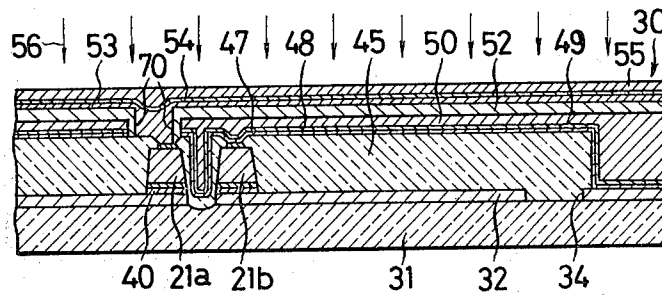


FIG.4N

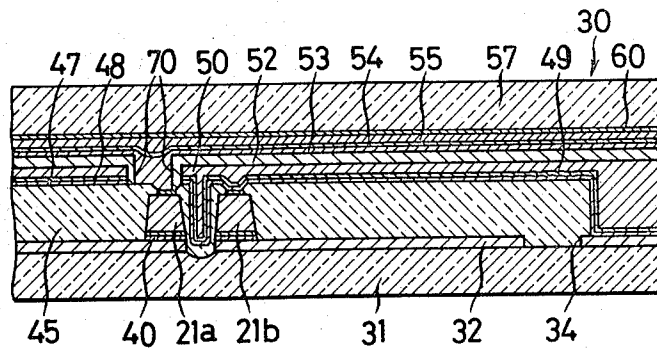


FIG. 7

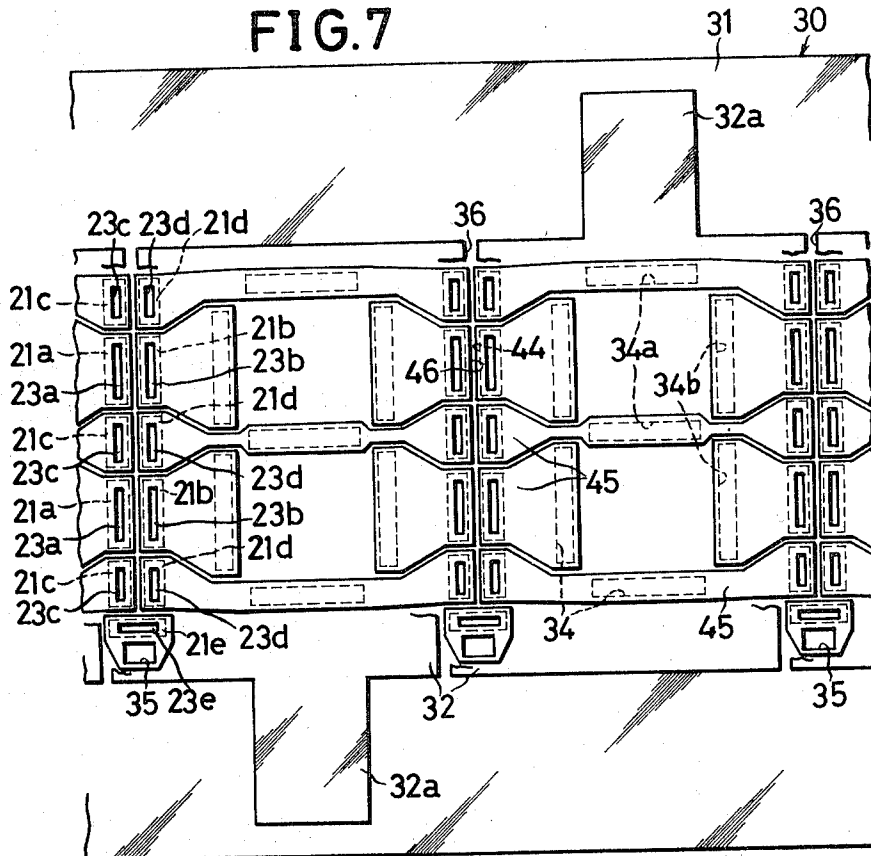


FIG. 8

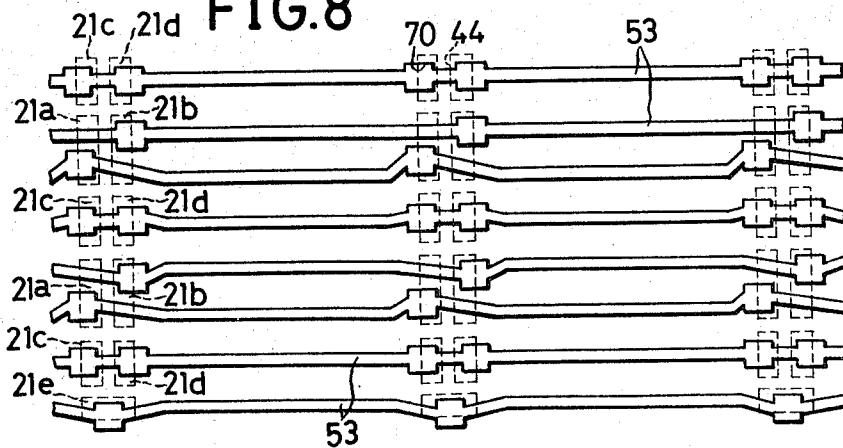


FIG. 9

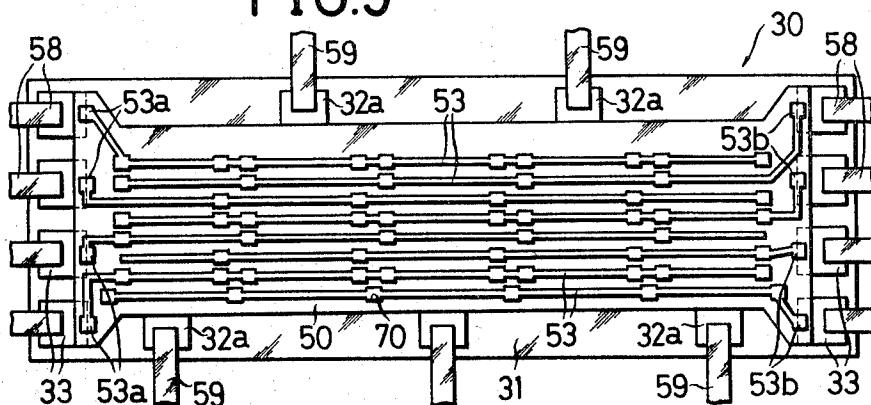
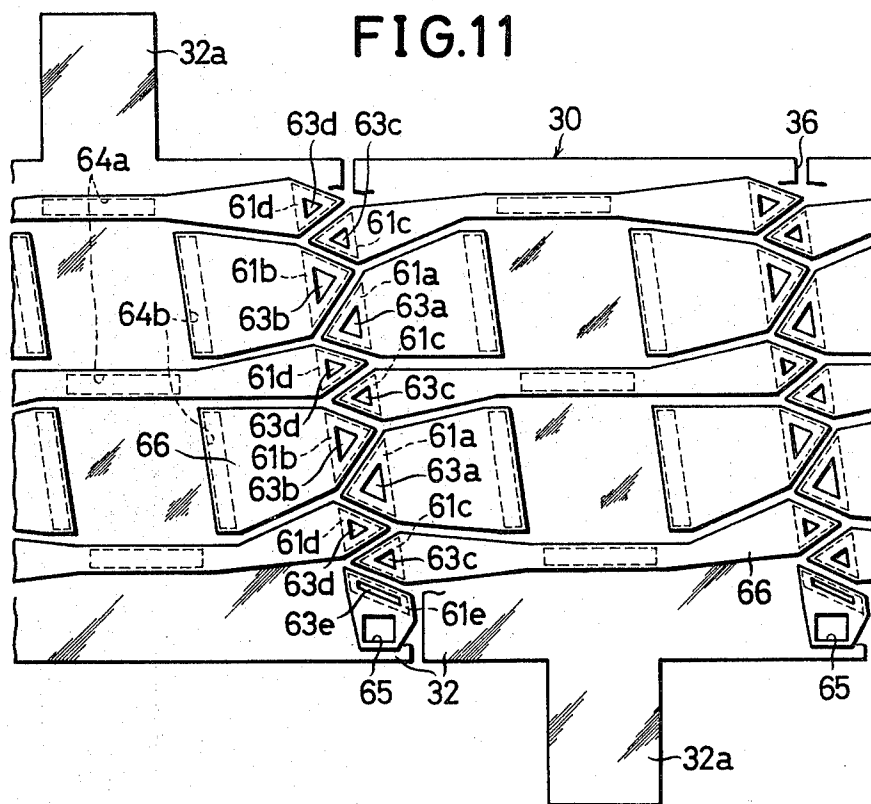


FIG. 11



ALPHA-NUMERIC DISPLAY DEVICE UTILIZING LIGHT EMITTING DIODES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an alpha-numeric character display device, and more particularly to an alpha-numeric character display device in which light emitting diodes are used to provide a display.

2. Description of the Prior Art

A display device is known in which a plurality of light emitting diodes are mounted on a plate in a desired shape, for instance, in the shape of a numeral "8". These light emitting diodes transmit light direct. However, as the light emitting diodes cannot be very large either, because of economy or because of reliability, the displayed pattern is so small that it is difficult for a large number of people to look at it.

Another display device has been proposed in which the light emitting diodes are molded with transparent resin functioning as a lens, and then mounted in a desired shape. However, this has the disadvantage that it is troublesome to manufacture it and uniform light emission cannot be obtained by it.

SUMMARY OF THE INVENTION

The present invention employs a plurality of light emitting diodes mounted on an opaque layer formed on a transparent plate. The opaque layer has a plurality of windows arranged in a desired design. A plurality of transparent layers are formed on the opaque layer to optically couple the light emitting diodes with the windows respectively to transmit light from the diodes to the windows. Preferably, reflective layers are formed on the transparent layers.

In the present invention, the terms "transparent" and "opaque" mean that the light emitted from the light emitting diodes is penetrable to sight and impenetrable to sight, respectively.

In an alpha-numeric character display device according to the invention, the size of the pattern of the display depends on the size of the windows, and therefore, the light emitting diodes may be small.

It is an object of the present invention to provide an alpha-numeric character display device having a relatively large display pattern.

It is a further object of the present invention to provide an alpha-numeric character display device which may be easily manufactured.

It is still another object of the present invention to provide an alpha-numeric character display device comprising a plurality of indicator units.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of one embodiment of an alpha-numeric character display device according to the present invention;

FIG. 2 is a cross sectional view taken along the line II-II of FIG. 1;

FIG. 3 is a plan view of a glass plate with coplanar conductive layers thereon;

FIG. 4A to FIG. 4N show in a sequence of diagrammatic sectional views the formation of the one embodiment of the alpha-numeric character display device;

FIG. 5 is a plan view of a light emitting diode pellet;

FIG. 6 is a side view of the light emitting diode pellet of FIG. 5;

FIG. 7 is a plan view of a part of the alpha-numeric character display device shown in FIG. 4F;

FIG. 8 is a plan view of a part of the alpha-numeric character display device shown in FIG. 4N, omitting partly the layers except the conductive layer;

FIG. 9 is a plan view showing the connection between a terminal for an outer lead line and the conductive layer in the alpha-numeric character display device as shown in FIG. 4N;

FIG. 10 is a sectional view of a part of the complete alpha-numeric character display device; and

FIG. 11 is a plan view of another embodiment of the alpha-numeric character display device according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 and FIG. 2 show the basic features of the alpha-numeric character display device of the invention.

An opaque layer, for example, a metal layer 11 is formed on a transparent glass plate 10. The metal layer 11 has seven windows 12 serving as display segments of a character in the shape of a numeral "8". Ten light emitting diodes 13 are mounted on the metal layer 11 in such a manner that their junctions are arranged in parallel with the surface of the glass plate 10. Seven transparent resin layers 14 are formed on the metal layer 11, and are in contact with the light emitting diodes 13 and with the windows 12. When electric currents are supplied to the light emitting diodes 13, light is transmitted outwardly from the light emitting diodes 13 through the transparent resin layers 14, the windows 12 and the glass plate 10, to display the numeral "8". Thus, a desired character is displayed depending on which segments are energized.

Reflector layers may be formed on the transparent resin layers 14, respectively, so that the light can more efficiently be transmitted to the windows 12 from the light emitting diodes 13. The protective resin layers may be coated on the light emitting diodes 13.

A manufacturing process for making another form of the present invention will now be described with reference to FIGS. 3 to 11.

As shown in FIG. 3, five conductive layers 32, as common electrodes for a group of the light emitting diodes and as optical masks, and eight conductive layers 33 as terminals for the outward lead, are formed on a transparent or semi-transparent insulating plate with the thickness of about 1.5 milli-meters, for example, a transparent glass plate 31, by means of electroless plating, vacuum evaporation or printing. The five conductive layers 32 correspond to the number of the digits displayed by the alpha-numeric character display device 30. These conductive layers 32 and 33 preferably are made of very reflective metal, particularly for the light emitted from the light emitting diodes, such as gold, aluminum, copper and so on. In this embodiment, a layer with the thickness of about 10 microns made of copper is formed by means of electroless plating. Moreover, metal, for example, gold is preferably plated on the surface of the conductive layers 32 and 33. A groove 36 with the width of 100 microns is formed between the respective conductive layers 32, by which the respective conductive layers 32 are electrically disconnected. Numeral "8" shaped windows 34, as the display segments of each digit in an alpha-numeric character display device 30, are located, separated

about 2 millimeters from the groove 36. The size of each window 34 is about 1.2 millimeters in length, and about 200 microns in width. The window 34 comprises three lateral windows 34a in parallel with each other, and four longitudinal windows 34b in parallel with each other. Another window 35 is formed on the conductive layer 32 to display a decimal point.

FIG. 4A to FIG. 4N show cross-sectional views taken along line IV—IV of FIG. 3.

As shown in FIG. 4A, transparent or semi-transparent photosensitive resin 37 available under the trademark of "SONNE KPM 1027" is coated on the whole surface of the glass plate 31 to a thickness of about 1.5 millimeters. The photosensitive resin 37 is partially exposed by the employment of a photo-mask, and then developed; whereupon non-exposed portions of the photosensitive resin 37 are removed to form longitudinal positioning windows 38 with the width of about 0.9 millimeters along the four grooves 36. The positioning window 38 communicates with the groove 36.

Conductive resin 40 is poured into the positioning windows 38, and then a light emitting diode pellet 22 as shown in FIG. 5 and FIG. 6, is mounted on the resin 40. The light emitting diode pellet 22 has an ohmic contact 24 on its whole undersurface and a plurality of ohmic contacts 23a, 23b, 23c, 23d and 23e on its upper surface. The whole of the glass plate 30 with the light emitting diode pellets 22 so positioned, is heated so that the light emitting diode pellets 22 are fixed in position, as shown in FIG. 4B, electrically to connect the respective ohmic contacts 24 to the conductive layers 32. The light emitting diode pellets 22 are, for example, 200 microns in thickness, 5.7 millimeters in length, and 0.9 millimeters in width.

As shown in FIG. 4C, a sand blast mask layer 41 is formed on the photosensitive resin layer 37 to a thickness of about 100 microns. In that case, a groove 42 is formed on the undivided pellet 22 along a dot-dash line 28 shown in FIG. 5. The sand blast mask layer 41 can be obtained by entirely coating the photosensitive resin and by the treatment of the usual exposure and development, employing the photo-mask, as above mentioned. The groove 42 is located above the groove 36.

By a sand blasting operation 43, as shown in FIG. 4D, the undivided pellet 22 is divided into light emitting diodes 21a and 21b. At that time, also light emitting diodes 21a, 21d and 21e are formed as shown in FIG. 5. As the sand blast mask layer 41 is formed on the whole surface of the photosensitive resin layer 37, and the contacts 23a and 23b are completely covered by the sand blast mask layer 41, the sand blasting does not damage the photosensitive resin layer 37 and the contacts 23a and 23b.

Next, the whole device shown in FIG. 4D is dipped into an acetone solution to swell the photosensitive resin layer 37 and the sand blast mask layer 41 which can be separated from the glass plate 31 and the conductive layer 32 as shown in FIG. 4E. Consequently, only the diodes 21a and 21b, and the conductive layer 32 remain on the glass plate 31.

Next, the diodes 21a and 21b, and the conductive layer 32 are dipped into a solution comprising H_2SO_4 , H_2O_2 and H_2O , and then let alone for about five minutes at a temperature of about 60°C. $H_2SO_4:H_2O_2:H_2O$ in the solution may be 3:1:1 in a ratio of volume. And then it is taken out from the solution to be boiled in a

H_2O_2 solution for a long time, for example seven hours. By the above mentioned operation, contaminations such as dust, dirt and so on, which sticks on the diodes 21a and 21b, the contacts 23a and 23b, and the conductive layer 32 can be removed. Since the surfaces of the light emitting diodes 21a and 21b, and the contacts 23a and 23b, are cleaned, the conductivity of the light emitting diodes 21a and 21b can be improved and the emitting efficiency thereof can be raised. Moreover, since gold is plated on the surfaces of the conductive layer 32 and the contacts 23a and 23b, they are not damaged by the above-mentioned surface treatment.

Next, a transparent photosensitive resin layer with the thickness of about 300 microns is formed on the whole surface of the conductive layer 32, and then a transparent layer 45 with a desired pattern is formed by the same method as in the formation of the above-mentioned photosensitive resin layer 37, or by the treatment of the exposure and the development, as shown in FIG. 4F and FIG. 7. The transparent layer 45 is formed so as to completely cover the window 34. And, a photosensitive resin is coated on the inner side and the bottom of the groove 44 to a thickness of about 100 microns to form a groove 46 between the light emitting diodes 21a and 21b. The transparent layer 45 is not formed on the surfaces of the contacts 23a and 23b as shown in FIG. 7, but the surfaces of the contacts 23a and 23b are designed to be exposed.

The locations of the transparent layers 45, the light emitting diodes 21a and 21b, and the windows 34 and 35 are shown in FIG. 7. Thus, the light emitting diode 21b corresponds to the window 34b through the transparent layer 45, and also other divided light emitting diodes correspond with the respective windows 34 through the transparent layers 45. The transparent layer 45 is formed in such a manner that one longitudinal window 34b corresponds to one light emitting diode 21a or 21b. Moreover, the transparent layer 45 is formed in such a manner that one lateral window 34a corresponds to two diodes 21c and 21d at both sides of one segment. And the transparent layer 45 surrounding the window 35 belongs to one light emitting diode 21e.

Thus, in the below-mentioned complete alphanumeric character display device 30, the light emitted from one light emitting diode 21a or 21b with the larger rectangular contact 23a or 23b, is transmitted to one longitudinal window 34b through the transparent layer 45, and the light emitted from two light emitting diodes 21c and 21d with the smaller rectangular contact 23c or 23d is transmitted to one lateral window 34a through the transparent layer 45. Consequently, a desired quantity of light is always transmitted to the windows 34a and 34b for a clear display.

Next, as shown in FIG. 4G, a transparent insulating layer 47 is coated on the surfaces of the transparent layer 45, the conductive layer 32 not covered by the transparent layer 45, the contacts 23a and 23b and the groove 46, to a thickness of about 2 microns. The insulating layer 47 may comprise acrylic resin or silicon resin and be about 2 to 10 microns in thickness.

Then, a very reflective metal particularly for the light emitted from the light emitting diodes, such as aluminum, copper, silver or gold, is coated on the insulating layer 47 to a thickness of about 1 micron, as shown in FIG. 4H, to form a reflector layer 48. Moreover, a roughness 49 may be formed on the portion of the reflector layer 48 located above the window 34, as shown

in FIG. 10, so that the light emitted from the light emitting diode 21b can be scattered on this portion to be effectively led outwardly from the window 34. The roughness 49 can very easily be formed by a method in which the surface of the insulating layer 47 corresponding to the above-mentioned roughness 49 is, in advance, roughened, and then the metal is coated on the surface by electroless plating.

As the reflector layer 48 is formed on the whole surface of the transparent layer 45, the transparent layer 45 is completely covered by the reflector layer 48 and the conductive layer 32 except the window 34, whereby the light emitted from the light emitting diode is repeatedly reflected in the transparent layer 45, to be led outwardly substantially only from the window 34 or 35. The layer 45 serves as an optical cavity.

Next, photosensitive resin is coated on the whole upper surface of the reflector layer 48 so much that the surface of the coating of photosensitive resin is almost flat, whereby an etching mask layer 50 is formed. The layer 50 is coated to a thickness of about 50 microns on the upper surface of the reflector layer 48 under which the transparent layer 45 is formed, and it is coated to a thickness of about 350 microns on the upper surface of the reflector layer 48 under which the transparent layer 45 is not formed. Then, a desired window 51 is formed on the etching mask layer 50, as shown in FIG. 41, by the same method as in the formation of the above-mentioned photosensitive layer 37. The etching mask layer 50 is designed not to be formed on a part of the upper surface and the outer circumference of the contacts 23a, 23b and 23c of the respective light emitting diode pellets 21a to 21e, corresponding to the windows 51. These windows 51 correspond almost to windows 70 shown in FIG. 8 and FIG. 9. The former is somewhat larger than the latter.

Next, by an etching operation, the portion of the reflector layer 48 formed on the part of the upper surface and the outer circumference of the contacts 23a to 23e corresponding to the windows 51, is removed. Since the gold is plated on the surface of the contacts 23a to 23e, the contacts 23a to 23e are not damaged by the etching operation. When the reflector layer 48 comprises aluminum or copper, a ferric chloride solution is used for the etching.

Next, a portion of the insulating layer 47 corresponding to the reflector layer 48 removed by the etching, is dissolved and removed to form the windows 51 on the contacts 23a to 23e, as shown in FIG. 4J. In this situation, ends 47a and 47b of the insulating layer 47, ends 48a and 48b of the reflector layer 48, and end 45a of the transparent layer 45 and the surface of the contacts 23a, 23b and 23c, are exposed in the windows 51, respectively.

An insulating layer 52 covers the upper surface and the end of the etching mask layer 50, and the ends 47a, 47b, 48a and 48b of the insulating layer 47 and the reflector layer 48, respectively, to a thickness of about 50 microns to form the window 70 with a smaller width than that of the window 51, but generally corresponding to the window 51. The insulating layer 52 is formed by the whole coating of the photosensitive resin available under the trademark of "SONNE KPM1027," and by the usual treatment of the exposure and the development employing the photomask as in the formation of the photosensitive resin layer 37.

Preferably, opaque conductive resin is coated on the whole surface of the insulating layer 52 by means of a brush or a roll to form a conductive resin layer 53 on the whole surface, as shown in FIG. 4L. The contacts 23a to 23e of the light emitting diode pellets 21a to 21e are electrically connected to the conductive resin layer 53. The conductive resin layer 53 is formed on the surface of the insulating layer 52 to a thickness of about 10 microns, and the window 51 is nearly completely filled with the conductive resin. Moreover, the conductive resin can be in tight contact with the contacts 23a to 23e, the end 45a of the transparent layer 45 and the insulating layer 52, because of its some fluidity, even if they are rather rough.

Next, an halation-protecting layer 54 comprising red colored resin is formed on the conductive resin layer 53, as shown in FIG. 4M, whereby the roughness of the conductive resin layer 53 can be flattened.

Photosensitive resin available under the trademark of "SONNE KPM 1027" is coated on the whole surface of the halation-protecting layer 54 to a thickness of about 50 microns as shown in FIG. 4M, to form a sand blast mask layer 55 with the same pattern as that of the conductive resin layer 53, as shown in FIG. 8 and FIG. 9, by the same method as in the formation of the above-mentioned photosensitive resin layer 37.

The halation-protecting layer 54 and the conductive resin layer 53 are partially removed by a sand blasting operation 56, as the above-mentioned sand blasting operation 43, to form the conductive resin layer 53 with the pattern as shown in FIG. 8 and FIG. 9. The pattern is designed to connect the contacts 23a to 23e of the light emitting diode pellets 21a to 21e linearly with each other in each display segment. As shown in FIG. 4L, the contact 23a is not electrically connected to the contact 23b, but the contact 23b is electrically connected to the corresponding contact 23b of the light emitting diode in each digit or each display segment. The contact 23a is likewise electrically connected to the corresponding contact 23a of the light emitting diode in each digit or each display segment. The contact 23a is likewise electrically connected to the corresponding contact 23a of the light emitting diode in each digit or each display segment.

A protective plate 57 with the same nature preferably, as that of the glass plate 31, is bonded on the sand blast mask layer 55 through a bonding layer 60 such as an epoxy resin layer to complete the manufacture of the alpha-numeric character display device 30. FIG. 10 shows the cross sectional view of the completed alpha-numeric character display device.

In the above-mentioned embodiment, a pair of the light emitting diodes 21a and 21b, divided from the undivided pellet 22, and the connections between their contacts are shown; but it will be understood that also the other contacts of the light emitting diodes divided from the undivided pellet 22 are connected to each other in the same manner as in the above-described embodiment, as shown in FIG. 9. As a result, an alpha-numeric character display device 30 capable of displaying numerals of five digits can be obtained in the connection as shown in FIG. 9. The ends 53a and 53b of the conductive resin layer 53 reach the conductive layer 33 through the insulating layer 52, the etching mask layer 50, the reflector layer 48 and the insulating layer 47. A window passing through these layers 52, 50, 48 and 47 can be formed in the same manner as in the

windows for the light emitting diode pellets as described above.

Thus, the ends 53a and 53b of the conductive resin layer 53 are connected to terminals 58 for the outward lead through the conductive layer 33, and the contact 24 of the light emitting diodes 21a and 21b is connected to a terminal 59 for the outward lead through the attaching portion 32a of the conducting layer 32 as a common electrode. Also, an alpha-numeric character display device 30 capable of displaying numerals of more digits can be easily manufactured in the same manner as in the above-mentioned embodiment.

The resulting alpha-numeric character display device 30 can be 400 to 500 microns in thickness except its glass plate 31 and protective plate 56. Even in addition to the thicknesses of the glass plate 31 and the protective plate 56, it can be about 3.5 millimeters in thickness, and hence it can be manufactured very thin.

In the device, the light emitting diodes 21a to 21e are arranged between the respective digits, and the transparent layer 45 surrounded by the reflector layer 48, the metal conductive layer 32, and the conductive resin layer 53 is disposed between the light emitting diodes 21a to 21e and the window 34 or 35. The transparent layer 45 is optically covered except its portions facing to the window 34 or 35 and the light emitting diodes 21a to 21e. Consequently, the light emitted from the PN junction 27 of the light emitting diodes 21a to 21e is repeatedly reflected between the reflector layer 48 and the conductive layer 32, finally to be transmitted outward from the window 34 through the glass plate 31. Since the roughness 49 is formed on the surface of the reflector layer above the window 34, the light in the transparent layer 45 can be scattered on the surface, whereby a uniform quantity of light can be transmitted from the window 34.

Moreover, in the alpha-numeric character display device 30, the light emitted from the longer rectangular light emitting diodes 21a and 21b is transmitted to the longitudinal window 34b, the light emitted from the two shorter rectangular light emitting diodes is transmitted to the lateral window 34a, and the light emitted from the light emitting diode 21e is transmitted to the window 35 for the display of the decimal point, whereby a sufficient and uniform quantity of light reaches all of the windows 34a, 34b and 35 for the clear display.

FIG. 11 shows another embodiment of the alpha-numeric character display device according to the present invention, generally similar to the basic features of FIG. 7.

In FIG. 11, light emitting diodes 61a, 61b, 61c, 61d and 61e; their contacts 63a, 63b, 63c, 63d and 63e, and windows 64 and 65, are arranged in nearly the same manner as in FIG. 7. In this embodiment, nearly right-angled triangular light emitting diodes 61a to 61d are opposed to the windows 64a and 64b, respectively, in such a manner that their longest sides are in parallel with the windows 64a and 64b. The diode 61e, having the shape of a parallelogram, is arranged opposite to the window 64 for the display of the decimal point. Transparent layers 66 are formed between the light emitting diodes 61a to 61e and the windows 64a, 64b and 65, respectively, as the above-mentioned transparent layer 45.

The windows 64 with a shape of a numeral "8," are formed with a slight inclination. A row of the light emit-

ting diodes is arranged in parallel with the windows 64. The manufacturing process of the embodiment is nearly the same as the manufacturing process shown in FIG. 4A to FIG. 4N. The light emitting diodes 61a to 61d may be obtained by the fact that the undivided light emitting diode pellet is divided by the sand blasting as above-mentioned, or light emitting diodes divided in advance may be individually arranged in the respective positions.

In the resulting alpha-numeric character display device 30, the light emitting diodes 61a and 61b, and the contacts 63a and 63b are triangular. A pair of shorter sides of the triangular are inclined to the window 64, and also the reflector layer located behind the light emitting diodes 61a to 61d is inclined to the window 64. Consequently, the light emitted from the light emitting diodes 61a and 61b, and reflected by the reflector layer, is apt to concentrate in the window 64, whereby a clearer display is possible, due to a greater quantity of light.

The present invention has been described with reference to the embodiments, but it will be understood that various modifications can be made on the basis of the concept of the invention. The number of the light emitting diodes is eleven in one undivided pellet of the above-mentioned embodiment, but it can be increased. The shapes of the light emitting diode and the window may be other than rectangular or triangular.

Although preferred embodiments of this invention have been described in detail with reference to the accompanying drawings, it is to be understood that the invention is not limited to the details shown and described, and that various changes and modifications can be made.

I claim as my invention:

1. An alpha-numeric character display device comprising, a planar transparent plate, a first opaque planar layer attached to said transparent plate and formed with windows arranged to form a plurality of display units with each unit having a number of windows arranged to selectively indicate a number of desired numbers or characters, a plurality of light emitting diodes mounted on said first opaque layer outside of said display units and mounted so as not to overlie said windows and at least one diode associated with each of said windows, a plurality of light transmitting planar layers formed over said first opaque layer and each covering one of said windows and extending to the diode associated with each of said windows such that light emitted by said diodes will pass parallel to said planar transparent plate, a second opaque layer covering said light transmitting planar layers such that light emitted from said diodes will be emitted from said windows, and electrical energizing means connected to said diodes to selectively energize them to produce a desired indication.

2. An alpha-numeric character display device according to claim 1, in which said windows are larger than their associated diodes.

3. An alpha-numeric character display device according to claim 1, in which the plane of each diode is triangular.

4. An alpha-numeric character display device according to claim 1, in which said first opaque layer is formed of a conductive metal.

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5. An alpha-numeric character display device according to claim 4, in which said opaque layers are highly reflective.

6. An alpha-numeric character display device according to claim 1, wherein said first opaque layer is made of metal and said light emitting diodes are electrically connected to said first opaque layer.

7. An alpha-numeric character display device ac-

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cording to claim 1, wherein said plurality of light emitting diodes are mounted between the respective display units.

8. An alpha-numeric character display device according to claim 1, wherein portions of said second opaque layer opposing said windows behind said light transmitting layers are roughened.

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