Sept. 2, 1969 R. F. HALL 3,465,194

COLD-CATHODE GLOW-DISCHARGE TUBE

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FIG.1

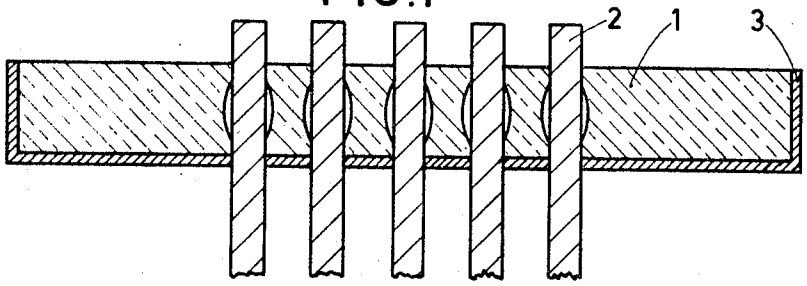


FIG.2

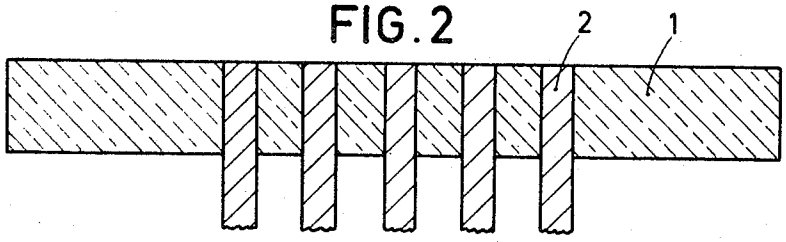


FIG.3

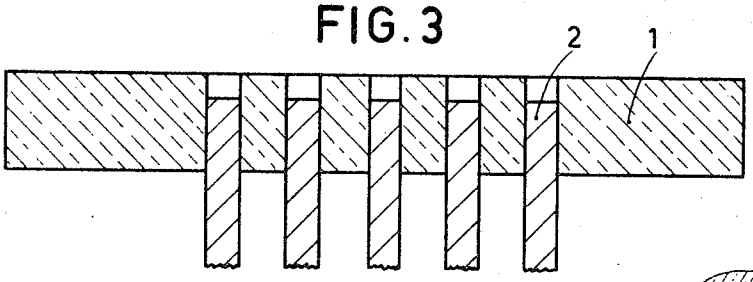
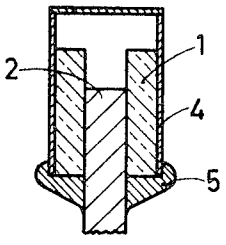


FIG.4



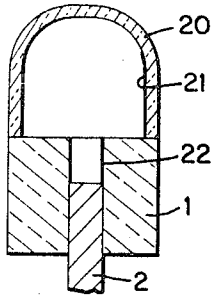


FIG.3a

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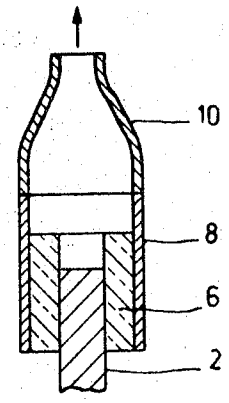

FIG.5

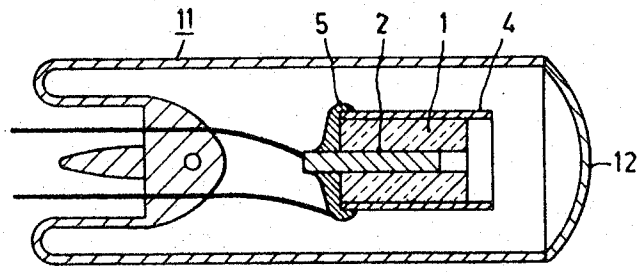

FIG.6

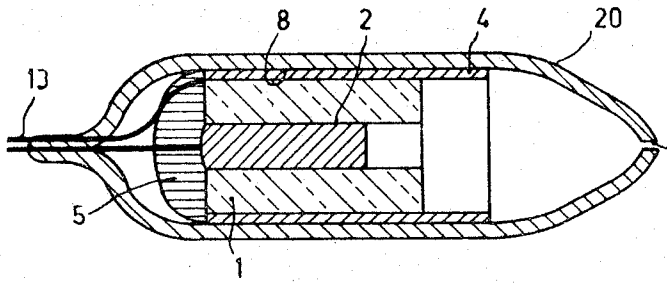

FIG.7

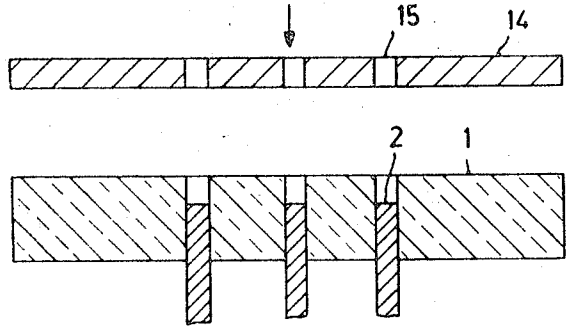

FIG.8

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COLD-CATHODE GLOW-DISCHARGE TUBE

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Continuation-in-part of application Ser. No. 660,331, Aug. 14, 1967. This application Oct. 11, 1967, Ser. No. 674,457

Claims priority, application Great Britain, Oct. 7, 1966, 44,937/66

Int. Cl. H01j *17/04, 61/04*

U.S. Cl. 313—209 9 Claims

ABSTRACT OF THE DISCLOSURE

A cathode assembly for a cold-cathode discharge tube comprising an electrically insulating member having a recess therein and a metal pin extending through from the recess through the member, an end surface of the pin forming an end wall of the recess as well as cathode surface.

This application is a continuation-in-part of application Ser. No. 660,331, filed Aug. 14, 1967.

This invention relates to cold-cathode glow-discharge tubes, for example gas-filled indicator or display tubes, and is concerned with a novel form of cathode and a method of making such cathode.

According to the present invention, there is provided a cathode assembly for a cold-cathode tube, comprising an electrically-insulating member having a recess therein and a metal pin extending from the recess through the member, wherein an end surface of the pin forms an end wall of the recess and also a discharge cathode surface.

Suitably, the electrically-insulating member forms a glass base for a cold-cathode tube and the metal pin also serves as an electrical connecting pin for the tube. In another construction, the member is tubular and the metal pin fits closely into the member.

A method according to the present invention of making a glow-discharge cathode comprises the steps of sealing the metal pin into the member and then etching the pin to a predetermined depth below a surface of the member to form a cathode surface in a recess in the surface of the member.

Suitably, the metal pin is of molybdenum and the pin is etched electrolytically in sodium hydroxide solution.

The invention will be described with reference to the accompanying drawing in which:

FIGURES 1, 2 and 3 show cross-sectional views of one embodiment of a cathode assembly in various stages of manufacture.

FIG. 3*a* shows one embodiment of a tube in cross-section according to the invention;

FIGURES 4, 5, 6 and 7 show a cross-sectional view of further embodiments.

FIGURE 8 shows a side view of the embodiment described with reference to FIGURES 1, 2 and 3, together with an anode structure.

Molybdenum pins of 1.25 mm. diameter were prepared by heating them for ten minutes at 900° C. in dry hydrogen. They were then "beaded," that is, they were coated with molten glass **100** over that portion which was to be sealed into a glass base. As illustrated in FIGURE 1, the pins were then held in position in a desired pattern, in this case a rectangular matrix in a graphite mold **3**.

The glass to be used to make the base **1**, was then placed in granular form in the graphite mold. The glass

was melted in an inert gas atmosphere of a composition of 90% nitrogen and 10% hydrogen to prevent oxidation of the molybdenum.

After the glass was melted it was cooled to solidify it and the glass base so formed was then removed from the mold. All the protruding pins on what was to be the inside of the finished tube were sheared off with a cutting wheel so as to be flush with the glass surface. The glass surface was then ground flat as shown in FIGURE 2.

The cathode pins were then etched electrolytically in sodium hydroxide solution of normal concentration to a depth of 0.8–1 mm. below the glass surface to form recesses in the surface of the glass. A tinned copper wire was used as the other electrode. Alternating current was used and during electrolysis, the electrolyte was agitated continuously to prevent bubbles from being trapped in the recesses forming between the pins and the surface of the glass. The etching current which was initially 1 a. decreased to 0.3 a. during the etching time of 35 minutes.

After etching, the base was washed in distilled water and then cleaned ultrasonically to remove any loose particles from the cavities. The completed cathode assembly is shown in FIGURE 3.

A glow-discharge tube (see FIG. 3*a*) was made by sealing the base into a glass bulb **20** which had a conductive tin oxide coating **21** formed over part of its inside surface. When sealed, the base and the bulb form the tube envelope and the conductive tin oxide coating serves as an anode. The tube was then pumped, baked and filled with neon to a pressure of 60–70 torr. A glow-discharge of 3 ma. was run to each pin as cathode for 5–10 minutes so as to "form" the cathode, i.e. deposit a layer **22** of cathode material on the sidewall of the recess and the tube was then ready for use.

It will be appreciated that other types of anode may alternatively be used in the cold cathode tube. With a plurality of pins formed on the same base, each cathode is positively isolated from its neighbors.

FIGURE 4 illustrates a second embodiment in which a single pin cathode assembly can be constructed without the aid of a mold.

In the manufacture of the assembly a molybdenum pin **2** of 1 mm. diameter was heated as previously described. The molybdenum pin was pushed into one end of a close-fitting ceramic tube **1** to within 1 mm. from the other end of the tube. A thin-walled nickel sleeve **4** serving as an anode was closely fitted over the ceramic tube. The nickel cylinder, the ceramic tube and the molybdenum pin were secured together as shown with a blob **5** of insulating adhesive, suitably a glass enamel.

Experiments indicate that the completed cathode assembly is suitable as a "decimal point" construction for a numerical indicator tube.

A single pin cathode assembly for a further construction of an indicator lamp shown in FIGURE 5 was manufactured as follows. A molybdenum pin **2** was heated as previously described and then glazed. The pin was then pushed into one end of a close-fitting sintered glass preformed tube **6** so that the pin is recessed a distance less than the diameter of the pin from the end of the tube. A thin walled metal sleeve **8** of Kovar or Fernico (registered trademarks) serving as an anode was glazed on its inside surface and then closely fitted over the sintered glass tube. The metal pin, the sintered glass tube and the metal sleeve were then heated so that the glazing melted. The assembly was then cooled.

As illustrated in FIGURE 5, a glass pinch **10** was secured around the open end of the metal sleeve by means of a glass-to-metal seal, and the recess under the open end of the metal sleeve and above the pin was then

evacuated and filled with neon gas at about 60 torr and sealed by the glass pinch to form a lamp.

Suitably, a cap may be secured to the base of the lamp or the lamp envelope itself may be contained to form such a cap with the metal pin forming the central contact. The glass pinch may be made to give a lens effect so that one may observe the broadened image of the cathode glow.

FIGURE 6 illustrates another construction, in which a single pin cathode assembly as illustrated in FIGURE 4 was sealed into a conventional neon tube envelope **11** to form an indicator lamp. The end **12** of the envelope was shaped so as to provide a lens effect.

FIGURE 7 illustrates a further construction, in which a single pin cathode assembly, as illustrated in FIGURE 3*a* also, was sealed into a neon tube envelope **20** allowing a slight gap of about 0.1 mm. between the metal sleeve **8** and the glass envelope **20** for differential expansion and for pumping gases in and out. The assembly has connecting wires **13** which were sealed into one end of the envelope and the tube was evacuated by a pinch **10** at the other end, which may then be made to exhibit a lens effect as described above.

FIGURE 8 illustrates the embodiment described with reference to FIGURES 1, 2 and 3 together with an anode structure comprising a blackened nickel plate **14** having holes **15**. These were located over the end surface of the molybdenum pins **2** within the base **1** so that the plate **14** is spaced about 0.5 mm. from the glass surface, and the base and the plate sealed into a conventional envelope to form a cold cathode tube. In operation, the cathode glow may be observed along the direction shown by the arrow. For simplicity, only 3 holes and 3 pins are shown.

The assembly illustrated in FIGURE 4 may be included in a tube which also contains other glow-discharge assemblies. Thus for example such an assembly may provide a decimal point indication in a number-indicating tube, or a plurality of such assemblies may be assembled to form a suitable pattern.

It has been found in operation that the cathodes such as have been described in the above embodiments can provide an intense, well-defined glow. Further it has been found that the recess forms a cavity from which material sputtered from the cathode is unable to escape and is deposited onto the walls of the cavity, and that the recessed cathode has the property of retaining the cathode glow within the recess. As a result of this tendency of the sputtered material to remain with the recess, even a closely-spaced window adjacent to the cathode tends to remain unobscured by sputtered material.

What is claimed is:

1. In a cold-cathode tube, a cathode assembly comprising an electrically-insulating member having a recess therein and a metal pin extending from the recess through the member, said pin having an end surface spaced from a surface of the insulating member which forms an end wall of the recess and also provides a discharge cathode surface, said recess having a sidewall covered with a deposited layer of cathode material whereby the cathode glow is retained within said recess.

2. A cathode assembly as claimed in claim **1** wherein the electrically-insulating member forms a glass base for a cold-cathode tube and wherein the metal pin also serves as an electrical connecting pin for the tube.

3. A cold-cathode tube as claimed in claim **1** having an envelope coated with a tin oxide coating which serves as an anode.

4. A cold-cathode tube as claimed in claim **1** including an anode plate having holes locatable over and for observation of said end surface of the pins.

5. A cathode assembly as claimed in claim **1** wherein the electrically-insulating member is tubular and the metal pin fits closely into the member.

6. A cathode assembly as claimed in claim **5** wherein the member is a ceramic tube.

7. A cathode assembly as claimed in claim **5** wherein the member is a glass tube.

8. A cold-cathode tube as claimed in claim **5** having an anode sleeve which fits closely over the tubular insulating member.

9. A cold-cathode tube as claimed in claim **8** wherein the sleeve is of nickel.

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U.S. Cl. X.R.

313—210, 217, 218