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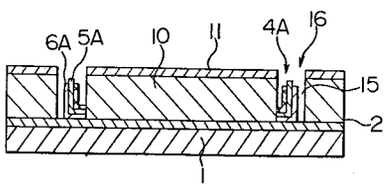
(54) Field emission cold cathode and method for manufacturing the same.

(57) A field emission cold cathode and a method for manufacturing the same is disclosed. The emitter electrode of the cold cathode comprises an emitter layer having an emission edge (5A) for emission of electrons and disposed perpendicular to a substrate (1) and a control electrode layer (11). The emitter electrode also comprises two supporting layers (6A) at both sides of the emitter layer. The emitter layer can be formed in a thickness of tens of angstrom by a conventional semiconductor process technology including a MBE process. An emitter of a reproducible and uniform layer can be obtained for the field emission cold cathode.

FIG. 1 (i)



EP 0 569 671 A1

FIELD OF THE INVENTION

The present invention relates to a field emission cold cathode and a method for manufacturing the same in which a fine process technology is used for fabrication.

BACK GROUND OF THE INVENTION

Fig. 2 shows a cross-section of a combination of an anode and a conventional cold cathode constituting a display unit. The cathode shown in Fig. 2 is called a cold cathode of a Spindt type among conventional cold cathodes fabricated by a fine process technology. An insulating layer 33 forming recesses therein, a gate 34 of a thin metal film having holes 39 each aligned with the recess, and emitters 32 each having a pointed tip and disposed at the recess are formed on a semiconductor substrate 31. The gate 34 serving as a control electrode for an emission current is applied with a positive voltage relative to both the emitters 32 and the semiconductor substrate 31 maintained at a common potential.

The semiconductor substrate 31, the emitters 32, the insulating layers 33 and the gate 34 constitute the cold cathode 35, and the anode 36 is disposed opposite to the cathode 35. Each of the emitters 32 has an extremely pointed tip, so that a very high electric field is generated around the tips, hence electrons are emitted from the emitters 32 in an amount corresponding to the voltage applied to the gate 34.

The space between the cathode 35 and the anode 36 is kept at a vacuum, and the electrons emitted from the cathode 35 reach and hit the anode 36 applied with the positive voltage and coated with a fluorescent material. The current of the electron beam emitted from one of the emitters 32 is of a small amount in an order of 10 - 50 μA at most, so that a number of emitters are arranged on the surface of the substrate 31 for obtaining a desired electron beam current.

Fig. 3 shows a cross-section of another combination of an anode and a cold cathode of a laid-down type among the conventional cold cathodes fabricated by the fine process technology. In Fig. 3, an emitter 32, a gate 34 and a laid-down anode 37 constituting a cold cathode 35 are formed on an insulating substrate 38 and an opposite anode 36 is disposed opposite to the cold cathode 35. A sheet-figured electron beam is emitted from the line-figured tip of the emitter 32 and reaches at the laid-down anode 37 or the opposite anode 36 applied with a positive voltage relative to the cathode 35 and coated with a fluorescent material.

With the cold cathode of a Spindt type shown in Fig. 2, the emitters 32 of about a 1 μm height are fabricated in such a way that a metal is deposited by a vapor deposition through the holes 39 of the gate 34 so as to form an extremely pointed tip figure of the emitter 32 during the deposition process. Such a process is different from a conventional process in the semiconductor fabrication technology, so that special designs for a manufacturing apparatus and a fabrication procedure are required. Besides, with such a cathode, although the amount of the current should be designed in part by the radius of the curvature of the emitter tips, it is difficult to fabricate the radius of the curvature of each tip with a good reproducibility and a uniformity.

With the cold cathode of a laid-down type shown in Fig. 3, although it has an advantage in which the conventional semiconductor fabrication technology is utilized, it is difficult to attain a sufficient electric field around the tip of the emitter 32, so that a sufficient current can not be obtained without applying high voltage between the gate 34 and the emitter 32. Consequently, a sufficient change rate of the emission current relative to the change of the gate voltage can not be obtained.

Besides, in Fig. 3, the electron beam emitted in a horizontal direction from the emitter 32 must be deflected by a right-angle with an accuracy to reach and hit a certain position of the anode 36. The position hit by the electron beam, however, changes due to only a slight change in the conditions such as the voltage change between the electrodes, so that it is difficult to realize a stable display unit utilizing the cold cathode of a laid-down type.

SUMMARY OF THE INVENTION

In view of foregoing, an object of the present invention is to provide a field emission cold cathode and a method for manufacturing the same in which a tip figure of the emitter of the cold cathode is reproducible and uniform.

Another object of the present invention is to provide a field emission cold cathode and a method for manufacturing the same in which a change rate in an emitter current relative to the change of the gate voltage is considerably large.

According to a first aspect of the present invention, there is provided a field emission cold cathode comprising: a substrate; an insulating layer carried by said substrate and having a recess therein; a control electrode layer formed on said insulating layer and having a cut-out at least partially overlapping said recess; and an emitter layer having an edge portion at said recess.

According to a second aspect of the present invention, there is provided a method for manufacturing a field emission cold cathode including steps

of: forming a structure having a perpendicular surface substantially perpendicular to a substrate; forming at least one emitter layer at least on said perpendicular surface; forming a filling layer on said emitter layer; removing partially said structure, said emitter layer and said filling layer substantially parallel to said substrate for exposing a cross-section of said emitter layer.

According to the present invention, the emitter layer emitting an electron beam from an edge thereof can be fabricated with a good reproducibility and a uniformity by using a semiconductor fabrication technology. Besides, a change rate in the emission current relative to the change of the gate voltage is considerably large, since the emission edge can be formed extremely sharp. Moreover, since the direction of the emission current can be substantially perpendicular to the control electrode layer, a stable and accurate electron beam reaching and hitting a certain position of a display screen can be obtained when it is applied to a display unit.

BRIEF DESCRIPTION OF THE DRAWING

Figs. 1(a) to 1(i) are cross-sectional views each for showing a step in a method according to an embodiment of the present invention for manufacturing a field emission cold cathode according to an embodiment of the present invention;

Fig. 2 is a cross-sectional view showing a combination of an anode and a conventional field emission cold cathode; and

Fig. 3 is a cross-sectional view of another combination of an anode and a second conventional field emission cold cathode.

PREFERRED EMBODIMENT

Figs. 1(a) to 1(i) each shows a cross-section of a field emission cold cathode in a fabrication step for showing a method according to an embodiment of the present invention for manufacturing a field emission cold cathode. In Fig. 1(a), a common conductive layer 2 is deposited on an insulating substrate 1. Next, a first oxide layer 3 is formed and subjected to a vertical etching treatment by a reactive ion etching (RIE) process for building a surface 3A of the first oxide layer 3, the surface being substantially perpendicular to the substrate 1. Subsequently, a set of layers including three conductive layers 4, the vertical portion of which is to be formed as an emitter electrode 4A, are deposited in an overlapping configuration as shown in Fig. 1(b).

The central conductive layer among the three conductive layers 4 constitutes an emitter layer 5 and the remaining two constitute supporting layers 6. Platinum, tungsten or molybdenum may be utilized as a material for the emitter layer 5. Since the supporting layers 6 are removed selectively from the emitter layer 5 by a later etching process, the supporting layers 6 should be formed of a material having a nature chemically different from the emitter layer 5. The emitter layer 5, which is formed in a tens to hundreds of angstrom thickness, for example, 50 - 500 angstrom, may be preferably grown by molecular beam epitaxy (MBE).

As shown in Fig. 1(c), a second oxide layer 7 is then deposited and a subsequent leveling treatment is carried out to the second oxide layer 7. Next, unnecessary portions of the three conductive layers 4 extending horizontally on the first oxide layer 3 is removed, for example, by grinding parallel to the substrate 1 to dispose the cross-section 8 of the three conductive layer 4 between the surfaces of the first and second oxide layers 3 and 7 as shown in Fig. 1(d).

Next, as shown in Fig. 1(e), a mask 9 is formed on the cross-section 8 by patterning a layer deposited at the region on the cross-section 8 of the three conductive layers 4. Since the mask 9 functions only as a sacrificial layer, such a material as resist titanium, gold, aluminium may be used which can be removed without interference with the other materials. Subsequently, as shown in Fig. 1(f), the first and second oxide layers 3 and 7 and the horizontal portion 4B of the three conductive layers 4 are removed by another RIE process selectively from the vertical portions 4A of the three conductive layers 4 using the mask 9 to obtain a vertical structure of the emitter electrode 4A.

Then, an oxide material and another conductive material are consecutively deposited for forming a third oxide layer 10 and another conductive layer serving as a control electrode 11. The control electrode layer 11 has a hole or a cut-out at the location where the mask 9 is formed. Such a metal as tungsten is preferably used as the conductive material for the control electrode layer 11. As shown in Fig. 1(g), the oxide and conductive materials are also formed as layers 12 and 13, respectively, above the emitter electrode 4A. The oxide layer 12 and the conductive layer 13 are then removed as shown in Fig. 1(h) by using an etchant which can etch only the material forming the mask 9.

Next, the supporting layers 6A among the three vertical conductive layers constituting the emitter electrode 4A are slightly removed at the tip portion by etching for exposing a tip of the central emitter layer 5A. Lastly, as shown in Fig. 1(i), another etching process is carried out for removing the unnecessary oxide layers 14 as remaining portions of the first and second oxide layers 3 and 7 disposed around the emitter electrode 4A. Hence, a

field emission cold cathode according to an embodiment of the present invention is obtained.

Now, a field emission cold cathode according to an embodiment of the present invention is described. The field emission cold cathode, as shown in Fig. 1(i), has an insulating substrate 1, a common conductive layer 2 formed on the substrate 1, an insulating layer 10 formed on the common conductive layer 2 and having a recess 15, a control electrode layer or a gate layer 11 disposed on the insulating layer 10 and having a hole or a cut-out 16 overlapping the recess 15, and an emitter electrode 4A including an emitter layer 5A and supporting layers 6A for supporting the emitter layer 5A and disposed at the recess 15. The emitter layer 5A has a perpendicular portion substantially perpendicular to the control electrode layer 11, and the perpendicular portion of the emitter layer 5A has an edge or a line-figured tip extending from between the supporting layers 6A at the recess 15 and below the cut-out 16.

With the embodiments as described above, the configuration is disclosed in which the common conductive layer 2 is formed on the insulating substrate 1, as shown in Fig. 1(i). It is possible, however, to form an emitter structure directly on a metal substrate or a semiconductor substrate. Further, each of the supporting layers may be an insulating layer instead of a conductive layer.

In order to realize a plane-figured cathode, such a construction may be employed in which the structure of Fig. 1(i) is formed as having a continuous configuration on a large chip area. Alternatively, it is possible to form a number of unit structures of the cathode of a certain dimension and arrange the same in a longitudinal and a lateral directions to form a plane-figured cathode structure extending on a large chip area.

Although such a configuration is described herein as an embodiment of the present invention in which a sheet-figured electron beam can be obtained from a line-figured edge of the thin layer, the concept of the present invention can be extended, for example, to another configuration in which emissions are obtained from a series of points of emitter tips arranged zigzag or serriedly at the edge of a thin layer or still another configuration in which emissions are obtained from a series of short lines of emitter tips arranged in a figure similar to teeth of a comb at the edge of a thin layer.

When other constructions are employed, for example, instead of the first, second and third oxide layer 3, 7 and 10, a similar advantage can be obtained so long as the selectivity of etching is secured in the manufacturing process. Besides, even when only one of the side surfaces of the emitter layer is provided with a supporting layer instead of both sides of the supporting layers, a similar advantage can be obtained.

When the manufacturing process according to the embodiment as described above is employed, an emitter layer extremely sharp and moreover uniform as well as reproducible in the tip figure can be obtained, since a thin layer of a tens or hundreds of angstrom thickness can be easily formed by utilizing a semiconductor process such as a MBE process for growing an emitter layer. Since the emitter layer can be supported at both or one of the sides thereof, the extremely thin layer serving as an emitter can be kept in a vertical position in a good stability.

The field emission cold cathode according to the embodiment of the present invention can be produced at a process completely equivalent to the conventional semiconductor process, hence the method is more advantageous when forming the field emission cold cathode on a larger chip area. Besides, since only the emitter layer of the emitter electrode should be a thin layer and the remaining members of the emitter electrode may be thick, heat-resistivity and mechanical strength of the emitter electrode may be large so that an emitter structure of a good stability is obtained.

Claims

1. A field emission cold cathode characterized by: an insulating layer (10) having a recess (15) therein; a control electrode layer (11) formed on said insulating layer (10) and having a cut-out (16) at least partially overlapping said recess (15); and an emitter layer (5A) having an edge portion at said recess.

2. A field emission cold cathode as defined in Claim 1 wherein at least said edge portion is substantially perpendicular to said control electrode layer (11).

3. A field emission cold cathode as defined in Claim 1 or 2 further comprising at least one supporting member (6A) for supporting said emitter layer (5A).

4. A field emission cold cathode as defined in Claim 3 wherein said supporting member (6A) is formed of a conductive layer.

5. A field emission cold cathode as defined in Claims 3 wherein said supporting member (6A) is formed of an insulating layer.

6. A field emission cold cathode as defined in one of Claims 1 to 5 further comprising a substrate (1) and a conductive layer (2) formed

on said substrate (1), wherein said insulating layer (10) is formed on said conductive layer (2).

7. A field emission cold cathode as defined in one of Claims 1 to 6 wherein said emitter layer (5A) has a thickness of less than 500 angstrom.

8. A field emission cold cathode as defined in Claim 7 wherein said emitter layer (5A) has a thickness of less than 100 angstrom.

9. A field emission cold cathode as defined in one of Claims 1 to 8 wherein said edge portion of said emitter layer (5A) includes a serrate edge for emission.

10. A display unit including a field emission cold cathode as defined in one of Claims 1 to 9.

11. A method for manufacturing a field emission cold cathode including steps of: forming a structure (3) having a perpendicular surface (3A) substantially perpendicular to a substrate (1); forming at least one emitter layer (4) at least on said perpendicular surface (3A); forming a filling layer (7) on said emitter layer (4); removing partially said structure (3), said emitter layer (4) and said filling layer (7) substantially parallel to said substrate (1) for exposing a cross-section of said emitter layer (4).

12. A method for manufacturing a field emission cold cathode as defined in Claim 11 wherein said at least one emitter layer (4) includes three conductive layer (5, 6).

13. A method for manufacturing a field emission cold cathode as defined in Claim 11 or 12 further including a step of forming an insulating layer (10) having a recess (15) for receiving said emitter layer (4A).

14. A method for manufacturing a field emission cold cathode as defined in one of Claims 11 to 13 further including a step of forming a gate electrode (11).

15. A method for manufacturing a field emission cold cathode as defined in one of Claims 11 to 14 further including a step of etching said structure (14) and said filling layer (10) adjacent to said emitter layer (4A) after said removing.

16. A method for manufacturing a field emission cold cathode as defined in Claim 11 wherein said removing is carried out by grinding.

FIG. 1 (a)

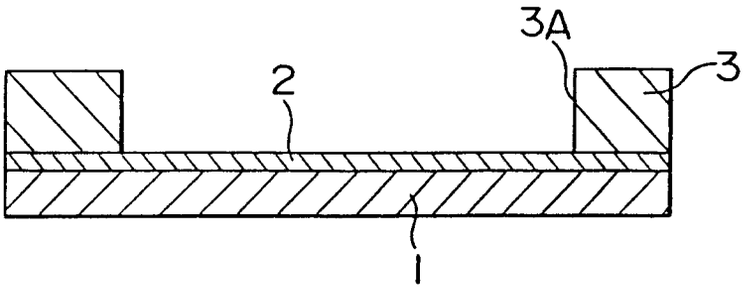


FIG. 1 (b)

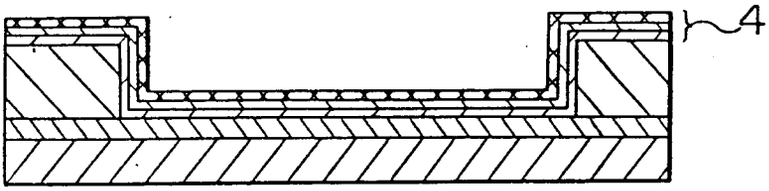


FIG. 1 (c)

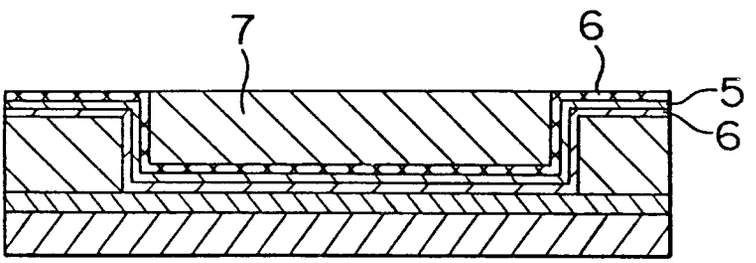


FIG. 1 (d)

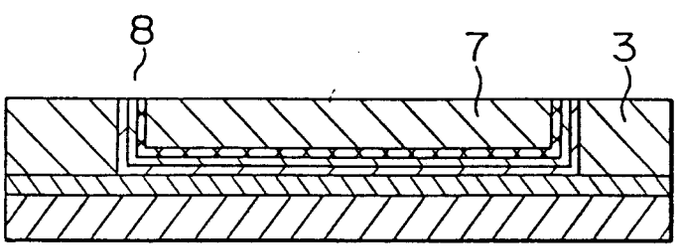


FIG. 1 (e)

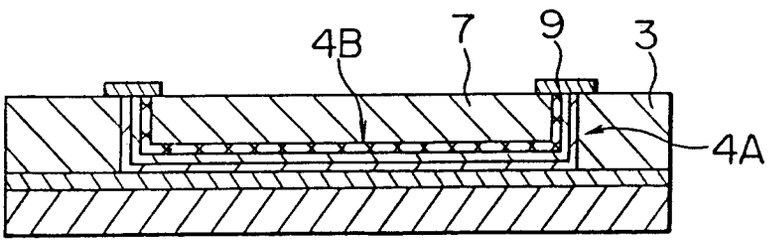


FIG. 1 (f)

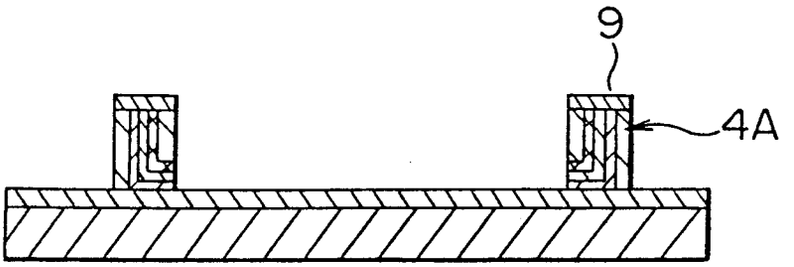


FIG. 1 (g)

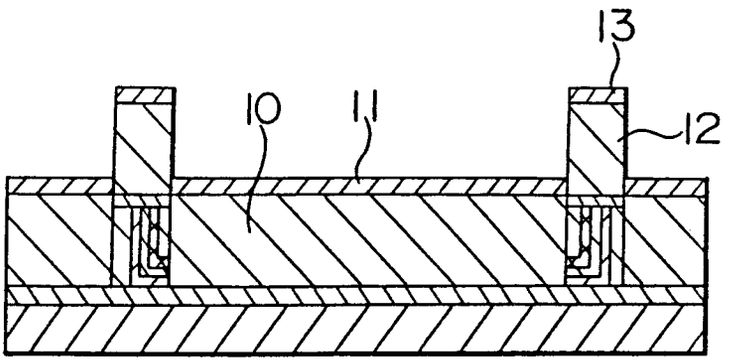


FIG. 1 (h)

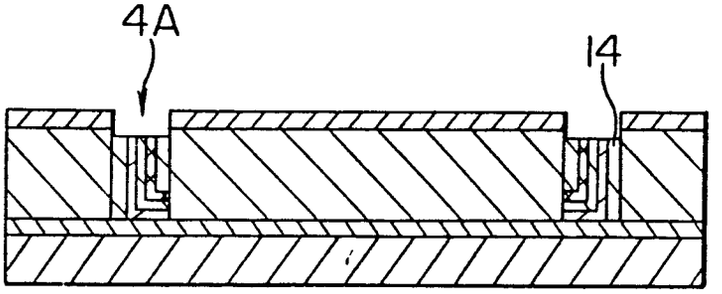


FIG. 1 (i)

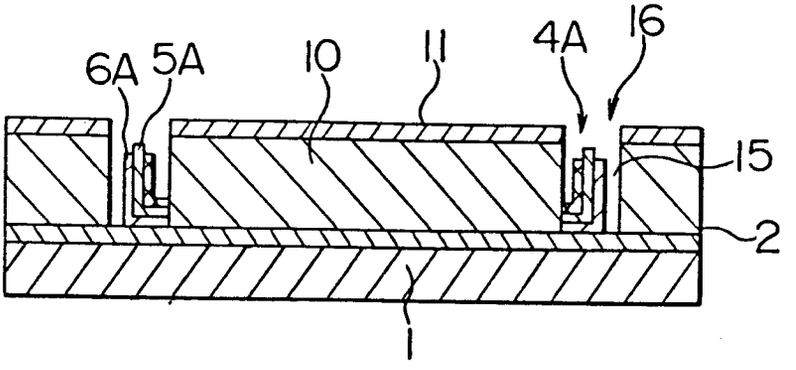


FIG. 2

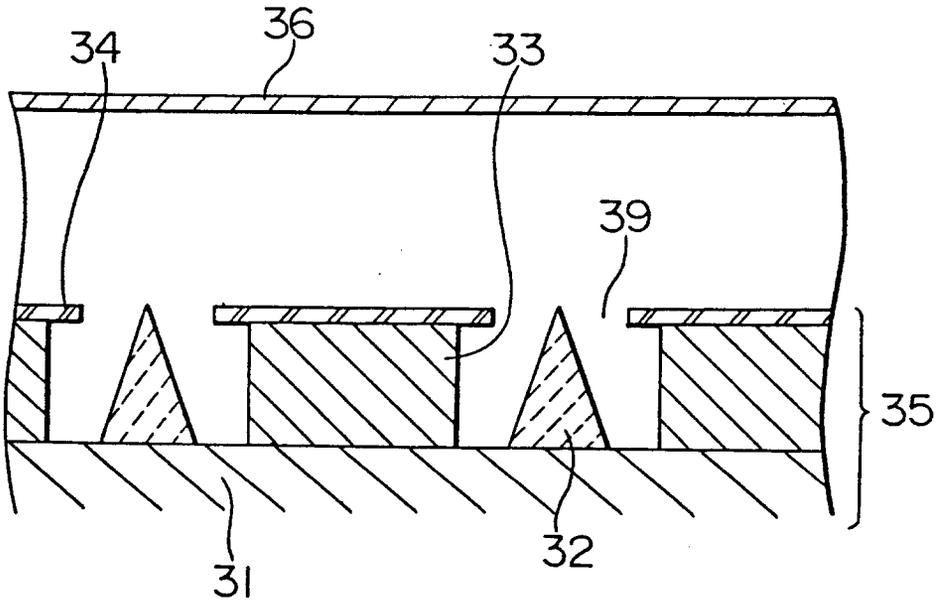
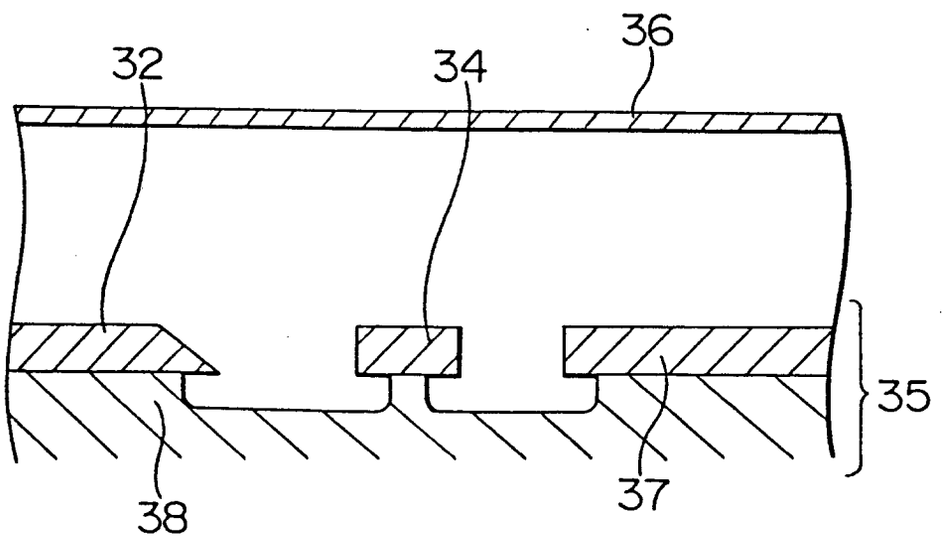


FIG. 3



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EUROPEAN SEARCH REPORT

Application Number

EP 93 10 3085

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	EP-A-0 400 406 (MATSUSHITA) * Abstract * * column 5, line 49 - column 8, line 58 * * column 10, line 4 - column 12, line 55 * * figures 3,4,7-11 *	1-5,10 11	H01J9/02 H01J1/30
A	WO-A-9 107 771 (MOTOROLA) * the whole document *	1-5	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 JUNE 1993	DAMAN M.A.

CATEGORY OF CITED DOCUMENTS

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