United States Patent [19]

Williams

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[54] **IMPROVEMENTS RELATING TO ELECTROLUMINESCENT LIGHT SOURCES**

[75] Inventor: **William George Williams,** Southall, England

[73] Assignee: **EMI Limited,** Hayes, Middlesex, England

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **313/108 A,** 313/309
[51] **Int. Cl.** **H05b 33/02**
[58] **Field of Search** ..... 313/108 A, 358, 309, 313/351; 315/169 TV

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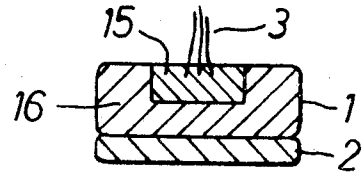
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Primary Examiner—Palmer C. Demeo
Attorney—Martin Fleit et al.

[57] **ABSTRACT**

Electrodes for injecting charge into electrically insulating materials, especially electroluminescent materials, are described. The electrodes are filamentary in structure ("filamentary" being defined so as to embrace needle-like and sharp edged members as well as fibrous members), and formed of or coated with carbon. Electroluminescent devices incorporating such electrodes are also described.

7 Claims, 8 Drawing Figures



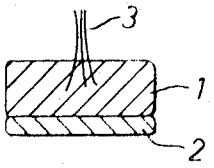


FIG. 1

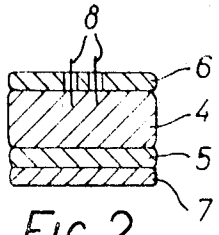


FIG. 2

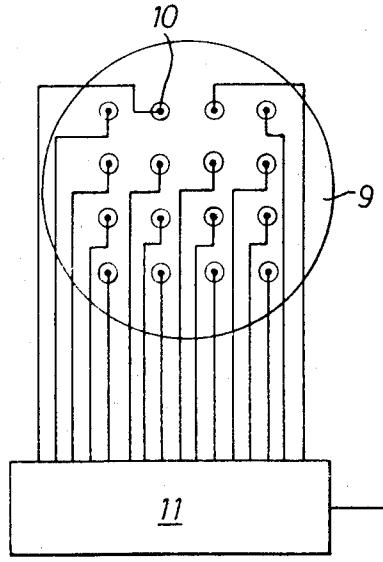


FIG. 3

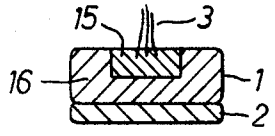


FIG. 4

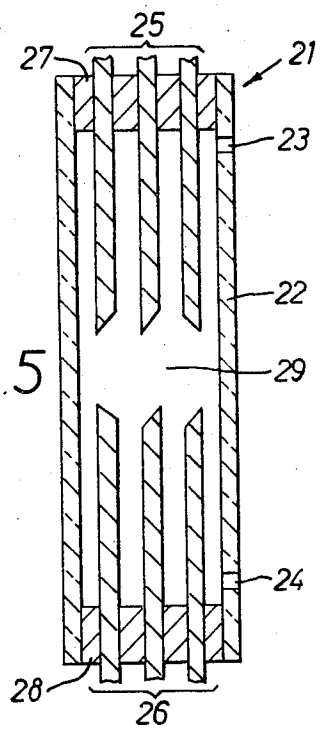


FIG. 5

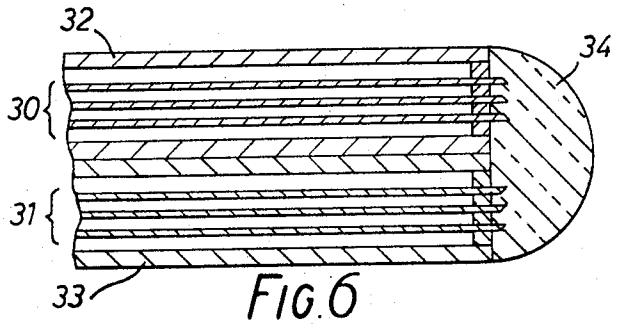


FIG. 6

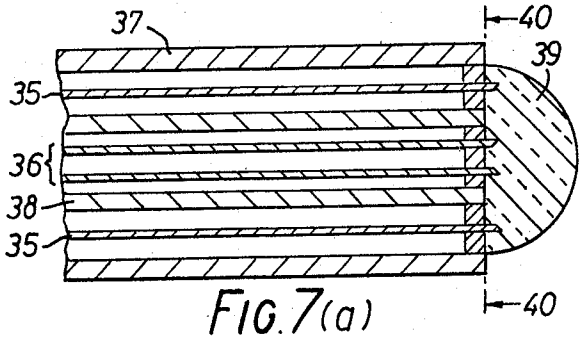


FIG. 7(a)

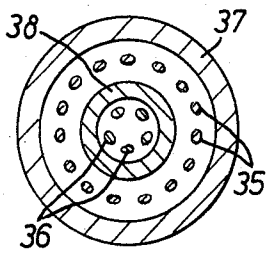


FIG. 7(b)

IMPROVEMENTS RELATING TO ELECTROLUMINESCENT LIGHT SOURCES

The present invention relates to the injection of electrical charge into electrically insulating materials, and it relates especially, though not exclusively, to the injection of electrical charge into electroluminescent materials.

Hitherto, difficulty has been experienced in injecting sufficient electrical charge into insulating electroluminescent materials to cause them to emit light of any substantial brightness.

It has been the practice to apply a potential across the electroluminescent material by means of electrodes deposited on the material, but although special consideration has been given to the electrodes with regard to their physical shape and the materials of which they are constructed, the aforementioned difficulty has prevailed.

It is an object of the invention there is provided an electrode for injecting electrical charge into an electrically insulating material, said electrode being filamentary and formed of, or coated with, carbon. The word "filamentary" as used herein is intended to include needle-like members as well as fibrous members.

According to the present invention there is provided an electroluminescent light source comprising:

a. a crystalline, organic electroluminescent material
b. contact means adapted to apply electrical potentials to respective regions of said medium.
c. at least one of said contact means comprising a plurality of filamentary members having carbon at least on their surfaces
d. said filamentary members being provided in intimate electrical contact with said material
e. said filamentary members being electrically connected together, and
f. said filamentary members extending outwardly from the surface of said material.

The invention also encompasses an electroluminsecent device comprising electroluminescent material having secured thereto or embedded therein at least one filamentary electrode of the kind described in the last preceding paragraph.

In order that the invention may be clearly understood and readily carried into effect, the same will now be described, by way of example only, with reference to the accompanying drawings of which:

FIG. 1 shows, in cross section, an electroluminescent device according to one example of the invention comprising a crystal of electroluminescent material with an electrode formed of a bundle of carbon fibres embedded therein,

FIG. 2 shows, again in cross section, another electroluminescent device according to an example of the invention, comprising a layer of electroluminescent material with carbon fibre electrodes embedded therein,

FIG. 3 shows, in plan view, part of the device shown in FIG. 2 adapted for use in a large area display arrangement,

FIG. 4 shows, in cross-section, a device similar to that shown in FIG. 1 but in which the electroluminescent material has been regionally doped,

FIG. 5 shows, in cross section and on an enlarged scale, another electroluminescent device in accordance with the invention,

FIG. 6 shows, in similar view to FIG. 5, a modified form of device according to the invention,

FIG. 7(a) shows, in similar view to FIGS. 5 and 6, an alternative modified form of device according to the invention, and

FIG. 7(b) shows a view on arrow 40 of FIG. 7(a).

Referring now to FIG. 1, a crystal of organic, electroluminescent material such as anthracene is shown at 1. An electrode 2, formed for example of gold or selenium-tellurium alloy is deposited on the lower face of crystal 1, and this electrode is electrically connected to the positive terminal of a source of direct potential (not shown). Such an arrangement has been shown to be suitable for the injection of positive charge into the crystal.

In accordance with an example of the invention a second electrode, that adapted to be coupled to the negative terminal of the source, and therefore employed for the injection of negative charge into the crystal, is formed of a bundle of carbon fibres 3. The fibres are preferably embedded in the crystal, as shown. The tips of the filaments may, however, be merely placed in electrical contact with the upper face of crystal 1 and secured thereto by suitable fixing means.

A device as described with reference to FIG. 1 can be produced by depositing, say, a gold electrode on one face of the crystal and melting a bundle of carbon fibres into the opposite face.

Referring now to FIG. 2, a layer of anthracene 4 is melted between two glass discs, 5 and 6 respectively. The disc 5 having been previously coated on its inner surface with tin oxide to form a transparent, positive charge injecting electrode 7 and the disc 6 carries carbon fibres 8 passing through holes formed perpendicularly to the plane of disc 6, so that the fibres 8 are embedded in and bonded to the anthracene layer 4. The single fibres shown at 8 may be replaced by respective bundles of fibres.

A display arrangement incorporating an electroluminescent device of the kind described in reference to FIG. 2 will now be described with reference to FIG. 3. It is sometimes required to produce an electroluminescent display arrangement in which the electrodes are arranged to define a plurality of addresses within the electroluminescent material, and it is then desired to be able to selectively excite a chosen electrode so as to cause illumination at the selected address. In such an arrangement, all other features could be as described with reference to FIG. 2, but the disc 6 and fibres 8 of these figures are replaced by the electrode arrangement shown in FIG. 3. In FIG. 3, the electrode arrangement shows a glass disc 9, having holes passing therethrough in a direction perpendicular to the plane of the disc. The holes are arranged in a rectangular array of rows and columns and each has an individual carbon fibre, such as 10 fixed therein by insulating means, and protruding toward the anthracene layer. Contacts are provided to each of the fibres 10 and these are individually connected via a switch circuit 11 to the negative terminal 12 of a source 13 of direct potential. The positive terminal 14 of source 13 is connected to the tin oxide electrode coating (7 of FIG. 2) not shown in FIG. 3 for clarity. By selectively operating the switch circuit 11, a respective one of the carbon fibre contacts such as 10 is energised and local electroluminescence occurs in the region of the energised contact. As mentioned with reference to FIG. 2, the individual carbon fibres

10 can be replaced by respective bundles of fibres. The disc 9 could be formed of plastics material, for example and the tin oxide coating may be carried on any insulating substrate.

In any of the preceding embodiments of the invention instead of carbon fibres, fine metallic wires or knife-like edges of metallic material, coated in each case with carbon may be used. As a further alternative, needle-like pointed, but relatively rigid members formed wholly of, or coated with, carbon can be used.

A typical device of the kind described in relation to FIG. 1, and using a single crystal of anthracene, 2mm thick and 1cm square was found to emit light at a minimum applied potential of 450 volts. The light intensity increases initially with increasing voltage, so that the light intensity can be varied by varying the applied voltage, in this example between 450 volts and 650 volts.

Referring now to FIG. 4, it has been found that if a material such as anthracene is doped with small amounts of other organic phosphors, such as tetracene, the radiation emitted from the doped region is that of the dopant. Thus devices can be constructed to emit light of a selected colour. Furthermore, in a device as described, for example, with reference to FIG. 1, the light has been observed to originate at the tips of the carbon fibres and then to spread progressively through the electroluminescent material as the voltage is increased. Thus, for example, by differently doping the regions 15 and 16 of the crystal 1 a range of colours of emitted light can be obtained, which will provide an indication of the applied voltage. It is feasible to provide greater sensitivity in such an arrangement by using more differently doped regions between the tips of the carbon fibres and the face of the crystal bearing the positive electrode. If such an arrangement were calibrated against a known voltage source, it could be used as a voltmeter for unknown voltage sources. Conversely the voltage may be deliberately changed to induce changes in the colour of transmitted light for signalling purposes or the like. Colour television pictures could be displayed in this manner without the need for a cathode ray tube.

In the preceding embodiment of the invention, only the negative charge injecting electrode has been formed of or coated with carbon. However, it has been discovered that it is advantageous if both electrodes are so formed or coated. One or both electrodes so formed or coated should be filamentary in structure.

Referring now to FIG. 5, a glass tube 21 having a fine bore (of the order of 1mm) forms the enclosure for an electroluminescent device. The wall 22 of tube 21 is formed with two small holes 23 and 24, and the purpose of these holes will become clear hereinafter. Two similar filamentary electrodes formed of respective bundles 25 and 26 of carbon fibres are inserted axially into the bore of tube 21. The two bundles 25 and 26 are inserted from opposite ends of the tube 21 and are urged towards one another until a gap 29 of the order of 1 or 2 mm exists between them. The two electrodes are then sealed in position by sealing means indicated at 27 and 28. Thus there is formed a cavity bounded laterally by the wall 22 of tube 21 and axially by the sealing means 27 and 28.

The cavity is then filled with molten anthracene in the following manner. The tube 21 is held vertically and the lower end of the tube is immersed in molten anthracene, under an inert atmosphere such as argon, to such a depth that the hole 24 is below the surface of the anthracene. The bore of tube 21 being fine, as previously stated, the cavity is filled with anthracene by capillary action and gas existing in the cavity is expelled via the upper hole 23. A crystal of anthracene so formed can be perfected by normal Bridgeman growth or left untreated. Holes 23 and 24 can be sealed by suitable material (not shown) after the cavity has been filled with anthracene or the anthracene can be allowed to seal the holes 23 and 24 when it crystallises.

Respective conductive cables are then connected to the electrodes comprising bundles 25 and 26 of carbon fibres and the cables are connected to the terminals of a source of direct potential. Such an electroluminescent device has been found to exhibit improved performance with respect to previous devices in that a decay with time of a direct current passed by the device, and theefore in the light energy emitted from the device tends to be reduced.

In an electroluminescent device of this kind which has been tested in practice, the gap 29 between the two bundles of fibres, and in which light is emitted, was 2 mm and with an applied direct potential of 1.5 kV a current of 5 μA was observed to flow, producing blue light of sufficient strength to be visible under normal room lighting. Increasing the direct potential to 3 kV caused an increase in current passed through the anthracene to almost 20 μA. The operating potential for a given current can be reduced by reducing the gap 29 between the fibre bundles 25 and 26. It will be appreciated that the tube 21 need not be made of glass, provided that if it is made of an opaque material, a part thereof is formed with a translucent window.

As previously described, if a material such as anthracene is doped with smal amounts of other organic phosphors, such as tetracene, the radiation emitted from the doped region is that of the dopant. Since the radiation emitted from a device of the kind shown in the drawing, is observed to orginate at the tips of the carbon fibres of the negative charge injecting electrode and then spread progressively through the anthracene as the applied potential is increased, it is possible, by doping different regions of the anthracene, to arrange that the emitted light changes colour at a prescribed applied voltage.

In certain electroluminescent displays which employ many electroluminescent devices, it is desirable that the devices are constructed so that the region in which light is emitted (e.g., region 29 in FIG. 5) can be surrounded by similar regions of other devices so as to produce a compact display. The devices shown in FIGS. 6 and 7 are constructed so as to achieve this end.

The device of FIG. 6 comprises two similar filamentary electrodes; one formed of a bundle 30 of carbon fibres inserted axially into support tube 32. The other electrode is formed of a bundle 31 of carbon fibres inserted axially into a support tube 33. Each group of fibres is sealed into its respective tube and the two tubes are placed side by side as shown and secured to one another. The tubes and the means for sealing the fibres therein are arranged to provide mutual electrical insulation between the two bundles of fibres 30 and 31. The right hand ends of the two electrodes are arranged so that the tubes 32 and 33 terminate in a common plane and an electroluminescent crystal 34 is grown on the plane as a base. Clearly the two bundles of fibres 30 and 31 need not lie in a single vertical plane as shown,

and there may be more fibres in one bundle than the other. The generalisations of the last preceding sentence also apply to the device shown in FIG. 5.

In the device shown in cross section in FIG. 7(a), the two filamentary electrodes are formed by two coaxially arranged bundles of fibres, 35 and 36 respectively. The fibres 36 are located and sealed axially within an inner tube 38 and the fibres 35 are located and sealed axially in the cavity between the outer wall of tube 38 and a larger and coaxial tube 37. The tubes 37 and 38 and the sealing means are arranged to provide mutual electrical insulation between fibres 35 and fibres 36 and the right hand ends of tubes 37 and 38 are arranged to be coplanar. An electroluminescent crystal 39 is grown 7(b) the plane. FIG. 8(b) is a view on arrow 40 of FIG. 7(a).

Alternative configurations will be evident to those skilled in the art and the above devices are shown by way of example only. The crystals 34 and 39 may be provided with transparent protective coatings. Moreover, it will be appreciated that tubes 32, 33, 37 and 38 do not need to be formed of transparent material, and these may be formed, for example of plastics or ceramic materials.

All the preceding devices have been described as being operated by means of a direct potential, however the aforementioned decay of light emission with time, although reduced by the expedient described above, is still troublesome in some cases.

In order to further reduce this problem, which is believed to be due to trapped space charges, a device has been constructed using carbon fibres as both the positive and negative charge injecting electrodes and operating under a.c. conditions. The devices shown in either of FIGS. 5, 6 or 7 are suitable for operation under a.c. conditions.

Such devices exhibit a reduced decay of light emission and it is thought that the alternating injection of carriers at least partially quenches the trapped space charge. A typical operating frequency is 50 Hz, although frequencies up to the order of 1 mHz could be used.

A convenient manner of forming a charge injecting electrode in accordance with an example of the invention is one in which an electrical cable having a central core formed of a plurality of copper strands is employed. The end of the cable insulation is stripped to bare a portion of the core, the copper strands are separated from one another and the ends of said strands are coated with carbon.

Electroluminescent materials other than anthracene could be used, for example perylene, napthalene and stilbene.

What I claim is:

1. An electroluminescent light source comprising:
   a. a body of a crystalline, organic electroluminescent material,
   b. contact means for applying electrical potentials to different regions of said body,
   c. at least one of said contact means comprising a plurality of electrically interconnected filamentary members having carbon at least on their surfaces,
   d. said filamentary members being provided in intimate electrical contact with said material, and
   e. said filamentary members extending outwardly from the surface of said body.

2. An electroluminescent light source according to claim 1 and including first and second ones of said contact means comprising a plurality of said filamentary members extending outwardly from the surface of said body, such that said electrodes are spaced apart by a region of said body.

3. An electroluminescent light source according to claim 2 wherein said electroluminescent body is enclosed by a casing member of which at least part is translucent, and wherein said contact means are secured to opposite ends of said body by electrically insulating sealing means.

4. An electroluminescent light source according to claim 3 wherein said casing member is provided with holes by means of which said electroluminescent material can be introduced after said contact means have been sealed to said casing member.

5. An electroluminescent light source according to claim 1 including firt and second ones of said contact means which comprise a plurality of said filamentary members, the first and second contact means being mutually electrically insulated, the ends thereof being sealed to a planar support means and protruding therethrough, and said electroluminescent body being provided on said planar support means, such that the protruding ends of said electrodes are embedded therein.

6. An electroluminescent light source according to claim 5 wherein said contact means are disposed in a laterally displaced relationship.

7. An electroluminescent light source according to claim 5 wherein the filamentary members of said first and second contact means are disposed in a substantially co-axial arrangement.

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