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ELECTROLUMINESCENCE DEVICES

2,929,950

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2 Sheets-Sheet 1

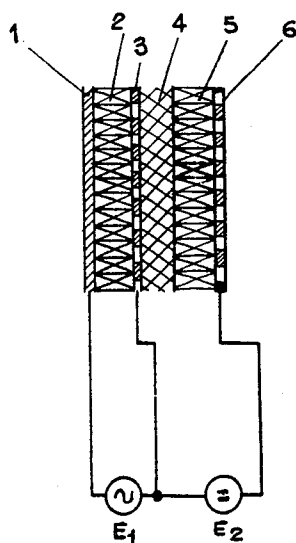


FIG. 1

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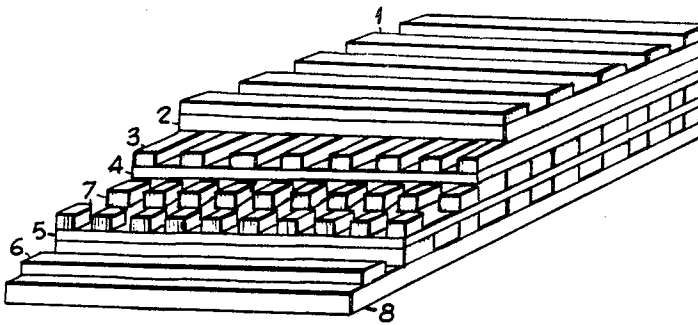


FIG. 2

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ELECTROLUMINESCENCE DEVICES

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Claims priority, application France December 30, 1955

11 Claims. (Cl. 313—108)

The present invention relates to electroluminescent devices of the kind wherein a thin semi-dielectric layer of electroluminescent material is inserted between a pair of electrodes one of which at least is translucent and wherein the electroluminescence is obtained by the application of an A.C. voltage across the said electrodes.

The object of the invention is to provide improved structures of devices of the above kind so that their electro-optical efficiency is substantially increased, at least in a ratio from five to one with respect to the elementary structure of these devices.

According to the invention, this increase of efficiency is obtained by incorporating in such an electroluminescent unit a photomultiplier unit constituted by a semi-conductive layer and a further electroluminescent layer, themselves inserted between a pair of translucent electrodes one of which is integral with the electrode of the electroluminescent unit which is translucent and applying an A.C. voltage at least across the electrodes of the electroluminescent cell and a D.C. voltage across the electrodes of the photomultiplier cell.

According to a further feature of the invention, the said photomultiplier unit includes between the semi-conductive layer and the electroluminescent layer thereof, a further layer of a highly conductive material, which is preferably opaque to the light emitted from the said electroluminescent layer, for cancelling therein any potential barrier between the said semi-conductive and electroluminescent layers and, preferably also, avoiding any retroaction of the light issued from the said electroluminescent layer upon the said semi-conductive layer.

It is obvious that there may be provided successive photomultiplier units in the device, each one having an electrode common with the next preceding one, in the direction of transmission and amplification of light there-through.

In the accompanying drawings, Fig. 1 shows a plain constitution of an electroluminescent device according to the invention whereas Fig. 2 discloses a more elaborate structure thereof.

Referring first to Fig. 1, an electrode 1 is coated with a thin layer of a semi-dielectric electroluminescent material 2 and, on the other face of the said layer, is applied another conducting electrode 3, such as a film of evaporated silver or gold, or the like. The electrode 1 may be opaque, if required and, in such a case, will preferably be polished to the degree used in optical surfaces for a good reflection of light therefrom. These three elements define together the electroluminescent unit proper of the device. The activation or drive thereof is made by applying between the armatures 1 and 3 a suitable A.C. electromotive force, E_1 .

A photomultiplier unit is combined with such an electroluminescent unit by virtue of the electrode 3 also constitutes the first electrode of the said photomultiplier unit. The latter includes: a semi-conducting layer 4 upon which is coated a second electroluminescent layer 5, of the same general character as the semi-dielectric

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layer 2, and a third translucent electrode 6 is coated over the layer 5. Across the electrodes 3 and 6 of the said photomultiplier unit is applied a D.C. electro-motive force, E_2 .

The connections of these e.m.f. sources must be such that no direct current can flow up to the armature 1 of the device, through the A.C. source. This connection may be made through a decoupling condenser, as is usual for this kind of coupling between an A.C. and a D.C. circuit.

The operation may be stated as follows: The A.C. source produces the activation of electroluminescence within the layer 2 and the light emitted therefrom passes through the translucent electrode 3 to the semi-conductor 4 of the photomultiplier unit. The semi-conductor 4 is chosen to be photoelectric with respect to the light from the said layer 2. The photomultiplier unit is unable to produce a light emission from the layer 5 when it is driven solely by the D.C. voltage E_2 . However this layer 5 will be activated, when in the presence of the said D.C. bias, the light from the electroluminescent layer 2 varies in accordance with the A.C. drive thereof. The semi-conducting layer 4 is energized by the said fluctuation and the resistivity thereof varies accordingly, and consequently varies the voltage difference across the electroluminescent layer 5. The said layer is then activated and emits the light from its own luminescence through the conducting and translucent electrode 6. It is the properties of the semi-conducting layer 4 which are preponderant in the light intensifying effect of the device. Even if some light passes through the said layer 4 and falls upon the semi-dielectric layer 5, this action is quite unimportant with respect to the overall efficiency. The electroluminescent layer 5 is submitted to a potential difference equal to the D.C. potential value E_2 minus the drop within the semi-conducting layer 4, and which constitutes the variable part of the activating voltage for this layer 5. It is quite apparent that the average energy level within this layer 5 will be appreciably greater than the corresponding level in the layer 2. Consequently the layers 2 and 5 may be made of the same material and the result of an increased overall efficiency be obtained in such a simple case.

In a preferred embodiment of a device according to the invention, the semi-conducting layer 4 is made of a monocrystalline body of cadmium, lead or antimony sulphide. A polycrystalline body of selenium may also be used but this latter is less efficient than the former composition of the layer 4.

The semi-dielectric electroluminescent layers 2 and 5 may each be made of a composition containing zinc or cadmium or barium or calcium sulphide with impurities of metallic salts for the activation thereof. Preferably however, use will be made of the special all-oxide compositions described in my copending application Serial No. 631,226, filed Dec. 28, 1956. Such compositions comprise more than 99% of a zinc, barium, calcium or cadmium oxide and the complement of a copper, lead, selenium, thallium, germanium or manganese oxide.

Further to the advantage of utilising the highly efficient properties of such compositions, their use also presents a special advantage for the manufacturing of the device proper. This may be termed as follows:

Within a vessel the atmosphere of which may be easily controlled, is first formed upon an auxiliary base plate of magnesium or aluminium a layer of an alloy of the metals or metalloids of the unoxidized component materials of the electroluminescent layer 2 to be made. For instance, this operation is made by selectively evaporating copper and zinc, in suitable proportions as above said, under a vacuum of say 10^{-4} millimetres of Hg within the said vessel. The raw materials are placed into cruci-

bles isotropically arranged with respect to the surface of the said auxiliary plate to be coated. Then, the electrode plate 1, previously mounted upon any suitable supporting plate therefor, is arranged in front of the said alloy layer and at a short interval thereto. An atmosphere of oxygen is introduced within the vessel and a suitable D.C. source is connected across the said auxiliary base plate and the electrodes, which are of substantially identical surfaces. The ionic discharge produced therefrom ensures the transfer of particles of the said alloy onto the electrode which for instance is made of rhodium and has an optical polish. In the said transfer process the alloy particles are oxidized and, further, the electrode is heated for instance from a high frequency heater to a temperature suitable for the progressive crystallization of the oxide composition depositing upon the said electrode plate 1. A monocrystal of the said composition is thus obtained.

This method of making a monocrystalline electroluminescent layer is fully described in my copending application Serial No. 631,224, filed December 28, 1956.

Upon the layer 2 a translucent electrode 3 is then deposited, for instance within the said vessel which is, for that part of the process, evacuated for the evaporation of a film of aluminium, for instance, which will constitute the said electrode 3.

The above process is repeated by introducing a base plate of magnesium bearing a layer of cadmium. This layer has for instance been obtained from a similar process of selective evaporation of a raw material. The transfer of the cadmium is made from the same ionic discharge process as above described, but in an atmosphere of H_2S at a pressure of about 10^{-1} mm. of Hg. The D.C. voltage is of about 600 volts between the cadmium and the electrode 3 for a spacing therebetween equal to 9.5 millilitres, and the ionic discharge current is of about 100 milliamperes per square decimetre. The cadmium particles extracted from the cadmium layer are converted into particles of cadmium sulphide and applied to the electrode 3 as a uniform coating thereto. A similar high frequency heating of the electrode plate ensures the crystallisation of the said cadmium sulphide layer so that finally a monocrystal of cadmium sulphide is formed upon the electrode 3 of the device. The temperature of crystallisation of the cadmium sulphide is of about $312^\circ C$. in the above said conditions. The thickness of the cadmium sulphide monocrystal may be about 20 microns whereas the thickness of the layer 2 was about 10 microns.

The cadmium bearing auxiliary plate is removed and the oxygen atmosphere is re-established after the reintroduction into the vessel of the auxiliary plate which bears the zinc-copper alloy. The operation is repeated for the formation upon the cadmium sulphide layer of a second layer of electroluminescent oxides, as a monocrystalline coating 5, of 10 microns of thickness.

Finally the electrode 6 is formed in the same manner as the electrode 3. The device is now completed.

In certain applications of the device according to the invention, it may prove useful to constitute the electrodes thereof as networks of conducting lines and usually the directions of the said conducting lines will vary from one electrode to the next one in the device. For instance the electrodes 1 and 6 will have their conducting lines parallel and the conducting lines of the electrode 3 will be transverse thereto. In a manufacturing process such as described above, each one of the electrodes may be formed by a process of photo-etching applied to the uniform surface obtained as described. The spatial distribution of the conducting lines define a pattern of spots or points which may be selectively activated throughout the structure of the device from a sequential scanning of the lines of the electrodes: for instance a first scanning voltage is applied to the conductors of the electrode 1 and another scanning voltage of a fre-

quency which is a multiple of the frequency of the first is applied to the conductors of the electrode 3. The electrode 6 may be lift undivided or else controlled together with the electrode 1 in such a scanning process. A modulating signal may be superimposed on the scanning voltages for the reproduction of the image represented by the said modulating signal.

Fig. 2 shows an arrangement of the device of Fig. 1 adapted for such a use, and also including further improvements with respect to the embodiment shown in Fig. 1. The embodiment of Fig. 2 includes a layer 7 inserted between the semiconducting layer 4 and the electroluminescent layer 5 of the photomultiplier part of the device.

The purpose of this layer 7 is two-fold and actually two distinct layers might have been provided for two special purposes but, when according to a feature of the invention the material of the layer 7 is chosen as a suitable metal or metallic salt, a single element may be used. The material of the layer 7 may be either indium or, preferably, indium antimonide. In such arrangements as that of Fig. 1, it will be apparent that some reduction of efficiency could arise from the fact that an electrical potential barrier effect is created between the semiconducting layer and the semi-dielectric layer of the photomultiplier part of the device. The value of the D.C. potential difference E_2 must then be higher than if this effect were negligible, and consequently the efficiency of the device may be increased by cancelling or at least reducing to a negligible value the barrier effect. The insertion of a layer 7 such as above said produces this reduction. But, in the arrangement of Fig. 2, further, this layer 7 is made of small separate spots, as obtained from a deposition of indium antimonide through a meshed screen, the meshes of which have been provided in registration with the points defined by the conducting lines of the electrodes 1 and 3. Of course, when the electrodes are made uniform, the layer 7 may also be made uniform.

When at least the points to become electroluminescent are predetermined by a form of the electrodes of the device, it will be of special advantage that the "definition" of these points cannot be destroyed from the back action of the spots which emit light in the layer 5. The provision of a suitably opaque layer between the photoelectric semi-conducting layer 4 and the said layer 5 will cancel such an action. As, however, the material used for layer 7 may be opaque to the light emitted from the layer 5, it will not be useful to provide a special layer and, with the layer 7, of indium antimonide, the two effects, electrical and optical, are achieved with the provision of a single additional layer instead of two.

I claim:

1. An electroluminescent device comprising the combination of an electroluminescent cell and a photomultiplier cell each having an end electrode and a common translucent electrode, said photomultiplier cell including at least one photoconductive layer over the said electrode and one electroluminescent layer over said photoconductive layer, a source of alternating current connected across the electrodes of the said electroluminescent cell and a source of direct current connected across the electrodes of the said photomultiplier cell.

2. An electroluminescent device according to claim 1, wherein the said alternating current is also applied across the end electrodes of the device.

3. An electroluminescent device according to claim 1, wherein an electrically highly conductive layer is interposed between the said photoconductive and electroluminescent layers of the photomultiplier cell.

4. An electroluminescent device according to claim 3, wherein the said conductive layer is opaque to the light emitted from the electroluminescent layer.

5. An electroluminescent device according to claim 4, wherein the material of the said conductive and opaque

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layer is chosen from a group consisting of indium and indium antimonide.

6. An electroluminescent device according to claim 1, wherein each of the electrodes comprises a plurality of separate conductors, in the form of a grid, the conductors of adjacent electrodes extending in different directions, the conductors of the common electrode extending in a different direction with respect to the end electrodes of the device.

7. An electroluminescent device according to claim 6, wherein the alternating current is applied between one end electrode and the remaining electrodes in parallel.

8. An electroluminescent device according to claim 6, wherein spots of a high conductivity material are interposed between the said photoconductive and electroluminescent layers of the photomultiplier cell at the spatial intersections of the conductors of the electrode grids of the photomultiplier cell.

9. An electroluminescent device according to claim 8,

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wherein the material of the said spots is opaque to the light emitted from the electroluminescent layer of the photomultiplier cell.

10. An electroluminescent device according to claim 9, wherein the said material is chosen from a group consisting of indium and indium antimonide.

11. An electroluminescent device according to claim 1, wherein the end electrode of the electroluminescent cell is light reflecting.

References Cited in the file of this patent

UNITED STATES PATENTS

2,698,915	Piper	Jan. 4, 1955
2,730,644	Michlin	Jan. 10, 1956
2,735,049	De Forest	Feb. 14, 1956
2,748,304	Botden	May 29, 1956
2,792,447	Kazan	May 14, 1957
2,798,823	Harper	July 9, 1957