June 20, 1967 J. ADAMS ET AL 3,327,151

LIGHT AMPLIFIER EMPLOYING AN ELECTRON MULTIPLYING ELECTRODE WHICH SUPPORTS A PHOTOCATHODE

Filed Aug. 19, 1964 2 Sheets-Sheet 1

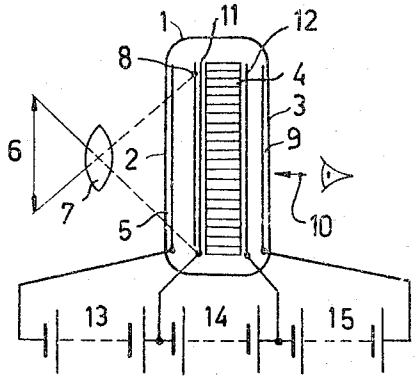


FIG.1

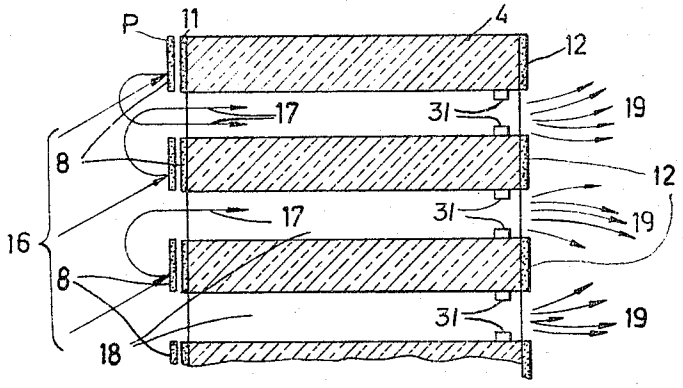


FIG.2

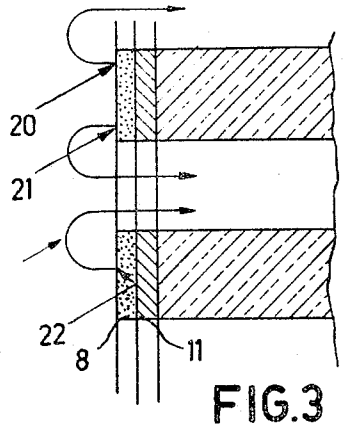


FIG.3

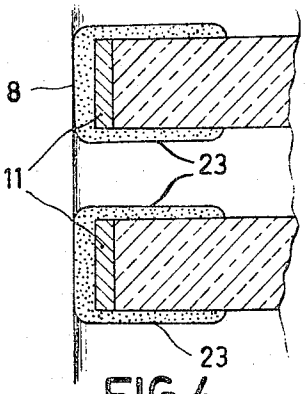


FIG.4

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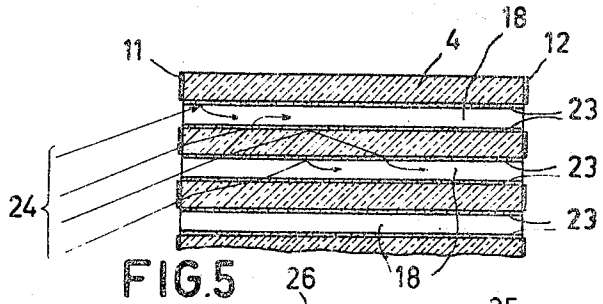


FIG.5

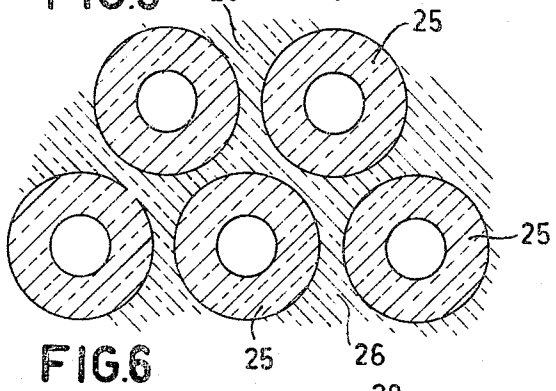


FIG.6

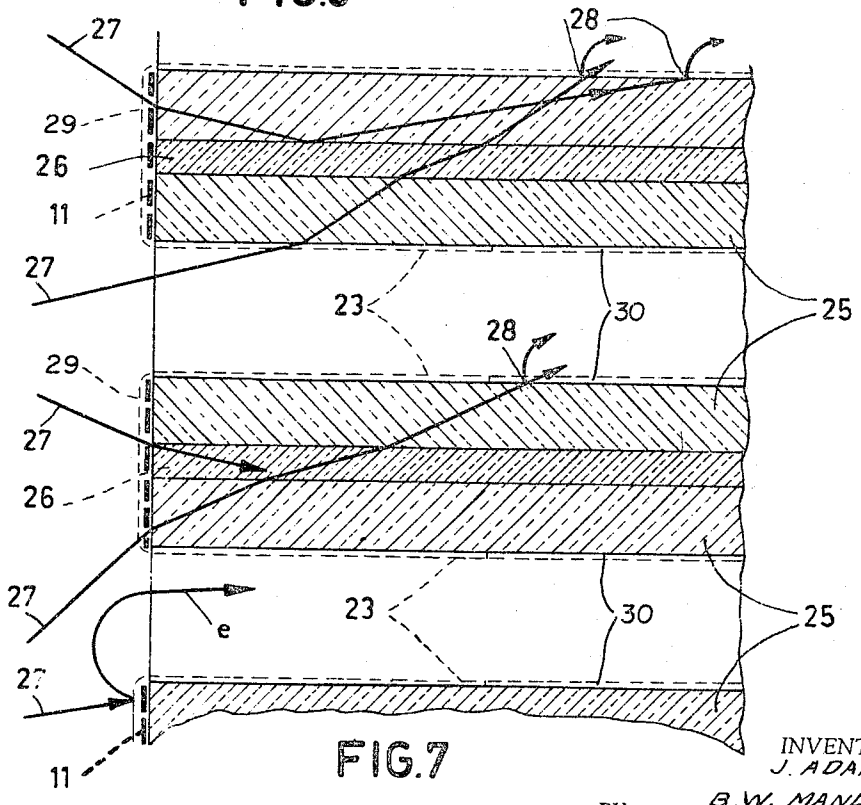


FIG.7

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LIGHT AMPLIFIER EMPLOYING AN ELECTRON MULTIPLYING ELECTRODE WHICH SUPPORTS A PHOTOCATHODE

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5 Claims. (Cl. 313—95)

The invention relates to an electron multiplying electrode for use in an electronic image converter and to an electronic picture tube comprising such an electrode.

An electron multiplying electrode, which serves for intensifying the flow of electrons passing from the electron source, for example a photo-electric cathode to a target screen of luminescent material, is formed by a thin plate of glass or a similar material of high electrical resistance, said plate being coated on either side with conducting faces and provided with a network of closely adjacent, narrow channels extending between the two faces. The electron multiplication takes place in the channels and is produced by an increase in electron velocity and secondary emission at places where the electrons strike the walls inside the channels. The secondary-emission intensification may be furthered by coating the inner faces with secondary-emission material.

In a cathode-ray tube for image conversion or image intensification such an electron multiplying electrode is employed in conjunction with an electron emitting cathode arranged at a short distance from and parallel to said electrode, while the photo-electrically emissive surface is applied to the wall of the tube or to a separate support. During the manufacture of the tube this arrangement is obtained by the separate formation of the photo-electric cathode to be applied to the wall inside the tube or to a support arranged afterwards in the tube. The invention has for its object to provide an improvement which involves an appreciable simplification of the operational phases required for the manufacture of such an image converter. According to the invention the electron multiplying electrode is at the same time the support of the photo-electric cathode, one of the side faces on the side facing the source of rays, the inner faces of the channels or both a side face and the inner faces of the electron multiplying electrode. Various embodiments are possible in which an effective conversion of incident rays into photo-emission is obtained; the details thereof will be described more fully with reference to the following description of the figures.

In the drawing:

FIG. 1 shows an electronic image converter comprising an electron multiplying electrode according to the invention,

FIG. 2 shows a further detail of said electrode,

FIG. 3 shows the coating of an external face with the photo-electric cathode.

FIG. 4 shows the photo-electric cathode applied to the inner faces of the channels,

FIG. 5 shows the photo-electric cathode applied to one side and to part of the inner faces of the channels,

FIG. 6 shows diagrammatically an electrode body consisting of an assembly of glass tubes,

FIG. 7 shows a number of light rays and their course upon reflection.

The drastically simplified model of an electronic image converter of the kind shown in FIG. 1 comprises an envelope, usually made of glass and having two flat head faces 2 and 3. This envelope bounds an evacuated space,

in which the electron multiplying electrode 4 is arranged. The head face 2 of the envelope is coated with a conducting layer 5 which is pervious to rays of visible and invisible light and other image-producing radiation. The rays from the object 6 are concentrated by the lens 7 and projected onto the side wall 8 of the electrode 4.

The other head face 3 of the envelope 1 is coated with a phosphor screen 9, in which electron energy is converted into luminescent light which can be perceived from the outside; this is indicated by the arrow 10.

The central part of the tube is occupied by the electron multiplying electrode 4, which is covered on both sides with metal coatings 11 and 12.

A voltage source 13 provides a higher potential for the coating 11 than that of the conducting layer 5 on the wall 2 of the envelope 1 and the voltage source 14 applies a higher potential to the coating 12. Between the coating 12 and a transparent, conducting substratum of the phosphor screen 9 there is arranged a voltage source 15.

In the embodiment shown in FIG. 2 the conducting coating 11 is covered by a photo-electric cathode 8. The photo-cathode 8 is formed by a homogeneous layer covering the surface 11 with the exception of the apertures of the coating 11, leading to the channels in the body of the electrode. The photo-electrons released when a light image is projected onto the photo-cathode emerge from the cathode surface in a direction away from the channels. On this side an electric field is directed to the photo-cathode 8, so that the electrons are deflected in the direction towards the channels. The field distribution at the inlets of the channels due to the electric voltage between the coatings 11 and 12 may be more or less sufficient for the electron paths to be deflected and in this case, if desired, the conducting layer 5 on the wall 2 and the voltage source 13 may be omitted. The drawing shows paths 17 for some of the electrons released by the incidence of the radiation 16. The electron multiplication in the channels 18 is indicated by the emerging beams of arrows 19.

The directional field at the inlets of the channels is not effective, when the inner faces of the channels are coated with photo-electric cathode material, as is shown in FIG. 5. Such a field and the conducting layer 5 with the voltage source 13 may then be dispensed with.

A photo-electric cathode covering, at least partly, both the side face 11 and the inner faces of the channels (see FIG. 4) will be explained more fully hereinafter.

A few insights may be derived from the photo-electric emission phenomena which are important for the way in which a major part of the incident rays is converted into photo-electrons. The conversion of light into photo-electric emission requires that when the light rays penetrate into a photo-electric layer photo-electrons are released. Most in use are photo-cathodes which emit on the side where the light emerges and which are applied to a transparent glass support. They have a thickness of a few hundred Angstroms. Such a photo-cathode has a quantum yield of about 10% so that many light rays leave the photo-cathode without effect. An increase in light absorption by enlarging the thickness of the layer provides little advantage since fewer electrons reach the surface with sufficient energy for emerging. A higher quantum yield can be achieved when rays penetrating into the photo-cathode are reflected and thus re-enter the inlet surface. The rays 20 and 21 of FIG. 3 release photo-electrons at the inlet surface. The light ray 22 has the same effect, but it has passed through the photo-electric layer 8 twice owning to the reflection at the surface of the conducting layer 11, which is applied to the photo-cathode material.

An increase in efficiency is furthermore obtained by enlarging the photo-cathode surface into the channel apertures as is shown in FIG. 4. Part of the incident light

gets lost in the channels and the walls thereof are also struck by a quantity of rays, which are incident in an oblique direction, which applies to almost all rays focused by a lens. A partial coating of the inner faces of the channels by a photo-cathode **23** raises the photo-electric emission to a considerable extent.

An important increase in photo-electric efficiency may be obtained by raising the number of reflections. Light rays leaving the photo-cathode after reflection on the support surface of the photo-cathode, i.e. at the surface of the conducting layer **11** get lost, but certain steps may be taken to reduce said loss of light. This will be explained with reference to FIG. 5.

In this embodiment the light incident on the front side propagates in the supporting body of the multiplying electrode. In order to reach said body, the conducting layer **11** on the inlet side must be transparent. The effect of a photo-cathode on this side, intensified by reflection on the conducting layer, thus gets lost. On the contrary, all passing light rays may contribute to the formation of photo-electric emission. To this end the supporting body **4** is made of transparent material, while the walls of the channels **18** are coated throughout their length with a photo-electric layer **23**, At all places where said layer is struck by light rays photo-emission may occur. The paths **24** of light rays shown in the figures are reflected once or several times.

An increase in the said number of reflections per light ray brings about stray reflections and loss of light due to absorption in the supporting material. The head face where the channels **18** open out may be provided with a reflecting, conducting layer **12**, so that light rays having passed through the support are reflected and the path of photo-electric emission is prolonged, but in this case the stray reflections should preferably be restricted to a given extent. This result is obtained by a given method of manufacture of the support provided with the channels **18**. FIG. 6 shows the assembly of separate glass tubes **25**, each forming one channel of the support and being fused together with the aid of low-melting-point glass **26**. FIG. 7 shows this layer between the walls of the channels **18**; a few lines **27** indicate the course of light rays penetrating into the material at different places and from different directions. The conducting coating **11** on the side of the incident light is transparent; it is indicated by a broken line. The broken line **29** indicates the coating of photo-electric cathode material in the channels **18** and at the inlet surface **11**.

The intermediate glass **26** may be opaque, but this is not conductive for the increase in light efficiency of the photo-cathode part by reflection. If the intermediate glass is transparent, the efficiency may be raised by a suitable choice of the refractive indices of the two kinds of glass.

When the refractive index of the glass **26** is higher than that of the glass **25** of the tubes, light rays entering the face **11** will be reflected on the intermediate layers and cannot leave the intermediate glass, so that they do not contribute to the photo-emission. The refractive index of the intermediate glass **26** should therefore preferably be lower than that of the glass **25** of the tubes. This can be achieved particularly when the photo-cathode layer is provided throughout the length of the channels and serves, at the same time, as a resistance layer, so that the internal resistance of the tube material need not fulfill particular requirements in view of a uniform voltage distribution along the wall.

In the foregoing the increase in photo-electric efficiency is emphasized with the increase in electron multiplication by secondary emission. In each of the channels electrons released by photo-emission are accelerated in the direction of the outlets under the action of the electric field between the conducting coatings on the two head faces of the support, the lines of force of which are substantially parallel to the axes of the channels and they describe zigzag paths where the electrons strike places

28 on the inner surfaces, while secondary emission is produced. When the inner surfaces are partly coated with photo-electric material **23**, the further part thereof is coated with secondary-emissive material **30**. The increase in photo-electric efficiency is attained for the major part by the partial coating of the channel walls on the inlet side of the electrons extending over about 20% of the length of the channels.

The aforesaid electron multiplying electrodes may be manufactured by using a support provided with channels and made from a kind of glass containing a comparatively high quality of lead (about 40% to 50% by weight). The conducting layer on the inlet side may be obtained by vapor-deposition of tin sulphide at a small angle to the surface so that hardly any material is deposited in the apertures.

On the outlet side chromium may be deposited on the surface. The vapor-deposition may be carried out at a small angle to the surface. If this angle is sufficiently large, a narrow collar **31** (see FIG. 2) of metal is formed in the apertures along the edges, which collar terminates in an uninterrupted coating when the vapor of source of metal vapor is turned around an axis at right angles to the center of the support.

Then by heating in air at a temperature just below the softening temperature of the glass the tin sulphide is converted into tin oxide.

After the conducting layers have been applied, the first operation for applying the photo-electric cathode layer is carried out. Antimony is evaporated from a source which is arranged at an angle to the axis at right angles to the surface in the center of the support on the inlet side, which angle is chosen so that the jet of vapor covers not only the surface but also penetrates into the channels down to a given depth, for example over 20% of the length of the channels.

The required activation of the antimony with caesium is performed in vacuo and to this end the support is arranged in an envelope.

Inside the envelope caesium is evaporated so that not only the antimony is activated to an effective photo-electric cathode but also so far uncoated parts of the channel walls are coated with caesium, said coating forming a layer of high electrical resistance, whereas the conductivity is sufficient for furthering a uniform potential distribution along the surfaces, when electric voltage is applied to the conducting coatings on the inlet side and on the outlet side of the support. The caesium deposit on the glass of the walls has an adequate secondary-emission coefficient.

Such electron multiplying electrodes are intended for use in image converters and image intensifiers or as the image transformating part in television camera tubes. Other uses are found in which the requirements for image point definition are less severe or a smaller number of channels is required, for example with light amplifiers and electron tubes in which only one channel suffices, for example photo-cells, photo-multiplying tubes and the like.

What is claimed is:

1. In a light amplifier, the combination of a photo-cathode and an electron multiplying electrode, said electron multiplying electrode constituting a support for the photo-cathode and comprising a thin plate-like member of insulating material having a plurality of closely adjacent narrow channels, said channels being coated with secondary emissive material and extending between opposite faces of said member, and an electrically conducting material covering the opposite faces of the plate-like member except for the apertures therein corresponding to the channels, said photo-cathode being constituted of a photo-electric cathode material covering said conducting material on one of said faces of said plate-like member and exposed to incident light.

2. An electrode as claimed in claim 1, wherein the photo-electric cathode covers one face of said plate-like member and part of the length of the inner surfaces of the channels.

3. An electrode as claimed in claim 1, in which the conducting layer covers the face of the plate-like member oriented towards the source of incident light and has a light reflecting surface on the side coated by the photo-electric cathode material.

4. An electrode as claimed in claim 1, wherein the support material is transparent to light.

5. An electrode as claimed in claim 4, wherein the support body is made of a plurality of glass tubes, which are interconnected by an intermediate material having a lower refractive index.

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