

[54] CHANNEL INTENSIFIER GLASS
COMPOSITIONS

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[51] Int. Cl.....H01j 43/08, H01b 1/08, C03c 3/04
[58] Field of Search313/103, 104, 105, 94, 65 T

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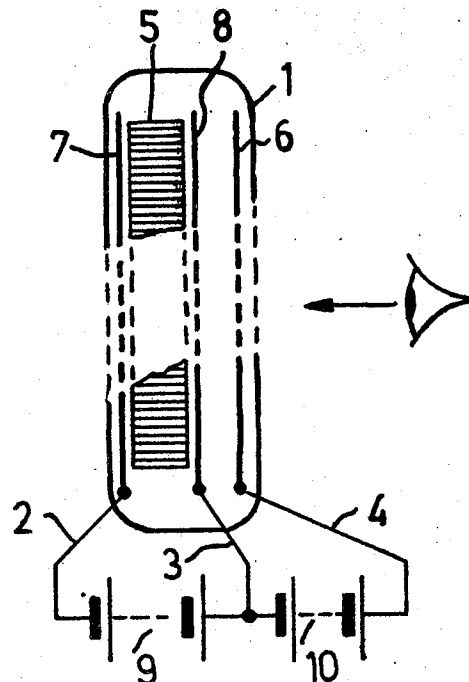
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Attorney—Frank R. Trifari

[57] ABSTRACT

An electronic image intensifier employing a resistive matrix in the form of a plate the major surfaces of which constitute the input and output faces of the matrix, a conductive layer on the input face of the matrix serving as an input electrode, a separate conductive layer on the output face of the matrix serving as an output electrode, and elongated channels each providing a passageway from one face of the assembly consisting of the matrix and input and output electrodes to the other face of the assembly. The distribution and cross section 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 image purposes. The matrix consists of a lead-bismuth silicate glass which has been reduced in hydrogen so that the channel surfaces have a conductive reduced oxide layer with a resistivity in the range 10^{10} to 10^{14} ohms/square.

6 Claims, 2 Drawing Figures



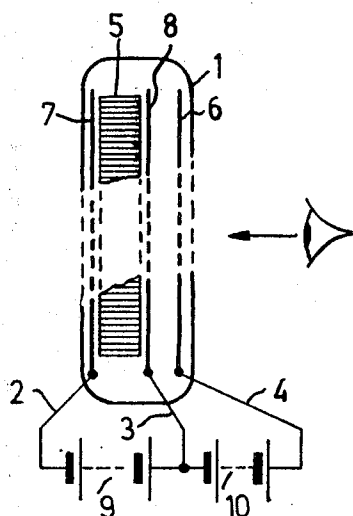


FIG. 1

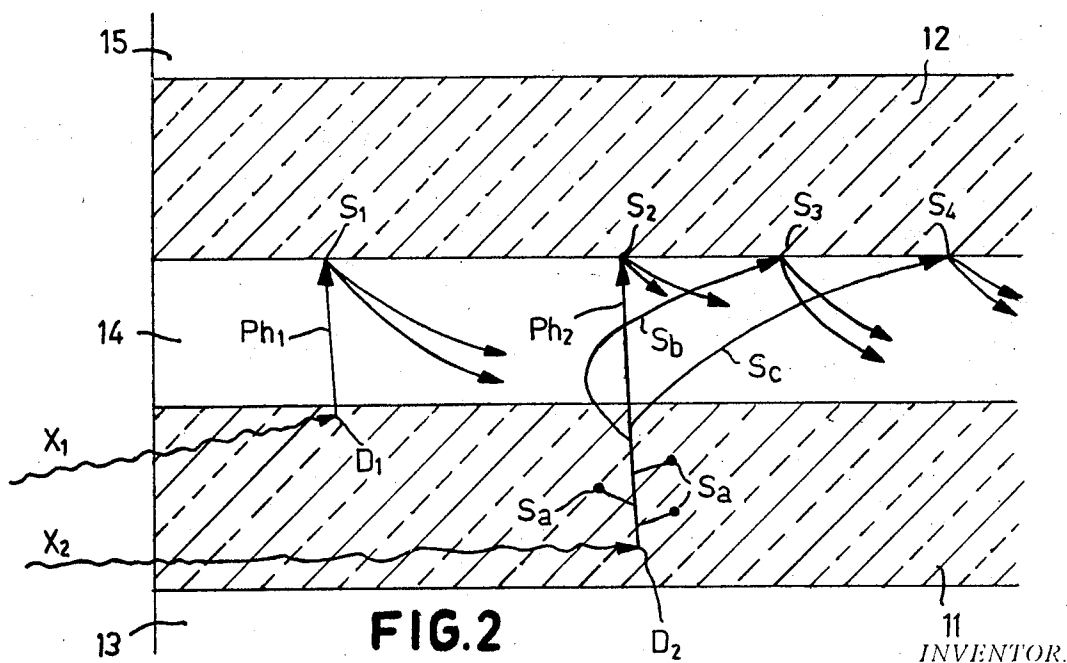


FIG. 2

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CHANNEL INTENSIFIER GLASS COMPOSITIONS

This invention relates to electronic image intensifier devices. More particularly the invention relates to "channel intensifier" devices and to electronic imaging tubes employing such devices. Such devices will be defined later but, briefly, they are secondary-emissive electron-multiplier devices comprising a matrix in the form of a plate having a large number of elongated 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, No. 1,064,074, No. 1,064,076, No. 1,090,406 and U.S. Pat. No. 3,492,759, while methods of manufacture are described in British Pat. Specifications No. 1,064,072 and No. 1,064,075.

In the operation of all these intensifier devices (when incorporated in electronic imaging tubes) a potential difference is applied between the two electrode layers of the matrix so as to set up an electron 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.

As a summary of this art, the devices referred to herein as "channel intensifier" devices (or, more briefly, "channel plates") are defined in the Patent Specifications referred to above in a definition given in the following terms:

A channel intensifier device is a secondary-emissive electron-multiplier device for an electronic imaging tube which device comprises a resistive matrix in the form of a plate the major surfaces of which constitute the input and output faces of the matrix, a conductive layer on the input face of the matrix serving as an input electrode, a separate conductive layer on the output face of the matrix serving as an output electrode, and elongated channels each providing a passageway from one face of the assembly consisting of matrix and input and output electrodes to the other face of said assembly, the distribution and cross sections of the channels and the resistivity of the matrix being 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 imaging purposes envisaged.

As imaging tube or system employing such a device can 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.

An embodiment of an X-ray image intensifier according to the invention is diagrammatically shown in cross section in FIG. 1 of the drawing, while

FIG. 2 serves for further explaining the manner in which the ray conversion takes place.

In an evacuated envelope 1, which is manufactured from insulating material, for example, glass or ceramic or from metal, for example, aluminum, the flat wall part on the left-hand side is permeable to X-rays and the flat wall on the right-hand side is transparent so that in certain cases these parts of the wall have to be provided with windows. In the drawing, the shape which these parts of the wall must have in that they are sufficiently strong is not shown because this is a known structural problem. The envelope is provided with lead-in conductors 2, 3 and 4 for electric voltages.

In the space enclosed by the envelope the secondary-emission intensifier 5 and a fluorescent screen 6 are arranged. It is noted in this connection that the simplest possible arrangement is shown. It is normal that in X-ray intensifiers a reduced image is reproduced on the viewing screen of the

photocathode image by electron optical projection. Further means required for that purpose may be provided in the present image intensifier without departing thereby from the way shown of converting the X-rays into radiation for the image observation.

The secondary-emission intensifier is lined on both sides with a conducting layer, the coating 7 being connected to the supply conductor 2 and the coating 8 to the supply conductor 3. The fluorescent screen is connected to the supply conductor 4. Increasing voltages are supplied from the two voltage sources 9 and 10 with the supply conductors 2, 3 and 4.

FIG. 2 shows a small portion of the secondary-emission intensifier 5, namely two joints 11 and 12 between successive channels 13, 14 and 15. The whole intensifier consists of channels spaced apart in a similar manner.

X-rays impinging upon the solid material are indicated by the waving lines X_1 and X_2 . The ray X_1 has penetrated to the point D_1 where a photoelectron is liberated. This electron substantially moves at right angles to the direction of the incident ray along the line Ph 1. The point where this electron is generated is so near to the surface of the solid substance that there is no chance for it to generate any further secondary electrons in the substance. Thus the photoelectron enters the channel 14 and crosses to the opposite side where one or more secondary electrons are liberated at the point where it impinges. Under the influence of the electric field produced by the applied voltages, the movement of these electrons is directed in the longitudinal direction of the channel. Under the influence of transverse components of the speed which are also operative, the electrons will repeatedly strike the wall of the channel as a result of which their number increases continuously.

Of the ray X_2 it is assumed that it penetrates to D_2 at which point a photoelectron is liberated. The longer travel of the electron in the solid substance presents the possibility of liberating further electrons S_a , S_b and S_c which, together with the first electron, move along the indicated tracks in which their number also increases. As in the case with the electrons indicated by S_a , these electrons are partly braked in the solid substance and are lost. Other electrons, for example S_b and S_c , reach a channel along a curved travel, since their energy is less than that of the photoelectron $Ph2$. The electrons together contribute to the formation of electron currents from each of the channels, the cross section of the channel being decisive of the image definition.

Among the problems encountered in the development of channel intensifier devices is that of choosing a suitable material from which to manufacture the matrix. If the matrix is to be made out of a large number of fine drawn tubes, e.g., as described in the said Pat. specification No. 1,064,072 then glass seems to be particularly suitable since it is capable of being worked into tubes of the required sizes. Conventional glasses may be made with the required level of bulk resistivity, but they are unsuitable for use in channel devices because they conduct by electrolysis and hence have a limited life. Some electronically conductive glasses have been developed, but their poor working characteristics prohibit their use in these devices. An alternative method of obtaining the right level of conductivity is to use a low-conductivity conventional glass on which an electronically conducting layer is deposited. Such a system would typically require a surface resistivity in the range 10^{10} to 10^{14} ohm/square depending on the device in question.

There are a number of well-known methods of increasing the surface conductivity of glass. Mostly, they consist of metallizing the surface using the techniques of vacuum evaporation, vapor deposition, firing of metal pastes, etc. All of these methods can give electronically conducting layers, but difficulty arises when high resistivities are required. High resistivities can be obtained with very thin layers, but the properties of the layers are difficult to reproduce since their structure, and therefore their electrical properties, are very dependent on the conditions under which the layer is deposited.

With thicker and more stable layers the electrical properties approach those of the bulk material. The highest resistivities are obtained by the use of metal-ceramic or metal oxide layers, but the limit seems to be about 10⁸ ohms/square.

The difficulty of forming this type of layer on other than plane surfaces or simple shapes also limits their use. Furthermore, in most cases the glass substrates cannot be worked once the layer has been deposited.

One rather less well-known technique is that of preparing special glasses containing the oxides of lead, bismuth or antimony and subjecting them to a reduction treatment, e.g., in a hydrogen atmosphere at high temperatures. The resistivity obtained is a complex function of the composition and structure of the glass and the method offers considerable range in resistivity. Such techniques have been described by R. L. Green and K. B. Blodgett in J. Am. Ceram. Soc., 31, to No. 4, p. 89, 1948, and by K. B. Blodgett in J. Am. Ceram. Soc., 34, No. 1, p. 14, 1951.

The heating of such glasses in a hydrogen atmosphere results in the reduction of lead and bismuth ions to their respective atoms. This involves the breakage of the bonds holding the ions in position in the glass structure. Thus the number of atoms reduced at a given temperature, and therefore the conductivity, depends on the strengths of the bonds and hence on the composition and structure of the glass, while another factor which determines the conductivity obtained is the position of the reduced atoms after treatment.

It is an object of the present invention to provide improved channel intensifier devices and an improved method of manufacturing such devices.

According to one of its aspects, the invention provides a channel intensifier device (as herein defined) wherein the matrix is made of a glass having substantially the following composition (in mol %):

- SiO₂-70 to 80
- Al₂O₃ 0 to 4
- PbO-7.5 to 18
- Na₂O- }
- K₂O } together 0-13
- Bi₂O₃ 0.5 to 4.0

and wherein the channel surfaces have a conductive reduced oxide layer with a resistivity in the range 10¹⁰ to 10¹⁰ ohms/square.

It is within the invention to depart slightly from the above composition, e.g., to the extent of including up to about 1% of added material composed of specific agents and/or unwanted impurities.

In the above composition it is desirable that changes in the reducible PbO-Bi₂O₃ content should be accompanied by compensating changes in the silica content.

The main effect of increasing the PbO and/or Bi₂O₃ at the expense of silica is to produce layers having more conductivity. In particular, as the reducible oxide content is increased the rate of fall in resistivity is greater for Bi₂O₃ than for PbO.

As for the Na₂O and K₂O components, previous work has shown that the amount of alkali present influences the resistivity obtained. However, it was found that exchanging Na₂O for K₂O had substantially no effect on the resistivity obtained. The sum of these components is preferably 5-13%.

The alumina has substantially no effect on the electrical properties of the material, its main or sole function being to increase the hardness of the glass. A preferred range of compositions is as follows (the percentages are mol % throughout):

TABLE A

SiO ₂	72.3 to 79.2
Al ₂ O ₃	1.1
PbO	7.5 to 18
Na ₂ O	5.9
K ₂ O	0 to 6.9

Bi₂O₃

0.5 to 4.0

Within this preferred range a first practical example can be given as follows:

TABLE B

SiO ₂	73.3
Al ₂ O ₃	1.1
PbO	10.8
Na ₂ O	5.9
K ₂ O	6.9
Bi ₂ O ₃	2.0

With a hydrogen reduction process adjusted to give (at the surfaces) a Log ρ value (ρ = resistivity in ohms/square) of about 12.15, this composition is suitable for a relatively small high-definition channel plate having channels about 40 μ in diameter or less.

A second example is as follows:

TABLE C

SiO ₂	72.3
Al ₂ O ₃	1.1
PbO	10.8
Na ₂ O	5.9
K ₂ O	6.9
Bi ₂ O ₃	3.0

With a hydrogen reduction process adjusted to give a Log ρ value of about 11.20, this composition is suitable for a relatively large and coarse channel intensifier device for use in an X-ray image converter, the channel diameter being approximately 100 μ .

Reverting in greater detail to the effects of the reduction process, Blodgett (in the second of the references cited) has shown that most of the conduction occurs within a distance of approximately 100 A. of the surface exposed to the hydrogen although the blackened layer is of the order 1 to 2 μ thick.

From energy considerations it is unlikely that the reduced atoms remain in atomic dispersion, there being probably some tendency to form more stable aggregates.

There is probably a concentration gradient in the reduced layer since the glass nearest the surface will be more completely reduced because of its proximity to the hydrogen atmosphere. Thus in the lower levels of the reduced layer the aggregates would be smaller and more widely spaced making conduction less likely. The fact that the current flow in these layers is very near the surface is a useful property in their application to channel multiplication where the current acts as a source of secondary electrons.

Thus the evidence points to a discontinuous structure and a conduction mechanism of the type associated with thin evaporated metal films.

What is claimed is:

1. A channel intensifier device comprising a platelike resistive matrix provided with a plurality of narrow parallel channels extending between opposite major surfaces of said matrix which constitute the input and output faces respectively of the matrix, and conductive layers on the input and output faces respectively of said matrix, said matrix consisting of a glass of substantially one of the following compositions (in mol %):

	Composition 1	Composition 2
SiO ₂	73.3	72.3
Al ₂ O ₃	1.1	1.1
PbO	10.8	10.8

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Na₂O
K₂O
Bi₂O₃

5.9	5.9
6.9	6.9
2.0	3.0

and wherein the channel surfaces have a conductive reduced oxide layer with a resistivity in the range 10^{10} to 10^{14} ohms/square.

2. A device as claimed in claim 1 wherein the inner surfaces of the channels have a Log σ value (as defined) of about 12.15 ohms/square.

3. A device as claimed in claim 1 wherein the inner surfaces

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of the channels have a Log σ value (as defined) of about 11.20 ohms/square.

4. A device as claimed in claim 2 wherein the channel diameter is about 40μ or less.

5. A device as claimed in claim 3 wherein the channel diameter is about 100μ .

6. An electronic imaging tube comprising in combination a channel intensifier device as claimed in claim 1 together with a photocathode.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,641,382 Dated February 8, 1972

Inventor(s) DEREK CREGEEN

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

Column 3, line 16, cancel "to"

line 46, " 10^{10} " (second occurrence) should read

-- 10^{14} --.

Signed and sealed this 20th day of June 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents