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(54) **Photo-conductive TV pick-up tube.**

(57) The invention relates to a photo-conductive TV pick-up tube in which the capacity of the photo-conductive film (5) is 15 to 150 $\mu F/m^2$, whereby it is possible to use a thin scanning electron beam and to markedly improve the resolution of the pick-up tube.

Photo-conductive TV pick-up tube

The present invention relates to a photo-conductive TV pick-up tube which is far higher in resolution than conventional ones.

In order to get a picture image with high resolution by a television camera, the number of scanning lines at a photo-conductive pick-up tube for producing a television signal has hitherto been increased. The photo-conductive pick-up tube is usually made up of a photo-conductive target for converting an optical image into an electric signal, an electron gun for emitting a scanning electron beam to detect the electric signal, and an electron beam control section for focusing and deflecting the electron beam.

In order to improve the resolution of a photo-conductive pick-up tube by increasing the number of scanning lines, various methods have been used, that is, the scanning electron beam has been made thin, or a photo-conductive film having a high resolving power has been used for forming the photo-conductive target. The photo-conductive pick-up tube having such a construction will be hereinafter referred to as "image pick-up tube for high definition television."

For example, a 1-in (2,54 cm-) image pick-up tube for high definition television using 1125 scanning lines and including a photo-conductive film which has a thickness of 4 to 6 µm and is made of an amorphous photo-conductive material containing selenium as main component, can produce an amplitude response of about 45 % at 800 TV lines (cf. the Journal of the Institute of Television Engineers of Japan, Vol. 39, No. 8, August 1985, pages 663 to 674).

The conventional image pick-up tube for high definition television has high resolution as mentioned above, but the resolution of the image pick-up tube is much less than that of a 35 mm or 75 mm video film. Accordingly, it is ardently desired to further improve the resolution of the image pick-up tube for high definition television.

When a scanning electron beam of large diameter is used in the above pick-up tube, the improvement in resolution is limited by the beam diameter. Accordingly, it is preferable to use a scanning electron beam having a small diameter. According to the prior art, however, there arises a problem that even when the beam diameter of the scanning electron beam is made small, the pick-up tube cannot have the desired high resolution.

The present invention is based on the finding that when a conventional image pick-up tube for high definition television is operated, the variation in the surface potential at the surface of the photo-conductive film due to incident light is great, which makes it impossible for the image pick-up tube to have the desired high resolution. In more detail, when the scanning electron beam is made thin to attain high resolution, it is deflected due to the avobe-mentioned great variation in the surface potential. This effect is remarkable in the vicinity of the edge of an optical image, and thus a reconstructed pattern will become fuzzy.

It is the object of the present invention to provide a photo-conductive TV pick-up tube, in which the variation in the surface potential at the surface of the photo-conductive film is only small, and the resolution of the pick-up tube is markedly improved.

Furthermore, the photo-conductive pick-up tube shall be small-sized and include a photo-conductive film which is low in manufacturing costs, particularly concerning a reduction of the deposition time of the photo-conductive film to enhance the manufacturing productivity.

This object is achieved according to the claims.

According to the conception of the invention, the variation in surface potential at the surface of the photo-conductive film is made small by increasing the capacity of the photo-conductive film.

The photo-conductive film preferably has a capacity of 15 to 150 $\mu F/m^2$, which leads to a marked reduction of the surface potential variation.

For further improving the resolution, the thickness of the photo-conductive film is made small which further reduces the variation of the surface potential of the photo-conductive film.

According to another preferred embodiment, the diameter of the scanning electron beam is made small.

In the following, the photo-conductive pick-up tube according to the present invention will be explained in more details with reference to examples and the accompanying drawings, whereby it is to be noted that operation, shape, size and structural details of the pick-up tube can be modified within the scope of the claims.

Fig. 1 shows a schematic cross-section of a photo-conductive pick-up tube, to which the present invention is applied.

Fig. 2 is a diagram showing to relation between the capacity per unit area of the photo-conductive film and the amplitude response for 2/3-in. (1,7 cm-) photo-conductive pick-up tube having a small beam-limiting aperture and using 1125 scanning lines.

Fig. 3 is a diagram showing the relation between the distance between the mesh electrode and the photo-conductive film, and the amplitude response for a 2/3-in. (1,7 cm-) photo-conductive pick-up tube having a small beam-limiting aperture and increased capacity of the photo-conductive film.

Fig. 4a and 4b are schematic representations showing examples of the cross-sectional structure of the beam-limiting aperture according to the invention.

Prior to the explanation of the present invention, the structure and operation of a photo-conductive pick-up tube will be explained.

Fig. 1 shows a schematic cross-section of a photo-conductive pick-up tube, to which the present invention is applied. It comprises a cathode 1, a scanning electron beam 2, an electrode 3 for controlling the electron beam 2, a beam limiting aperture 4, a photo-conductive film 5, a mesh electrode 6, a transparent electrode 7, a face plate 8 made of glass, and a glass bulb 9. When an external power source 10 is connected between the cathode 1 and the transparent electrode 7 as shown in Fig. 1, and further the photo-conductive film 5 is scanned with the focused electron beam 2, the surface of the photo-conductive film 5 on the scanning side is negatively charged, and the potential of this surface becomes nearly equal to the cathode potential. That is, the photo-conductive film 5 is charged up to a level substantially equal to the output level of the external power source 10. When light is incident upon the photo-conductive film 5, the resistance thereof decreases, and thus the negative charges on the surface of the photo-conductive film 5 are decreased by discharge. Accordingly, a charge pattern corresponding to the intensity distribution of the incident light is formed on the surface of the photo-conductive film 5 on the scanning side, that is, a variation in the surface potential is caused by the intensity distribution of the incident light. When the photo-conductive film 5 is scanned with the electron beam 2, the electron beam 2 lands on the photo-conductive film 5 in accordance with the above variation in the surface potential, and hence a charging current corresponding to the discharged electric quantity flows through an amperemeter 11. Thus, the optical image formed on the photo-conductive layer 5 is time-sequentially converted into a signal current.

In connection with the invention the relation between the resolution of such a photo-conductive pick-up tube and the capacity of the photo-conductive film has been investigated in detail, and it has been found that the resolution can be markedly improved by making the diameter of the beam limiting aperture 4 small and by increasing the capacity of the photo-conductive film 5.

Fig. 2 shows an example of the relation between the capacity per unit area of photo-conductive film and the amplitude response for a 2/3-in. (1,7 cm-) photo-conductive pick-up tube provided with a beam limiting aperture having a diameter of 10 μm which is operated with 1125 scanning lines. Fig. 2 shows that the amplitude response, that is, the resolution of the pick-up tube, can be greatly improved by making the capacity per unit area (hereinafter referred to as "normalized capacity") of the photo-conductive film $\geqq$ 15 $\mu F/m^2$. The resolution becomes higher the larger the normalized capacity is made. However, when the normalized capacity is made too large, the lag, namely, the delay of the photo-response, becomes remarkable. Accordingly, it is desirable from the practical point of view to make the normalized capacity of the photo-conductive film $\leqq$ 150 $\mu F/m^2$; the upper limit of the normalized capacity should be determined in accordance with the specific purpose, for which the pick-up tube is used.

In a case where the photo-conductive film is made of an amorphous photo-conductive material which contains selenium having a high resolving power as a main component, by making the thickness of the photo-conductive film $\leqq$ 3,5 μm, the normalized capacity of the film can be made greater than 15 $\mu F/m^2$, and the resolution of the pick-up tube can be markedly improved thereby.

The improvement in resolution by increasing the normalized capacity of the photo-conductive film is remarkable in a case where the diameter of the beam limiting aperture 4 is made small, and a large number of scanning lines is used. When the diameter of the beam limiting aperture is large, it is impossible to greatly improve the resolution by increasing the normalized capacity of the photo-conductive film , since the resolution is restricted by the beam diameter determined by the aperture 4.

Accordingly, it is desirable that the diameter of the beam limiting aperture 4 is made smaller than 15 μm for a 2/3-in. (1,7 cm-) pick-up tube, and smaller than 25 μm for a 1-in. (2,54cm-) pick-up tube. However, the electric quantity carried by the electron beam 2 decreases as the diameter of the beam limiting aperture 4 is smaller. It is desirable from the practical point of view to make the diameter of the aperture 4 greater than 5 μm as a lower limit.

Further, it is desirable to taper the beam limiting aperture 4 in the direction from its exit toward its entrance, thereby enhancing the transmissivity for the electron beam 2. Fig. 4a and 4b show examples of the beam limiting aperture 4. Preferably, the cross section profile of the (enlarged) portion of the beam limiting aperture 4 which is parallel to its center axis, is defined by a polygon-like plurality of straight lines or a curved line on each side of the center axis, as shown in Figs. 4a or 4b, respectively.

Fig. 3 shows an example of the relation between the resolution of a 2/3-in (1,7 cm-) photo-conductive pick-up tube having the above-mentioned construction, and the distance between the mesh electrode and the photo-conductive film. As can be seen from Fig. 3, in order to improve the resolution of the pick-up tube to a great extent, the distance between the mesh electrode 6 and the photo-conductive film 5 must be in a range from 1 to 3 mm, and preferably in the range from 1 to 2 mm.

In the above description, a 2/3-in. (1,7 cm-) photo-conductive pick-up tube has been explained, by way of example. Of course, according to the invention, the resolution of other photo-conductive pick-up tubes, such as 1-in. (2,54 cm-) photo-conductive pick-up tubes, can also be improved analogously.

For example, a 1-in. (2,54 cm-) photo-conductive pick-up tube and a 2/3-in. (1,7 cm-) photo-conductive pick-up tube according to the present invention were operated so as to have 1125 scanning lines, and produced an amplitude response of more than 80 % and of about 40 %, respectively, at 800 TV lines, while conventional photo-conductive pick-up tubes of the same size gave an amplitude response of about 45 % and of about 30 %, respectively. As is evident from the above, the resolution of photo-conductive pick-up tubes can be markedly improved on the basis of the present invention.

Now embodiments of photo-conductive pick-up tubes according to the present invention will be explained.

Embodiment I

A transparent electrode containing SnO_2 as its main component is deposited on a 1-in. (2,54 cm-) diameter glass substracte by a chemical vapor deposition method, and an amorphous photo-conductive film made of selenium, arsenic and tellurium and containing more than 50 % by mass of selenium is deposited on the transparent electrode by a vacuum deposition method in a vacuum of less than 1,3 mPa (10^{-5} Torr). The thickness of the photo-conductive film is made such to be in the range from 0,35 to 3,5 μm. Next, a porous Sb_2S_3 film is deposited on the photo-conductive film in an atmosphere of argon kept at a pressure of 1,3 Pa (10^{-2} Torr) so that the tickness of the Sb_2S_3 film lies in a range from 40 to 100 nm (400 to 1000 Å), to be used as an electron beam landing layer. Thus, a photo-conductive target having a normalized capacity of more than 15 $\mu F/m^2$ is formed.

The above photo-conductive target, an electron gun, a mesh electrode an an electrode structure for focusing and deflecting the electron beam are mounted in a glass bulb, which is then evacuated. In this pick-up tube, the diameter of the beam limiting aperture is made equal to 15 μm.

Embodiment II

A transparent electrode containing SnO_2 or In_2O_3 as its main component is deposited on a 2/3-in. (1,7 cm-) diameter glass substrate by a chemical vapor deposition method or by sputtering, and a CeO_2 film is deposited on the transparent electrode to a thickness of 15 nm (150 Å) by a vacuum deposition method, to be used as a hole blocking layer. Next, first, second and third photo-conductive layers are successively deposited by a vacuum deposition method so that a photo-conductive film having a thickness of 0,35 to 3,5 μm is formed on the CeO_5 film. The first photo-conductive layer is an amorphous Se-As layer which has a thickness of 10 to 100 nm (100 to 1000Å), and in which the mean arsenic content is less than 15 % by mass. The second photo-conductive layer serves as a sensitizing layer and is an amorphous Se-Te-As layer which has a thickness of 20 to 150 nm (200 to 1500 Å), and in which the mean tellurium content lies within a range from 20 to 50 % by mass and the mean arsenic content is less than 5 % by mass. The third photo-conductive layer is an amophous Se-As layer, in which the mean arsenic content is less than 15 % by mass. Finally, a porous Sb_2S_3 film is deposited on the photo-conductive film to a thickness of 40 to 100 nm (400 to 1000 Å) in an inert atmosphere kept at a pressure of 1,3 Pa (10^{-2} Torr), to be used as an electron beam landing layer. Thus, a photo-conductive target having a normalized capacity of more than 15 $\mu F/m^2$ is obtained. In the above-mentioned photo-conductive film most of incident light is absorbed by the first and second photo-conductive layers. Accordingly, even when the third photo-conductive layer is made thin to increase the normalized capacity thereof, the sensitivity of the photo-conductive film is not decreased.

The above photo-conductive target, an electron gun, a mesh electrode and an electrode structure for focusing and deflecting the electron beam are mounted within a glass bulb, which is then evacuated. In this pick-up tube, the electron gun is of a diode type, the beam limiting aperture has a cross-section such as (enlarged) shown in Fig. 4a, that is, the cross-section profile of the portion of the aperture which is parallel to its center axis, is shaped polygon-like and defined by two straight lines on both sides of the center axis, the minimum diameter of the beam limiting aperture being 10 µm; the mesh electrode is formed of a 1500 to 2000-mesh copper screen, and the distance between the mesh electrode and the photo-conductive target lies in a range from 1 to 2 mm.

The photo-conductive pick-up tubes explained in the embodiments I and II are preferred embodiments of the present invention. However, these embodiments have been described for explaining the technical conception of the present invention. Accordingly, it is to be understood that the present invention is not limited to the specific embodiments described above.

Claims

1. A photo-conductive TV pick-up tube comprising:
a photo-conductive film (5) having a capacity of 15 to 150 $\mu F/m^2$ for converting an optical image into electric signals,
a mesh electrode (6) disposed so as to confront the photo-conductive film (5), and
an electron gun (1, 3) for emitting a scanning electron beam (2) and being provided with a beam limiting aperture (4) limiting the diameter of the emitted electron beam.

2. The pick-up tube according to claim 1, wherein the diameter of the beam limiting aperture (4) is 5 µm to 25 µm.

3. The pick-up tube according to claim 1 or 2, wherein the photo-conductive film (5) is formed of an amorphous layer, at least a portion of which contains selenium as its main component.

4. The pick-up tube according to one of claims 1 to 3, wherein the thickness of the amorphous layer of the photo-conductive film (5) is 0,35 to 3,5 µm.

5. The pick-up tube according to one of claims 1 to 4, wherein the beam limiting aperture (4) is tapered in the direction opposite to the propagation direction of the electron beam (2).

6. The pick-up tube according to one of claims 1 to 5, wherein the cross-section profile of the portion of the beam limiting aperture (4) which is parallel to its center axis, is defined by a polygon-like plurality of straight lines on both sides of the center axis (Fig. 4a).

7. The pick-up tube according to one of claims 1 to 5, wherein the cross-section profile of the portion of the beam limiting aperture (4) which is parallel to its center axis is defined by a curved line on both sides of the center axis (Fig. 4b).

8. The pick-up tube according to one of claims 1 to 5, wherein the cross-section of the enlarged portion of the beam limiting aperture (4) which is parallel to its center axis, is defined by two straight lines, on one side of the center axis (Fig. 4a).

9. The pick-up tube according to one of claims 1 to 8, wherein the distance between the photo-conductive film (5) and the mesh electrode (6) is 1 to 3 mm.

10. The pick-up tube according to one of claims 1 to 9, wherein the diameter of the beam limiting aperture (4) is ≦ 15 µm for a 2/3-in. (1,7 cm-) pick-up tube and is ≦ 25 µm for a 1-in. (2,54 cm-) pick-up tube, and is ≧ 5 µm in all cases.

FIG. 1

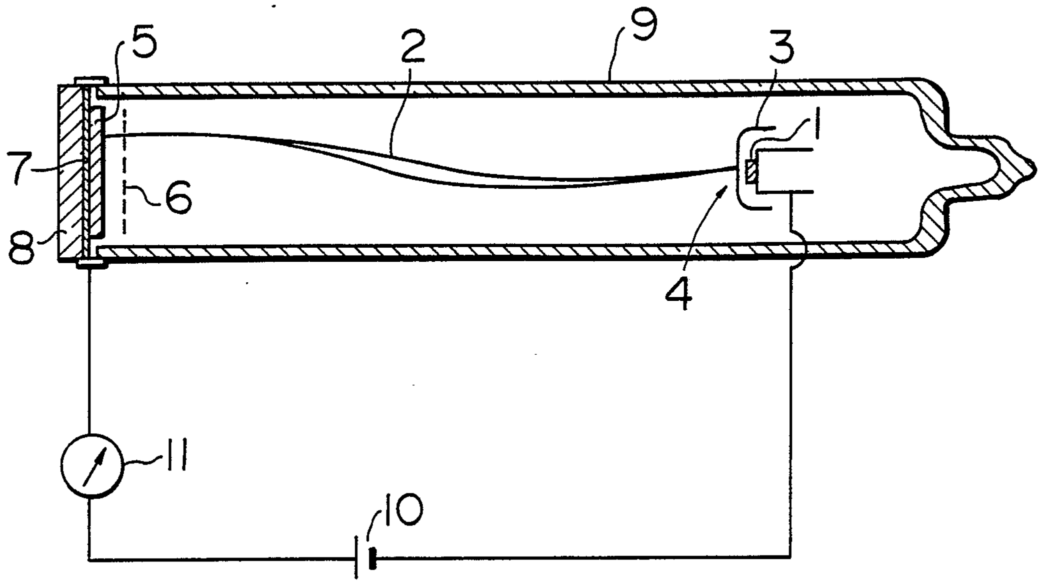
5
2
9
3
1
7
6
8
4
11
10

FIG. 2

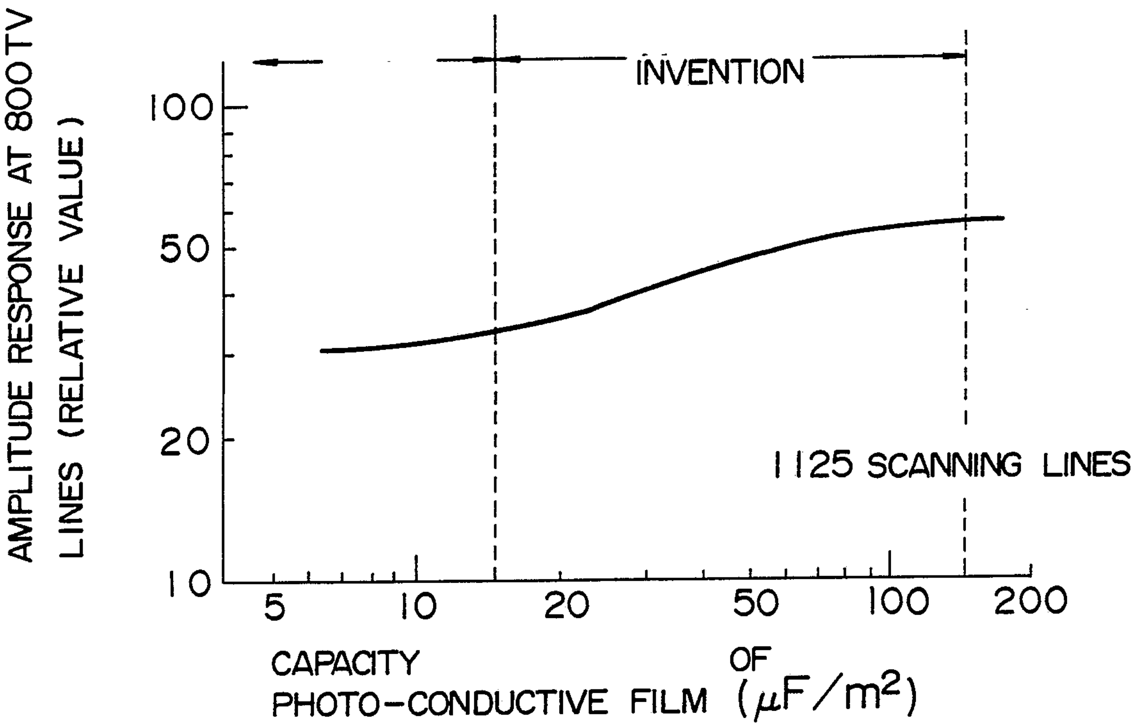
INVENTION
100
50
20
10
5
10
20
50
100
200
1125 SCANNING LINES
AMPLITUDE RESPONSE AT 800TV LINES (RELATIVE VALUE)
CAPACITY OF PHOTO-CONDUCTIVE FILM ($\mu F/m^2$)

FIG. 3

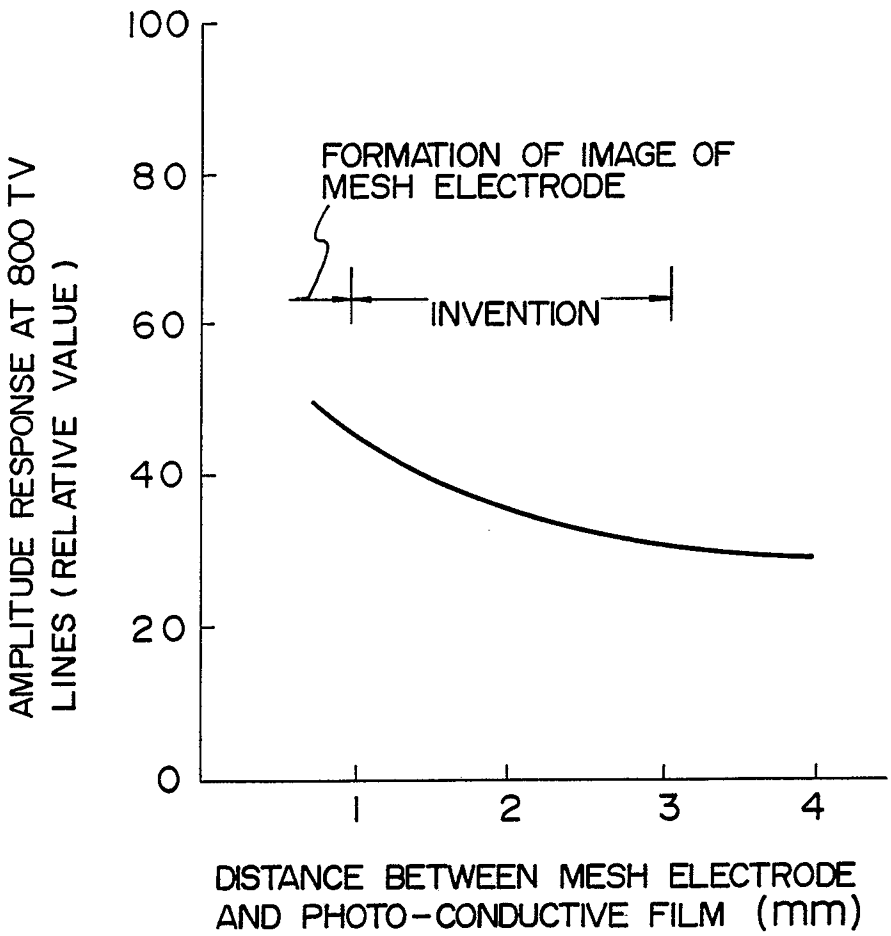
100
80
60
40
20
0
FORMATION OF IMAGE OF MESH ELECTRODE
INVENTION
AMPLITUDE RESPONSE AT 800 TV LINES (RELATIVE VALUE)
1
2
3
4
DISTANCE BETWEEN MESH ELECTRODE AND PHOTO-CONDUCTIVE FILM (mm)

FIG. 4a

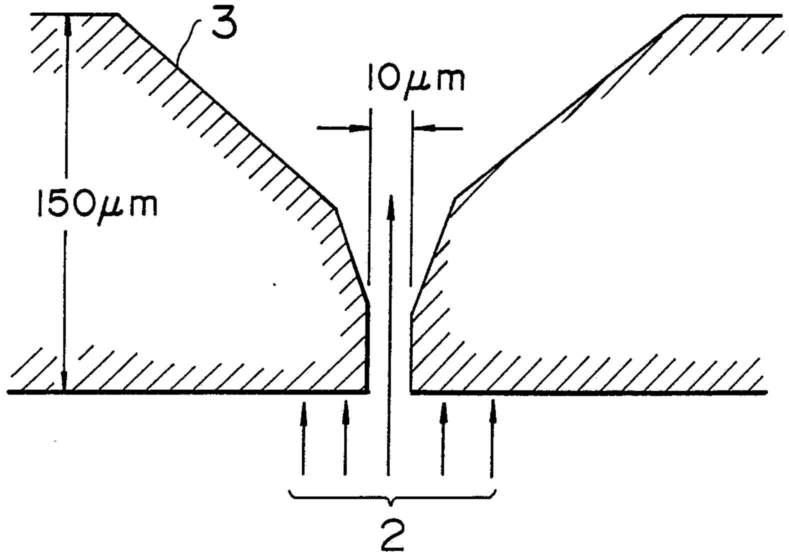

FIG. 4b