United States Patent [19]

Matsushita et al.

[11] **3,798,480**

[45] **Mar. 19, 1974**

[54] **INDICATOR DISCHARGE TUBE**

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[73] Assignee: **Okaya Denki Sangyo Kabushikikaisha,** Tokyo, Japan

[22] Filed: **Dec. 27, 1971**

[21] Appl. No.: **212,779**

Related U.S. Application Data

[63] Continuation of Ser. No. 849,949, Aug. 14, 1969, abandoned.

[52] **U.S. Cl.** **313/109.5**

[51] **Int. Cl.** **H01j 17/10**

[58] **Field of Search** 313/109.5

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Assistant Examiner—James B. Mullins
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[57] **ABSTRACT**

An indicator discharge tube having an insulating base plate with a plurality of grooves of predetermined shapes formed therein at predetermined locations, an anode electrode disposed opposite the insulating base plate, a plurality of cathode electrodes respectively disposed in the grooves of the insulating base plate, one portion of the anode electrode lying between adjacent cathode electrodes, and a tube having enclosed therein the insulating base plate, the anode electrode and the cathode electrodes in an airtight manner.

3 Claims, 19 Drawing Figures

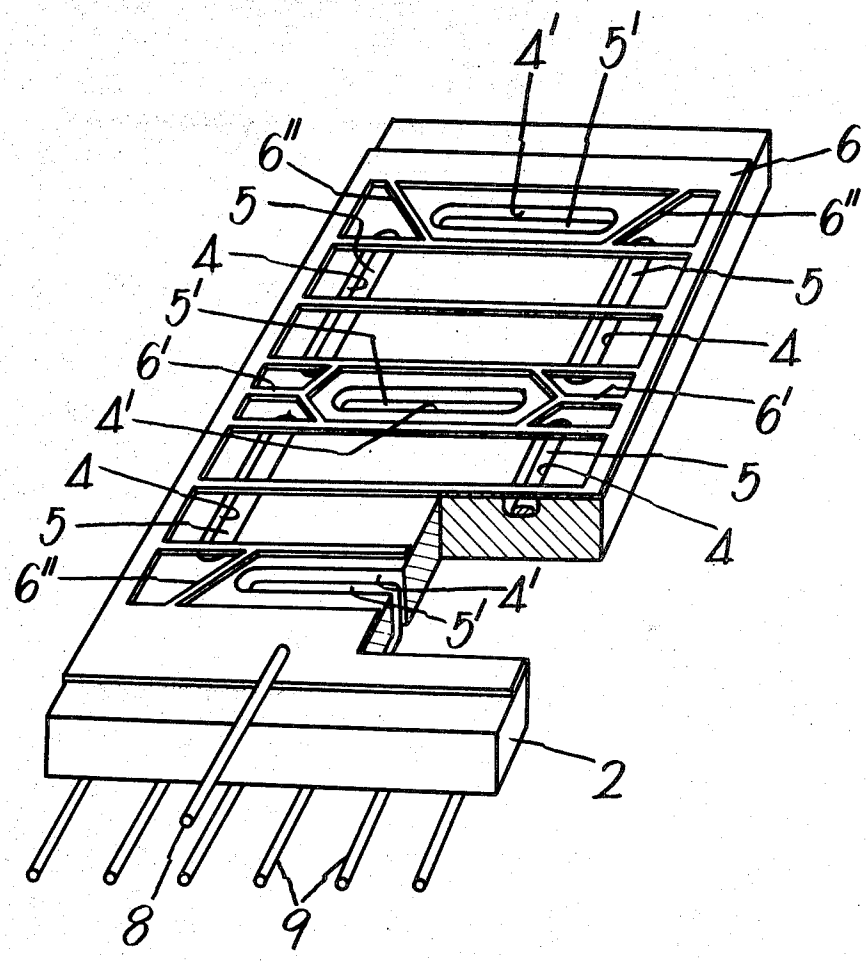

Fig. 1

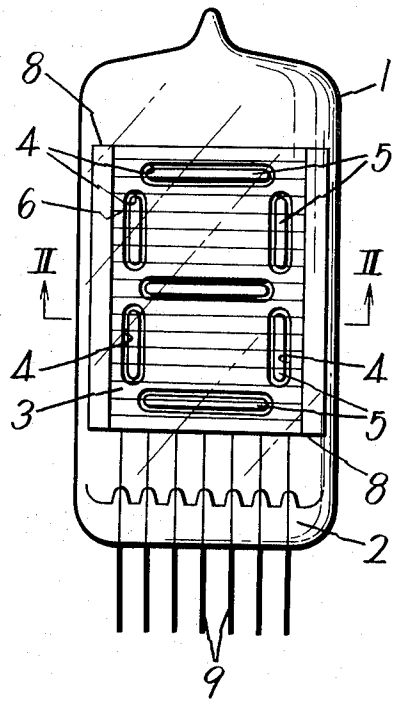

Fig. 2

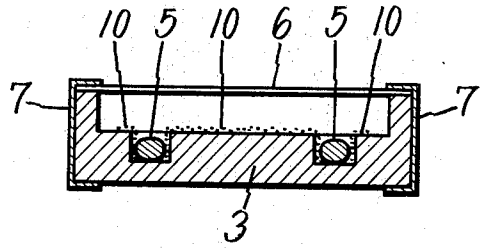

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Fig. 3

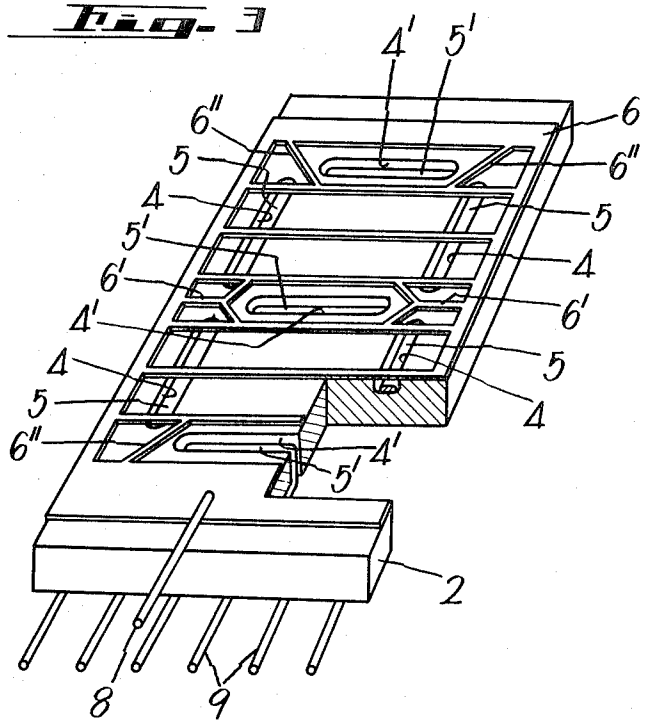

Fig. 4

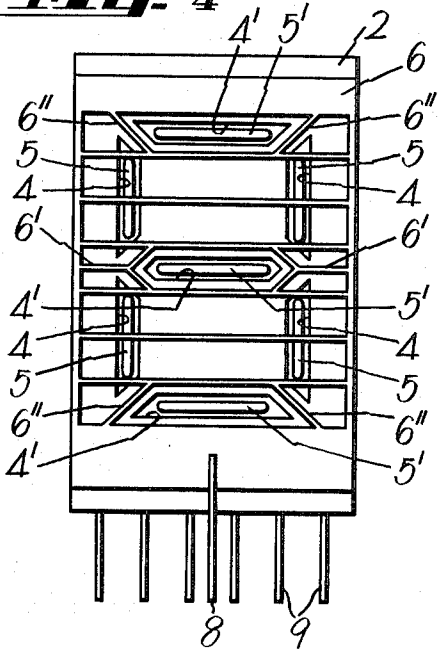

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Fig. 5

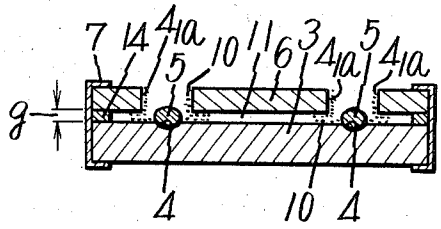

Fig. 6

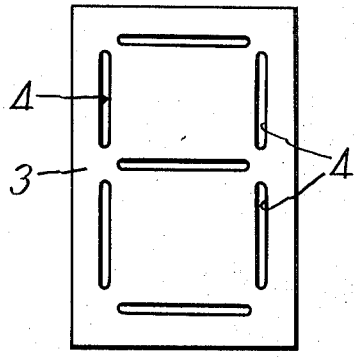

Fig. 7

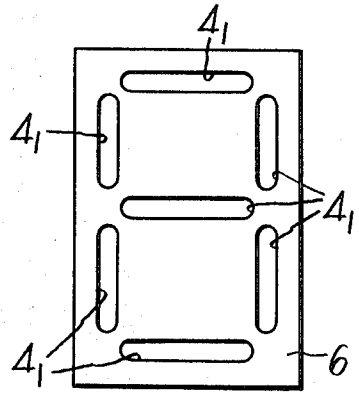

Fig. 8

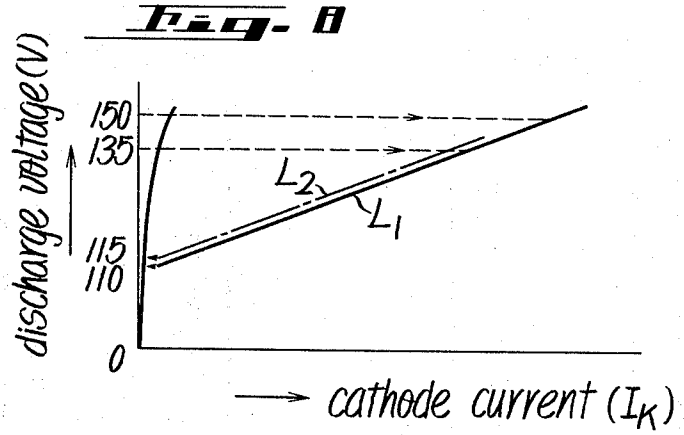

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Fig. 9

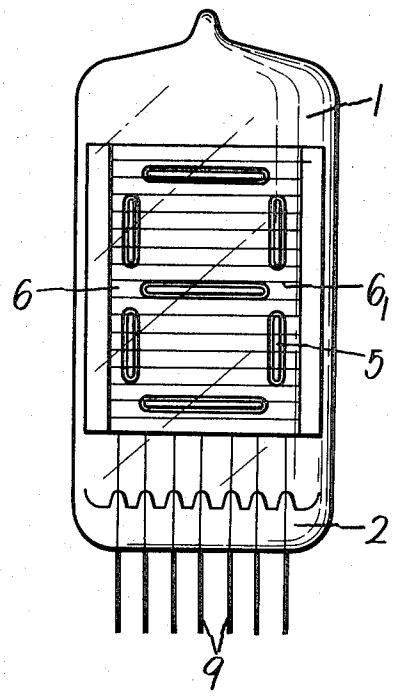

Fig. 10

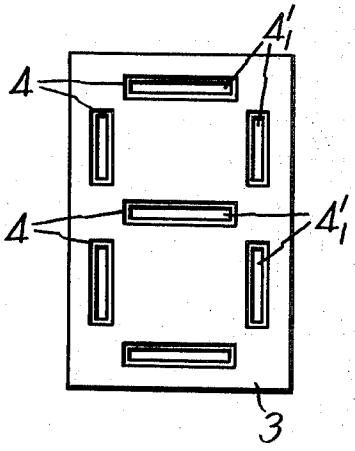

Fig. 11

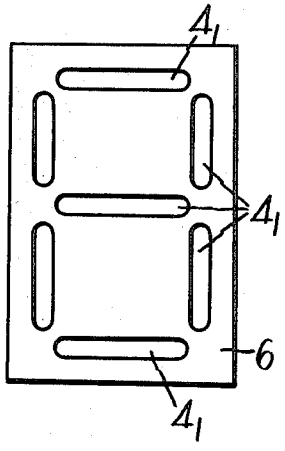

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Fig. 12

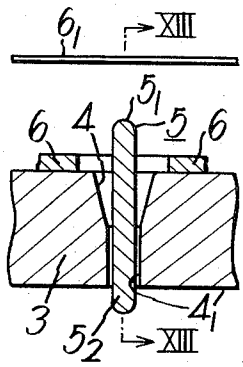

Fig. 13

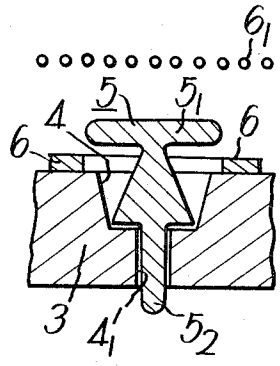

Fig. 14A

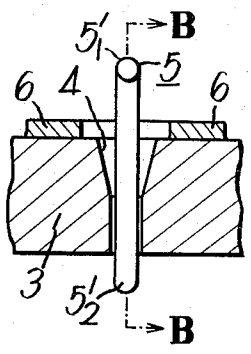

Fig. 14B

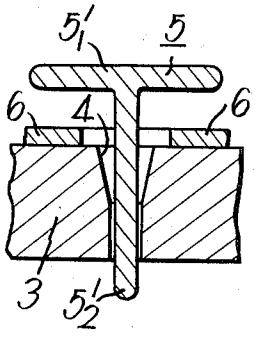

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Fig. 15A

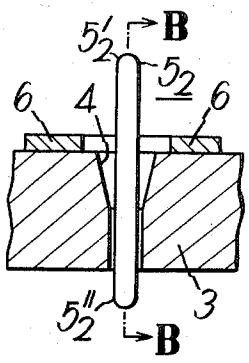


Fig. 15B

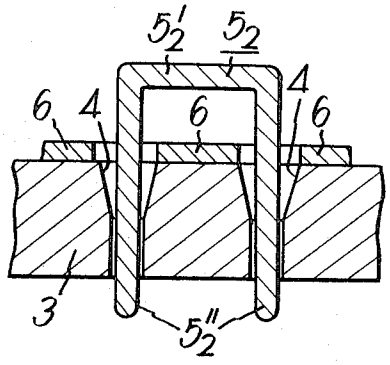


Fig. 16A

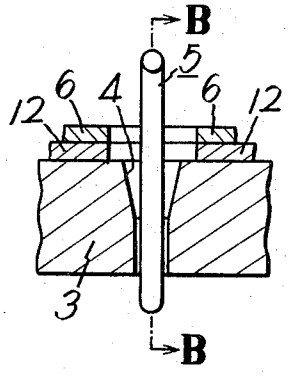
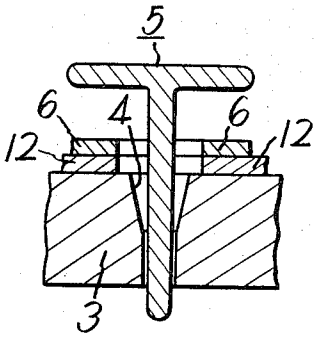


Fig. 16B



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INDICATOR DISCHARGE TUBE

This is a continuation, of application Ser. No. 849,949, filed Aug. 14, 1969, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an indicator discharge tube, and more particularly to an indicator discharge tube which is adapted to display numerals, characters or the like through the use of a plurality of electrodes.

1. Description of the Prior Art

In conventional types of indicator discharge tubes, indicator electrodes, that is, cathode electrodes made of, for example, nickel, tantalum, stainless steel or the like are embedded in grooves formed in an insulating base plate in a manner not to jut beyond the surface of the base plate and a voltage is impressed between the cathode electrodes and an anode electrode disposed apart from the cathode electrodes to produce discharge therebetween, thereby providing a display of a numeral, letter or the like. In the prior art indicator discharge tubes, however, the metal making up the cathode electrode is deposited on the surface of the insulating base plate due to the so-called cathode sputtering and finally covers substantially the entire area of the surface of the insulating base plate between adjacent cathode electrodes after long use, which leads to short-circuiting of adjacent cathode electrodes to render them inoperative.

SUMMARY OF THE INVENTION

Accordingly, the primary object of this invention is to provide a novel indicator discharge tube which is free from the aforementioned defects experienced in the conventional indicator discharge tubes.

Another object of this invention is to provide a novel indicator discharge tube in which an anode electrode is interposed between adjacent cathode electrodes to avoid short-circuiting therebetween resulting from the cathode sputtering so as to eliminate the drawbacks encountered in the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view of a conventional indicator discharge tube;

FIG. 2 is an enlarged cross-sectional view, partly cut away, taken along the line II—II in FIG. 1;

FIG. 3 is an enlarged perspective view; partly cut away, showing the principal part of an embodiment of indicator discharge tubes of this invention,

FIG. 4 is a front view showing another example of the indicator discharge tube of this invention;

FIG. 5 is an enlarged cross-sectional view of the principal part of another modified form of the indicator discharge tube of this invention;

FIG. 6 is a front view of an insulating base plate used in the example of FIG. 5;

FIG. 7 is a front view of an anode electrode for use with the insulating base plate depicted in FIG. 6;

FIG. 8 is a graph showing the discharge characteristic of the indicator discharge tube depicted in FIG. 5;

FIG. 9 is a front view of another modified form of the indicator discharge tube of this invention;

FIG. 10 is a top plan view of one example of an insulating base plate used in the indicator discharge tube shown in FIG. 9;

FIG. 11 is a top plan view of an anode used in the indicator discharge tube shown in FIG. 9;

FIG. 12 is an enlarged cross-sectional view of the principal part of the indicator discharge tube depicted in FIG. 9;

FIG. 13 is a cross-sectional view taken along the line XIII—XIII in FIG. 12;

FIG. 14A is an enlarged cross-sectional view of the principal part of another modification of the indicator discharge tube of this invention;

FIG. 14B is a cross-sectional view taken along the line B—B in FIG. 14A; and

FIGS. 15A, 15B and 16A, 16B are diagrams similar to FIGS. 14A and 14B, showing other examples of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to a detailed description of the present invention, one example of conventional indicator discharge tubes will be described in detail with reference to FIGS. 1 and 2. Reference numeral 1 indicates an airtight envelope formed of transparent glass or the like, 2 a stem and 3 an insulating base plate. A plurality of grooves 4 are formed in the insulating base plate 3 on one side thereof in a predetermined pattern, and cathode electrodes 5 usually made of nickel, tantalum, stainless steel or the like are embedded in the grooves 4 in a manner not to stand out from the surface of the insulating base plate 3. A grid-like anode electrode 6 is disposed in opposing but spaced relation to the insulating base plate 3 on that side where the cathode electrodes 5 are disposed. Further, support frames 7 which are mounted on both side edges of the anode 6 and the corresponding edges of the insulating base plate 3 and insulating plates 8 as of mica or the like are disposed between both marginal edges of the insulating base plate 3 and the anode electrode 6, by which the relative position of the anode electrode 6 to the cathode electrodes 5, that is, the insulating base plate 3 is determined and they are assembled together. The insulating base plate 3, the cathode electrodes 5 and the anode electrode 6 are housed in the airtight envelope 1. In this case bores (not shown) are respectively formed through the insulating base plate 3 which intercommunicate with the grooves 4 with the cathode electrodes 5 disposed therein, through which bore one end of each lead wire 9 is connected to each cathode electrode 5 and the other end is led out on the side of the insulating base plate 3 opposite from the cathode electrodes 5 and is further led to the outside of the airtight envelope 1 through the stem 2. The airtight envelope 1 is filled with an inert gas such as neon, argon or the like or a mixture of them at a pressure which may be in the range of about several ten to one hundred mm. of Hg.

With such an arrangement, the metal making up the cathode electrodes 5 is sputtered therefrom by discharge and deposited on the surface of the insulating base plate 3 as indicated by dots 10 in FIG. 2 in practical use and finally the sputtered metal covers the entire area of the surface of the insulating base plate 3 between adjacent cathode electrodes 5. This causes short-circuiting of adjacent cathode electrodes to prevent discharge of the cathode whose discharge initiating voltage is higher. Thus, the prior art indicator discharge tubes fail for this reason.

With reference to the drawings one embodiment of this invention will hereinafter be described. In the drawings similar elements to those in the foregoing are identified by the same reference numerals.

In FIG. 3 reference numeral 3 indicates an insulating base plate, in one surface of which are formed a plurality of grooves 4 in a predetermined pattern. Cathode electrodes 5 are respectively disposed in the grooves 4 in a manner not to jut beyond the surface of the insulating base plate 3 and an anode electrode 6 having anode elements 6′ and 6″ formed therein in a predetermined pattern is mounted on the insulating base plate 3 in such a manner as shown in FIG. 3. As clearly shown in FIG. 3, the anode electrode 6 lies in a plane above the cathode electrodes 5. Openings are formed in the anode electrode to form the anode electrode elements 6′ and 6″. Namely, the anode elements 6′ and 6″ partially or entirely surround some of the cathode electrodes 5, in the illustrated example cathode electrodes 5′ placed in the grooves 4′ formed transverse to the lengthwise direction of the insulating base plate 3. As seen in FIG. 3, anode elements are mounted so as to overlie the base plate 3 in an area between each of the grooves 4 to provide electrical repulsion of sputtering on the base plate between the grooves 4. The insulating base plate 3 with the cathode and anode electrodes thus mounted thereon is housed in an airtight envelope (not shown).

In the illustrated example seven grooves 4 and 4′ are provided in the surface of the insulating base plate 3 at predetermined locations in the form of an "8" and a metal cathode material is deposited by means of electrodeposition, vapor deposition or the like over the entire area of the bottom of each of the grooves 4 and 4′. Further, bores are formed in the insulating base plate 3 from the bottom of each of the grooves 4 and 4′ to the back of the base plate 3 in a direction at right angles thereto, through which bores the lead wires 9 are connected at one end to the cathode electrodes 5 and 5′, the lead wires 9 being arranged on the back of the base plate 3. Reference numeral 18 designates lead wires of the anode electrode 6.

In the present example the anode elements 6′ and 6″ contiguous to the anode 6 are provided in such a manner as to surround the grooves 4′ formed in a widthwise direction of the insulating base plate 3 and anode elements 6′ are provided across two grooves 4 formed in a longitudinal direction of the insulating base plate 3. Thus, the grooves 4 and 4′ are isolated from adjacent ones by the anode elements 6′ and 6″ each disposed therebetween.

The electrode assembly of such a construction is mounted on, for example, a ceramic stem 2 such as shown in FIG. 1 and is then sealed up in a transparent glass envelope. In order to provide for enhanced airtightness of the envelope 1, the ceramic stem 2 is sealed up at the open end portion of the glass envelope 1 with glass. The airtight glass envelope 1 is filled with a gas such, for example, as neon, argon or the like.

A predetermined voltage is applied to selected ones of the cathode electrodes 4 and 4′ through the lead wires 9 and to the anode 6 through the leads 18. This causes the selected cathode electrodes 4 and 4′ to produce glow discharge to provide a display of a desired numeral, letter, symbol or the like.

FIG. 4 illustrates another example of this invention which is exactly the same in construction and operation as that depicted in FIG. 3 except in that the grooves 4 and 4′ formed in the insulating base plate 3 are trapezoidal.

With such an arrangement of the cathode electrodes 5 and 5′ and the anode electrode 6 as has been described above, positively ionized metal particles which are sputtered from the cathode electrodes held at a positive potential are repelled by the anode electrodes held at a positive potential and consequently the sputtered metal particles are not deposited on the insulating base plate 3. This ensures the prevention of a trouble such as short-circuiting of the cathode electrodes resulting from bad insulation therebetween and provides for prolonged service life of the indicator discharge tube. Further, the cathode electrodes are formed in the grooves, and hence are easy to make, and since the anode is merely disposed on the insulating base plate, it does not require any special support means and is rigid in structure. In addition, the lead wires of the cathode electrodes pass through the bores formed in the insulating base plate and are led on the back of the base plate to the outside in parallel relation to one another, so that the lead wires can be easily mounted on the insulating plate and can be prevented from contacting adjacent ones. Consequently, miniaturization of the tube does not introduce the possibility of bad insulation, and hence appreciable miniaturization of the overall structure of the tube is possible with this invention. Further, since the indicator discharge tube of this invention is simple in construction, it requires less manufacturing operations and is inexpensive.

FIGS. 5 to 7 illustrate another example of the indicator discharge tube of this invention, which will hereinbelow be described. In FIGS. 5 to 7 similar elements to those in the foregoing examples are identified by the similar reference numerals.

In the illustrated example, an anode electrode 6 is disposed on an insulating base plate 3 in such a manner that the anode portion is interposed between adjacent cathode electrodes 5 as shown in FIG. 5. In the present example the insulating base plate 3 and the anode electrode 6 are assembled together with a narrow gap 11 having a distance g therebetween.

In this case, it is exactly the same as in the foregoing examples that neon mixed with a small amount of argon is sealed in an airtight space defined by the airtight envelope 1 and the stem 2 at a pressure of several ten to one hundred mmHg and that the anode electrode 6 and the insulating base plate 3 supported by a support frame 7 are fixedly mounted in the airtight envelope 1 by means of mica plates 8.

In the present example, there are formed in the upper surface of the insulating base plate 3 grooves 4 shallow only enough to position the cathode electrodes 5 in such a manner that the cathode electrodes 5 formed of a metal such as stainless steel may substantially entirely stand out from the surface of the insulating base plate 3. The anode electrode 6 is formed of a suitable sheet metal having formed therein slits 4_1 at places corresponding to the cathode electrodes 5 so that the cathode electrodes 5 may be seen through the slits 4_1, and insulating spacers 14 as of mica or like material are interposed between the insulating base plate 3 and the anode electrode 6 in a manner to provide the gap 11 therebetween.

With such an arrangement, metal particles 10 sputtered from the cathode electrodes 5 are deposited on

the insulating base plate 3 and side walls 4_{1a} of the slits 4_1 of the anode electrode 6 during discharge but since the anode electrode 6 is a metal plate, it is not adversely affected by the metal particles 10 deposited thereon. Further, since the gap 11 is very narrow, the metal particles 10 sputtered from the cathode electrodes 5 do not go far into the gap 11. Consequently, the deposition of the metal particles 10 is not likely to damage the insulation between adjacent cathode electrodes 5 and the metal particles 10 deposited on the anode electrode 6 and the insulating base plate 3 do not contact one another because of the presence of the gap 11.

One example of numerical values of the indicator discharge tube of this example is as follows:

thickness of the anode electrode 6 — : 0.8 mm.
width of the slits 4_1 — : 0.8 mm.
diameter of the cathode electrodes 5 — : 0.3 mm.
length of the cathode electrodes 5 — : 4 mm.
width g of the gap 11 — : 0.05 to 0.1 mm.
gas sealed in the envelope 1 — : mixture of argon 0.7 percent and neon 99.3 percent
pressure of the gas — : 100 mmHg

With the above indicator discharge tube, discharge initiating and terminating voltages Ez and Ex are respectively 135 V and 115 V as indicated by a curve L_2 in FIG. 8. In the case of the prior art discharge tube of the construction shown in FIG. 1 these voltages Ez and Ex are respectively 150 V and 110 V as indicated by a curve L_1 in FIG. 8. The differences between Ez and Ex are 20 V in the former and 40 V in the latter. Namely, the present invention reduces by half of the difference between the discharge initiating and terminating voltages, as compared with that obtainable with the prior art construction.

As has been described above, this embodiment not only prevents short-circuiting of adjacent cathode electrodes due to the sputtering with a simple construction but also reduces by half the difference between the discharge initiating and terminating voltages, as compared with that obtainable with the conventional indicator discharge tube.

Referring now to FIGS. 9 to 13, a description will be given of another example of this invention. In the figures similar reference numerals to those in the foregoing examples designate similar elements.

In the present example a plurality of grooves or slits 4 of predetermined shapes are formed in an insulating base plate 3 on one surface thereof at predetermined locations and an anode electrode 6, which has formed therein elongated apertures or slits 4_1 substantially identical with the grooves 4 at places corresponding thereto, is attached to the insulating base plate 3 in such a manner that the slits 4_1 of the anode electrode 6 are substantially aligned with the grooves 4 of the insulating base plate 3. Further, cathode electrodes 5 are respectively disposed in the grooves 4 of the insulating base plate 3 in a manner to jut beyond the surface of the anode electrode 6 and then the insulating plate 3 with the cathode electrodes 5 and the anode electrode 6 mounted thereon is sealed up in the airtight envelope 1.

A detailed description will hereinbelow be made in connection with the indicator discharge tube of the above construction. The insulating base plate 3 is made of an insulating material such, for example, as ceramic or the like, and seven grooves 4 of predetermined shapes are formed in the insulating base plate 3 on one side thereof at predetermined locations in the form of an "8" as shown in the figures. The slits 4_1, which are substantially identical in shape with the grooves 4 of the insulating base plate 3 but a little larger than them, are bored through the anode electrode 6 at places corresponding to the grooves 4 (refer to FIG. 11). The anode electrode 6 is formed of a conductive metal material such as iron or the like. The anode electrode 6 is mounted closely to the insulating base plate 3 in such a manner that the slits 4_1 of the former may be aligned with the grooves 4 of the latter. The cathode electrodes 5 are formed of a metal material such as nickel, tantalum, stainless steel or the like which are substantially T shaped as depicted in FIGS. 12 and 13. The length of one side 5_1 of each of the T-shaped cathode electrodes 5 corresponds to that of each groove 4 in its lengthwise direction and the width of the other side 5_2 corresponds to that of the groove 4. The free end portion of the side 5_2 of each cathode electrode 5 is inserted into an aperture $4_1'$ formed in the bottom of each groove 4 substantially at the center thereof in a manner so that the side 5_1 of the cathode electrode 5 juts beyond the anode electrode 6 and lies parallel with the groove 4. The cathode portion of the cathode electrode 5 lying between the groove 4 and the side 5_1 is triangular shape in cross section. One end of each lead wire 9 is connected to the free end portion of the side 5_2 of each cathode electrode 5 and the other end is led to the outside through the stem 2 made of glass or the like. The insulating base plate 3 having mounted thereon the cathode electrodes 5 and the anode electrode 6 as above described is sealed up in the glass envelope 1. In this case, the envelope 1 is filled with an inert gas such as neon, argon or the like and sealed. Further, an auxiliary member may be inserted into the envelope 1 for holding the insulating base plate 3 in position in a conventional manner.

In the indicator discharge tube of the above construction, the application of a predetermined voltage to the anode electrode and selected cathode electrodes causes discharge therebetween to provide a display of a desired numeral, letter or the like in exactly the same manner as in the prior art indicator discharge tubes. In the present example, however, the anode electrode 6 is attached to the insulating base plate 3 with no gap therebetween, so that the surface of the insulating base plate 3 is not exposed contiguous to adjacent cathode electrodes 5. Consequently, although metal particles of the cathode electrodes are ionized and sputtered therefrom, the ionized metal particles are repelled by the anode electrode, so that the ionized sputtered metal is not deposited on the anode electrode and the surface of the insulating base plate in the vicinity of the anode electrode. The sputtered metal is deposited only on the surface of the insulating base plate in the proximity of the cathode electrodes. Since the ionized metal sputtered from the cathode electrodes is not deposited on the surface of the insulating base plate over the entire area between adjacent cathode electrodes to such an extent as to cause short-circuiting therebetween, the insulation between cathode electrodes is not decreased. Consequently, the indicator discharge tube of this example is long-lived and highly reliable in operation.

In the case where a grid-like or mesh-like electrode 6_1 formed of a conductive metal material such, for ex-

ample, as iron or the like is disposed in opposing but spaced relation to the anode electrode **6** and the cathode electrodes **5** in the envelope **1** as shown in FIGS. **9, 12** and **13** and a positive potential substantially equal to that fed to the anode **6** is applied to the electrode 6_1, the sputtered metal can be repelled by the electrode 6_1 also by which it is possible to avoid blurring of the interior surface of the envelope **1** as experienced in the prior art indicator discharge tubes.

By forming the grooves **4** of the insulating base plate **3** to be gradually wider as the anode electrode **6** is approached, as depicted in FIGS. **12** and **13,** the insulation of the cathode electrodes **5** from the anode electrodes **6** can be further enhanced and discharge between the electrodes more difficult. Very little of the ionized metal sputtered from the cathodes is deposited on the surface of the insulating base plate in this region and this also provides for enhanced insulation of the electrodes.

FIG. **14** shows a cathode electrode 5_1 which is different in shape from that exemplified in FIGS. **12** and **13** and consists of substantially rod-like cathode members $5_1'$ and $5_2'$ as of nickel or the like assembled in the form of a substantially T. The cathode electrode 5_1 has exactly the same advantages as those of the foregoing one and an additional advantage such as ease in manufacture. In this case the grooves **4** of the insulating base plate **3** need not be elongated as the foregoing but may be circular in cross-section and the slits 4_1 of the anode electrode **6** may be of a similar shape. The grooves **4** are similarly formed to be gradually wider as the anode electrode **6** is approached.

FIG. **15** shows still another cathode electrode 5_2, which is a substantially U-shaped metal rod as of nickel or the like. The free ends $5_2''$ of the cathode electrode 5_2 are inserted into the grooves or slits **4** formed in the insulating base plate **3** in a manner so that its major portion $5_2'$ may lie above the anode electrode **6.** In this case, the cathode electrode 5_2 is retained to the insulating base plate **3** at two points, it is firmly held on the base plate **3** as compared with the cathode electrodes previously described, and hence the cathode electrode in this case is strong against a shock. The grooves **4** of the insulating base plate **3** are formed in the same manner as in the foregoing examples and two grooves are provided for each cathode electrode.

FIG. **16** illustrates a further modified form of the indicator discharge tube, in which an insulator as of ceramic or the like or mica plate **12** is disposed between the insulating base plate **3** and the anode electrode **6** to provide for enhanced insulation between the electrodes. The shapes and relative arrangement of the cathode and anode electrodes may be any of those in the foregoing examples.

It is a matter of course that an anode electrode for indicating a decimal point can be provided in any of the indicator discharge tubes, if necessary.

As has been described in the foregoing, the indicator discharge tubes of this invention avoid short-circuiting between the cathode electrodes and blurring of the interior surface of the air-tight envelope which result from the sputtering of the cathode material and, as a result of this, the indicator discharge tubes are extremely long-lived. Further, the indicator discharge tubes has many advantages such as excellent insulation between the cathode and anode electrodes and excellent shock-proof property and so on.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this invention.

We claim as our invention

1. An indicator discharge tube comprising:

an insulating base plate having a first surface formed with a plurality of grooves;

a plurality of cathode segments with one of said cathode segments mounted in each of said grooves and with their upper surfaces lying below said first surface of said base plate, and

an anode electrode insulatingly mounted on said base plate and lying in a plane over said cathode segments and formed with openings which define a plurality of anode elements, said anode elements positioned to overlie said base plate in the area between adjacent ones of said grooves to prevent metallic particles sputtered from said cathode segments from being deposited on said insulating base plate in the area between said grooves and thus prevent breakdown of insulation by metallic particle deposition on said insulating base in the areas between said cathode segments.

2. An indicator discharge tube according to claim **1** wherein certain of said openings of said anode structure are trapezoidal in shape.

3. An indicator discharge tube according to claim **1** wherein certain of said openings of said anode structure are six-sided in shape.

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