United States Patent [19]

Stone

[11] **3,781,979**

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[54] **IMAGE INTENSIFIERS AND THE LIKE**

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[21] Appl. No.: **196,289**

[30] **Foreign Application Priority Data**

Nov. 18, 1970 Great Britain 54,817/70

[52] **U.S. Cl.** **29/592,** 29/25.14

[51] **Int. Cl.** **H01s 4/00**

[58] **Field of Search** 29/592, 25.14; 313/103, 104

[56] **References Cited**

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1,175,599	12/1969	Great Britain	313/103
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Assistant Examiner—M. J. Keenan
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[57] **ABSTRACT**

Method of manufacturing a channel plate having membranes or films at an end of each channel, comprising allowing a liquid to extend by capillary action along the channels to form a meniscus at the channel mouths, solidifying the menisci to provide temporary supports, forming the membranes on the temporary supports and removing the temporary supports to leave the membranes behind. Also, the channel plate produced by this method.

10 Claims, No Drawings

IMAGE INTENSIFIERS AND THE LIKE

This invention relates to electron multiplier and image intensifier devices. More particularly the invention relates to "channel intensifier" devices (referred to also more briefly as "channel plates") and to electronic tubes employing such devices. Such devices are secondary-emissive electron-multiplier devices comprising a matrix in the form of a plate having a large number of elongate channels passing through its thickness, said plate having a first conductive layer on its input face and a separate second conductive layer on its output face to act respectively as input and output electrodes.

Secondary-emissive intensifier devices of this character are described, for example, in British Pat. specifications, No. 1,064,073 (PHB 31172), No. 1,064,074 (PHB 31173), No. 1,064,076 (PHB 31184), No. 1,090,406 (co-pending British Applications 32722/63 and 36758/63: PHB 31211) and No. 1.154,515 (co-pending British Application 22339/67; PHB 31754), while methods of manufacture are described in British Patent Specifications No. 1,064,072 (PHB 31171 Comb.) and No. 1,064,075 (PHB 31183).

In the operation of all these intensifier devices a potential difference is applied between the two electrode layers of the matrix so as to set up an electric field to accelerate the electrons, which field establishes a potential gradient created by current flowing through resistive surfaces formed inside the channels or (if such channel surfaces are absent) through the bulk material of the matrix. Secondary-emissive multiplication takes place in the channels and the output electrons may be acted upon by a further accelerating field which may be set up between the output electrode and a suitable target, for example a luminescent display screen.

With channel plates the distribution and cross-sections of the channels and the resistivity of the matrix are such that the resolution and electron multiplication characteristic of any one unit area of the device is sufficiently similar to that of any other unit area for the purposes envisaged, the greatest uniformity being usually required for imaging.

If such a channel plate is used in an imaging tube or system, the latter will be referred to for convenience as an "image intensifier" tube or system rather than as an "image converter" tube or system even in applications where the primary purpose is a change in the wavelength of the radiation of the image.

In channel plate technology cases have arisen where it is desirable to provide a very thin membrane to obturate the end of each channel. This can be extremely difficult to achieve, particularly if the membranes have to be sufficiently thin to be electron permeable or if it is desired to avoid penetration of membrane material to the walls of the mouths of the channels beyond a fraction of a diameter.

Other difficulties can arise as illustrated by reference to one of the methods used by Applicants to form channel plates for image intensifiers employing a conductive film over the input face (and over the mouths of the channels) in accordance with British Patent Specification 1,175,599 (PHB 31816). In this particular method an aluminium film is evaporated onto a support film of nitrocellulose which is placed on the channel plate and then baked away. It is difficult to prepare large films which are uniform and free of small holes. Use of this method also results in carbonaceous residues from the

nitrocellulose remaining between the aluminium and the input electrode (usually of nichrome). Also, the aluminium film produced has poor adhesion on channel plates having large open areas.

It is an object of the present invention to provide an improved method of channel plate manufacture which permits such problems to be overcome.

The invention provides a method of manufacturing a channel plate including in addition a membrane obturating an end of each channel or a channel plate wherein such membranes are formed as extensions of the input electrode of the plate so that said electrode and membranes form, together, a continuous layer, which method includes the steps of:

A. allowing a liquid to extend by capillary attraction along the channels so as to form a meniscus at the mouth of each channel

B. rendering the meniscus surfaces solid so that they provide temporary supports for the formation of the desired membranes

C. forming said membranes on said temporary supports, and

D. removing the temporary supports so as to leave meniscus-shaped self-supporting membranes

If desired membranes are of the kind described in the aforesaid British Pat. specification 1,175,599 (PHB 31816) and the chosen membrane material is aluminium, then the above process is applied to the input face of the channel plate and the aluminium is applied, e.g., by vacuum deposition on the temporary supports. If the channel plate is of the kind having an input electrode distinct from the membrane, such electrode is formed on the channel plate matrix (usually nichrome on a glass matrix) before the aluminizing process. Conversely, if the plate is of the type wherein the membranes and input electrode form, together, a single continuous layer, then the process according to the present invention is applied to the channel plate matrix without the previous provision of a separate input electrode.

As will be understood from the following description, the liquid may for example be a simple liquid or it may be dispersion or emulsion. As for the methods of solidifying the meniscus support surfaces, various chemical and physical processes can be used and these include freezing (in the case of a simple liquid) and "breaking" an emulsion. Moreover, some of said processes (e.g. heating) may involve removal of the liquid from the channels as well as solidification of the meniscus support surfaces (as will be explained in the last of the examples, this situation may require means for preventing premature loss of liquid from the channels).

Specific embodiments of the invention will now be described by way of example as applied to the formation of aluminium membranes on a glass matrix which may or may not have a separate nichrome input electrode.

Example (a): A freezing method

This may be carried out by allowing a suitable liquid to extend into the channels by capillary action, freezing the liquid, evaporating the metal layer on the meniscus surfaces, allowing the frozen liquid to melt and finally removing the liquid. A method of evaporating metals on to a frozen liquid is known and can be a very clean method. However, it is difficult to retain the meniscus at the mouth of the channels because the liquid contracts into the channels on freezing. It is also difficult to remove the liquid without breaking the aluminium film.

Example (b): Formation of a meniscus film from a dispersion

This method provides each channel with exactly the same quantity of support film forming material, so that uniformity can be achieved regardless of channel plate diameter.

i. Practical requirements

1. a suitable dispersion of very fine particles
2. a convenient method of causing the dispersed particles to come out of the liquid (known as "breaking" the emulsion) and form a film on the surface.
3. a film forming material with suitable properties such as strength and good adhesion to nichrome and/or glass.
4. a film forming material which can be readily and completely removed after serving its purpose as a temporary support film.

ii. Practical methods using Emulsion Lacquers

Dispersions of very fine particles (e.g. 0.1μ) of organic polymers in water are available as emulsions and referred to as emulsion lacquers. The emulsion has very low viscosity like water, so that it will readily fill the smallest channels normally used.

The particles can be quickly caused to come out of the water ("breaking" the emulsion) and form a film on the meniscus by a wide range of physical and chemical means. The physical means include the use of heat, ultrasonics and electrical means. The chemical methods include the addition of electrolytes or surfactants and changing the pH value.

All of these methods cause the particles in the water to come together at the surface. A film of lacquer is then formed on the surface of the water.

For the use of emulsions with channel plates the plate can be supported above the floor of a dish with the input side uppermost. The emulsion lacquer is poured into the dish until it reaches the bottom of the plate. The emulsion lacquer then rises by capillary attraction in the channels and forms meniscus surfaces at the input side. The emulsion is then broken by one of the methods referred to above. The lacquer layer formed on the meniscus surface also adheres at the edge of the meniscus to the nichrome or glass at the mouth of each channel. This layer is hardened (and also the water under the lacquer is removed) by warming the channel plate in an oven. The film of lacquer of meniscus shape remains across the mouth of each channel. The aluminium is then evaporated and the lacquer removed by baking. The aluminium film produced is, of course, of meniscus shape across each channel.

Emulsions of various film forming polymers can be used, but methacrylates appear to be the most suitable at present. They can be readily removed after use by baking as is known from their use as temporary support films in the aluminising of T.V. tubes.

Example (c): A Preferred Emulsion Method in Detail

The emulsion used is poly-2-ethoxyethyl methacrylate in water. The polymer content used in only 0.3 percent by weight.

The emulsion is poured slowly into the dish containing the channel plate which is supported off the floor of the dish. When the emulsion level reaches the bottom of the channel plate it rises in the channels and can be observed when it reaches the top of the channels. In order to break the emulsion the dish and channel plate are warmed to 50°C and this temperature maintained for ten minutes. The lacquer film will then have formed on the meniscus surface. The channel plate is then transferred to an oven at 80°C for 2 hours in order to harden the film and remove the water under the lacquer film.

The channel plate is then placed in a vacuum evaporation equipment, the pressure reduced to 10^{-4} torr and the aluminium layer (e.g., 1,000A. thick) deposited on the channel input side. The channel plate is then baked in air in an oven at 350°C for 30 minutes to remove the lacquer.

When emulsion methods using heat to remove the liquid (as in Examples (b) and (c)) are applied to channel plates having channel diameters smaller than 100μ there is an increasing risk that the heating process will cause premature loss of liquid from the channels. As the column of liquid in a channel is shortened by removal of liquid from the open end (i.e., the end remote from the meniscus film) capillary attraction increases at both ends and, if this occurs before the meniscus surface has solidified sufficiently, the meniscus film can be punctured or torn by the capillary forces.

This can be prevented by retaining additional liquid outside, but in contact with, the remote ends of the channels. This can for example be achieved by using a method wherein, during solidification of the meniscus surfaces, additional liquid is retained outside, but in contact with, the remote ends of the channels (i.e. the ends remote from said meniscus surfaces) thereby to prevent premature loss of liquid from the channels. An example of the use of a mesh for this purpose will be given under a separate heading since it is applicable not only to the above specific Examples. However, before describing the use of a mesh, a further detailed Example will be described which is similar to Example (c).

Example (d): A second Preferred Emulsion Method in Detail

1. Preparation of the Emulsion Lacquer

The emulsion used is Poly-2-ethoxyethyl methacrylate in water. It has a solids content of 33 percent which is diluted to 0.6 percent solids before use.

It is essential to purify the emulsion lacquers before use in channels because the impurities have a detrimental effect on channel performance. These impurities consist of inorganic salts, emulsifying agents and unreacted monomer which are required for the preparation of the emulsion. Purification is carried out by ultra filtration.

2. Preferred Method of Breaking the Emulsion

This is carried out by directing radiant heat directly on the emulsion menisci at the ends of the channels. An infra-red lamp is used and located so that the top of the lamp bulb is 10 cms below the channel face. The heating time depends on the size of the channel plate but 2-5 minutes are normally required.

3. Procedure for Forming the Supports

Sufficient purified lacquer is poured into a round-bottom dish to give a liquid surface greater than the channel plate diameter. The channel plate is placed in the lacquer so that only its lower surface is immersed. The lacquer rises in the channels by capillary attraction and forms a meniscus at the top of each channel.

The channel plate is gently removed from the lacquer and the surplus drops of lacquer hanging from the lower surface and removed by wiping with a filter paper previously wet with water.

The channel plate is then inverted and supported horizontally by a clamp on the sides of the channel plate so that both faces are accessible.

A mesh having a diameter slightly smaller than that of the plate is then completely immersed in a dish of lacquer and then withdrawn when a layer of emulsion will be found over all the holes in the mesh. The mesh is placed on top of the channel plate. Additional lacquer is then run into the gap between the channel plate and the mesh until the gap is filled.

The lower face of the channel plate is now heated in order to cause the emulsion particles to form a solid plastic film on the liquid meniscus surfaces on the lower ends of the channels. The heat is applied by an infra-red lamp from a distance 10 cms below the channel plate for several minutes.

After the lamp is switched off the channel plate is allowed to stand until all the emulsion between the mesh and plate has disappeared. Emulsion then remains only in the channels above the solidified film at the bottom of the channels.

The mesh is removed from the channel plate which is then transferred to an oven at 70°C for 1 hour to dry out the liquid in the channels. The plate is put in the oven with the solidified film on the bottom side.

The channel plate is then placed in a vacuum evaporation equipment.

4. Deposition of Metal

The channel plate is located on a rotating table (the centre of which is heated) 15 cms above the aluminium source. The table surface is at an angle of 45° to the horizontal. The evaporating chamber is then pumped down below 10^{-4} Torr, and the table rotated at about 20 rpm while a 500 A. layer of aluminium is deposited on the lacquer layer. The channel plate is then baked in air in an oven at 350°C for 30 minutes to remove the lacquer leaving an aluminium film in each channel in the shape of a meniscus.

A non-reflecting black layer is required for some types of devices. This black layer can be provided on top of the first aluminium layer by evaporating aluminium through an inert gas such as nitrogen or argon at a pressure above 10^{-1} Torr.

The Use of a Mesh for Fine Channel Plates

A special problem is found in using emulsion lacquers in fine channel plates (channel diameters of 100 μ or less) which does not arise in capillary tubes of larger diameter (e.g., 500 microns). When the latter are filled with lacquer while being held vertically and heated from below the reduction in liquid volume by evaporation results in the top meniscus falling while the bottom meniscus stays in position. This allows a film to be formed without difficulty at the mouth of the tube.

However in channel plates with channel diameters of 100 microns or less, upon heating from below, the liquid menisci withdrawn from both ends. Furthermore, the initial rate of withdrawal from the channel mouth is very rapid so that any film formation is not at the mouth of the channel.

This problem can be met by retaining the meniscus at the mouth of the channel which is being heated to secure film formation.

Various methods of preventing the withdrawal of the meniscus from the channel mouth are possible. These include the application of pressure to the opposite end, the application of a voltage across the channel plate (to retain liquid at one end by electro-osmosis) and the use of cold lacquer to reduce the evaporation losses. The preferred method essentially provides a reservoir of water to the top surface of the channel which makes up evaporation losses and ensures that the lower meniscus is retained at the mouth of the channel.

In order to provide a reservoir it is not enough to cover the top surface with water since it will immediately fall through the channels. It is necessary to prevent this happening by providing some support for the reservoir of liquid but not too much support or it will not flow into the channels and keep the channels full of lacquer.

These requirements are met by the provision of a mesh located about 0.5–1 mm above the top surface of the channel plate and parallel to it. The channels are filled with water and the space between the channel plate and mesh is filled with water, the latter space acting as the reservoir. The capillary forces associated with the mesh are sufficiently strong to restrain the water while still allowing this excess liquid to act as a reservoir.

The result of this method is to maintain the meniscus at the mouth of the channel during the period of heating so that a satisfactory solid film can be produced.

The mesh has a further advantage in the subsequent removal of the reservoir water since it can rapidly evaporate through the mesh.

The mesh can be of woven wire or electroformed, made of nickel or stainless steel, and with a pitch about 0.8 mm. The mesh is at least 2 mm smaller in diameter than the channel plate it is used on. It can be supported 0.5 mm above the channel plate by bending down the edges of the mesh by that amount.

Care is necessary in the preparation of emulsions of high purity and also in ensuring that no residues of the lacquer remain in the channels.

Advantages of these preferred versions (c) and (d) of the process are:

a. A high degree of uniformity of the membranes.
b. No carbonaceous layer between nichrome and aluminium.
c. Large dust particles do not stick to the lacquer, since it is all in the channel mouths and thus below the face of the channel plate (this contrasts with the earlier method described herein with reference to Pat. specification No. 1,175,599: PHB 31816). Therefore, particles which would otherwise block several channels can be blown off and do not cause the formation of pinholes. Any dust particle small enough to reach the lacquer will only occupy one channel and will be an acceptable blemish.
d. Improved adhesion of the aluminium on channels of high open area, i.e., on a thin-walled matrix.
e. As a minor advantage, no inflammable solvents are involved.

Channel plates in accordance with the invention can be used in imaging tubes, for example an image intensifier tube of the "proximity" type or a tube of the "electron-optical diode" or "inverter" type.

The invention may also be used for other imaging tubes, for example cathode-ray display tubes and camera tubes.

What we claim is:

1. A method of manufacturing a channel plate including in addition a membrane obturating an end of each channel or a channel plate wherein such membranes are formed as extensions of the input electrode of the plate so that said electrode and membranes form, together, a continuous layer, which method includes the steps of:

A. allowing a liquid to extend by capillary attraction along the channels so as to form a meniscus at the mouth of each channel

B. rendering the meniscus surfaces solid so that they provide temporary supports for the formation of the desired membranes

C. forming said membranes on said temporary supports, and

D. removing the temporary supports so as to leave meniscus-shaped self-supporting membranes.

2. A method as claimed in claim 1 employed for the provision of metallic membranes, wherein metal is evaporated onto the temporary supports.

3. A method as claimed in claim 2 wherein the metal is aluminium.

4. A method as recited in claim 1 wherein the liquid in the channels is frozen so as to solidify the meniscus support surfaces.

5. A method as recited in claim 1 wherein the liquid in the channels is an emulsion and said emulsion is broken so that the dispersed particles in each channel are separated from the liquid and travel to one end of the liquid column to form a meniscus support surface.

6. A method as claimed in claim 5 wherein the action of heat is used to solidify the meniscus surfaces and to remove the liquid.

7. A method as recited in claim 5 wherein during solidification of the meniscus surfaces, additional liquid is retained outside, but in contact with, the remote ends of the channels, said channel ends being remote from said meniscus surfaces, thereby to prevent premature loss of liquid from the channels.

8. A method as recited in claim 7 wherein a mesh is held close to the face of the channel plate remote from the desired supports, said mesh having such pitch and such spacing from the channel plate as to enable it to retain liquid between itself and the plate.

9. A method as recited in claim 5 wherein the emulsion is a dispersion of organic polymer particles in water.

10. A method as recited in claim 3, further comprising the step of providing on said aluminum membrane a non-reflecting black layer, said layer being produced by evaporating aluminum through an inert gas.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,781,979 Dated January 1, 1974

Inventor(s) HENRY DERMOTT STONE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 16, delete "(PHB 31172)";

line 17, delete "(PHB 31173)" and "(PHB 31184)";

lines 18 and 19, delete "(co-pending...PHB31211)";

line 19, delete "(co-";

line 20, delete the entire line;

lines 22 and 23, delete "(PHB 31171 Comb.)";

line 23, delete "(PHB 31183)";

line 62, delete "(PHB 31816)".

Column 2, lines 2, 33, & 55, change "nichrome" to --Nichrome--;

lines 26 & 27, delete "(PHB 31816)";

line 42, after "be" insert --a--.

Column 3, lines 17 & 47, change "nichrome" to --Nichrome--;

line 39, change "floor" to --bottom--;

line 61, change "in Detail" to --Suitable for Channel Diameters Greater than 100 Microns--;

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CERTIFICATE OF CORRECTION

Patent No. 3,781,979 Dated January 1, 1974

Inventor(s) HENRY DERMOTT STONE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, after insert --Example (d): A Preferred Emulsion
line 15, Method Suitable for Channel Diameters of 100
Microns or Less--.

Column 4, line 39, change "." to --,-- and insert --the other
steps being described below in Sections 1
to 4:--.

Column 5, line 8, change "A" to --To retain additional
liquid (as mentioned above) a--;
line 34, delete "(";
line 35, change "heated)" to --located--.

Column 6, lines 39-41, delete in their entirety--;
line 45, change "nichrome" to --Nichrome--;
line 51, delete "PHB 31816)".

Signed and sealed this 23rd day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents