ABSTRACT

An indicator display tube in which indicator electrode units, each consisting of anode and cathode segments, lie in the same plane and in which all of the cathode segments similarly located in each unit are simultaneously energized and the anode electrodes are energized on a time sequential basis in such a manner that only the indicator electrode unit having its anode electrodes energized will glow at a particular time. The cathode segments of each indicator unit are connected in parallel which substantially reduces the number of leads to the display tube over conventional indicators which require a separate lead for energizing each of the cathode segments. The indicator display tube is designed dimensionally and otherwise for preventing accidental discharge of adjacent indicator electrode units which would produce erroneous message displays. The tube has each indicating unit preconditioned in advance of each firing to shorten the turn on time of each indicator unit.

5 Claims, 15 Drawing Figures
INDICATOR DISPLAY TUBE HAVING PREDETERMINED SPACING BETWEEN BASE PLATE AND COVER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to an indicator display tube and, in particular, to a novel indicator display tube and to a method for making it.

2. Description of the Prior Art

Generally, indicator display tubes, which are of the type including a plurality of indicator units mounted inside a transparent envelope for displaying numerals, symbols, letters or the like, have been used with electronic counters and other various indicating devices. One example of such indicator display tubes is the so-called "Nixie" tube in which an anode and a plurality of cathodes are aligned in a stack one above another and the cathodes are selectively energized to provide a display of a desired numeral or letter. Another type of indicator display tube utilizes cathode segments mounted in a common plane and an anode in the form of a wire screen or mesh mounted in a second plane.

For displaying a number containing a plurality of figures with the Nixie tube, it is necessary to employ the same number of Nixie tubes as that of the figures, which inevitably leads to bulkiness of an indicator display device. Accordingly, the Nixie tube is not suitable for such number display. The indicator display tube with cathodes in a common plane is small and thin but requires the same number of leads as used in Nixie tubes. The large number of leads are difficult to form and to lead out of the envelope and results in complexity in the external wiring.

U.S. Pat. No. 3,588,571 discloses an indicator display tube of the type in which many indicator electrode units, each consisting of an anode and a plurality of cathode segments are formed on an insulating plate with the cathode segments in each unit connected in common to those in the other units and connected to common energizing leads but in which the anodes are connected to separate energizing leads which are led out of the envelope. This indicator display tube has advantages in that the number of the leads required is smaller than that of the prior art tubes. However, such tube is likely to provide an incorrect message display because the indicator units are driven on a time sequential basis and the repeating glow discharge causes the ionizable gas, for example argon or neon which is sealed in the envelope, to produce ions which diffuse toward electrodes of adjacent units which lowers the discharge initiating voltage between anode and cathode segments of the adjacent electrode units and causes them to glow.

In my copending application Ser. No. 177,990, filed Sept. 7, 1971, now abandoned I have disclosed an indicator display tube which has a number of indicator electrode units with their anode and cathode segments formed in a common plane and includes means provided between adjacent indicator electrode units to prevent accidental discharges. The cathode segments of each electrode unit are electrically interconnected to corresponding ones of the other units and are simultaneously energized. The anodes of each unit are energized on a time-sequential basis in such a manner that a particular electrode unit which has its anode energized provides a display. The means to prevent accidental discharges is in the form of a barrier electrode.

SUMMARY OF THE INVENTION

The present invention involves the geometrically dimensioned and designed arrangement of the cathode segments and anode electrodes of a plurality of indicating units arranged in a flat envelope in such a way that accidental discharge is substantially eliminated under ordinary operating conditions, even over a wide range of ambient temperatures.

An object of this invention is to provide an indicator display tube which is adapted to prevent an incorrect message display and which is simple in construction.

A further object of this invention is to provide an indicator display tube which is compact, convenient and has long life.

Still a further object of this invention is to provide an indicator display tube which is easy to manufacture.

Other objects, features and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view schematically illustrating one example of an indicator display tube of this invention;
FIG. 2 is a plan view of a cover plate of the indicator display tube of this invention;
FIG. 3 is a plan view of the glass backing plate of the invention;
FIG. 4 is a sectional view taken on line IV—IV of FIG. 2;
FIG. 5 is a sectional view taken on line V—V of FIG. 3;
FIG. 6 is a plan view of the backing plate illustrated in FIG. 3 with a plurality of interconnecting leads formed thereon;
FIG. 7 is a plan view of the backing plate of FIG. 6 with an insulating layer formed over the interconnecting leads;
FIG. 8 is a plan view of the backing plate of FIG. 7 with a plurality of indicating units and selecting leads formed over the insulating layer;
FIG. 9 is a plan view of the backing plate of FIG. 8 with an insulating layer formed thereon;
FIG. 10 is a sectional view taken on line X—X of FIG. 1;
FIG. 11 is a circuit diagram showing the indicator assembly of FIG. 1 together with a drive circuit therefor;
FIG. 12 is a diagrammatic plan view of the cathode segments of one indicating unit indicating what the dimension "L" is;
FIG. 13 is a diagrammatic fragmentary view of a portion of the base plate and cover with cathode segments and anode electrodes of one indicating unit indicating what the dimension "r" is;
FIG. 14 shows two characteristic curves of ambient temperature vs. cathode prebias voltage; and
FIG. 15 illustrates the application of prebias voltage to cathode elements of each indicating unit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 there is illustrated generally one example of a gaseous glow type indicator display tube 1 produced according to this invention. The indicator display tube 1 is made up of a base plate 2 of an insulating material
as, for example, glass. A plurality of indicator units 40, 41, 42, 43, 44, and 45, of the same pattern are formed by printing techniques on the base plate 2 in alignment with one another and a transparent cover plate 3, as of glass, is attached to its periphery in an airtight manner to the base plate 2 and its center is spaced a predetermined distance from the indicator units.

The indicator display tube 1 of the present invention is constructed in the following manner: The insulating base plate 2 such as illustrated in FIG. 3 has the indicator units and the interconnecting leads formed thereon. The transparent cover plate 3 is attached to the base plate 2 after the indicator units are formed. The cover plate 3 is formed with a depression or hollow portion 4 in which the indicator units are received as shown in FIG. 4.

Both of the plates 2 and 3 may be made of glass or ceramic and generally the base plate 2 is larger in area than the cover plate 3 as may be observed by comparing FIGS. 2 and 3. The plate 3 is transparent. FIG. 4 is a sectional view taken on line IV—IV of FIG. 2 and illustrates the depression 4 in the cover plate 3.

FIG. 5 is a sectional view taken on line V—V of FIG. 3.

FIG. 6 is an enlarged plan view of the base plate 2 and illustrates a plurality of interconnecting leads 10 to 18 which are formed on the insulating base plate 2 by suitable thin film techniques such as, for example, by printing. It is to be particularly noted that the interconnecting leads 10 to 18 are grouped so that they will align with indicator units to be formed above a particular group. Thus, the interconnecting leads for the first indicator unit are designated by numerals 10 to 18 and the interconnecting leads for the second unit are designated by numerals 19′ to 18′. The interconnecting leads are formed of silver paste which adheres well to the glass base plate 2.

After the interconnecting leads are formed by printed circuit techniques on the base plate 2, the plate and leads are baked to provide suitable bonding.

It is to be realized that the lengths of the interconnecting leads 10 to 18 are such that they will be capable of interconnecting the cathode and anode elements of the indicator units to suitable selecting leads as will become more apparent in the description.

FIG. 7 is a plan view of the base plate 2 in which a glass insulating layer 20 has been deposited on the base plate 2 so as to cover a substantial portion of the interconnecting leads 10 to 18. The insulating layer 20 may be formed by a glass coating method by applying glass coating by spraying two or three times and then by drying it to provide it with a suitable insulation coating 20 over the interconnecting leads.

Windows are formed in the insulating layer 20 at opposite ends at each of the interconnecting leads 10 to 18 so as to allow electrical conducting paths to be formed through the insulating layer 20 to the interconnecting leads 10 to 18. For example, windows 30a and 30b are formed through the insulating layer 20 at opposite ends of the interconnecting lead 10. Windows 31a and 31b are formed at opposite ends of the interconnecting lead 11 and additional windows 32a and 32b and 33a and 33b are respectively formed at opposite ends of leads 12 to 18. Additional windows intermediate the ends of lead 14 are formed and are designated 34c and 34d.

It is to be realized, of course, that the windows formed through the layer 20 are formed for each of the indicator units although they are only particularly numbered in FIG. 7 for the first indicator unit.

FIG. 8 illustrates the next step of the method of making the indicator unit and illustrates a plurality of indicating units 40 to 45 which are formed on the top of the insulating layer 20.

In the next step the plurality of indicator units 40 to 45 (the number of depending upon the desired number) are formed on the insulating layer 20 and aligned with the windows through the layer 20 so that electrical contact will be made with the interconnecting leads. Each of the indicator units comprises electrically conducting anode segments 51, 52 and 53 as well as an associated plurality of cathode elements 61 to 68.

It is a particular feature of the present invention that the spacing between the under surface of the cover plate 3 and the confronting face of the base plate 2 be chosen so that the ratio of this dimension (herein referred to as t) to the maximum spread of the cathode segments of each individual indicating unit (herein referred to as L) be less than 0.4 and greater than 0.05. The barrier electrode may under such circumstances be eliminated for most applications. The dimensions L and t are clearly shown in FIGS. 12 and 13, respectively.

At the time of forming the anode and cathode segments, a plurality of selecting leads 71 to 78 are formed on the insulating layer 20 with the leads 71 to 74 extending along the top of the indicator units 40 to 45 shown in FIG. 8 and the selecting leads 75 to 78 extending along the bottom of the indicator units 40 to 45 as shown in FIG. 8. The anode and cathode segments and selecting leads are formed by suitable thin film techniques and are formed so as to align with the windows 30a to 38a and 30b to 38b so that electrical connections will be made between the selecting leads 71 to 78 and the anode and cathode segments.

A plurality of external leads 81 to 84 are formed on the insulating plate 2 adjacent the lower edge relative to FIG. 8 and are respectively connected to the selecting leads 71 to 74. A plurality of external leads 91 to 94 are respectively connected to the selecting leads 75 to 78 and are formed on the insulating plate 2 along the bottom edge as shown in FIG. 8.

It is to be realized that the indicator units 40 to 45, the selecting leads 71 to 78 and the external leads 81 to 84 and 91 to 94 are formed at the same time by a silk screen process and when the indicator units 40 to 45 and selecting leads 71 to 78 are printed on the insulating layer 20, each of the elements 61 to 68 and 51 and 53 are respectively connected to the associated selecting leads through the windows 30a to 38d formed in the insulating layer 20. For example, the cathode element 62 is formed so that it aligns with window 31b which connects it to one end of the interconnecting lead 11 and the selecting lead 74 is formed over the window 31a so that the selecting lead 74 is connected to the cathode segment 62 through the interconnecting lead 11. Simultaneously, all of the corresponding cathode segments 62 of all of the indicator units 40 to 45 are connected to lead 74 through associated windows and thus all of the segments 62 of all of the indicator units are electrically connected together and to the external lead 84. Similarly, all of the cathode segments 61 are connected by interconnecting lead 10 to selecting lead.
3,906,287

72 and to external lead 82. All of the cathode segments 63 are connected by interconnecting leads 13 to selecting lead 73 which is connected to external lead 83. Each of the cathode segments 64 is connected by interconnecting lead 12 to selecting lead 71 which is connected to external lead 81. Each of the cathode segments 65 is connected by interconnecting lead 15 to selecting lead 75 and to external lead 91. Each of the cathode segments 66 is connected by interconnecting lead 16 to selecting lead 76 which is connected to external lead 92. Each of the cathode segments 67 is connected by interconnecting lead 17 to selecting lead 77 which is connected to external lead 93. Each of the cathode segments 68 is connected by interconnecting lead 18 to selecting lead 78 which is connected to the external lead 94.

Thus, in the structure defined thus far, the associated cathode segments of all of the indicator units 40 to 45 are electrically connected together and thus can be electrically energized by the eight cathode selecting leads 81 to 84 and 91 to 94. The three anode segments 51, 52 and 53 of each of the indicator units 40 to 45 are interconnected together by the interconnecting lead 14 and a separate external lead is formed along the lower edge of the insulating plate 2 so that the anode segments of each of the indicator units can be individually energized. For example, an external lead 110 is connected to interconnecting lead 14 of the indicator unit 40 which is connected to the anode segments 51, 52 and 53 of the indicator unit 40 and the indicator unit 40 will be energized when the external lead 110 is energized with a selective pattern of the cathode segments.

Likewise, the anode segments of the indicator unit 41 are connected through an interconnect lead to the external anode lead 111 for the indicator unit 41. An external lead 112 is connected to the associated anode segments of the indicator unit 42 in a similar manner. An external lead 113 is connected to the anode segments of the indicator unit 43 and an external lead 114 is connected to the anode segments of the indicator unit 44. An external lead 115 is connected to the anode segments of the indicator unit 45.

The indicator display tube of the present invention is adapted to prevent an incorrect message display which is caused by accidental discharge of the indicator units. This is accomplished by keeping certain critical dimensions within a given ratio. Specifically, it has been found that accidental firing of an adjacent unit is substantially eliminated if the ratio of the t/L is less than 0.4. It has further been found that if this ratio of t/L is greater than 0.05 the adjacent indicating unit is preconditioned so that the time to fire the same is very short.

When display tubes are used having a plurality of indicating units are enclosed within a single envelope and with anode-cathode segments lying in a single plane, an incorrect message is apt to be displayed, because the units are driven on a time sequential basis and the repeating glow discharge causes the ionizable gas to produce ions which diffuse toward electrodes of adjacent indicating units which lower the so-called discharge initiating voltage between anode and cathode segments of the adjacent indicating units and causes them to glow. This is commonly referred to as “cross-talk” or “leak glow”.

To amplify on the problem here involved, it will be recognized that in a flat type display tube driven on a time sequential basis, a part of the ions produced by a specific indicator unit should diffuse toward the next indicator unit in order to cause a rapid glow of the next unit when the next unit is energized. If ions do not diffuse toward the next unit, it will take more time than can reasonably be tolerated to produce an indication in this next unit. On the other hand if too many ions or too much ionized gas, is diffused toward the next indicator unit, an incorrect indication might be produced.

Now the amount of ions produced by one indicator unit depends on the area of the unit's cathode segments and also on the amount of remaining ions depending on the height h of the cover plate. The amount also depends on the temperature, the type of ionizable gas employed and on the drive time.

FIG. 14 shows a characteristic of room temperature vs. cathode prebias voltage, that is a predetermined voltage for each of the cathode segments. A curve A shows a characteristic of a tube having a dimension of t/L = 0.5. As shown on curve A, the increase of temperature requires a high cathode prebias voltage to prevent an incorrect message. This means that an integrated circuit having high breakdown voltage should be used for driving the cathode circuit. Ordinarily, an increase of temperature produces a lot more ions, and hence the inoperative indicator electrodes should scatter these increased ions by high voltage.

A curve B in FIG. 14 shows the characteristic of a tube having a dimension of t/L = 0.28. As shown on curve B, a high cathode prebias voltage is not required if temperature increases, so that it is not necessary to provide an integrated circuit having high breakdown voltage.

The cathode prebias voltage referred to above, may be exemplified by the schematic circuit shown in FIG. 15. Three indicator units 121, 122, 123 are shown, each having an anode 124 and seven cathode segments 125. A source of electrical potential 126 is provided whose positive side is connected to the anodes 124. This source may be of example be about 180 to 200 volts. The negative side of the source is grounded. A voltage divider network is provided by two resistors 127 and 127. Transistors 128 of the npn type are provided corresponding in number to the number of cathode segments. The emitters are connected to ground through biasing resistors 129. The collectors are connected, respectively, to differently positioned cathode segments. For example, the collector 130 of the transistor 128 is connected through a bias 132 to the bottom cathode segment of each indicator unit. The switching means for selecting which anode to be energized is not shown. This description in connection with FIG. 15 is merely to make clear by way of a simple example what is meant by the term cathode prebias voltage.

Under some circumstances it is desirable to employ a barrier electrode between each indicating unit in addition to maintaining the t/L ratio within the limits specified. Such a barrier electrode arrangement is shown in the drawings wherein the barrier electrode is designated at 100. The barrier electrode 100 may be formed around the indicator units 40 to 45 on the insulating layer 20 at the same time as the indicator units and leads and has suitable windows for the indicator units as shown. A lead 101 is also formed on the insulating layer 20 and extends from the barrier electrode 100 to an external lead 102 so that a suitable voltage may be applied. The leads 101 and 102 are formed at
the same time that the barrier electrode 100 is formed. The leads, cathode and anode segments and barrier electrode are all formed of silver paste which adheres well to the glass insulating layer 20.

In the next step, as shown in FIG. 9, a second insulating layer 120 of glass is deposited over the selecting leads 71 to 78 and 101 but the indicator units are left uncovered by this second insulating layer 120. In other words, the cathode segments 61 to 68 and the anode segments 51 to 53 of each of the indicator units are left uncovered by the second insulating layer 120. The external leads are also left uncovered by the second insulating layer 120.

Since the cathode segments of each indicator unit are bombarded by ionized ions emitted from the space discharge layer which can cause them to sputter, it is necessary to form the cathode segments of a metal which resists sputtering and which has a low work function.

For accomplishing this, a thin nickel layer is formed on the plurality of indicator units 40 to 45 and over the barrier electrode 100 by electroplating in a plating bath as described below.

For nickel plating, a neutral plating bath is employed and the thickness of a plated layer is selected so that deposition of the nickel layer on the silver paste is enhanced. The preferred composition of the plating bath and the plating conditions are as follows:

<table>
<thead>
<tr>
<th>Composition of Plating Bath</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Nickel sulfate</td>
<td>240g/l</td>
</tr>
<tr>
<td>Nickel chloride</td>
<td>40g/l</td>
</tr>
<tr>
<td>Boric acid</td>
<td>25g/l</td>
</tr>
<tr>
<td>Nickel carbonate</td>
<td>5g/l</td>
</tr>
<tr>
<td>Nickel hydroxide</td>
<td>5g/l</td>
</tr>
</tbody>
</table>

These conditions cause the nickel layer to be deposited 5 to 10 microns thick on the silver paste layer.

After the indicator units are formed on the base plate 2, the cover plate 3 is attached to the base plate 2 as shown in FIG. 10 by suitable cement or other means so as to form a sealed chamber between the base plate 2 and cover plate 3 which encloses the indicator units. The external leads have portions which extend beyond the cover plate 3 on the base plate 2 so that electrical connection can be made.

The base plate 2 is formed with an opening to which an exhaust tube (not shown) may be connected so as to evacuate the space between the cover plate 3 and the base plate 2 and a suitable ionizing gas may be inserted into the space between the cover plate 3 and the base plate 2 and the opening sealed by a suitable seal in a conventional manner.

FIG. 11 schematically shows the indicator tube assembly of FIG. 10 with a driving circuit. The indicator display tube of this invention operates as follows:

Assume that the number "I.8" is to be displayed. The switches S1, S2, S3 and K1 are closed to ground the cathode segments 63, 67, and 68 and an anode voltage supply switch K1 is closed to supply an anode voltage to the anode segments 51, 52 and 53 of the indicator unit 40 causing the cathode segments 63, 67 and 68 to glow to display "I.8".

Then, the switches S1, S2, S3 and K1 are opened and a switch K2 to the anodes of indicator 41 is closed together with switches S1, S2 and S4 to S8 to cause the cathode segments 61 to 67 of the indicator unit 41 to glow so that indicator 41 displays "8". Thereafter, "1." and "8" are alternately displayed by the indicator units 40 and 41. The switching speeds can be increased until the ",", "", and "8" appear to an observer to be simultaneously displayed. Electronic matrix switching means for sequentially closing switches as above are well known and will not be described.

Conventional indicator tubes which do not have the above described I/L ratio or which do not have a barrier electrode as employed in the present invention can give an incorrect message display because as the glow discharge is repeated for predetermined periods of time the inert gas, such as for example, neon or argon which is sealed in the envelope, will be ionized and the ions will diffuse through the envelope and lower the discharge initiating voltage between and cathode segments of indicator units which should not glow. Thus, when the indicator unit 40 displays "1.", the cathode segments 63, 67, and 68 of the remaining indicator units 41 to 46 are all grounded together as well as those of unit 40 and even if no anode voltage is supplied to the anode segments of the units 41 to 45, glow discharge would be produced between the anode segments 51 to 53 of unit 40 and the cathode segments 63, 67, and 68 of the other units and would produce an erroneous display such as "1.1.".

In the present invention, the barrier electrode 100 is formed so that it surrounds the indicator units 40 to 45 and is supplied, through a switch K0, with a positive voltage which is lower than a voltage supporting discharge between the anode and cathode segments and which does not exceed the discharge initiating voltage between the electrode 100 and the anode and cathode segments. For example, when a positive voltage of 175V is impressed on the anode segments 51 to 53 of the indicator unit 40, the barrier electrode 100 is supplied with a positive voltage of about 100V. Thus, positive ions produced in the vicinity of the indicator unit 40 are repelled by the positive voltage fed to the barrier electrode 100 toward the inner wall of the cover plate 3 and electrons are attached by the barrier electrode 100 and the anode segments 51 to 53 which are being energized. Thus, ions are prevented from diffusing or spreading in the envelope and hence do not cause neighboring indicator units to glow. That is, the provision of the barrier electrode effectively avoids the possibility of an incorrect display from resulting because of the diffusion of ionized ions.

In the foregoing example, the barrier electrode 100 is formed integrally over the entire area of the base plate 2 but the same effect can be obtained by forming separate barrier electrodes between adjacent indicator units.

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

I claim:
1. An indicator display tube comprising: an envelope including a transparent cover and a plate of insulating material with the edges sealed together, a plurality of indicator units arranged in line in a longitudinal direction thereof, each of said plurality of
indicator units consisting of a plurality of cathode segments and at least one anode for each indicator unit and said cathode segments being coated on said plate and said indicator units being successively energized,

the spacing between the inside surface of said transparent cover and said plate to the maximum length of the cathode segments forming a single indicator unit being between 0.05 and 0.4,

a plurality of cathode leads corresponding to the number of cathode segments and each connected to corresponding ones of said cathode segments of said indicator units and extending longitudinally of said indicator units,

a plurality of anode leads each connected to said anode of each of said indicator unit,

a plurality of first external leads connected to corresponding ones of said cathode leads and arranged in line and at right angles to said cathode leads,

a plurality of second external leads each respectively connected to one of said anode leads and lying parallel to said first external leads, and

an ionized gas sealed in said envelope.

2. A display tube according to claim 1, wherein an insulating layer having a plurality of windows is formed on said cathode leads, and a plurality of connecting means corresponding to the number of cathode segments in all indicator units connecting the corresponding cathode segments of said indicator units to respective ones of said cathode leads through said respective windows.

3. An indicator display tube comprising:

a planar layer of insulating material,

a transparent cover attached at its edges to said planar layer to form an envelope, said cover being smaller than said planar layer,

a plurality of indicator units arranged in line in a longitudinal direction thereof, said indicator units being enclosed in said envelope and each of said indicator units consisting of a plurality of cathode segments formed on said planar layer and at least one anode corresponding to said cathode segments and being successively energized,

the ratio of the spacing between the inside surface of said transparent cover and the inside surface of said planar layer to the maximum length of the cathode segments forming a single indicator unit being between 0.05 and 0.4,

a plurality of cathode leads corresponding to the number of said cathode segments in each indicator units and disposed in said envelope, said cathode leads extending longitudinally of said indicator units,

a plurality of anode leads corresponding to the number of said anodes,

a plurality of first external leads connected to corresponding ones of said cathode leads and arranged in line and at right angle to said cathode leads, said first external leads being formed on said planar layer and having ends extending out of said envelope,

a plurality of second external leads each respectively connected to one of said anode leads and lying parallel to said first external leads, and

an ionized gas sealed in said envelope.

4. An indicator display tube according to claim 3 wherein the ratio of the spacing between the inside surface of said transparent cover and the inside surface of said planar layer to the maximum length of the cathode segments forming a single indicator unit being between 0.05 and 0.25.

5. An indicator display tube according to claim 3 wherein the ratio of the spacing between the inside surface of said transparent cover and the inside surface of said planar layer to the maximum length of the cathode segments forming a single indicator unit being between 0.28 and 0.4.