

PATENT SPECIFICATION

(11) 1 273 671

DRAWINGS ATTACHED



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- (21) Application No. 9066/70 (22) Filed 25 Feb. 1970
(31) Convention Application No. 802 853 (32) Filed 27 Feb. 1969 in
(33) United States of America (US)
(45) Complete Specification published 10 May 1972
(51) International Classification H05B 33/00 G09F 9/34
(52) Index at acceptance
C4S 66Y 68X 68Y 731 733
G5C 31A 31Q
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(54) IMPROVEMENTS IN OR RELATING TO ELECTROLUMINESCENT DISPLAY DEVICES

(71) We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195 Broadway, New York City, New York State, United States of America, a Corporation organised and existing under the laws of the State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electroluminescent display devices.

Recent advances in the efficiency and reliability of electroluminescent diodes show that these devices could well replace incandescent lamps in any applications. At present however, a severe restriction on their use is the high cost of the diode materials which tends to limit the size of the device for a given application. In small displays the current cost of material for the area of a normal-sized character is still so high that character arrays are prohibitively expensive except for the most sophisticated applications. Although in the case of indicator light units the viewing area is small, the unit is normally required to be inexpensive and so the cost factors of the material is still a disadvantage. If it were possible to satisfactorily and significantly increase the luminescent area viewed for a given amount of electroluminescent material then clearly considerable cost savings would be possible.

According to this invention an electroluminescent display device comprises an electroluminescent diode having an active area capable of emitting light of less than 2,000 square mils (as measured in a plane parallel to the plane of the diode), and a reflector operatively associated with the diode for increasing the apparent light-emitting area thereof, the reflector comprising a specular surface having at least two facets and a reflective area (as measured in a plane parallel to the plane of the diode)

ten or more times the active area of the diode, the or each normal to one of said facets making an angle of at least 35° with the normal to the plane of the diode, and the or each normal to another of said facets making an angle of at least 60° with the normal to the plane of the diode.

The said reflective area may have a length which is at least 3.5 times its width.

Preferably one of the facets extends from below the plane of the diode towards an intended viewing position.

A display device may comprise a plurality of electroluminescent display devices in accordance with the invention arranged in a suitable format whereby in operation the selective energisation of one or more of the devices produces a representation of a character, numeral or other symbol.

The device functions in the following manner. Assume the diode to be a point light source. (This assumption is warranted by the small size of the diode). The light radiates in all directions towards a viewer with equal intensity, and from any viewing point will appear intense but very small. Usual diodes are so small that the light-emitting area is on the edge of the resolving power of the eye, so that even though the light is visible, it is subjectively unpleasant to view. A character format made from such light sources would appear as an array of unpleasant points of light and is rather ineffective.

The faceted reflector associated with the diode increases the apparent light-emitting area. Each facet reflects the light from the diode so that the viewer apparently sees many light-emitting diodes spread over the area of the faceted reflector. If the facets are circular, the reflected light will actually appear as a ring from each facet. The important factor which makes the faceted reflector so effective is the size of the dimensions involved. The physical separation between the images reflected from the facets is small

enough that the eye does not clearly resolve it. The overall effect to the viewer is that of a light source continuously and evenly distributed over the faceted reflector. It is important to recognise that this same effect cannot be produced by an ordinary reflector, nor is it effective for larger scale devices where the eye can resolve a series of spots or rings. This will be explained in more detail below.

The invention will now be described and explained with reference to the accompanying drawings in which:

Fig. 1 is a schematic representation of a small electroluminescent diode mounted on a standard header and a plot of the light flux therefrom;

Fig. 2 is a schematic representation in cross-section of an electroluminescent display device in accordance with this invention and a plot of the light flux therefrom;

Fig. 3 is a perspective view of an electroluminescent format for displaying numerical characters incorporating display devices in accordance with this invention;

Figure 4 is a transverse section on the section line 4—4 in Fig. 3 showing the shape of the slot;

Fig. 5 is a longitudinal section on the section line 5—5 of Fig. 3, and

Fig. 6 is a perspective view of part of a format similar to that shown in Fig. 3.

Referring now to Fig. 1, the intensity profile of light emanating from the surface of a GaP electroluminescent diode 11 was obtained by vertically scanning across the surface with a photometer. The header 10 is formed of beryllium oxide which was chosen for high reflectivity.

Fig. 2 shows a plot for a GaP electroluminescent diode 20 mounted on a faceted reflector 21.

A comparison of the light intensity profiles of Figs. 1 and 2 shows the effects of the faceted reflector. Under ordinary interior lighting conditions the illumination level varies from 5 foot-candles in a relatively dimly lit room to over 100 foot-candles in an exceptionally well illuminated area. If a diode array display or a diode indicator light is to be properly visible it is necessary that the light from the diode be sufficient to contrast with the background light. Experiment has shown that the light level from display devices 61. The whole plate is the display should generally exceed sixty foot-lamberts and that it would be highly desirable for this level to exceed 100 foot-lamberts. Fig. 1 reveals that the diode in the standard mount satisfies these criteria only at the centre region, i.e. over the area corresponding to the actual area of the diode.

In Fig. 2 however, the first recommended brightness level, 60 foot-lamberts, is met over

the major part of the area of the display device so that the diode size is effectively increased by a factor of approximately 40. (The diode in this case was 15 mils square and the maximum diameter of the reflector was 95 mils.) The secondary brightness level of 100 foot-lamberts is exceeded over a significant portion of the display device.

The presence of several discrete peaks in the profile is not resolvable by the eye. The eye tends to integrate the light over the whole area giving it a bright, uniform appearance. This effect distinguishes the action of a faceted reflector from that of an ordinary reflector. A spherical or continuously curved reflector would produce a uniform increase in brightness across the reflector but this increase is, with the limited amount of light available, not nearly as effective as the series of peaks in Fig. 2. If the background illumination exceeds the uniform brightness produced with a curved reflector then the display will not be visible. However, if the same amount of light is distributed in a series of peaks, as in the profile of Fig. 2 for example, and these peaks exceed the background level, the eye will detect the illumination and it will appear, as explained above, that the entire reflector area is brightly illuminated.

Thus the combination of the limited light-emitting area of the electroluminescent diode (such that the area is at the fringe of the resolving power of the eye) and the faceted reflector body give a result which is expected to be of considerable practical use. The diode areas used for much of the empirical studies were 15 mils square. On the basis of material cost considerations and the optical principles upon which this invention is based, this invention finds application with electroluminescent diodes having an area of less than 2,000 mils².

Since the flat regions of the faceted reflector 21 of Fig. 2 produce "dead spots" in the brightness profile, it is ordinarily desirable that the flat area does not exceed one quarter of the overall reflector area. One way of minimizing this ineffectual region is to construct the first facet contiguous to the diode (as is the case in one of the embodiments described below). In carrying out this invention at least two facets are necessary to achieve the desired effect. From the results of extensive empirical studies one of the facets must make an angle of at least 35° with the plane of the electroluminescent diode (light-emitting surface), while the other must be at an angle of at least 60° with respect to the same reference plane. These angles have been found to give good wide-angle viewing. If more than two facets are used, angles intermediate and outside these values can be used to advantage for the further facets. Increasing the angle of the

outermost facet increases the low angle effectiveness and increasing the overall number of facets increases the brightness uniformity. Clearly of course the latter expedient, if carried too far, will destroy the effectiveness of the invention. Accordingly, it is suggested that the number of discrete light-reflecting facets be restricted to four or less.

The invention can be applied with advantage to character displays of which the so-called numeric display utilising a seven bar format is of principal interest.

Fig. 3 is a plan view of a seven bar format character display using disk-shaped electroluminescent diodes 30 (this shape is selected as exemplary but is unimportant to the overall effect—the diodes could be made from square chips). Diodes 30 are mounted in each bar of the format and the bars are recessed in their centres with the facets extending upwardly and towards each end. This is more clearly seen in Figs. 4 and 5.

Each display device has a pedestal 31 supporting its electroluminescent diode 30. The first reflecting facet 33 extends from a point relatively close to the base of the pedestal (see Fig. 5). The elevation of the diode on the pedestal increases the total light flux reflected by the three facets 33, 34 and 35. The slight slope to the side walls evident from Fig. 4 enhances reflectivity in the slot structure. Such faceted slot structures could of course form alphanumeric formats as well as other displays utilising bar formats.

As a practical matter the active light-emitting area of the diode may be less than 0.3% of the total apparent area of the reflecting surface (area of the slot of the surface) and such a structure is very effective from a subjective viewing standpoint. Smaller reflectors or larger diode area-to-reflector area ratios may also be used of course. It is to be expected that the invention will find application for ratios as large as 1 to 10.

Various methods may be employed for constructing the structures described above. A simple technique is to form the faceted slots in a soft metal surface by the well-known "coining" process. Copper and gold are sufficiently soft and ductile to be used in this technique. Other fabrication methods will be evident to those skilled in the art.

A particularly attractive method for fabricating a structure like that of Figs. 3 to 5 is to mould the reflector using a transparent resin. The reflector body may be produced to correspond to the structure appearing in Fig. 5 and the inner reflecting surface produced by spray or vapour coating with an appropriate reflecting material. Alternatively, a mould shaped similarly to the structure of Fig. 5 can be used in which

case the reflector would comprise a male member. In this way the diodes can be placed in the mould prior to casting so that the casting process effectively encapsulates the diodes. Appropriate electrodes (not shown) can be provided prior to casting. This form of assembly is shown in Fig. 6 in which the cover plate 60 is integral with the display devices 61. The whole plate is moulded or cast in one integral piece with the electroluminescent diodes 62 placed in the mould prior to moulding and thus incorporated into the assembly during the moulding operation. Diode leads 63 extend from the casting. The assembly can be moulded from any of a variety of known transparent resins e.g. polymerised methylmethacrylate. The faceted surfaces 64 are covered with a reflecting coating such as evaporated aluminium.

In some cases it may be desirable to provide a filter in the display device. For instance, combining a red light filter with a red-emitting gallium phosphide diode will reduce any background illumination reflected from the reflecting surfaces. If an assembly such as that shown in Fig. 6 is employed it is convenient to incorporate the active filtering material into the casting resin. For example, an appropriate amount of a stable organic dye such as thioindigo red can be mixed into the resin prior to casting.

Although the boundaries of each faceted surface appear curved in Fig. 3, a straight boundary is equally effective in an elongated slot structure. For the usual character format, a slot having a length of at least 3.5 times the average width is necessary for legibility. However, exceptions to this requirement may be made in certain cases e.g. for forming hyphens, periods, or for certain bars of a complex array. If a moulding or coining technique is used to form the assembly the shape of the bars can easily be varied. It is not essential that they be rectangular in shape but a degree of elongation equivalent to that described above will ordinarily be used.

The slope of the side walls evident from Fig. 4, while not essential to the invention, is considered to be a preferred expedient. A slope of at least 1% on each side wall is recommended. More severe slopes can be used to improve low-angle viewing. In a small slotted structure it is not considered feasible to have faceted side walls. Multiple reflections including the side walls no doubt occur in the structures described.

The recommendations discussed in connection with the facets of Fig. 2 which encircle the diode (that the number of facets be restricted to at least two but not more than four) must obviously be adjusted in the case of the structure of Figs. 3—5. Since

the side walls interrupt each facet the number of discrete facets may be considered to be twice the number in the Fig. 2 case.

WHAT WE CLAIM IS:—

- 5 1. An electroluminescent display device comprising an electroluminescent diode having an active area capable of emitting light of less than 2,000 square mils (as measured in a plane parallel to the plane of the diode),
10 and a reflector operatively associated with the diode for increasing the apparent light-emitting area thereof, the reflector comprising a specular surface having at least two facets and a reflective area (as measured in a plane parallel to the plane of the diode)
15 ten or more times the active area of the diode, the or each normal to one of said facets making an angle of at least 35° with the normal to the plane of the diode, and
20 the or each normal to another of said facets making an angle of at least 60° with the normal to the plane of the diode.
2. A display device as claimed in claim 1 wherein one of said facets extends from
25 below the plane of the diode towards an intended viewing position.
3. A display device as claimed in claim 1 or 2 wherein said deflective area has a length at least 3.5 times its width.

4. A device as claimed in claim 3 wherein the longitudinally extending walls of the reflector are vertical.

5. A device as claimed in claim 3 wherein each longitudinally extending wall of the reflector extends upwardly diverging away from said diode.

6. A device as claimed in claim 1 or 2 wherein the number of said facets does not exceed four.

7. An electroluminescent display device substantially as herein described with reference to Fig. 2, or to Figs. 3 to 6 of the accompanying drawings.

8. A display device comprising a plurality of devices as claimed in any one of claims 1 to 6 arranged in a suitable format whereby in operation the selective energisation of one or more of said devices produces a representation of a character, numeral or other symbol.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1972.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.

