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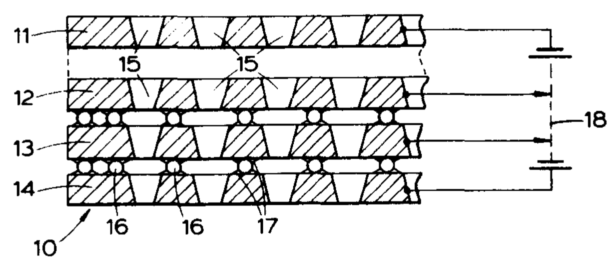
(54) Electron multipliers.

(57) An electron multiplier using a laminated channel plate assembly. The electron multiplier is usable in display tubes and image intensifiers.

A problem in channel plate electron multipliers is to space apart accurately the dynodes in a simple and inexpensive way.

In the present invention this problem is overcome by using discrete separating elements (16) such as ballotini to space apart the dynodes (11, 12, 13, 14). The elements (16) are bonded to the surface of one dynode of adjacent pairs of dynodes and is either bonded to or clamped against the other dynode of the pair.

Various methods of making the laminated channel plate assembly are disclosed.



EP 0 006 267 A1

"ELECTRON MULTIPLIERS"

The present invention relates to electron multipliers and more particularly to electron multipliers of the channel plate type which may be used in electronic imaging and display applications.

In present practice a channel plate is a secondary-emissive electron multiplier device which can be in the form of a glass 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 and a large number of channels with resistive walls passing through its thickness so that the electric field inside each channel varies uniformly along its length. The multiplier device can also be in the form of a channel plate structure comprising a plurality of discrete dynode metal channel plates in a stack, each plate being separated from the others.

Different types of channel plate structures are known for example from British Patent Specifications 1,401,969, 1,402,549 and 1,434,053. Figures 5 and 6 of British Patent Specification No. 1,402,549 disclose the use of screen printed glass dots as a means of separating adjacent channel plates of a stack. In order to bond the plates together to form a channel plate structure it is necessary partly to melt the glass dots. A problem may arise here in that accurate spacing between the channel plates may be lost due to the glass dots changing shape when partly melted. In order to avoid this problem it is proposed in that Specification to form spacing separating elements from a high melting point glass, which separating elements may be machined to an accurate thickness after application. Thereafter bonding separating elements of a low melting point glass are applied to the same surface of each channel plate as the spacing separating elements. The plates are then arranged in a stack with the channels in the plates being aligned as desired and the stack is heated to a temperature to melt partly the low melting point glass bonding elements which bond themselves to the surface of an adjacent plate. In the case of plates not made of a secondary emissive material, for example mild steel, it is to provide a secondary emissive material in each channel. The repeated heating of the plates in order to apply high melting point and low melting point glass separating elements to the plates and the heating to bond the elements to adjacent plates can affect adversely the secondary emissive material. This can have the effect that the channels do not behave uniformly over the area of the channel plate structure.

Accordingly it is an object of the present invention to space apart accurately the channel plates in a reliable and simple way.

According to one aspect of the present invention there is provided a channel plate structure comprising a stack of discrete electrically conductive dynodes separated from each other by an array of discrete separating elements distributed across the area of the channel plate, which elements are less conductive than the dynodes.

According to a second aspect of the present invention there is provided a method of manufacturing a channel plate structure, comprising applying a glass enamel to a surface of at least some of a plurality of perforate, electrically conductive dynode forming sheets, firing the glass enamel, temporarily positioning discrete separating elements on the enamelled surfaces, bonding the spherical elements to the enamelled surfaces by melting the glass enamel thereon, and arranging the sheets in a stack with the free surfaces of the spherical elements contacting a surface of an adjacent sheet.

The discrete separating elements may be spherical and comprise small glass spheres known as ballotini. The provision of the discrete elements enables a greater consistency to be achieved in the electrical characteristics of the channel plate structure and in the spacing of adjacent channel plates, otherwise known as dynodes, from each other. In the case of using ballotini as insulating separators higher values of resistance and voltage breakdown limits between adjacent dynodes, compared with screen printed glass, are obtained. By way of comparison, laboratory-made channel plates having a working area of 150 x 200 mm^2, a channel pitch of the order 0.8 mm. and a spacer thickness of the order of 0.1 gave the following typical results:

Separator	Dynode-dynode resistance	Voltage breakdown limit
Ballotini	consistently $> 10^{11}\Omega$	> 1000 Volts
Screen printed glass	variable, usually $10^5-10^9\Omega$ sometimes much lower	400 Volts(approx)

Another advantage of using discrete elements as insulating or resistive separators is that their small size means that any electrons which drop-out in passing from one dynode to the next are unlikely to land on the elements causing a negative charge to build-up, which charge will oppose the passage of further electrons through the channels. Rather any drop-out electrons are likely to land on the dynode surface which is conducting and thereby they do not cause charging.

If it is desired that the separating elements should be resistive, that is be slightly conductive, rather than insulating, the elements, such as ballotini may be made a glass containing a high lead content which when heated in a reducing atmosphere of hydrogen causes a resistive surface to be produced thereon. The resistive elements thus formed act as part of a resistor chain for biasing the dynodes.

The discrete separating elements may be arranged singly or in clusters as desired. Further they may be arranged more densely at the edge of each dynode than at the centre thereof. Such a distribution of the elements enables a greater bond strength to be given at the edges thereby minimising the risk of adjacent dynodes peeling apart and affecting adversely the uniformity in the performance of the channel plate structure. The separating elements may be arranged regularly between the channels of each dynode and where the borders of the dynodes are imperforate, the density of the elements may be much greater.

The discrete separating elements may be bonded to adjacent dynodes and thereby form an integrated stack. Alternatively the elements may be bonded to one side of a plate forming a dynode and the channel plate structure is assembled by arranging the separated dynodes as a stack which is then clamped.

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein

Figure 1 is a diagrammatic cross section through a portion of a stack of four dynodes having spherical separating elements, each dynode comprising a single,perforate electrically conductive plate of the type shown in Figure 1 of British Patent Specification No. 1,402,549,

Figure 2 is a diagrammatic cross section through a portion of a stack of four dynodes having spherical separating elements, each dynode comprising a pair of mating, perforate electrically conductive plates of the type shown in Figure 4 of British Patent Specification No. 1,434,053, and

Figure 3 is a diagrammatic sectional view of an image display tube having a channel plate structure made in accordance with the present invention.

In the interests of brevity, the description of Figures 1 and 2 will be confined to only that which is necessary to understand the present invention. For details of the fabrication of the dynodes and their various alternative arrangements of the dynodes, reference is made to British Patent Specifications Nos. 1,401,969, 1,402,549 and 1,434,053 the details of which specifications are incorporated herein by way of reference.

Figure 1 shows a channel plate structure 10 in which each of the dynodes 11, 12, 13 and 14 comprises a single, perforated metal plate. Channels 15 in the dynodes 11 to 14 converge in the direction of electron multiplication and are aligned with each other. The dynodes 11 to 14 are separated by spherical separating elements 16 in the form of ballotini which are bonded by glass enamel 17 to adjacent dynodes. By way of illustration the density of the elements 16 at the imperforate edges of the dynodes 11 to 14 is greater than in the centre thereof. Further although the elements 16 are shown positioned between each channel opening of a dynode, they could be spaced apart by integral multiples of the distance between the centres of adjacent channels 15 of a dynode.

As the illustrated separating elements 16 are electrically insulating it is necessary that each dynode be biassed separately by a power supply 18.

Figure 2 shows an alternative embodiment of a channel plate structure 10 to that shown in Figure 1. Dynodes 20 to 23 each comprise two, juxtaposed, mating perforated metal plates 25, 26 of which at least the channels 15 in the plate 26 of each dynode is secondary emissive as is illustrated diagrammaticaly by the electron multiplication of an electron beam incident in the channel of the dynode 21. The separating elements 16 comprise ballotini arranged at suitable intervals between the channels. Once again taps of the power supply 18 are connected to respective dynodes.

An example of one method for manufacturing channel plate structure of Figure 2 will now be given, which method can readily be adapted to manufacture the structure of Figure 1.

Pairs of metal plates 25, 26, for example mild steel plates, having matching arrays of convergent apertures therein are cleaned. A high yield secondary emissive surface is deposited by way of evaporation in the apertures of at least the plates 26. The plates 25, 26 are then assembled to form dynodes with the smaller diameter openings of the apertures being arranged remote from each other.

The outer surface of each pair of part-dynodes are coated with a bonding medium which at a later stage, is used to bond the ballotini to the dynodes. The bonding medium conveniently comprises a thin layer of glass enamel applied for example by screen printing or settling from a suspension. If the dynode material and the bonding medium have matching coefficients of expansion the bonding medium e.g. glass enamel may be applied all over the outer dynode surface, otherwise it should be applied locally in the form of dots which coincide with the subsequent positions of the ballotini to prevent the risk of the dynodes curling with temperature changes. The enamel is fired to a glassy state, the temperature being typically in the range 350 to 450°C. One of each adjacent pair of part-dynodes from adjacent dynodes is then coated with a sticky medium such as pine oil, the purpose of which is to hold the ballotini temporarily in place. A stencil or the other dynode plate is then placed over the sticky medium and ballotini having for example a nominal diameter of 100 microns are brushed across the surface of the stencil. The stencil consists of a thin sheet of perforated metal, the perforations being so located and of such a diameter that one glass sphere (or a cluster of a small number of ballotini if so desired) is placed at each of the required locations. The stencil is removed leaving correctly located ballotini adhering to the part-dynode by means of the sticky medium. The part-dynode is taken through a heating cycle to remove the sticky medium by volatilisation and to allow the glass layer to melt so that the ballotini are permanently bonded to the part-dynode. The next step is to place an enamel coated part-dynode against a ballotini coated part-dynode in a jig which holds them in register whilst they are taken through a further heating cycle. The temperature is raised until the enamel melts and the two part-dynodes become bonded with ballotini separating them. Care has to be exercised to ensure that the enamel does not cover the ballotini so as to cause a bridge to be formed between the two dynodes adversely affecting the insulation.

An alternative technique involves clamping the part-dynodes together instead of bonding them. In this case one part-dynode is coated with ballotini as described above. The other part-dynode is not coated with enamel however. Because of the flexible nature of part-dynodes this method may only be adequate for multipliers with an area no greater than a few hundred cm^2 (for a part-dynode thickness of about 0.15 mm).

In the above-mentioned examples the bond between ballotini and a dynode is effected by a glass enamel. However glass is not the only suitable bonding medium, others may include potassium silicate solution, polyimide adhesive and Silvac (a propriatary vacuum-compatible adhesive).

The above methods are also relevant to resistive spacers. Resistive separating elements can be provided by using ballotini made of lead-containing glass and reducing the surface of each sphere by heating in hydrogen. Where resistive elements are used, the dynodes need not be coupled separately to the power supply 18 as shown in Figures 1 and 2. Instead the power supply can be connected between the first and last dynode and the resistive elements act as a potential divider enabling each dynode to be bias as required.

Figure 3 diagrammatically illustrates a channel plate cathode ray tube 30 comprising a metal, for example mild steel, cone 31 having a substantially flat plate glass screen 32 closing the open end of the cone 31. A channel plate 10 made in accordance with the present invention is disposed at a small distance, for example 10 mm, from the screen 32. An electron gun 33 is disposed adjacent the closed end of the cone 31 and a deflection coil assembly 34 is disposed adjacent to, but spaced from, the electron gun 33.

In operation a low energy electron beam 35 from the electron gun 33 is deflected in raster fashion across the input side of the channel plate structure 10 by the coil assembly 34. The beam undergoes electron multiplication in the structure 10 and the output electrons are applied substantially normally to the screen 32.

In an alternative construction of the display tube, the channel plate structure may be placed like a shadow mask in a conventional cathode ray tube having a glass envelope.

The channel plate structure described above may be used in other practical applications such as electron multipliers, image intensifier tubes, data display tubes, X-ray image intensifiers and certain types of gas discharge tubes.

Although the spherical elements conveniently comprise ballotini because they are readily available, the elements may be of any compatible material having a sufficiently high resistance less than that of the dynodes and a melting point sufficiently high such that the elements will not be deformed during the normal processing of the channel plate assembly.

Further although one technique has been described for laying down the ballotini, other techniques using currently known technology for handling such materials may be used.

The discrete separating elements may have other shapes besides spherical, such as cylindrical, ellipsoidal prismatic and cubic. Irrespective of the precise shape of the elements, the technique for laying them down must ensure that they are in the desired positions and orientates so that the dynodes are separated by a substantially constant distance from each other.

CLAIMS:

1. A channel plate structure comprising a stack of discrete, spaced apart electrically conductive dynode plates, characterised in that the dynode plates are separated from each other by an array of discrete separating elements distributed across the area of the channel plate, which elements are less conductive than the dynodes.

2. A structure as claimed in Claim 1, characterised in that the separating elements are substantially spherical and comprise ballotini.

3. A structure as claimed in Claim 1 or 2, characterised in that the elements are made of glass having a surface comprising a lead film.

4. A structure as claimed in any one of Claims 1 to 3, characterised in that each dynode plate comprises two perforate, electrically conductive mating sheets in electrical contact with each other.

5. A structure as claimed in any one of Claims 1 to 4, characterised in that the separating elements are arranged more densely at the edge of each dynode plate than at the centre thereof.

6. A structure as claimed in any one of Claims 1 to 5, characterised in that the separating elements are bonded to the

dynode plates.

7. An imaging cathode ray tube including a channel plate structure as claimed in any one of Claims 1 to 6.

8. A method of manufacturing a channel plate structure, characterised by applying a glass enamel to a surface of at least some of a plurality of perforate, electrically conductive dynode forming sheets, firing the glass enamel, temporarily positioning discrete separating elements on the enamelled surfaces, bonding the separating elements to the enamelled surfaces by melting the glass enamel thereof, and arranging the sheets in a stack with the free surfaces of the separating elements contacting a surface of an adjacent sheet.

9. A method as claimed in Claim 8, characterised in that when each sheet constitutes a dynode, all but one of the sheets forming a stack has an array of separating elements bonded to one surface thereof.

10. A method as claimed in Claim 8, characterised in that when each sheet constitutes half of a dynode, the sheets are arranged in mating pairs, and an array of separating elements is provided on one sheet of each mating pair.

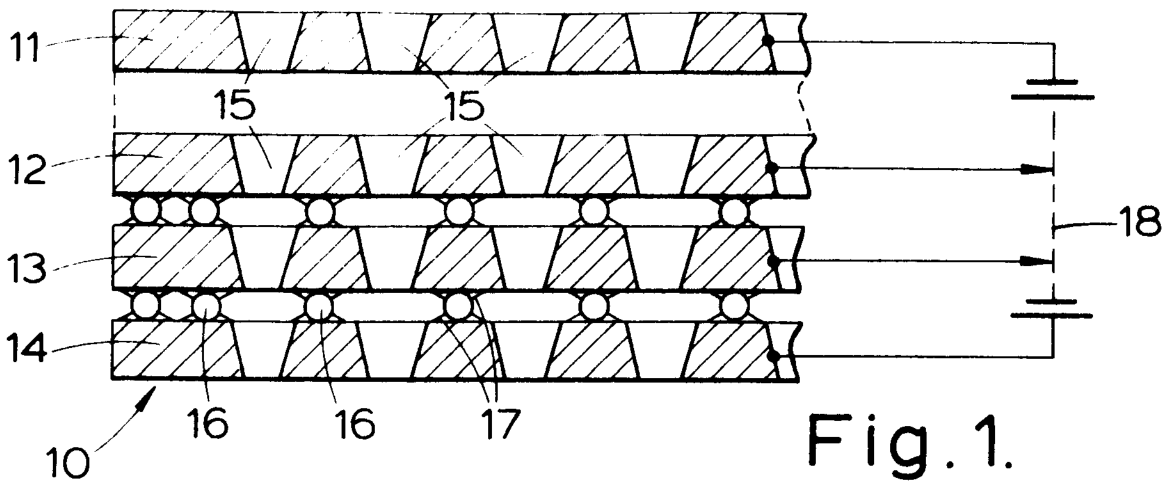


Fig. 1.

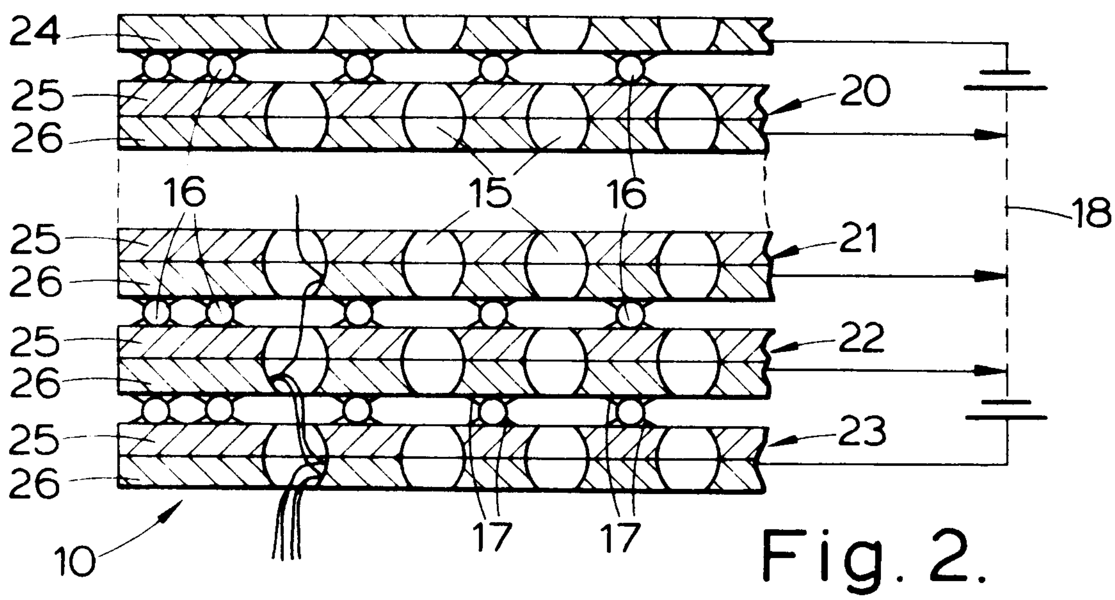


Fig. 2.

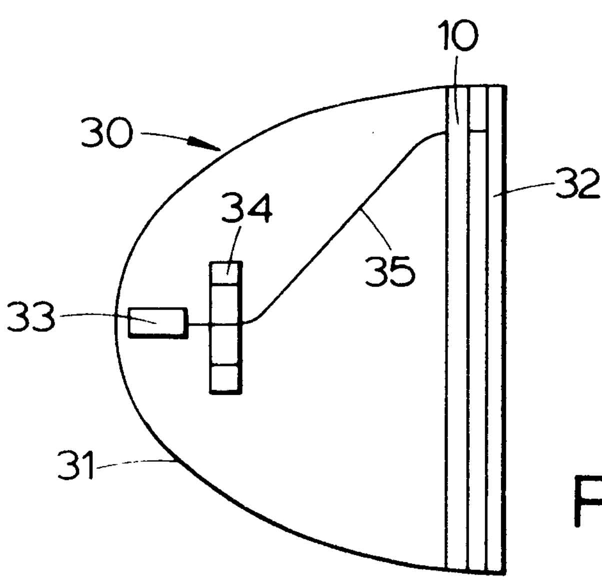


Fig. 3.

0006267

Application number

79 200 291.7

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EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
D	GB-A-1 401 969 (MULLARD LIMITED) - -	
D	GB-A-1 402 549 (MULLARD LIMITED) & DE-A-2 260 864, & FR-A-2 164 790 - -	
D	GB-A-1 434 053 (MULLARD LIMITED) & DE-A-2 414 658, & FR-A-2 224 870 - -	
A	GB-A-1 431 490 (MULLARD LIMITED) * Page 3, line 34; Page 3, lines 71 to 80; Page 4, line 10; * - -	3,8
A	GB-A-1 405 256 (MULLARD LIMITED) * Page 2, lines 14 to 21* - -	1
A	GB-A-1 446 774 (MULLARD LIMITED) * Page 5, lines 5 to 13 * & DE-A-2 418 199, & FR-A-2 226 749 - -	7
A	GB-A-1 457 213 (MULLARD LIMITED) * Page 2, lines 104 to 109* & DE-A-2 602 863, & FR-A-2 299 722 - -	4
A	DE-A-2 554 030 (N.V.PHILIPS) * Page 5 and 6, lines 18 to 25 and 1 to 5* & FR-A-2 294 542 - - - -	1,4

CLASSIFICATION OF THE APPLICATION (Int. Cl.²)

H 01 J 31/50
H 01 J 43/10
H 01 J 43/18

TECHNICAL FIELDS SEARCHED (Int.Cl.²)

H 01 J 1/32
H 01 J 9/12
29/50
31/50
43/00
43/02
43/04
43/06
43/10
43/18
43/20
43/22

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Wien	14.August 1979	Irsigler

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