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(54) **Channel plate electron multipliers.**

(57) In channel plate electron multipliers 13 having continuous channel dynodes 20 extending between input, 12, and output, 14, faces of the plate, a conducting electrode 22 is required on these faces to make reliable connection to the secondary emitting layer inside each channel. By evaporating the metallic electrode onto the faces at an angle to the channel, the electrode metal penetrates a small distance into each channel, ensuring a good connection. On the input face, incoming electrons can then land on metal of poor electron emissivity, degrading the multiplier signal-to-noise ratio at the input stage of the multiplication process. In accordance with the invention, the penetration depth is a minimum on channel wall parts facing a predetermined direction 26 in the input face so that incoming electrons arriving at an angle to the channel axes at that face from that direction land on unobscured secondary emitting surface.

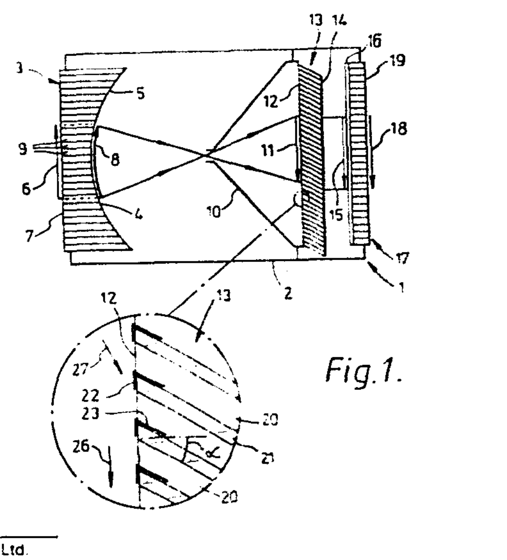

Fig.1.

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Croydon Printing Company Ltd.

CHANNEL PLATE ELECTRON MULTIPLIERS

This invention relates to electron multipliers and more particularly to channel plate electron multiplers having continuous channel dynodes extending between input and output faces of the plate, and now referred to as channel plates. Such channel plates are used in electronic image intensifier tubes where they are used to provide the major part of the image intensification.

A channel plate requires conducting electrodes on both the input and output faces of the plate. These electrodes must provide a reliable connection to the high resistance secondary emitting layer on the inside wall of each channel. A voltage can then be applied, via the electrodes, to all channels and a potential gradient established along the channels, needed for electron multiplication by secondary emission. Conventionally these electrodes are prepared by vacuum evaporation of a suitable conducting material, for example nichrome, onto each face. To ensure reliable connection to each channel, the geometry of the evaporation apparatus is generally arranged so that the electrode material penetrates a small distance into the channels. This arrangement also ensures that the secondary emitting layer deep within the channel is not contaminated by electrode material, which could occur if the evaporation source were positioned on the axis of the channels. Conventional practice has been to rotate the channel plate about the channel axis during evaporation from an off-axis source to produce a substantially uniform depth of penetration of the electrode material down all parts of the wall of each channel. Typically the direction of evaporation is chosen to be about 45 degrees so that the penetration depth is about one channel diameter.

Such channel plates and image intensifiers are described in British Patent Specification 1,164,894 in which a diode inverter intensifier is described in which an electron optical image inverting stage is placed between a photocathode and the channel plate.

In such an image intensifier the channel plate is a plane parallel-sided slab set normal to the intensifier axis. The electron optical design of the inverter between the photocathode, which receives the input light image, and the input face of the channel plate, which receives the input image converted to photoelectrons, is such that the angle at which the primary photoelectrons land on the channel plate varies as a function of position across the input face of the channel plate. If the channels were normal to the input face, a significant proportion of the photoelectrons would penetrate far down the channels near the plate centre before they struck the channel walls and would not then be multiplied by secondary emission to the same extent had they struck the walls near the channel entrance. The gain provided by the channel plate for these electrons would be reduced. This effect would be more pronounced near the intensifier axis since the input electrons are there more nearly parallel to this axis and the intensified image would have a "black spot" in the centre. In some channel plate intensifiers this effect is avoided by placing a thin electron-scattering membrane over the input face of the plate so that most incoming electrons are deflected onto the channel walls near the entrance. Such a membrane might also be used to stop positive ions migrating back along the channels to the photocathode and degrading its sensitivity. However, such a membrane absorbs some electrons and for best sensitivity it is not desirable.

If a scattering membrane is not used, the "black spot" can be avoided by cutting the channel plate so that the channels at the input face are at a bias angle to that face as described in British Patent Specification 1,164,894. The incoming primary electrons then strike the channel walls near the entrance of each channel. However, if the penetration depth of the electrode material is substantially one channel diameter all around each channel entrance, a substantial proportion of the incoming primary electrons will strike channel walls where the secondary emissive layer is masked by the electrode material and will produce considerably fewer secondary electrons or none at all. The mere loss of channel gain which then occurs could be restored by increasing the voltage applied to the channel plate. But the loss in signal-to-noise ratio which also occurs thereby at the input face cannot be restored by a gain increase. This loss reduces the reliability with which low contrast targets can be detected at low levels of scene illumination.

The problem of obtaining early electron collisons with the channel walls is also discussed in British Patent Specification No. 1,154,515. Therein the beneficial effects of tilting the channels or of having asymmetrical penetration of the electrode material around the inside of each channel entrance are mentioned. However, in this specification this problem is discussed in relation to a proximity image intensifier in which the photocathode is in extremely close proximity to the input face of the channel plate. In this case the accelerating field in front of the photocathode tends to direct the electrons into the channels in a direction more or less parallel to the axes of the channels. Consequently there is a tendency for the electrons to fail to strike the channel walls at an early stage, so reducing the total multiplication available from a given channel length. However, the incoming electrons are not necessarily lost and the input signal-to-noise ratio need not suffer on this account. In particular, input electrode material on the inside walls of the input ends of the channels does not absorb electrons since most incoming electrons are well past the input end before they strike the channel wall. This remains true in spite of measures taken in British Patent Specification 1,154,515 to get earlier collisons, that is to say, tilting the channels relative to the plate input face and having asymmetrical penetration of the electrode material on channel entrances to give a deflecting lens effect. This is because, as stated above, the initial energy of the electrons is low and their paths are controlled predominantly by the electric field configuration in the input region. In this connection it is to be noted that the channels may be tilted for another reason set out in British Patent Specification 1,064,073. The effect of tilting is to reduce the strong dependence of channel gain on the length-to-diameter ratio of a channel by confining multiplication to one side of the channel and making the position of the opposite wall unimportant. The uniformity of channel gains is thereby improved.

However; the channel input conditions in an intensifier tube having a diode inverter stage before the channel plate or in a proximity tube with a finite gap which necessitates a relatively high voltage between the photocathode and the channel plate input to limit sideways spreading of the image, are very different. In consequence of this higher input energy there is little lens effect at the channel entrance and the incoming electrons are little deflected as they enter the channels.

A proportion of the incoming electrons therefore strike the channel walls immediately inside the end of the channels masked by the electrode material and are lost by absorption.

It is an object of the invention to reduce the loss in signal-to-noise ratio which thereby occurs at the channel inputs. To this end, the invention provides a channel plate secondary electron multiplier comprising, continuous dynode channels extending from an input face to an output face of the plate, and first and second conductive layers on the input and output faces forming the plate input and output electrodes respectively, said first layer penetrating inside the channel walls to a depth not substantially greater than the channel width and which depth varies as a function of position around the wall of each channel, characterised in that the penetration depth is substantially zero on wall parts facing a predetermined direction in the input face so that electrons arriving at said input face at an angle to the channel axes at said face and from said predetermined direction land upon channel wall parts having a minimum area of secondary emitting surface obscured by said conductive layer.

Preferably the axes of the channels at the input face are inclined at a common bias angle to the normal to the input face, said predetermined direction being the direction in which the angle between the channel axes and the input face is least.

The invention also provides an electronic imaging tube comprising, in order from the image input, a photocathode, an electron optical image inverting stage, a channel plate secondary electron multiplier comprising continuous dynode channels extending from an input face to an output face of the plate, first and second conductive layers on the input and output faces forming the plate input and output electrodes respectively, said first layer penetrating inside the channel walls to a depth not substantially greater than the channel width and which depth varies as a function of position around the wall of each channel characterised in that the penetration depth is substantially zero on wall parts facing a predetermined direction in the input face and in that the axes of the channels at the input face are inclined at a common bias angle to the input face, said predetermined direction being the direction in which the angle between the channel axes and the input face is least so that electrons arriving at said input face from the electron optical image inverting stage land upon channel wall parts having a minimum area of secondary emitting surface obscured by said conducting layer.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawing in which:-

Figure 1 shows a schematic section of a micro-channel plate image intensifier incorporating a channel plate electron multiplier in accordance with the invention, and

Figure 2 shows a sectional view of the input ends of the channels of a channel plate in accordance with the invention.

Referring to Figure 1, a micro-channel plate image intensifier 1 is shown in schematic cross-section. A vacuum envelope 2 has a fibre optic input window 3 having a semi-transparent photoemissive layer 4 upon its interior surface 5. An optical image 6, focused upon the exterior surface 7, is transferred by the optical fibres 9 to the interior surface 5 and to the photoemissive layer 4 where it gives rise to an electron image 8. A focusing anode 10, held at a suitable positive potential with respect to layer 4, for example 2kV, forms an inverted electron image 11 on the input face 12 of a micro-channel electron multiplier plate 13. The axes of the channels 20 are inclined at a common bias angle to the normal to input face 12. The output face 14 of plate 13 is held at a positive potential of 200 to 1000 volts, depending on the gain required, with respect to input face 12. An intensified electron image 15 is proximity-focused onto a luminescent phosphor screen 16 on the interior surface of a fibre optic output window 17, which transfers a visible image 18 to the exterior surface 19 where it may be viewed with an eyepiece (not shown). Such micro-channel plate image intensifiers are available commercially, for example Mullard (Trade Mark) Type No. XX1500, and will not be further described herein.

The magnified insert in Figure 1 shows a section of the channels 20 inclined at a common bias angle α, typically 14.5 degrees, to the normal to the input face 12. The channel walls 21 are of conductive glass treated to emit secondary electrons. Such channel plates, together with methods of manufacture, are described in Patent Specification No. 1,368,753 wherein further references to the art may be found. A first conductive layer 22 of nichrome metal is laid down by vacuum evaporation from a direction 27 onto input face 12. Layer 22 penetrates down the inside of the channel walls at 23 on the sides of channel walls facing into direction 27. The opposite sides of the channel walls, facing a predetermined direction 26 in input face 12 corresponding to the evaporation direction 27, are masked by the channel ends during evaporation and the secondary emissive property of these side walls is not degraded.

Figure 2 shows in more detail the asymmetry in the penetration depth of the first conductive layer which is achieved by evaporation of the layer from direction 27. The penetration varies from a maximum 23 round to zero on the opposite wall facing the predetermined direction 26. In the plan view of the channel ends the projected area of first conductive layer layer 22 is shown as two small areas 25 obscuring a minimum area of secondary emitting surface. Incoming electrons 24 arriving normal to input face 12 will thus be incident almost entirely upon a good secondary emitter. This may be compared to a channel plate having a bias angle of 14.5 degrees and the former symmetrical penetration by one channel diameter of the conductive layer in which 30% of primary electrons arriving normal to the channel plate surface will strike the conductive electrode material. On this simple view, a 30% reduction in noise power factor is possible using the invention. In practice, a reduction in noise power factor from 3.6 to 2.95 is obtained equivalent to a 20% increase in photocathode sensitivity.

It should be noted that, with the former symmetrical penetration, the electrostatic field at the channel entrance is reduced owing to the presence of the conductive layer. In consequence the extraction field for secondary electrons is not as favourable as it would have been without the penetrating layer. With the asymmetrical penetration according to the invention, the extraction field for first secondary electrons is asymmetric and is more favourable.

If the incoming primary electrons arrive normal to the input face, or at least distributed over a small range of angles, typically $\pm 10^{\circ}$, around normal, then the channels are inclined to the input face to obtain the benefit of the invention. But if the incoming electrons arrive at an angle to the normal to the input face the channels may have zero bias angle provided that the direction of electron arrival is chosen in relation to the asymmetry of penetration so that the electrons land on the channel walls having least penetration of the conductive layer.

If the electrons arrive normally, it is only necessary that the channels have a bias angle at the input face. The channel may then be curved so that, for example, the output end of each channel is normal to the output face. In an image tube this may be desirable to avoid astigmatism in the image.

The invention is also applicable in non-imaging applications, for example in single channel electron multipliers used as electron detectors in mass spectrometers and space experiments.

CLAIMS:

1. A channel plate secondary electron multiplier comprising, continuous dynode channels extending from an input face to an output face of the plate, and first and second conductive layers on the input and output faces forming the plate input and output electrodes respectively, said first layer penetrating inside the channel walls to a depth not substantially greater than the channel width and which depth varies as a function of position around the wall of each channel, characterised in that the penetration depth is substantially zero on wall parts facing a predetermined direction in the input face so that electrons arriving at said input face at an angle to the channel axes at said face and from said predetermined direction land upon channel wall parts having a minimum area of secondary emitting surface obscured by said conductive layer.

2. A channel plate electron multiplier as claimed in Claim 1, characterised in that the axes of the channels at the input face are inclined at a common bias angle to the normal to the input face, said predetermined direction being the direction in which the angle between the channel axes and the input face is least.

3. A channel plate electron multiplier as claimed in any one of the preceding claims wherein said continuous dynode channels extend in a curve between the input and output faces.

4. An electronic imaging tube comprising, in order from the image input, a photocathode, an electron optical image inverting stage, a channel plate secondary electron multiplier comprising continuous dynode channels extending from an input face to an output face of the plate, first and second conductive layers on the input and output faces forming the plate input and output electrodes respectively, said first layer penetrating inside the channel walls to a depth not substantially greater than the channel width and which depth varies as a function of position around the wall of each channel characterised in that the penetration depth is substantially zero on wall parts facing a predetermined direction

in the input face and in that the axes of the channels at the input face are inclined at a common bias angle to the input face, said predetermined direction being the direction in which the angle between the channel axes and the input face is least so that electrons arriving at said input face from the electron optical image inverting stage land upon channel wall parts having a minimum area of secondary emitting surface obscured by said conducting layer.

5. An electronic imaging tube as claimed in Claim 5, characterised in that the continuous dynode channels extend in a curve between the input and output faces.

6. An electronic imaging tube as claimed in Claim 4 or Claim 5 in the form of an image intensifier or image converter tube comprising a luminescent viewing screen on the output side of the channel plate.

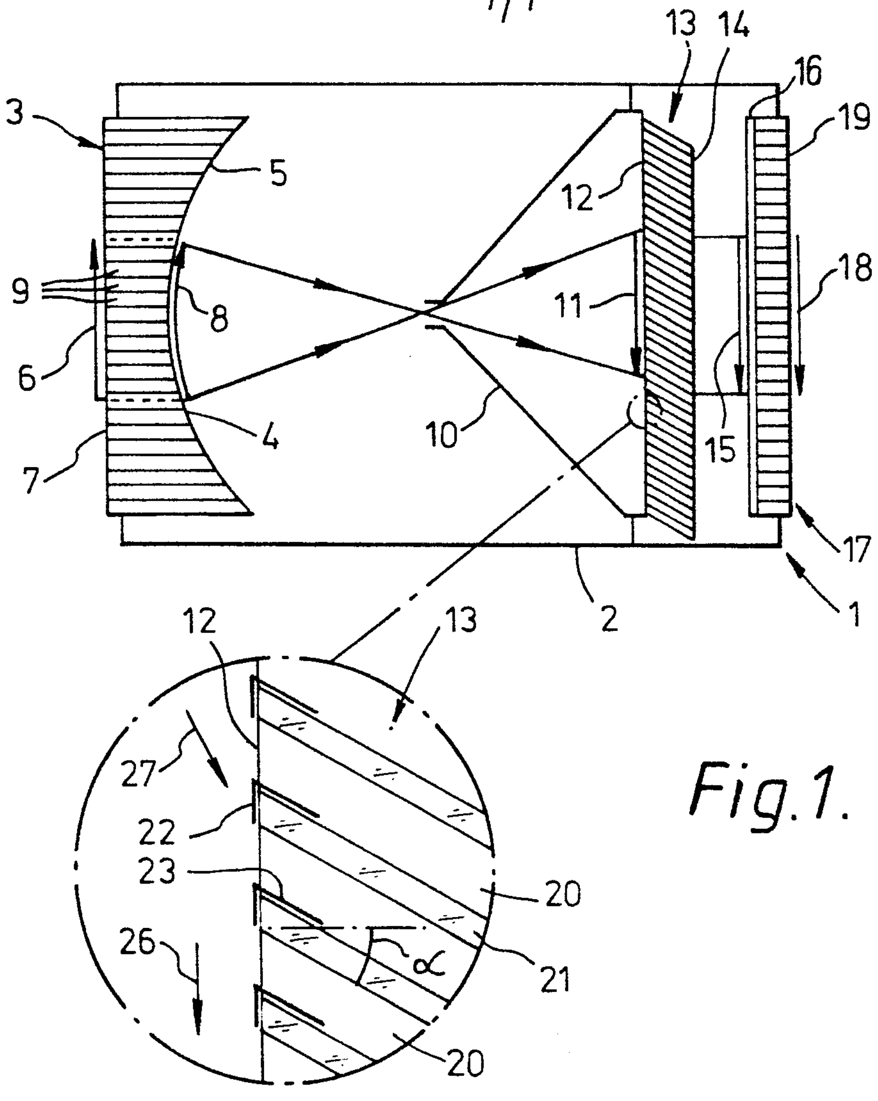
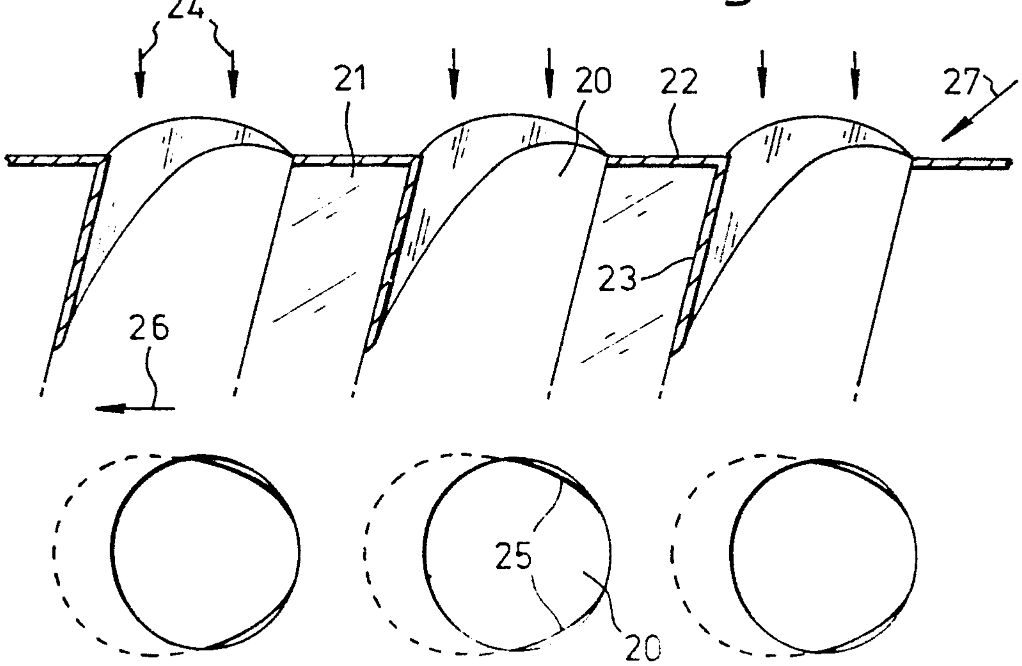


Fig.1.

Fig. 2.



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EUROPEAN SEARCH REPORT

0091170
Application number

EP 83 20 0464

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
D,A	GB-A-1 154 515 (MULLARD LTD.) * Page 3, lines 106-112; page 5, lines 5-42; figures 4,9 *	1,4	H 01 J 43/24 H 01 J 31/50
A	US-A-4 153 855 (R.M. FEINGOLD) * Column 1, lines 25-44; column 2, lines 23-37; figure 5 *	1	
A	US-A-3 974 411 (R.D. FAULKNER et al.) * Column 2, line 51 - column 3, line 24; figure 2 *	1,2	
A	ELECTRO-OPTICAL SYSTEMS DESIGN, vol. 8, no. 8, August 1976, pages 52-55, Chicago, USA J.J. STAFFORD et al.: "Designing a LLLTV camera" * Page 53, lines 1-14; figures *	4,6	

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

H 01 J 43/00
H 01 J 31/00
H 01 J 29/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13-07-1983	DAGLISH B.D.

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