PHOTOCATHODE COMPRISING CHANNELED MATRIX WITH CONDUCTIVE INSERTS IN CHANNELS TIPPED WITH PHOTOCONDUCTIVE MATERIAL

Filed Oct. 28, 1964 2 Sheets-Sheet 1

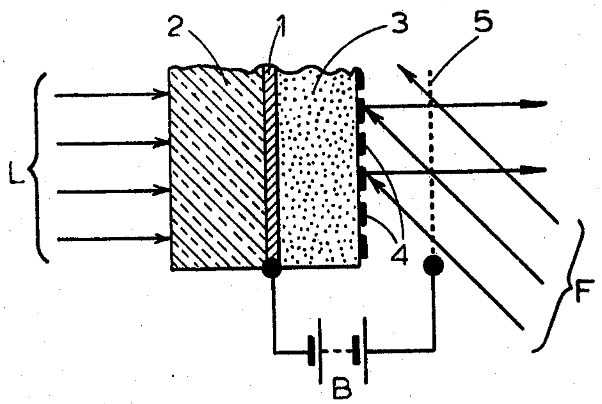

FIG.1

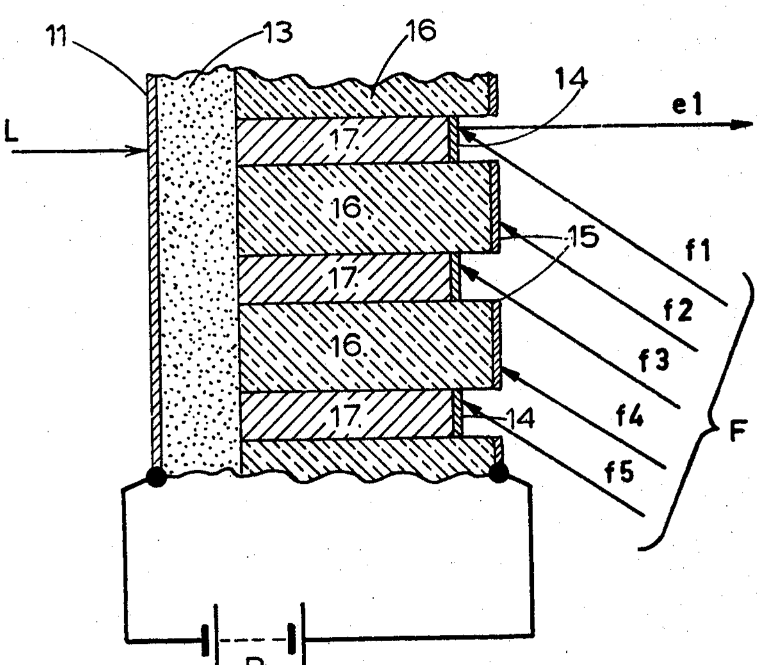

FIG.2

INVENTOR.
P.SCHAGEN
B.W.MANLEY
BY Frank R. Trifari
AGENT

June 4, 1968 P. SCHAGEN ET AL 3,387,162

PHOTOCATHODE COMPRISING CHANNELED MATRIX WITH CONDUCTIVE INSERTS IN CHANNELS TIPPED WITH PHOTOCONDUCTIVE MATERIAL

Filed Oct. 28, 1964 2 Sheets-Sheet 2

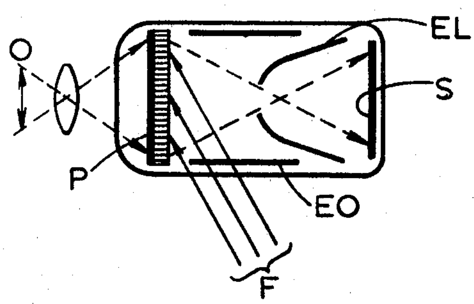

FIG.3

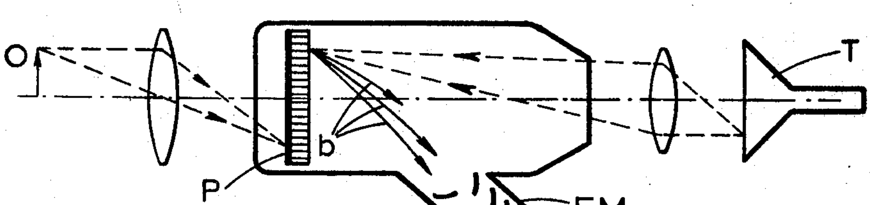

FIG.4

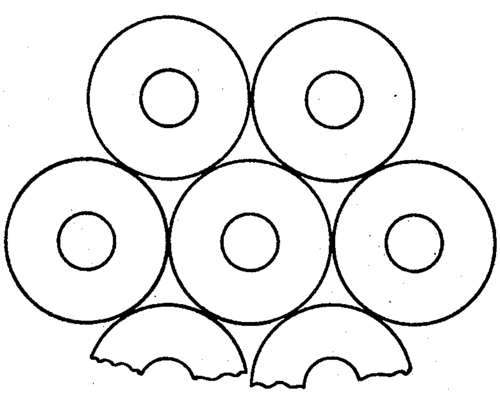

FIG.5

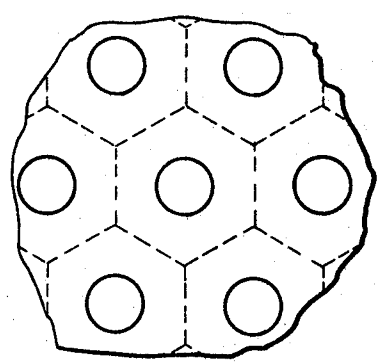

FIG.6

INVENTOR
P. SCHAGEN
BY B.W. MANLEY
AGENT

United States Patent Office

3,387,162

Patented June 4, 1968

1

3,387,162

PHOTOCATHODE COMPRISING CHANNELED MATRIX WITH CONDUCTIVE INSERTS IN CHANNELS TIPPED WITH PHOTOCONDUCTIVE MATERIAL

Pieter Schagen, Redhill, and Brian William Manley, Burgess Hill, England, assignors to North American Philips Company, Inc., New York, N.Y., a corporation of Delaware

Filed Oct. 28, 1964, Ser. No. 407,046
Claims priority, application Great Britain, July 7, 1964, 32,939/63
4 Claims. (Cl. 313—96)

ABSTRACT OF THE DISCLOSURE

A photocathode for an image transducer which employs a plate of insulating, or highly resistive material provided with a plurality of channels each having a conductive insert therein which does not extend beyond a surface of the plate serving as an output face. The other major surface of the plate, which serves as an input face is covered with a photoconductive material which is in contact with the inserts. An external conductive layer provided on the exposed surfaces of the photoconductive material serves as an input electrode which is connected to the inserts by the photoconductive material. A separate photoemissive element is provided on the output end of each insert and a conductive layer provided on the output face having apertures corresponding to the inserts and channels serve as a grid which is spaced from the photoemissive elements.

This invention relates to photocathodes for images intensifiers, image converters, camera tubes and the like.

Such photocathodes are usually of the photoemissive type. It is known, that photocathodes of the emissive type have the drawback that their quantum efficiency is low, that is to say, the number of electrons that may be detached from the material per light quantum is small, the efficiency usually being to the order of 10^{-1}.

A solution to this problem is provided in the form of a photocathode having a superficial electron emitting layer adapted to be rendered continuously emissive, said layer being mounted closely adjacent to a body whose electrical properties are so modified by light that variations in the intensity of illumination of said body alter the condition of equilibrium of the emission from said emitting layer, whereby variations in the intensity of the illumination of said body alter the condition of equilibrium of the emission from elemental areas of said emitting layer.

The electron emitting layer may be a photoelectric mosaic rendered emissive by being constantly illuminated, there being arranged in front of the emitting surface a grid electrode by which electrons tend to be accelerated away from the emission surface, the body whose properties cause the variation in the emission when light is incident on the body being a sheet of photoconductive or photovoltaic material of relatively small conductivity parallel to its surface, adjacent to which said emitting layer may be formed, and on which an optical image of a picture to be transmitted may be produced whereby the equilibrium condition of said emission is disturbed locally in accordance with the light and shade of the optical image.

As some photoconductive materials are highly sensitive to radiation far into the infrared, devices utilizing a photocathode according to the invention may prove useful

2

for fog penetrating devices or for devices for viewing under conditions of low illumination.

Preferably the control grid should be as fine as possible in order to necessitate the application of only a small bias potential between the grid and the conductive sheet for full control, owing to the fact that a large grid bias voltage involves the setting up of a large potential difference across the photoconductive layer and thus there is a risk of a breakdown of the insulation.

It is also important to have a very uniform spacing between the grid and the cathode and this is very difficult to achieve with a separate very fine grid structure.

It would also be valuable from the point of view of high effective quantum efficiency, to achieve accurate registration between the apertures of the grid and the emissive elements of the mosaic, but this is very difficult to achieve with a separate grid structure. (The term "effective quantum efficiency" is used to denote the number of electrons emitted by the photoemitter for every input photon which strikes the photoconductor.)

A further limitation of the prior construction arises from the lack of separation between photoconductor and photoemitter. The preparation of a surface to render it photoemissive is a critical process. On the other hand photoconductors are frequently heavily dependent upon the material with which they are in contact. Thus it may happen that a photoconductor which is suitable for a particular application is incompatible with the photoemitter which is to be used.

Apart from physical separation, optical separation of photoconductor and photoemitter is also desirable. Although in principle it is possible to choose a photoemitter which responds only to wavelengths outside these which excite the photoconductor, in practice, there will usually be some overlap. In conditions of low light level, this would detract from the usefulness of the device. A separating layer which is opaque to the source of flooding radiation which excites the photoemitter, is therefore necessary in most applications, which is relatively difficult.

It is an object of the present invention to provide as improved photocathode structure and to avoid the above disadvantages. It is a further object of the invention to provide a method of manufacturing such an improved photocathode and grid combination.

It is a further object of the invention to use such a photocathode structure in a camera tube in such manner as to take advantage of the low-noise properties of the structure.

The invention provides a photocathode structure comprising:

(a) A matrix of insulating or highly resistive material in the form of a plate the major surfaces of which constitute the input and output faces of the matrix, said plate having a two-dimensional array of elongated channels each providing a passageway from one face of the matrix to its other face;

(b) A conductive insert in each channel which insert does not extend beyond the output face of the matrix;

(c) Photoconductive material on the input face of the matrix in contact with said inserts;

(d) An external transparent conductive layer provided on the exposed surfaces of said photoconductive material to act as an input electrode which electrode is connected to the inserts by the intervening photoconductive material;

(e) A separate photoemissive element on the output end of each insert; and

(f) A conductive layer provided on the output face of the matrix which layer has apertures correspondingr to the inserts and channels so as to act as a grid which is spaced from said photoemissive elements.

With such a construction the photoconductor and photoemitter are physically separated by the conductive inserts, and the matrix and inserts can be made opaque to the desired flooding radiation. The photoconductor will be described first as a continuous layer, though it may be subdivided (as will be explained).

A further major advantage is that the separate fine and delicate grid of the earlier specification is replaced by a layer which is rigidly carried by the matrix. A rigid spacing can thus be obtained between the photo-emissive elements and the grid and there is the further advantage that accurate registration is obtained (and rigidly maintained), between the apertures in the grid and the photoemissive elements.

In each case the block or plate may be sectioned or sliced to form a number of matrices and the faces of each slice may then be appropriately machined and polished. The input face will then be smooth and will be ready for the application of the photoconductive layer and, subsequently the transparent electrode. As for the output face, the metal inserts may be etched away to a predetermined depth so as to create the necessary spacing between the photoemissive elements and the grid. After the etch, the photoemissive material is deposited in the recesses so formed and the material is made to adhere to the ends of the inserts. As for the grid, it may be formed by forming a conductive layer on the output face of the insulating matrix after the inserts have been etched back and coated with photoemitter.

Reference will be made to the accompanying drawings in which

FIGURE 1 shows a detail of a photocathode already known.

FIGURE 2 shows an example of section of a photocathode structure in accordance with the invention.

FIGURE 3–6 relate to applications and methods of manufacture.

Referring to FIGURE 1, the photocathode comprises a continuous metal layer **1** which is so thin as to be transparent, supported on a sheet **2** of glass or mica or other suitable transparent material. A layer of photoconductive material **3** for example of zinc selenide, zinc sulphide or selenium is applied to the metal layer or formed on the metal layer **1**, for example by settling or evaporating or spraying on to that layer. On the layer **3** is formed a mosaic **4** of minute photoemissive cells consisting for example of a mosaic of minute oxidised and caesiated silver globules. Arranged in front of the mosaic **4** is a grid **5** beyond which is a further accelerating electrode system (not shown).

It was suggested that this arrangement operates somewhat in the following manner. As the photo mosaic **4** is continuously illuminated (by substantially uniform flooding radiation F) and the grid **5** is at a slightly positive potential with respect to the conductive layer **1**, as long as no emission penetrates into the photoconductive sheet **3** the emission from each element of the mosaic **4** will continue until the potential of the mosaic is slightly higher than that of the grid **5** in which case an equilibrium condition is established so that only sufficient electrons are emitted from the mosaic to neutralize those which are conducted through the photoconductor as "dark current" (electrons emitted by the mosaic are forced to return thereto under the action of the retarding field due to the grid). If now a picture (as light L) is projected through element **1** on to the photoconductive layer **3** then the conductivity of the layer **3** perpendicular to its surface will be caused to vary over each elemental area in accordance with the local illumination thereof so that current may flow from the conductive film **1** to the elements of the mosaic **4** the current to each element varying in accordance with the distribution of illumination on the element **3**. Thus the local emission from the element **4** will vary in accordance with the local illumination of the element **3** and more or less electrons will be emitted from the elements of the mosaic **4** in accordance with said illuminations and will pass through grid **5** into the accelerating field set up beyond the grid. Moreover, the variation in the emission of the elements of the mosaic **4** will depend on the effect of the light L on the element **3** and will not be determined by response to light F on mosaic **4**. Thus the quantum efficiency of the photocathode will be that of the photoconductive layer **3**. It is thus to be seen that the sensitivity may be increased with respect to a conventional photoemitter.

Referring to FIGURE 2 the glass substrate used in the prior construction of FIGURE 1 is omitted in this case. Instead the input side of the structure is constituted by a thin transparent conductive layer **11** constituting the input electrode. This is formed on a photoconductive layer **13** and this layer in turn is formed on the input face of a glass matrix **16**. This matrix has a regular array of channels passing from its input face to its output face, each channel being occupied by a metal insert **17** which is in contact with the photoconductor. The inserts **17** do not quite reach the output face of the matrix and are thus set back a small distance from such face. The exposed end of each insert **17** carries a photoemissive element **14**. Fnally there is a layer of conductive material **15** on the output face of the matrix and this layer has openings corresponding to the the photoemissive elements **14** and thus acts as a grid electrode which is in accurate register with respect to said elements (this grid corresponds, of course, to the separate fine grid **5** of FIGURE 1).

As will be seen, the photoemissive elements **14** are separated physically from the photoconductor by the inserts **17** and this contrasts with the adjacent arrangement of elements **3** and **4** in FIGURE 1. In addition to this physical separation, the glass of the matrix **16** is preferably made opaque so as to provide optical separation. This prevents certain rays of the flooding radiation F from penetrating into the glass between the elements **14** and parts of the grid layer **15** which could otherwise occur.

The flooding radiation F is light which is constantly directed at the entire output face of the structure so as to excite the photoemitter, but the degree of actual emission varies locally and depends on the number of photons striking any given part of the input face of the structure. (The term "light" should be understood as including also invisible light such as ultra-violet and infra-red.) This is illustrated schematically in FIGURE 2 by the fact that only one of the flooding rays (ray *f1*) causes emission of an effective photoelectron *e*, this being due to the presence of an image photon L in the same area. This is not true of the areas struck by flooding rays *f3* and *f5* and therefore the photoelectrons liberated thereby are forced back (as shown) by the field of the grid **15**. Other rays (*f2* and *f4*) are ineffective because they are directed at parts of the grid layer.

An appropriate forward potential is applied between the input electrode **11** and the grid layer **15**, and this is represented schematically by a source B which corresponds effectively to the source B of FIGURE 1.

FIGURE 3 shows schematically an application of a photocathode structure such as that of FIGURE 2. The device shown is an image intensifier comprising the photocathode P, and an object O is imaged by an optical system on to said photocathode.

A luminescent screen is provided at S at the other end of the envelope, and an electrostatic lens element (having rotational symmetry) is provided at EL. In addition, electron optical means EO are provided to assist the lens in focussing the electrons emitted by the photocathode so that they cross over and are imaged on the screen S. The flooding radiation is shown again at F. The electron-optic means EO–EL are electrostatic and may be of conventional design, but magnetic means may be used as an alternative.

Instead of providing constant flooding light all over the face of the photocathode, it is possible to excite the photoemissive elements sequentially by a scanning light beam which scans such output face in a regular manner (this excitation radiation will still be referred to as "flooding radiation" for convenience). When this is done, it is possible to use the photocathode in a camera system instead of an image intensifier or converter, a signal plate being then used in place of the luminescent screen S and the electron optics (such as EO) being omitted. Such use of a photocathode structure in accordance with the invention in a camera tube utilises the low-noise properties of such a structure as aforesaid, and this will now be explained more fully.

With existing camera tubes, the performance at low light levels is limited by noise generated within the camera system. In the case of the image orthicon the limitation is due mainly to the noise of the scanning electron beam. It has been proposed frequently to overcome this limitation of the image orthicon by using a photon beam instead of an electron beam to explore the target. There is then no equivalent beam noise and if the electrons produced from the target by the photon beam, and representing the signal, were amplified in an electron multiplier like that used in an image orthicon, there would be no significant amplifier noise. The problem has always been the preparation of a target for such a tube: it must be sensitive to light on each side but there must be no interaction between the two sides. Photocathode constructions according to the present invention can readily fulfil this requirement by providing optical separation as described above.

An example of a camera system in accordance with the invention will now be described with reference to FIGURE 4. In this figure, an object O is again imaged by optical means onto the photocathode P, the latter being constructed e.g. as shown in FIGURE 2. Optical scanning of the output face of the photocathode takes the place of the continuous flooding used in the intensifier case and is effected e.g. by a flying-spot scanner comprising a cathode-ray tube T and an associated optical system.

Signal electrons *b* emitted from the photocathode at the instantaneous location of the scanning spot are collected by an electron multiplier EM which provides the output signal.

In the image intensifier case, the operation of the intensifier relies upon the fact that for each electron conducted through the photoconductor, a photoelectron leaves the photoemitter and excites the screen. If the resistance of the photoconductor is low even in the dark, the screen appears illuminated. Upon exposing the photoconductor to light, the screen brightness increases. Even objects of 100% contrast thus appear on the screen with reduced contrast. In objects of low contrast, especially at low light levels, the images are difficult to interpret. For this reason it is preferable to use high-resistance photoconductors, and the higher the dark resistance, the less any background effects are significant. This is important in the image intensifier case, and also for the camera case though less since the background signal can be biased off.

Thus, in the camera case, low resistivity can be used. In such case, resolution can be maintained or improved by breaking up the photoconductor layer into separate islands. This can easily be done by spraying the material into recesses of the glass matrix and then removing the surplus photoconductor as will be described later (this construction can also be used, if desired, for an image intensifier or converter).

The matrix for a photocathode according to the invention for use in an image intensifier or converter (e.g. as shown in FIGURE 3) or a camera system (e.g. as shown in FIGURE 4) can be made of glass or the like by the following method which is suitable for a practical matrix having the following dimensions:

TABLE

Diameter of matrix	cm	2½–10
Diameter of an insert	μ	10–25
Length of an insert	mm	Approx. 1

In its broadest aspect the preferred method of manufacturing a matrix for the photocathode includes, the steps of arranging a number of fine insulating tubes parallel to each other in a stack and bonding said tubes together to form a rigid channeled block or plate. If it is a block it can then be sliced or sectioned to obtain one or more plates. Preferably the tubes are of glass or other vitreous material and preferably the tubes are obtained by drawing thicker tubing down to a smaller diameter and cutting it into lengths.

Following said steps, the faces of the plate may require to be ground to the desired form and they may be polished to the desired finish. The layers **11–13–15** are applied to the faces of the matrix, e.g. by an evaporation technique. The metal for the inserts may, as aforesaid, be taken up by capillary action after the tubes have been bonded or sealed together though it is preferable for a metal core to be drawn down with the tubing (this is the case in processes A and B below). In either case the exposed output ends of the inserts may be dissolved or etched back.

The tubing may be drawn down to the desired final diameter with a single draw; alternatively, a two-stage drawing system may be adopted in which lengths of partly drawn tubing are sealed together in bundles which are then given a further draw as will be described. The lengths of tubing will not tend to collapse during the drawing and sealing operations if, they are filled with a metal core, as is preferable since it also provides the inserts; however, it is also possible to perform said operations with "air-cored" tubes, i.e. tubes containing air or a gas. As for the sealing operations (whereby the tubes are bonded or sealed to each other) these may be performed simply by heating the bundle or stack of tubes to a sufficient temperature to cause softening; alternatively a lower temperature may be made acceptable by previously applying an external low-melting-point glaze to the tubes, the latter method being particularly desirable when a metal core is not used. Specific examples of these various alternatives will now be described. First, however, it should be noted that the use of a glaze is not automatically tied to the use of air or gas cores but, in practice, there is a tendency for the two features to go together for the following reason. With a metal core the glass can be heated to such a point that a tube will soften and become sealed to a neighbouring tube, and such a high temperature can be used because the metal core will support each tube internally and prevent it from collapsing. Conversely, when there is no solid internal support, the heating of the glass must be limited and hence the low melting point glaze becomes important.

Embodiments of the method will now be described by way of example with reference to FIGURES 5 and 6 of the drawings accompanying the provisional specification.

If the inserts are to be set back from the grid (as in FIGURE 2) and the tubes are filled with some solid core material during drawing, then such core material is preferably a metal which may be partially removed later by etching or dissolving in some suitable solvent. Suitable metals which can be etched back are indium, lead, tin, zinc, aluminum, copper, tungsten, gold.

The stacking and sealing steps are illustrated in FIGURES 5 and 6 respectively for the preferred case in which the interstices between tubes are filled in.

Three processes will now be described in greater detail by way of example.

1. PROCESS A (SINGLE DRAW WITH METAL CORE)

Broadly, a long thin tube (referred to here as a fibre) can be made consisting of a glass coating on a wire.

Lengths of fibre are laid together to form a bundle, sealed together and the resulting bundle may be sliced to provide a number of matrix plates.

1.1. Preparation of fibre

1.1.1 MELTING A METAL IN A GLASS TUBE AND DRAWING THE GLASS TUBE

A low-melting-point metal is melted in a glass tube of large diameter (for example 0.5 cm.) which has the appropriate ratio of outer to inner diameter (this ratio can be substantially preserved through any drawing process). The glass tube is then heated to softening point (the metal remaining molten), its ends may have to be closed, and it is drawn down to a fibre which is tubular and contains the molten metal as a core. The fibre is cooled and wound on to a bobbin.

1.1.2. DRAWING METAL AND GLASS TUBE TOGETHER

A metal which softens or melts at about the softening point of the glass is heated in a glass tube of the appropriate dimensions. Then the glass, with its core, is drawn down as described in paragraph 1.1.1.

1.1.3. DRAWING A THIN PRE-FORMED WIRE OF A REFRACTORY METAL THROUGH A SOFT OR MOLTEN MATRIX MATERIAL

(a) A thin wire of e.g. 10μ tungsten may be pulled through a trough of molten tube material, e.g. glass, so that said material adheres to the preformed wire as a coating and the wire suffers little or no elongation (in this case the tube material does not need to be one that can be drawn).

(b) Alternatively, such a preformed wire may have its leading end embedded in a relatively short thick rod of glass. The rod is then heated to softening point and its free or leading end is pulled together with the leading end of the wire. Thus the wire advances substantially without elongation while the glass is drawn progressively down to smaller and smaller diameters as a sheath which envelops a gradually increasing length of wire.

1.2. Assembling and sealing the fibre

A fibre prepared by any of the above methods and drawn down to an inner diameter e.g. of 10μ is wound into a hank, e.g. on a bobbin. When enough turns have been wound and the hank is thick enough, the resulting unsealed bundle is cut into lengths of a few centimetres which are packed together in a tubular glass former of lower melting point having a diameter of a few centimetres. The former is then evacuated and heated until its walls collapse inwards so as to compress the fibres together.

The former containing the fibres is sliced (e.g. as shown in FIGURE 5) and the slices are ground and polished. Sections will be of required thickness, e.g. in the range 1–10 mm. (1 mm. corresponds to the table given previously).

Each slice then consists of a matrix of glass with tiny metal rods running through its thickness.

2. PROCESS B (TWO DRAWS WITH MEAL CORE)

2.1. Preparation of fibre

It is possible to apply techniques similar to those of fibre optics and draw metal-cored fibres down initially to a lesser extent than in the foregoing examples. The resulting relatively thick intermediate fibres are much easier to handle than fibres about 30μ in diameter (in this case the intermediate fibres may be 200μ–300μ in diameter).

When a sufficient length of 200–300μ fibre is obtained an intermediate bundle is made by sealing the fibres together and it is then cut into lengths of, say 10 cm. Each of these lengths of bundle is then treated in the same way as the original tube and drawn down until it is about 50μ in diameter. This fibre is quite easy to handle and yet it is a multiple fibre containing many 10μ fibres. This technique can be applied to the methods described in paragraphs 1.1.1 and 1.1.2 supra but not the method described in paragraph 1.1.3.

2.2 Assembling and sealing the fibre

The multiple fibres (which can be handled more easily than those described in earlier paragraphs) are bundled in a tubular former as described in paragraph 1.2 and this former may be evacuated and heated, and the further processing is similar to that described previously at 1.2.

3. REMOVING THE CORE MATERIAL

Core material may be removed from the ends of the inserts (to form the desired recesses) by a suitable chemical method. One chemical method is to etch out copper (from borosilicate glass for instance) by the use of dilute nitric acid in an ultrasonic bath. In one example the process consists of alternate treatments in dilute nitric acid and tap water (the water is used to wash away the saturated acid from the point at which etching is desired).

4. PROCESS C (DRAWING HOLLOW TUBES DOWN WITHOUT METAL CORE)

So far we have described methods of drawing fibres which have a metal core. It is also possible to draw hollow tubular fibres and this may be done by one or two draws. A difficulty arises in packing the hollow tubular fibres together to make a sealed bundle (whether intermediate or final) e.g. as in the methods of paragraphs 1.2 and 2.2 supra. At this stage the tubes may collapse, but this can be prevented by coating the fibres with a low-melting-point glaze (e.g. an enamel or frit) which will effectively seal them together at a lower temperature. This can be done, for example, by drawing the fibre down from a thick starting tube which is already coated on the outside with such a glaze.

Another possibility is to keep the insides of the tubes full of trapped air while the former in which they are sealed together is collapsed under vacuum. The pressure inside the tubular fibres can be controlled suitably by sealing them off (at each end) at ambient air pressure when the whole is at room temperature so that they are held open while compression is applied to the bundle.

5. METHODS OF ASSEMBLY

Various examples have been described which involve the drawing down of glass or like tubes with or without metal cores and the subsequent formation of a bundle of drawn tubes which are sealed together with or without the aid of a glaze. In such bundling it is difficult to obtain close regular packing and, in the case of hollow ("air-cored") tubes, the difficulty is greater than it is in conventional fibre-optic technology where more pressure can be applied to compress a bundle since the fibres are solid. This is a further reason for preferring tubes drawn with metal cores to drawn "air-cored" tubes, and much of the existing fibre-optic technology can be applied to the assembly of metal-cored tubes. To facilitate close or regular packing of the tubes, it is possible to form an initial or primary bundle of polygonal cross-section and seal the tubes thereof together, after which said bundle is drawn and cut into lengths, a number of such lengths of polygonal bundle (all of substantially the same size and shape in cross-section) being then fitted together as an intermediate or final bundle with little or no interstitial spacing and sealed together.

6. EXAMPLE OF OPERATIONS SUBSEQUENT TO FORMATION OF THE MATRIX, AND EXAMPLE OF FINAL PRODUCT

As a starting point, let it be assumed that a glass matrix has been made by a method as described above, and that such matrix is of glass opaque to ultraviolet and has an array of inserts of fine copper wire having diameters of about 25μ. On the output face these are recessed some

100μ by etching, then coated (by electrodeposition) with a few microns of gold which is to act as the photoemitter. Aluminium is then evaporated from a grazing angle on to this face of the block so as to ensure electrical insulation from the gold. On to the opposite face of the block is deposited (e.g. by evaporation processes) the layer of photoconductor and then a transparent electrode. The evaporated aluminium now acts as the control grid whilst the gold islands are still in contact with the photoconductor via the conducting copper rods. It is possible to flood the gold with ultraviolet radiation to produce photo-emission without stimulating the photoconductor, the latter being shielded from the flooding radiation by the glass and copper matrix which is opaque to ultraviolet.

Instead of a continuous layer of photoconductor (such as layer **13** of FIGURE 2) it is possible, as aforesaid, to use separate photoconductor elements each recessed into the matrix. This can be understood, for example, by supposing that the glass **16** of the matrix of FIGURE 2 is extended up to the electrode **11**, leaving plugs of the material **13** to connect said electrode with the inserts **17**. From such an arrangement the method of manufacture just described can be modified as follows. Instead of depositing the photoconductor by evaporation on to a continuous input face of the matrix, the input ends of the copper inserts are first etched back to provide recesses, and the photoconductor is then sprayed on to said face so as to fill the recesses. The excess photoconductor is then removed until the glass of the matrix is exposed and the input electrode is then applied as before. One advantage of such a construction is the total removal of transverse conductivity in the photoconductor.

In either event the photoconductor may be a compound of lead oxide and lead sulphide (if deposited by evaporation, this can be done in a gaseous atmosphere).

What is claimed is:

1. A photocathode comprising:

(a) a matrix of insulating material in the form of a plate the major surfaces of which constitute the input and output faces of the matrix, said plate having a two-dimensional array of elongated channels each providing a passageway from one face of the matrix to its other face;

(b) a conductive insert in each channel which insert does not extend beyond the output face of the matrix;

(c) photoconductive material on the input face of the matrix in contact with said inserts;

(d) an external transparent conductive layer provided on the exposed surfaces of said photoconductive material to act as an input electrode which electrode is connected to the inserts by the intervening photoconductive material;

(e) a separate photomissive element on the output end of each insert; and

(f) a conductive layer provided on the output face of the matrix which layer has apertures corresponding to the inserts and channels so as to act as a grid which is spaced from said photoemissive elements, said photoemissive elements being all set back from said grid.

2. A photocathode as defined in claim **1** wherein the matrix and inserts are opaque to flooding radiation.

3. A photocathode as claimed in claim **1** wherein the photoconductive material is in the form of a continuous layer having substantially uniform thickness and the input ends of the inserts are substantially flush with the input face of the matrix.

4. A photocathode as claimed in claim **1** wherein the photoconductive material is subdivided into separate elements each of which connects a conductive insert to the input electrode, and wherein the material of the matrix surrounds said separate elements and extends to the input electrode.

References Cited

UNITED STATES PATENTS

1,381,474	6/1921	Kunz	313—100
1,935,649	11/1933	McCreary	313—66 X
2,120,765	6/1938	Orvin	313—66 X
2,195,486	4/1940	Gray	313—96 X
2,945,973	7/1960	Anderson	313—66 X
3,020,433	2/1962	Day	313—66 X

FOREIGN PATENTS

901,572	1/1954	Germany.	

ROBERT SEGAL, *Primary Examiner.*