# United States Patent [19]

**Stone et al.**

[11] **3,898,498**

[45] **Aug. 5, 1975**


[54] **CHANNEL MULTIPLIER HAVING NON-REFLECTIVE AMORPHOUS ALUMINUM LAYER OBTURATING CHANNEL ENTRANCES ON SIDE FACING PHOTOCATHODE**


[75] Inventors: **Henry Dermott Stone; Iain Craig Paton Millar; David Henry Nicholls,** all of Salfords, near Redhill, England

[73] Assignee: **U.S. Philips Corporation,** New York, N.Y.



[22] Filed: **Jan. 14, 1974**

[21] Appl. No.: **433,534**

[30] **Foreign Application Priority Data**

Jan. 18, 1973 United Kingdom..... 2678/73

[52] **U.S. Cl.**..... **313/95;** 313/105 X

[51] **Int. Cl.**... **H01j 39/02;** H01j 43/22; H01j 39/14

[58] **Field of Search**..... 313/95, 105 CM



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,243,626 | 3/1966 | Helvy et al. | 313/95 |
| 3,585,433 | 6/1971 | O'Keefe et al. | 313/94 |
| 3,603,832 | 9/1971 | Manley et al. | 313/95 |



*Primary Examiner*—Robert Segal

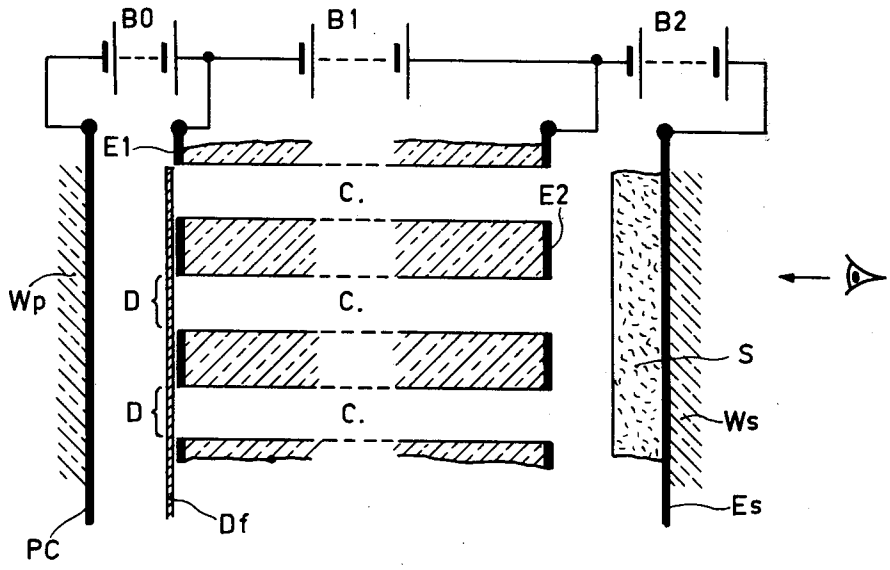
*Attorney, Agent, or Firm*—Frank R. Trifari; Ronald L. Drumheller



[57] **ABSTRACT**

An improved non-reflective input electrode membrane for a channel plate electron multiplier comprising a layer of reflective aluminum on the side facing the channel plate and a layer of non-reflective amorphous aluminum on the other side.


**3 Claims, 4 Drawing Figures**



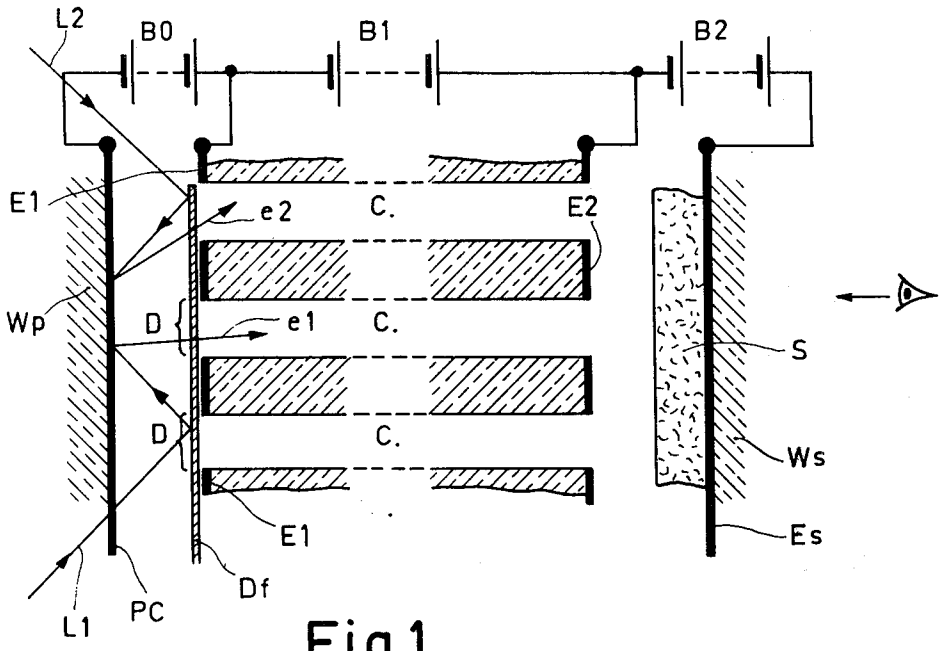



Fig.1

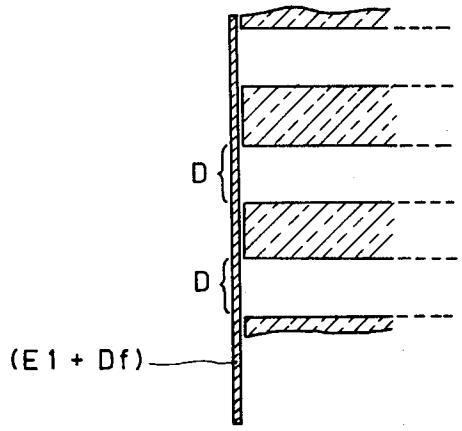



Fig.4

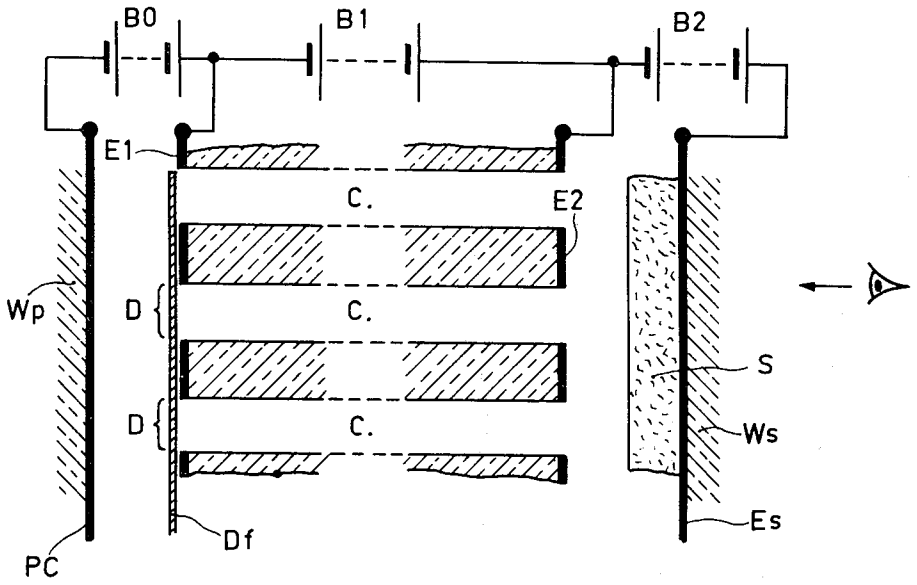



Fig.2

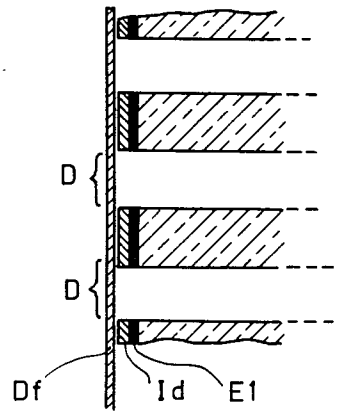



Fig.3

# CHANNEL MULTIPLIER HAVING NON-REFLECTIVE AMORPHOUS ALUMINUM LAYER OBTURATING CHANNEL ENTRANCES ON SIDE FACING PHOTOCATHODE

This invention relates to electron multipliers and more particularly to electron multipliers of the channel plate type. The invention is applicable to channel plates for use in electronic imaging and display applications.

The type of device now known as a "channel plate" is a secondary-emissive electron-multiplier device comprising a matrix in the form of a plate having a large number of elongate channels passing through its thickness, said plate having a first conductive layer on its input face and a separate second conductive layer on its output face to act respectively as input and output electrodes.

Secondary-emissive intensifier devices of this character are described, for example, in Patent specification No. 1,064,073 (PHB 31172), No. 1,064,074 (PHB 31173), No. 1,064,076 (PHB 31184), No. 1,090,406 (PHB 31211) and No. 1,154,515 (PHB 31754), while methods of manufacture are described in Patent specification No. 1,064,072 (PHB 31171 Comb.) and No. 1,064,075 (PHB 31183).

The channel plates described in these specifications can be regarded as continuous-dynode devices in that the material of the matrix is continuous (though not necessarily uniform) in the direction of thickness, i.e. the direction of the channels. In their operation a potential difference is applied between the two electrode layers of the matrix so as to set up an electric field to accelerate the electrons, which field establishes a potential gradient created by current flowing through resistive surfaces formed inside the channels or (if such channel surfaces are absent) through the bulk material of the matrix. As in all channel plates, secondary-emissive multiplication takes place in the channels.

In contrast with the present conventional continuous-dynode channel plate, plates of laminated construction have been described having a matrix formed of alternate conductor and separator layers so that the inner wall of each channel is discontinuous along its length.

One known type of laminated construction is in the form of a channel plate as herein defined wherein the matrix is formed as a sandwich of alternate insulator and conductor layers with aligned apertures providing the channels, the arrangement being such that each insulator layer is set back with respect to the preceding conductor layer in order to prevent charging of the insulator, and the conductor layers act as discrete dynodes. An alternative laminated construction is provided in co-pending British application No. 53371/71 in the form of a channel plate as herein defined wherein the matrix is formed as a laminated structure comprising alternate conductor layers and resistive separator layers with aligned apertures providing the channels. In this case the insulating separator layers have been replaced by resistive separator layers, so that the laminated channel plate structure has alternate layers of conductor and resistor.

Among earlier Patent Specifications describing channel plates there is U.S. Pat. No. 3,603,832 in which a channel plate is defined as a secondary emissive electron multiplier device for an electronic tube which device comprises a resistive matrix in the form of a plate the major surfaces of which constitute the input and output faces of matrix, a conductive layer on the input face of the matrix serving as an input electrode, a separate conductive layer on the output face of the matrix serving as an output electrode, and elongate channels each providing a passageway from one face of the assembly consisting of matrix and input and output electrodes to the otherface of said assembly.



As is explained in U.S. Pat. No. 3,603,832, there are problems of ion feedback and optical feedback in channel plates, and in some situations also a "dark spot" problem. The invention of U.S. Pat. No. 3,603,832 permits any of these problems to be overcome, and the invention provides an improvement in or modification of a channel intensifier device as therein defined including an electrically conductive membrane obturating the entrance to each channel which membrane is electron-permeable as defined and is electrically connected to the other membranes. (The term "electron permeable" is used in the sense that individual electrons can penetrate through a membrane or can produce secondary electrons within the membrane which emerge from the output side thereof).

The invention of U.S. Pat. No. 3,603,832 is applicable both to image intensifier tubes of the "proximity" type and those of the "inverter" type, the latter being the type in which the tube comprises a channel plate which is remote from the photo-cathode and an interposed electron-optical system adapted to invert the electron image. With regard to proximity tubes, it is found that proximity-focussed image intensifiers using aluminium membranes give a rather low contrast image, owing to the high reflectivity of the aluminium film. Any stray light, either transmitted by the photocathode itself, or from external sources, is reflected back by the aluminium film to the photocathode, releasing further electrons and reducing the contrast of the final image. This problem does not arise in a normal inverter-type intensifier since the electrode system required for the electron-optics shields the photocathode from any stray light reflected from the channel plate).

The present invention provides an improvement in or modification of the channel intensifier device or channel plate described in U.S. Pat. No. 3,603,832 wherein the exposed surfaces of the channel plate on its input side, including those of the conductive membranes, are non-reflective with respect to radiation of wavelengths to which the photocathode is sensitive.

Such a channel plate can provide improved contrast in an imaging tube and, for the reason previously stated, is useful mainly in image intensifier tubes or stages of the proximity type.

As in the case of the membranes of U.S. Pat. No. 3,603,832, the present membranes may be formed as a continuous layer which is superimposed on the input electrode. In such case the membrane layer may be insulated from the input electrode so as to permit it to be held at a potential different from that of said electrode. Alternatively, the membranes may be formed as extensions of the input electrode of the device so that said electrode and membranes form, together, a continuous layer.

Preferably the membranes are substantially opaque to visible radiation (and possibly other radiation such as ultra-violet) since this permits the device also to prevent or reduce optical feedback when used in a tube with a display screen. (In this connection the term "substantially opaque" is used to indicate that the membranes must be at least sufficiently opaque to

backward radiation from the display screen to prevent cumulative or runaway optical feedback in the tube). In such a tube the screen requires no metal backing and the material of the screen is chosen to emit light of wavelengths to which the membranes are substantially opaque.

As in the case of U.S. Pat. No. 3,603,832, aluminium is a preferred material for the membranes, and the embodiments described hereinafter by way of example will be given primarily in terms of aluminium films, and will include a method of rendering aluminium films non-reflective.

Referring now to the accompanying diagrammatic drawings which illustrate the embodiments,

FIG. 1 is a fragmentary enlarged showing of a small part of a channel plate according to U.S. Pat. No. 3,603,832 as applied to an image intensifier tube of the proximity type;

FIG. 2 is a similar view of a channel plate according to the present invention with non-reflective membranes;

FIG. 3 shows a variant of the channel plate of FIG. 2 wherein the membrane film is spaced from the input electrode by an insulating layer; and

FIG. 4 shows an arrangement in which the membranes D are formed as extensions of the input electrode of the device so that said electrode and membranes form together, a continuous layer.

The problem referred to in the preamble will now be explained more fully with reference to FIG. 1 of the drawings which shows a small part of a channel plate (with its channels C, input electrode E1 and output electrode E2) and a part of a co-operating display screen S. The screen may be of known type laid on a plain glass or fibre-optic windows Ws which may form part of an evacuated envelope. The screen comprises a layer of phosphor S with a conductive layer Es on the window side (this replaces the more usual metal backing layer). The arrangement is of the proximity type and therefore includes a photocathode layer PC close to the input face of the channel plate (such layer may be on an input window Wp which may also form part of the envelope).

H.T. sources Bo-B2-B2 are shown schematically for applying the required electron-acceleration voltages to layers PC-E1-E2-Es in known manner.

In accordance with the parent Patent Specification, a metal film Df provides membranes or diaphragms D which are shown obturating the entrances to the channels C. Such membranes are of conductive material (e.g. aluminium) and may be formed as a continuous layer of film Df which is superimposed on the input electrode E1 of the channel intensifier device as shown.

The reflection problem described in the preamble is illustrated by a light ray L1 which traverses the PC layer while failing to cause photo-emission, is reflected by the layer Df back to the PC layer and then causes emission of an unwanted photo-electron *e*1. A similar effect can be caused by a ray of stray light L2 entering from the periphery of the tube and causing emission of a photo-electron *e*2.

FIG. 2 shows a construction according to the present invention which may be identical with the arrangement of FIG. 1 except for having a non-reflective surface on the input face of the layer Df.

The membrane layer Df may be in contact with E1 as shown in FIG. 2 or it may be insulated from the input electrode E1 so as to permit it to be held at a potential different from that of said electrode, the latter alternative being illustrated by an insulating layer Id in FIG. 3.

As a further alternative, the membranes may be formed as extensions of the input electrode of the device so that said electrode and membranes form, together, a continuous layer, and this is illustrated by the combined layer (E1 + Df) shown in FIG. 4.

The membranes D can be made as separate elements with their edges in electrical contact with the input electrode, in which case it must be ensured that the input electrode is also non-reflective. However, the use of a continuous layer or film Df permits easier manufacture, which can be carried out in two stages, the first stage providing a first self-supporting layer or film of aluminium which is crystalline (and therefore reflective) and the second stage providing a second layer of aluminium which covers the first and is amorphous and therefore non-reflective or "black." The second layer would not be self-supporting but it relies on the support of the first layer. The first layer can be formed by known methods or, for example, by methods described in U.S. Pat. No. 3,781,979. Examples of the formation of the first layer will now be given.

First, a lacquer film is formed by known methods, for example flotation on water. Said film is then placed over the input face of a matrix which already has a separate input electrode as in FIGS. 2 or 3. Then aluminium is evaporated on to the film in vacuo in crystalline form.

As an alternative applicable to FIG. 4, the film is formed on a substrate (e.g. glass) from which it can be later released in known manner. Aluminium is then evaporated on to the film. The film is then released from the substrate and placed on the channel plate matrix with the aluminium side out of contact with the matrix.

If the matrix is of glass and the necessary low degree of conductivity has been, or is to be obtained by reduction of a metal (e.g. lead) compound in the glass, then the above process requires special measures since the final baking (after the second layer has been formed) is done in air or oxygen. In particular, the reduction can be repeated a second time after the baking, or it can be postponed until after the baking.

To minimise electron absorption this first or "shiny" layer should be as thin as possible, but not so thin as to lose its strength. We found the correct thickness to be around 200 A (this was measured during deposition of the layer using a Film Thickness Monitor).

In the second manufacturing stage the aluminium film is made non-reflecting in accordance with the present invention and, in this example, this is done by evaporating an amorphous layer of aluminium on the normal shiny aluminium film. To change the action of the evaporation process from crystalline to amorphous deposition an inert gas is now introduced so that the gas molecules cause sufficient collisions with the aluminium atoms to prevent the latter from being deposited in an orderly manner. For example, nitrogen (ordinary industrial grade is good enough) can be introduced into the system to a pressure of 0.05 torr and the further quantity of aluminium will then be evaporated in amorphous form.

After the deposition of the first and second layers has been completed, the channel plate is baked (in known manner) so as to burn off the lacquer and leave an alu-

minium film in contact with the electrode E1 (FIG. 2) or prepared insulating layer formed on E1 (as layer Id of FIG. 3).

The amount of amorphous aluminium to be evaporated is best determined visually by observing the reflection of the glowing filament from the channel plate. This extra layer should have minimum thickness consistent with the required light absorbing properties since it appears to be rather effective in stopping incident electrons. X-ray channel image intensifiers of the proximity type using black aluminsed channel plates have generally had to be operated with Bo (photocathode-channel-plate input) voltages of around 4 kV, and in such a tube the effect of this aluminising process was to increase the contrast at 1 cycle/cm from 60 percent to 80 percent.

The effectiveness of the black layer of aluminium can be seen from the results of an experiment measuring the reflectivity of various channel plates. An ordinary aluminised channel plate reflected 65 percent of incident light whilst a black-aluminsed channel plate reflected only 3 percent. This is comparable with a non-aluminised channel plate, which reflected 2 percent of incident light.

As a summary relating to the preferred film thickness values, the amorphous layer preferably has a thickness which lies between that of the self-supporting film and a value five times the thickness of the film. In a particular preferred case the thickness of said film is about 200A and that of the amorphous layer is between 300A and 800A.

As a practical example given by way of illustration a channel plate according to FIG. 2 may have substantially the following dimensions and values:-

TABLE

| | | |
|---|---|---|
| Plate diameter | = | 124 mm |
| Channel diameter | = | 100 $\mu$ |
| Channel pitch (distance between channel centres) | = | 125 $\mu$ |
| Electrodes E1-E2 | = | Nichrome (Trade Mark) evaporated at a grazing angle |
| Film Df | = | Aluminium 500–1000 angstroms thick |

Although shown as continuous-dynode structures and described as having continuous glass matrices, the channel plates of FIGS. 2 to 4 can be replaced by laminated structures such as those referred to in the preamble (typically alternate metal and glass layers) without affecting the formation and function of the aluminium films Df.

What we claim is:

**1.** In a channel plate image intensifier device of the type wherein a photocathode closely faces the input side of a channel plate electron multiplier, said input side having an electron permeable input electrode membrane obturating the entrances to the channels of said channel plate electron multiplier, the improvement wherein said input electrode membrane comprises a layer of reflective aluminum facing said channels and a layer of non-reflective amorphous aluminum facing said photocathode.

**2.** In a channel plate image intensifier device, the improvement defined in claim **1** wherein said layer of non-reflective amorphous aluminum is thicker than but not more than five times thicker than said layer of reflective aluminum.

**3.** In a channel plate image intensifier device, the improvement defined in claim **2** wherein the thickness of said layer of reflective aluminum is approximately 200 angstroms and the thickness of said layer of non-reflective amorphous aluminum is between 300 angstroms and 800 angstroms.

* * * * *