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(54) Radiation edge emitter

(57) An edge emitter (110) with a cap (112) on top of a (transparent electrode-insulating film-active film-insulating film-reflective electrode) stack (114-122) has a refractive index substantially matched to that of the active film (118). The cap (112) is thicker than the active film (118) and is made of a material with an attenuation lower than that of the active film (118) material. An emitting side surface (132) of the cap (112) is more transmissive than its other side surfaces (134-138) and its top surface (130). A significant portion of the electroluminescent radiation from the active film (118) entering the cap (112) is re-directed towards the emitting side surface (132) and thereby radiated from the edge emitter (110).

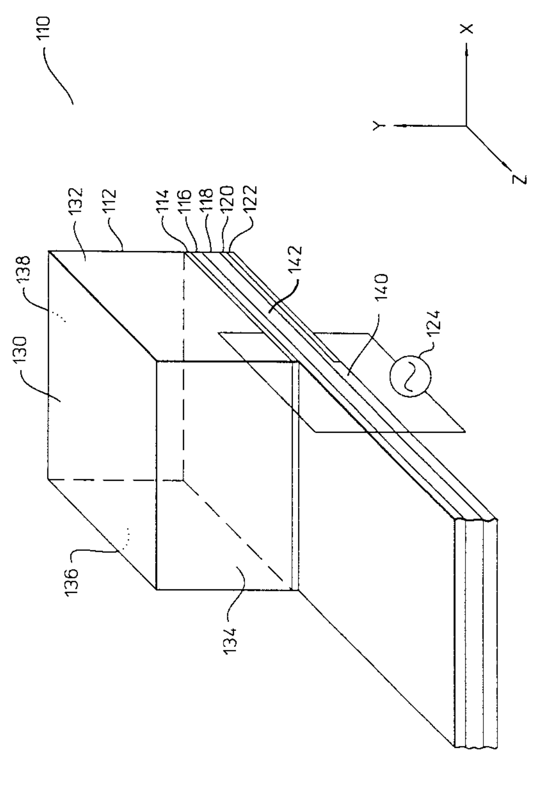

FIG. 3A

Description

The present invention relates generally to light generated by electroluminescence, and particularly to edge emitters for emitting light generated by electroluminescence.

Typically, an edge emitter emitting light through electroluminescence has a structure with multiple films, known as a thin film electroluminescent stack. The stack typically includes five films, a conductive electrode, an insulating film, an active film, another insulating film and another electrode. The basic idea is to excite dopant ions in the active film. When the excited dopants relax, light is generated. Voltages on the top and bottom electrodes create electric fields for excitation.

The insulating films and the active film are typically built as a sheet, with the top and the bottom electrodes as strips E1 and E2. Figure 1 shows a representation of the top view of this structure. The intersection of the two strips defines a pixel. In the present example, the pixel has a length of 1 and a width of w. The width w is much smaller than the length 1. The film stack is fabricated so that one of the width sides is exposed to form the edge of the edge emitter. The idea is to have a large area generating light, and a small edge to define the size of a small beam of emitted light.

Light is generated in the active film between the two strips. After generation, most of the light propagates laterally in the film stack across the entire sheet through total internal reflections. Preferably, all the light generated should be directed to the narrow edge. However, due to the geometry of the film stack, only a small percentage of the light comes out from the edge.

As an example, if the edge emitter is used for the print head of a 600 dots-per-inch (dpi) printer, there should be many pixels on a line, one adjacent to the other. Each pixel is responsible for one dot of the printer. In this embodiment, the width of each dot is about 0.035mm. Based on a pixel length of 3 mm and common edge emitter materials, a light power of 20,000 nW can be generated under each pixel. Although the power generated is high, probably, only about 70 nW will be coupled out through the edge. This gives a 0.35% optical efficiency.

One approach to increase the optical output is to increase the area of the pixel to generate more light. To keep the light beam from the edge small, the width has to be small. Therefore, the way to increase the area is to increase the length of the pixel. However, the film stack has attenuation. Measured attenuation lengths of a typical film stack lie in the range of 0.07 to 0.5 mm. Further increasing the length of a pixel will not increase the power emitted.

The present invention seeks to provide an improved edge emitter.

According to an aspect of the present invention there is provided an edge emitter as specified in claim 1.

The present invention can provide an edge emitter with significantly higher optical efficiency and in which a significantly higher percentage of light generated by each pixel can be directed towards its corresponding edge instead of propagating along the sheet in undesirable directions.

A cap is provided on top of a thin film electroluminescent stack which gathers, guides and re-directs a significant portion of generated radiation into the direction of the edge of the edge emitter.

The preferred embodiment has a stack with a top transparent electrode, a bottom reflective electrode and an active film in between; the top electrode is directly under the cap, which is preferably thicker than the thin film electroluminescent stack. The cap is made of a material with a lower attenuation than the film stack, and a refractive index substantially matched to that of the active film. At least the top surface and all the side surfaces of the cap, except the side surface adjacent to the edge, are preferably smooth and reflecting surfaces. Generated radiation is preferably coupled out from the surface adjacent to the edge or the emitting side surface.

In operation of this embodiment, instead of propagating laterally along the film stack, significant amount of the light generated in the active region propagates into the cap. The light in the cap, reflected by the reflecting surfaces, is guided to emit out of the cap from the emitting side surface. With the thickness of the cap more than the thickness of the film stack, light generated goes through fewer total internal reflections before emitted through the edge and the emitting side surface. This translates to reduced light attenuation. If the cap has a lower attenuation that the film stack, light attenuation will be further reduced.

In a tested embodiment in which the cap material was not totally matched to the active film material, one with a refractive index of about 2.3 and the other of about 1.5, the optical efficiency still showed a 100% improvement.

The cap is preferably about 10 times thicker than the active film. The elements of the emitter are preferably chosen such that the wavelength of the electroluminescent radiation is larger than the thickness of any one element selected from the group of the electrode and the films, except the active film. The radiation may be light.

The invention also extends to a printer incorporating an edge emitter of the type specified herein.

An embodiment of the present invention is described below, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows the top view of a prior art edge emitter;

Figure 2 shows a system with an array of a preferred embodiment of edge emitter;

Figures 3A-B show cross-sections of preferred edge emitters;

Figure 4 shows another preferred embodiment increasing the reflection of the top surface;

Figure 5 is a ray diagram comparing the paths of the generated radiation between the prior art and one cross-section of the preferred embodiment of edge emitter;

Figure 6 is a ray diagram comparing the paths of the generated radiation between the prior art and another cross-section of the preferred embodiment of edge emitter;

Figure 7 shows another embodiment of edge emitter;

Figure 8 shows another embodiment of edge emitter; and

Figure 9 shows a printer using the edge emitters described herein.

Figure 2 shows a system 100 with an array 106 of preferred edge emitters 108.

The array 106 is on a glass substrate 102. The system also shows a driver with multiplexers 104 running the edge emitters. The driver with multiplexers 104 will not be further described because they should be obvious to those skilled in the art. With the appropriate drive, each edge emitter would emit electromagnetic radiation, such as the radiation 109.

Figure 3A shows a cross-section of a preferred embodiment of an edge emitter 110.

For clarity, the glass substrate 102 is not shown. The emitter is made of a cap 112 situated on top of a thin film electroluminescent stack to form a modified edge emitter. In this description, this modified edge emitter is simply referred to as an edge emitter. The thin film electroluminescent stack preferably includes a transparent electrode 114; two insulating films, 116 and 120, sandwiching the active film 118; and a reflective electrode 122. The electrodes are conductive.

Electric fields are applied across the active film 118, such as by connecting a voltage source 124 on the two electrodes. The electric field across the active film excites dopant ions in the active film 118; and ther the excited dopants relax to generate radiation. The fabrication processes of the preferred embodiments will not be described because such processes should be obvious to those skilled in the art.

The preferred embodiment 110 shows the transparent and the reflective electrodes well registered, with one directly on top of the other. In another preferred embodiment, one electrode can be much wider than another. It is only in the regions of overlap that there will be excitation and recombination.

Structurally, the reflective electrode 122, the two insulating films, 120 and 116, and the transparent electrode 114 are quite thin; the active film 118 is thicker, but the cap 112 is even thicker than the active film. In the preferred embodiment shown, the insulating film 120 on top of the reflective electrode fills in the gap between adjacent reflective electrodes, such as in the region 140. In another preferred embodiment, the reflective electrode 122 is much wider than the transparent electrode 114.

Typically, the refractive index of the active film 118 is different from the refractive indexes of the insulating films. However, the insulating films are quite thin relative to the wavelength of the radiation generated in the active film. Thus, the effect of the mismatch in refractive indexes between the active film and the insulating films is very small.

Materials for the cap should be selected according to their electromagnetic properties. This includes their refractive indexes, which should be similar to the index of the active film so as to enhance coupling of the radiation generated in the active film 118 into the cap 112. The cap should be made of a material with less attenuation per unit length of the generated radiation than the active film 118. Other factors to consider are the manufacturability of the cap on the transparent electrode in the desired dimensions. This includes the achievable smoothness of the surfaces, which is important, as will be explained.

The cap 112 has four side surfaces 132, 134, 136, 138, and a top surface 130. Preferably, radiation is directed to go out from one of the side surfaces (the emitting side surface 132) and from the edge 142 of the active film 118. For this description, the radiation is emitted along the x-direction.

To enhance the directivity of the radiation, the emitting side surface 132 is made to have a higher transmission than the other side surfaces (the reflecting side surfaces 134, 136 and 138) and the top surface 130.

Figure 3B shows another preferred embodiment 150 of edge emitter. It has two capped structures, 152 and 154. The reflective electrode 156 is common for both structures. However, each cap structure has its own transparent electrode, such as the cap 154 has the transparent electrode 158, and the cap 152 has the electrode 162.

Numerous methods may be used to achieve difference in transmission among the surfaces. Six of such methods will be described. The methods described only serve to be illustrative; other methods may also be used. A first method is to have a smooth top surface and reflecting side surfaces; optically, this means that those surfaces have high finesse. On the other hand, the emitting side surface is roughened, such as by sandblasting it.

A second method is to metallize the top surface and the reflecting side surfaces. A third method is to coat a film of material with a refractive index much lower than that of the cap on the reflecting side surfaces and the top surface. The mismatch in refractive indexes reflect incident radiation on those surfaces. A fourth method combines the second and the third method by first forming the low refractive index material on those surfaces and then metallize them. Sometimes, it might be preferable to ignore the edge 142 of the active film 118, and focus on the emitting side surface 132, especially when the cap is much thicker than the active film. Note, also, that the emitting side surface 132 of the cap may not have to coincide with the edge 142 of the stack; it may extend beyond the edge. This may improve the ease in manufacturability of the edge emitter. In one preferred embodiment, if the emitting side surface 132 extends beyond the edge 142 of the stack, the transparent electrode 114 also extends beyond the edge with the cap.

Figure 4 shows another preferred embodiment of edge emitter showing a sixth method to increase the reflection of the top surface. The top surface 170 of a cap 172 is grooved to redirect light penetrating through the transparent electrode 174 of a thin film electroluminescent stack under small angles towards the emitting side surface 176. If the top surface is just smoothed, without other enhancement on its reflectivity, most of the incident radiation, except those within a cone, will still be reflected. The angle of the cone is the critical angle of the cap material. A cap material with refractive index of 2.3 would reflect about 90% of the incident light. The grooved structure further redirects a significant portion of the radiation within the cone towards the emitting side surface. Thus, radiation penetrating through the transparent electrode under small angles is also re-directed towards the emitting side surface.

The implementation of the above six methods should be obvious to those skilled in the art, and will not be further described in this specification.

Figure 5 shows a ray diagram comparing the paths of the generated radiation between the prior art and one perspective of the preferred embodiment of edge emitter 110. The perspective is a cross-section parallel to the reflecting side surface 134.

In a typical prior art edge emitter, radiation generated at 200 is directed across the active film 118 before it is radiated out of the edge emitter 110. The guiding is done through numerous total internal reflections, as shown by the path 202.

In the embodiment shown, radiation generated at 200 propagates to the cap 112. The cap is thicker than the active film 118. This leads to fewer total internal reflections before the radiation hits the emitting side surface 132. In this example, radiation 200 follows the path 204 with one total internal reflection before it goes out of the emitting side surface 132. The attenuation per unit length of the cap 112 is less than that of the active film 118. Thus, in this example, a higher percentage of the light generated radiates out of the emitter 110. In general, a thicker cap improves the guiding of the radiation towards the emitting side surface because a thicker cap reduces the number of internal reflectionsbetween the top surface and the thin film electroluminescent stack before emission. However, for certain applications, the cap should not be too thick. This is because a thick cap increases the size of the beam of radiation coming out of the emitter.

Figure 6 shows a ray diagram comparing the paths of the generated radiation between the prior art and another perspective of the preferred embodiment of edge emitter 110. This perspective is the cross-section parallel to the emitting side surface 132. In the prior art, radiation generated at 250 is guided along the plane of the active film through the path 252 by numerous total internal reflections. Such a radiation just propagates along the thin film electroluminescent stack and is typically lost and will not radiate from the edge 142 of the active film 118.

In the preferred embodiment, the radiation generated follows the path 254 in the cap. In the cap, the emitting side surface is more transmissive than all the side surfaces and the top surface. As long as the radiation path 254 is not absolutely parallel to the emitting side surface 132, ultimately, if the radiation is not attenuated, the radiation would go out of the emitting side surface 132. This is achieved by internal reflections along "spiralling" paths.

Working Example

The preferred embodiment will be further clarified by a consideration of the following example.

The reflecting electrode 122 is made of aluminum. The two insulating films are made of siliconoxinitride, with a refractive index of about 1.7. The active film is made of zinc sulphide doped with manganese. The refractive index of the active film is about 2.3. The transparent electrode is made of indium tin oxide, with a refractive index of about 2. Zinc oxide may also be used as the transparent electrode. The cap is made of acrylics with a refractive index of 1.56.

The reflecting electrode has a thickness (y-direction) of about 100nm (1000 Angstroms); the two insulating films have thicknesses of about 200nm (2000 Angstroms); the active film is about 1 micron thick; and the transparent electrode is about 200nm (2000 Angstroms) thick.

The cap is about 10 micrometres thick (y-direction), 0.07mm wide (z-direction) and 3mm long (x-direction). The reflecting side surfaces and the top surface are metallized by aluminum with a thickness of about 100nm (1000 Angstroms). The reflective performance can be further improved if there is a film with a refractive index lower than that of the cap, such as cryolite, between the cap and the metallized surface. Cryolite has a refractive index of 1.33.

The electroluminescent radiation is yellow, with a wavelength of 600 nm. The optical efficiency of the above structure increases by about 100%, as compared to a similar structure without the cap 112. Note that in the above structure, the cap material is not perfectly matched to the active film material.

Conclusion

The preferred thin film electroluminescent stack described is made of five films, the transparent electrode, the first insulating film, the active film, the second insulating film and the reflective electrode. However, other thin film stacks may be used. For example, the stack may only have the first insulating film or may only have the second insulating film. In another preferred embodiment, the reflective electrode is not reflective, but is just an electrode; for this embodiment, the edge emitter may not be as efficient because some of the radiations propagate through the "reflective electrode."

Other materials may be used for the cap, such as a chalcogenide glass, with a refractive index of 2.1 to 2.6, and BCB, a commonly known plastic material, with a refractive index of 1.5. Similar to the acrylics, BCB is relatively easy to form cap structures. Different materials with different refractive indexes can be used. In general, a better match in refractive index between the cap and the active film would provide an edge emitter with a higher efficiency.

The preferred embodiments have an emitting side surface having a higher transmission than the other side surfaces. In another embodiment, the emitting side surface has a higher transmission than at least one side surface, such as the surface 136, which is directly opposite to the emitting surface 132 in Figure 3A. This is achieved, for example, by roughening the emitting side surface, or by making one side surface reflective. With such a structure, radiations generated have a certain preferred directivity; more radiations emit from the roughened surface than from the reflecting surface, or more radiations propagate along directions away from the reflecting surface.

Another improvement to the preferred embodiment is to curve the emitting side surface of the cap into a lens structure to generate lens action, improve outcoupling and/or the angular distribution of the emitted radiation. Similar results may be achieved by Fresnel grooving the emitting side surface. Methods to achieve such curving or grooving are well-known to those skilled in the art and will not be further described.

The preferred embodiments have a cap which is a rectangular block. The cap may be made of other structures with more side surfaces or curved surfaces; an example is shown in Figure 7, with the cap 402 having a curved top surface sitting on a thin film stack 404. In this embodiment, the side surface 404 has a higher transmission coefficient than other surfaces.

Figure 8 shows another preferred embodiment in which a cap 502 encapsulates an electroluminescent film stack 504; both the cap and the film stack sits on a substrate 506. In this embodiment, the bottom surface 508 of the cap 502 is also a reflecting surface.

The preferred embodiments can be used in a printer 600, as shown in Figure 9, with the thin film electroluminescent sources as pixel illuminators.

From the foregoing it will be appreciated that the cap gathers, guides and re-directs radiations generated into the direction of the edge. This, in turn, significantly increases the optical efficiency of an edge emitter.

The disclosures in United States patent application no. 08/330,152, from which this application claims priority, and in the abstract accompanying this application are incorporated herein by reference.

Claims

1. An edge emitter comprising a thin film electroluminescent stack including a first transparent electrode (114), a second electrode (122) and an active film (118) in between the two electrodes; and a cap (112) disposed over the transparent electrode and including a side surface with a transmission coefficient higher than the transmission coefficient of at least one other surface of the cap, the higher transmission coefficient side surface providing an emissive side surface and the or each lower transmission surface being a reflective surface.

2. An edge emitter according to claim 1, comprising a first insulating film (116) between the transparent electrode and the active film (118) and/or a second insulating film (120) between the active film (118) and the second electrode (122).

3. An edge emitter according to claim 1 or 2, wherein the cap (112) is thicker than all the layers of the edge emitter.

4. An edge emitter according to claim 1, 2 or 3, wherein the refractive index of the cap (112) is substantially matched to or longer than the refractive index of the active film (118).

5. An edge emitter according to any preceding claim, wherein the attenuation per unit length for electroluminescent radiation is higher in the active film (118) than in the cap (112).

6. An edge emitter according to any preceding claim, wherein a top surface (170) of the cap is grooved to reflect electroluminescent radiation back into the cap.

7. An edge emitter according to any preceding claim, wherein the cap (112) is formed of a Chalcogenide glass.

8. An edge emitter according to any preceding claim, wherein the or each reflective surface of the cap is coated with a material with a refractive index lower than the refractive index of the cap.

9. An edge emitter according to claim 8, wherein the or each reflective surface is metallized.

10. An edge emitter according to any preceding claim,

wherein the emissive surface (132) is roughened, curved and/or Fresnel grooved.

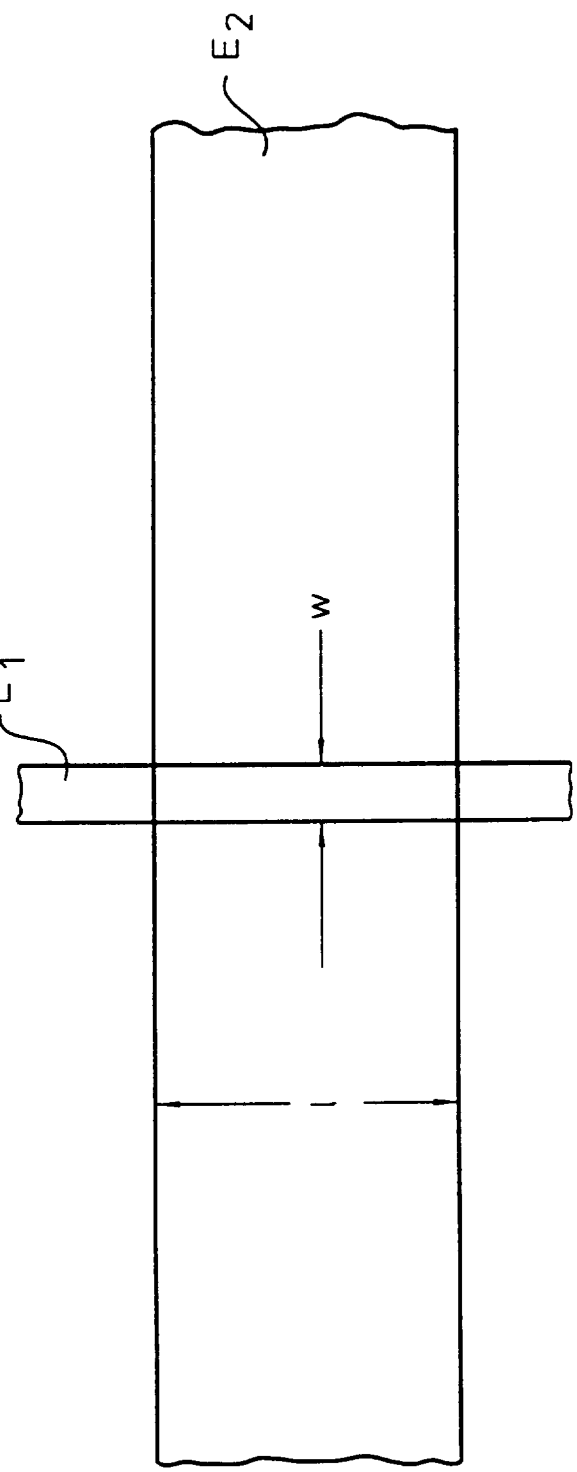

FIG. 1 (PRIOR ART)

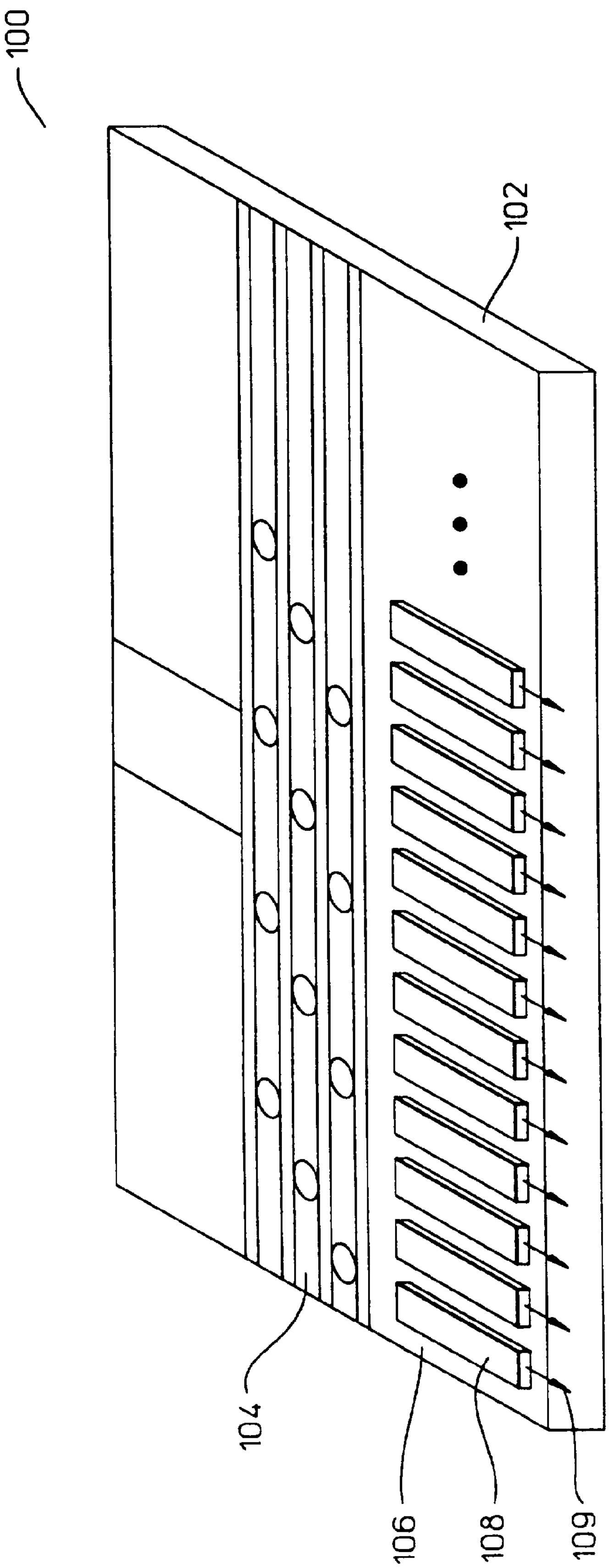

FIG. 2

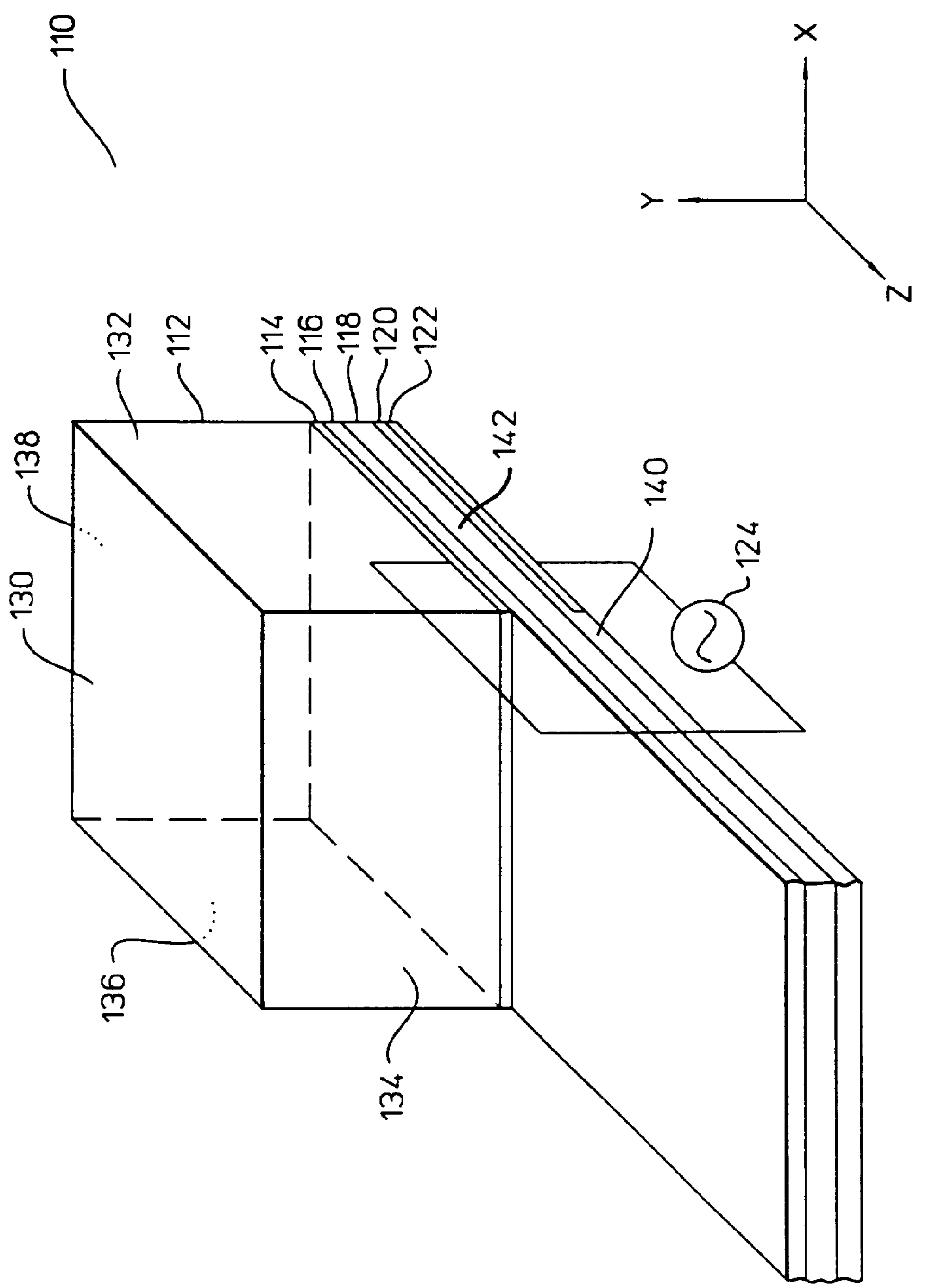

FIG. 3A

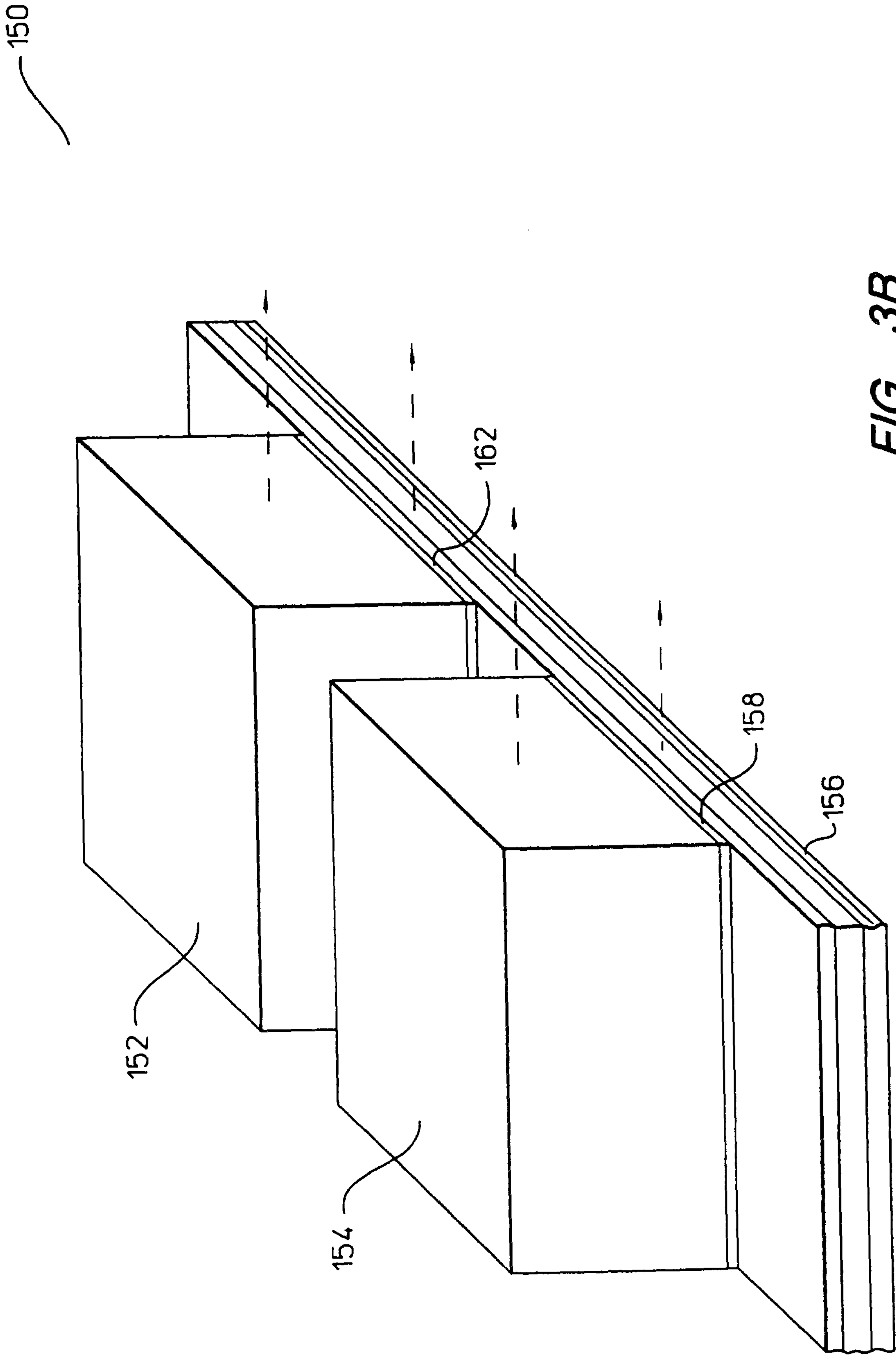

FIG. 3B

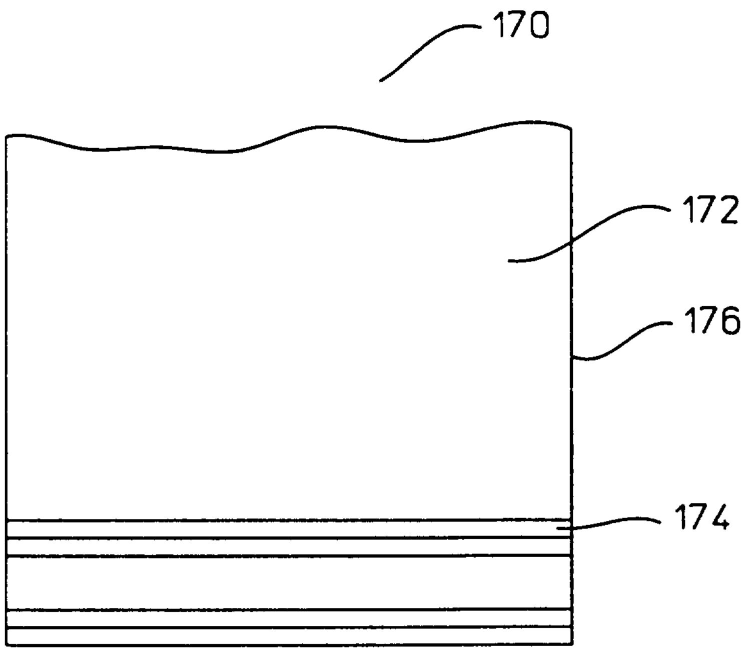

FIG. 4

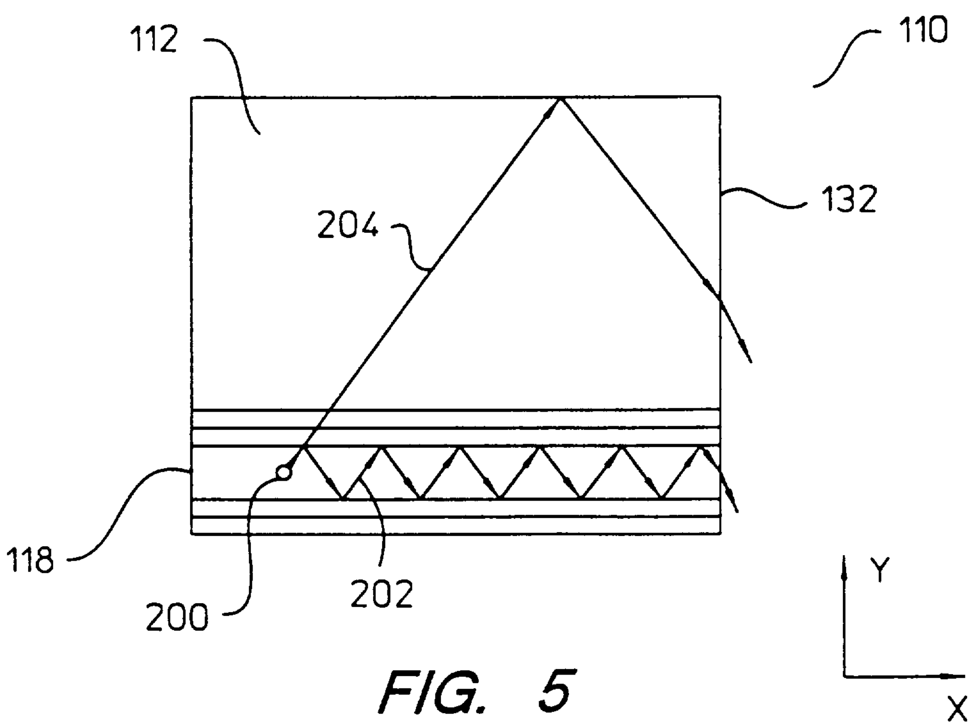

FIG. 5

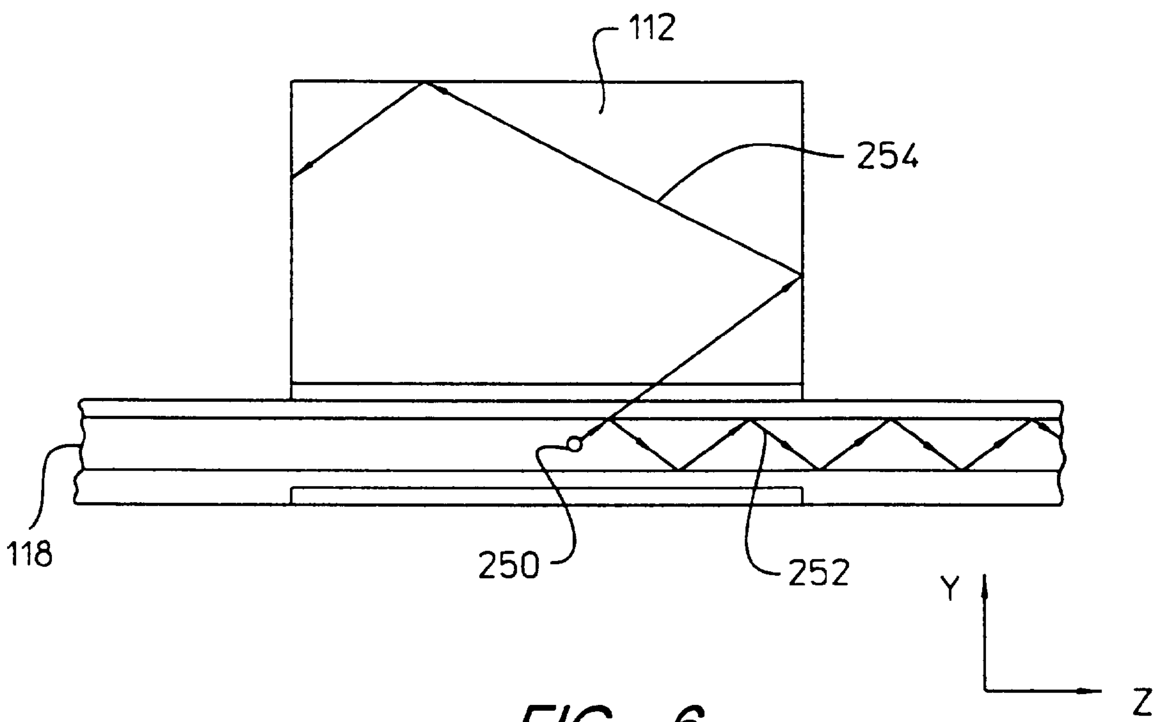

FIG. 6

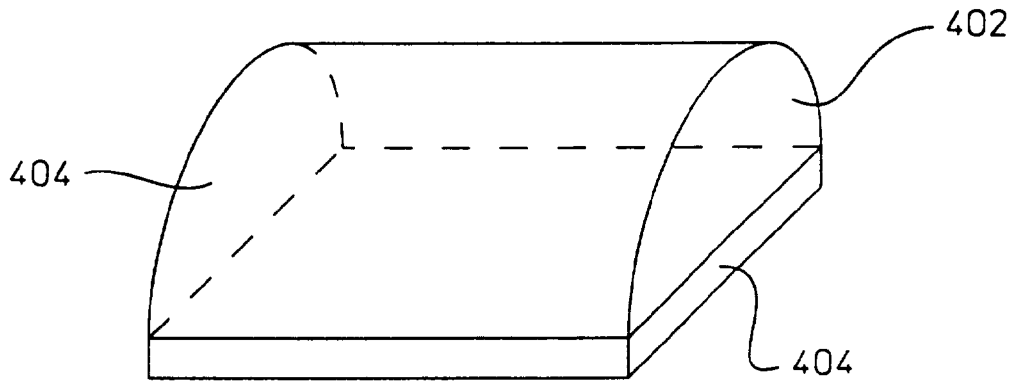

FIG. 7

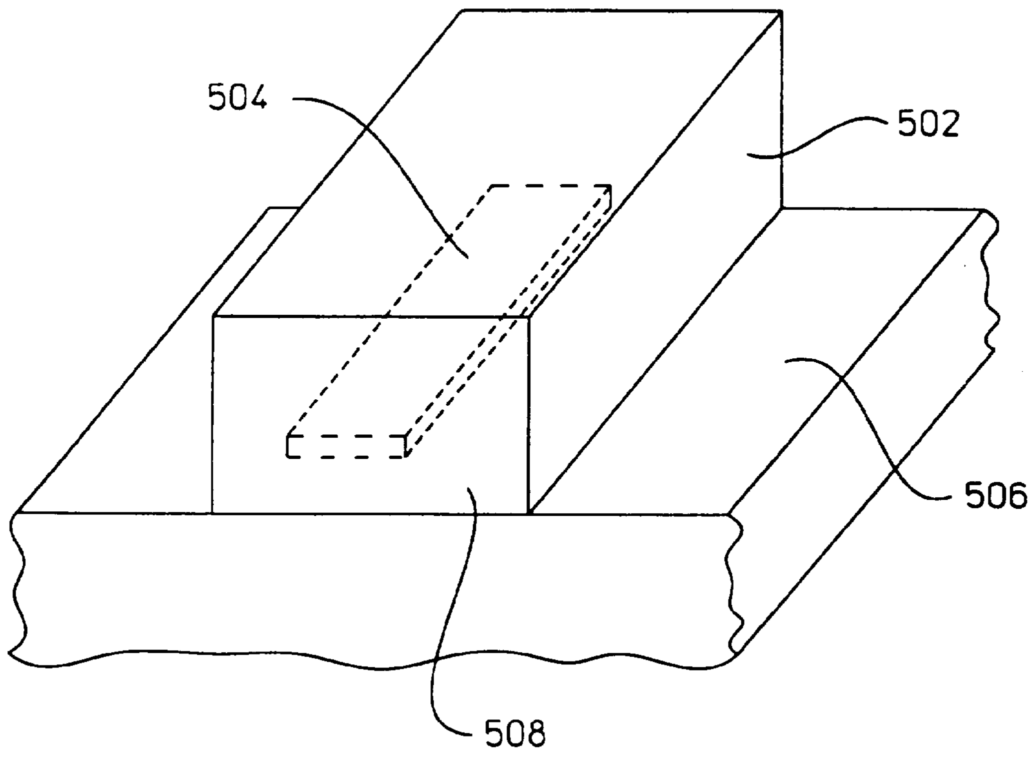

FIG. 8

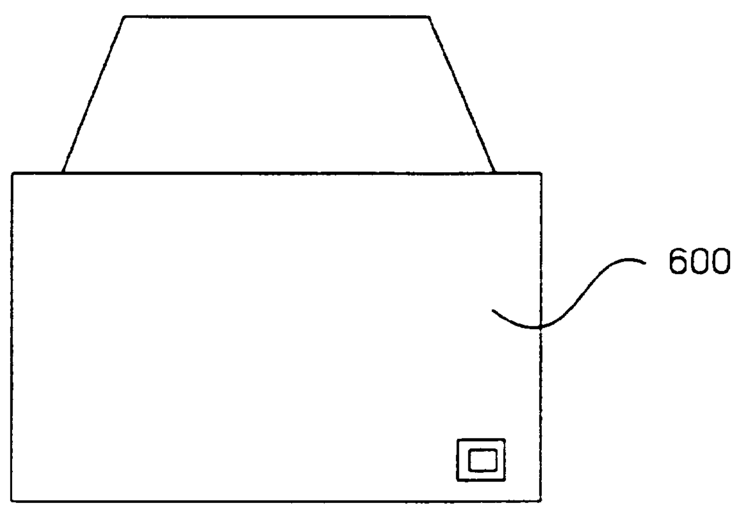

FIG. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 7381

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.6)
A	EP-A-0 515 174 (WESTINGHOUSE ELECTRIC) * the whole document * -----	1-4	H05B33/12 H05B33/04 H05B33/24
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 January 1996	Drouot, M-C

CATEGORY OF CITED DOCUMENTS

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A : technological background
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D : document cited in the application
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