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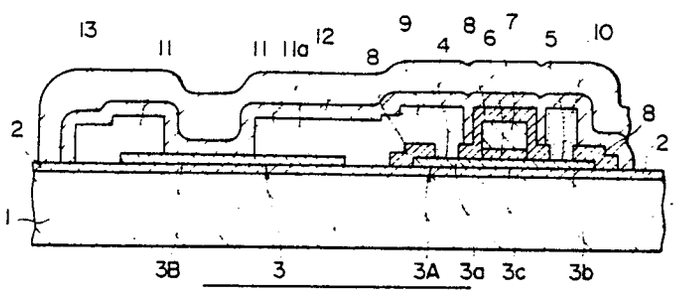
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(54) Thermal print head containing super-thin polycrystalline silicon film transistor.

(57) Disclosed is herein a thermal print head containing super-thin polycrystalline silicon film transistors, comprising: heating resistors (3B, 2I) formed in a thin polycrystalline silicon layer (3) formed over a substrate (I); and a driving circuit comprising super-thin film transistors (4, 5, 6) each having a thin active layer (3c), formed in the polycrystalline silicon layer (3).

FIG. 1



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THERMAL PRINT HEAD CONTAINING SUPER-THIN POLYCRYSTALLINE SILICON FILM TRANSISTOR

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to a thermal print head having heating resistors which are heated selectively for printing information on a thermosensitive recording sheet and, more specifically to a thin film thermal print head having heating resistors and a driving circuit which are formed through the application of thin-film techniques.

Description of the Prior Art:

Most conventional thermal print heads of a line type of a serial type employ either a direct drive system or a diode matrix system for driving the heating resistors thereof. To form such a thermal print head in a compact construction, the integral semiconductor chips, such as IC chips and diodes, are mounted directly on the substrate of the thermal print head. However, directly mounting semiconductor chips on the substrate is subject to many restrictions relating to forming a compact thermal print head and the productivity of the thermal print head manufacturing processes. Accordingly, an improved thermal print head has been desired.

As illustrated in Fig. 6, when a semiconductor chip 102 is mounted on a substrate 101 of a thermal print head and is sealed with a sealing material 103, the projecting portion of the sealing material 103 and a cover 104 must be positioned outside the paper feeding space through which a thermosensitive recording sheet is fed by a platen 105, and hence the reduction of the distance W_1 between the front end of the semiconductor chip 102 and the platen 105 is limited to a certain extent, which is an impediment to the reduction in size of the thermal print head.

On the other hand, the dimension W_2 of the substrate is dependent on the length of the semiconductor chip 102 and the wire bonding pitch. Accordingly, the dimension W_2 can be reduced to a certain extent by employing a LSI chip as the semiconductor chip 102. However, such a semiconductor chip is expensive. Furthermore, the least wire bonding pitch is limited to a value on the order of 150 to 200 μm. For example, the dimension W_2 is approximately 3 mm when the semiconductor chip 102 is a 32-bit driver, and is approximately 7 mm when the same is a 64-bit driver.

The conventional thermal print head has many problems such as:

1) low reliability due to many joints formed by wire bonding, soldering and/or thermocompression bonding,

2) the semiconductor mounting process requires expensive equipment, such as a wire bonder and a resin baking oven, and skilled labor,

3) the necessity of many materials and parts such as IC chips, gold wires and a die bonding paste requires many assembling processes and, hence, high manufacturing cost, and

4) IC chips in addition to the semiconductor chip 102 are necessary when other circuits, for example, a counter circuit, a temperature sensing circuit and a memory circuit, are required to be mounted on the substrate 101 of the thermal print head.

Japanese Patent Provisional Publication No. 58-153672 discloses a thin film thermal print head comprising a driving amplifier for driving a recording device, i.e., heating resistors, and recording control circuit each containing thin film transistors.

However, in this known thermal print head having such a driving unit comprising ordinary thin film transistors, the perimeter of the gate needs to be very large when the driving unit is used for switching a large current, because of the low electron mobility μ of the thin film transistors. Consequently, the size of the device is increased, which restricts the reduction in size of the thermal print head. Thus, this known thermal print head has problems such as large power loss and, hence, low efficiency due to the large driver ON resistance, and difficulty in high-speed recording and high-gradational recording due to the inferior frequency characteristics of the field effect transistors incapable of responding to high-frequency waves of frequencies on the order of 4 to 6 MHz.

Thus, many restrictions are placed on the conventional thermal print head in constructing the same in a compact construction and the conventional thermal print unit is disadvantageous in respect of the productivity of the manufacturing process and the manufacturing cost. Although another thermal print head employing a driving unit comprising ordinary thin film transistors has been proposed, it is difficult to apply this thermal print head to high-speed printing and high-gradational recording due to its inferior characteristics.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a thermal print head containing super-thin polycrystalline silicon film transistors, having less restrictions on the size of the substrate, capable of being formed in a compact construction, and capable of being manufactured through a mass-production system at a reduced cost.

It is another object of the present invention to provide a thermal print head containing super-thin polycrystalline silicon film transistors, capable of high-speed printing and high-gradational printing.

According to the present invention, a thin polycrystalline silicon film is formed over an insulating substrate, a heating resistor and a driving circuit is formed by using the polycrystalline silicon film on the same insulating substrate, and the driving circuit is constituted by a thin film transistor having a thin active layer.

The insulating substrate is a silicon substrate provided, at least in a portion thereof, with an insulating layer having at least one thermal resistance layer, a thin polycrystalline silicon layer is formed over the insulating layer having the thermal resistance layer, and a heating resistor and a driving circuit is constituted by using the thin polycrystalline silicon film.

Furthermore, according to the present invention, at least one thermal resistance layer is formed on at least a portion of the insulating silicon substrate, then a thin polycrystalline silicon layer is formed over the thermal resistance layer, and then a heating resistor and a driving circuit are formed by using the thin polycrystalline silicon layer.

The thin film transistor having a thin active layer is disclosed in U.S. Patent Application Serial Nos. 683,860 and 683,932 which have been made previously by the applicant of the present application. The present invention is one of the utility inventions made by the practical application of the thin film transistor having a thin active layer, previously invented by the applicant of the present invention.

According to the present invention, since the driving circuit is formed by using the thin polycrystalline silicon film formed over an insulating substrate, the size of the projection of the driving circuit can be reduced to a value below several microns, which eliminates restrictions on the size of the substrate.

Furthermore, since the thickness of the polycrystalline silicon layer serving as the active layer or active region of the transistor of the driving circuit is 800 Å or below, which is substantially the same as the thickness of the depletion layer, the electron mobility μ is increased, and thereby a driver chip of several milliampare to several tens milliampare in capacity having a minute area can be manufactured. Furthermore, since the operation frequency of the logic circuit is comparatively high, the thermal print head is capable of high-speed printing and high-gradational printing.

Furthermore, according to the present invention, since the insulating substrate is a highly heat-conductive silicon substrate, and a 1 to 500 μm thick thermal resistance layer, preferably, 10 to 150 μm thick thermal resistance layer, is formed over the insulating substrate so that the thermal conductivity of the insulating substrate is in an appropriate range, or a 0 to 350 μm thick second thermal resistance layer is formed so that the total thickness of the thermal thickness layer is below 500 μm, to control the heat generation of the thermal resistance layer properly and to prevent the excessive accumulation of heat in the thermal resistance layer and the insulating substrate, therefore, the heating resistor can be regulated so as to prevent blurs and irregular print density in the print for improved print quality, and hence the thermal print head is capable of high-speed printing.

Furthermore, since the thermal resistance layer serving as a heat accumulating layer can be easily formed over the silicon substrate, the substrate forming process is simplified, and since the driving circuit is formed in the thin polycrystalline silicon layer, the driving circuit can be formed in a minute projection, which eliminates restrictions on the size of the substrate. Still further, since the thermal print head of the present invention is manufactured without resorting to complex processes including a wire bonding process, the reliability thereof is enhanced.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an enlarged sectional view of a thermal print head containing a super-thin polycrystalline silicon film transistor, in a first embodiment, according to the present invention;

Figure 2 is an enlarged sectional view of a thermal print head containing a super-thin polycrystalline silicon film transistor, in a second embodiment, according to the present invention;

Figure 3 is an enlarged sectional view of a thermal print head containing a super-thin polycrystalline silicon film transistor, in a third embodiment, according to the present invention;

Figure 4 is an enlarged sectional view of a thermal print head containing a super-thin polycrystalline silicon film transistor, in a fourth embodiment, according to the present invention;

Figure 5 is a block diagram showing, by way of example, the constitution of the circuit of a thermal print head;

Figure 6 is a typical side elevation of a conventional thermal print head; and

Figure 7 is an enlarged sectional view of a thermal print head containing a super-thin polycrystalline silicon film transistor, in a fifth embodiment, according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First, the constitution of the circuit of a thermal print head containing a super-thin polycrystalline silicon film transistor (hereinafter, designated simply as "thin-film thermal print head") embodying the present invention will be described with reference to Fig. 5.

A data signal, namely, a picture signal, is given through a signal terminal 51 to a shift register circuit 52. After data for one line has been given to the shift register circuit 52 according to clock signals applied to a signal terminal 53, the data is transmitted by parallel transmission to a latch circuit 55 in response to a strobe signal applied to a signal terminal 54 and is latched by the latch circuit 55. The data latched by the latch circuit 55 drives a driver device 58 through a gate circuit 57 in accordance with the instruction of an enable signal for determining print timing, applied to a signal terminal 56 to supply current selectively to heating resistors 59 to selectively make the heating resistors 59 generate heat.

According to the present invention, for example, the driver device 58 comprises MOS FETs, while other circuits comprises CMOSs. The MOS FETs and the CMOSs are formed integrally with the heating resistors in thin-film transistors comprising a thin polycrystalline silicon film, a thin conductive film and an insulating film in a laminated structure. The thin-film transistor is formed in a super thin polycrystalline silicon film transistor having a source active layer and a drain active layer formed of a polycrystalline silicon film of 800 Å or below in thickness.

First Embodiment:

Referring to Fig. 1 showing a thin-film thermal print head, in a first embodiment, according to the present invention, a heating resistor is formed of the same material as the active layer of the MOS FET of a driver device, and the source and drain of the MOS FET are used as the electrodes of the heating resistor.

In this embodiment, an insulating layer 2 of SiO_2 or the like is formed over the entire surface of the substrate 1 of a thermal print head, and a thin polycrystalline silicon layer 3 is formed over the insulating layer 2. The substrate 1 may be a quartz plate, a glass plate, a glazed ceramic plate or a convex plate having a slightly elevated portion in which a heating resistor is formed, for example, a partly glazed substrate. Although the insulating layer 2 is not necessarily needed, normally, an insulating thermal resistance layer is formed. The insulating layer 2 serves as a heat accumulating layer which accumulates heat generated by a heating resistor 3B, while the substrate 1 serves as a heat conducting layer which transmits heat accumulated in the insulating layer 2 to a heat radiating plate. Print quality and the printing speed of the thermal print head is greatly dependent on the materials forming the substrate 1 and the insulating layer 2, and the thickness of the insulating layer 2. In this embodiment, the substrate 1 is formed of either single crystal silicon or polycrystalline silicon. Silicon has a thermal conductivity in an appropriate range for the heat conducting layer. The insulating layer 2 is formed of SiO_2, which has a comparatively low thermal conductivity in an appropriate range for the heat accumulating layer, and has particularly desirable properties facilitating the formation of a thin film in a desired thickness. The SiO_2 insulating layer 2 may be formed through an ordinary thermal oxidation process in which the surface of the silicon substrate 1 is oxidized or a vacuum film forming process such as a sputtering process. The smaller the thickness of the insulating layer 2 the better is the print quality. And also, the greater is the energy consumption of the insulating layer 2. Therefore, it is not desirable to form the insulating layer 2 in an excessively small thickness. Accordingly, the SiO_2 insulating layer 2 is formed in a thickness in the range of 1 to 500 μm appropriate for optimum heat conduction. When the thickness of the SiO_2 insulating layer 2 is 1 μm or below, the energy consumption of the insulating layer 2 is excessively high and, when 500 μm or above, an excessively large amount of heat is accumulated in the substrate 1 and satisfactory heat radiation is impossible, which causes the deterioration of the print quality including blurred printings and irregular printing density. Although the SiO_2 insulating layer 2 may be formed in a thickness in the range of 1 to 500 μm, practically, it is preferable to form the SiO_2 insulating layer 2 in a thickness in the range of 10 to 150 μm. A cooling plate 24 for radiating the heat transferred thereto from the substrate 1 may be attached adhesively to the backside of the substrate 1 having the insulating layer 2 over the upper surface thereof with the film 23 of a flexible adhesive such as a silicon adhesive as

illustrated in Fig. 7 when necessary. The cooling plate 24 is formed of a material having a large thermal conductivity, such as aluminum, copper or aluminum oxide.

The polycrystalline silicon layer 3 is used as an active layer for forming the thin-film transistors of the driving circuit, and the heating resistor. The opposite end portions of the polycrystalline silicon layer 3A for the driving circuit of the polycrystalline silicon layer 3 is doped with an n-type impurity to form n-type regions 3a and 3b having a low resistance. The n-type regions 3a and 3b serves as a source region 4 and a drain region 5, respectively. When the MOS FET is in operation, a channel is formed between the source region 4 and the drain region 5 in the polycrystalline silicon layer 3A, and the region between the source region 4 and the drain region 5 serves as an active layer 3c.

An insulating gate layer 6 of SiO_2 is formed on the polycrystalline silicon layer 3A. Gate electrodes 7 of doped polycrystalline silicon (DOPOS) are formed on the insulating gate layer 6. The material of the gate electrodes 7 is not limited to doped polycrystalline silicon; the same may be formed of Ta-SiO_2, Ta-Si, TaN or NiCr.

An insulating layer 8 of SiO_2 is formed over the polycrystalline silicon layer 3A and the gate electrodes 7. The insulating layer 8 is provided with openings through which electrodes 9 and 10 of Al, W, Ti of Mo connected to the source region 4 and the drain region 5, respectively, are formed to constitute the driving circuit.

In the ordinary MOS FET thus constituted, the thickness of the polycrystalline silicon layer 3A in which the channel is formed is on the order of 1500 Å. However, in the MOS FET of the present invention the thickness of the polycrystalline silicon layer 3A is as thin as 800 Å or below, and hence the field effect electron mobility μ is very large, which is inferred to be due to the thickness of the polycrystalline silicon layer 3A smaller than the thickness of the channel induced in the active layer 3c when a gate voltage of an ordinary magnitude is applied to the gate electrode 7. The thickness of the polycrystalline silicon layer 3A is in the range of 20 to 800 Å, preferably, 200 Å.

On the other hand, the polycrystalline silicon layer forming the active layer 3c is used for forming heating resistors 3B as well as the driving circuit. Lead electrodes 11 are connected to the polycrystalline silicon layer forming the heating resistors 3B in the process for forming the lead electrodes 9 and 10. In this embodiment, lead electrodes lla among the lead electrodes 11 are formed integrally with the lead electrodes 9 of the source region 4 to connect the driving circuit and the heating resistors 3B electrically. Wiring of the driving circuit may be formed in two wiring layers, for example, a wiring layer of a material having a comparatively high resistivity containing a wiring for transmitting signals such as enable signals, latch signals, data signals and clock signals between the active elements of the driving circuit, and a wiring layer of the same material as the source and drain electrodes containing a wiring for V_H, G_H, V_D and G_D.

An oxidation resistant layer 12 and an abrasion resistant layer 13 are formed over the heating resistors and the driving circuit. The oxidation resistant layer 12 and the abrasion resistant layer 13 function as a protective film for the heating resistances 3B and as a passivation film for the FETs of the driving circuit.

In the thermal print head thus constituted, since the drivers of the driving circuit are thin-film transistors, the dimension t in Fig. 6 namely, the height of the drivers on the substrate, is substantially zero (several microns or less). Accordingly, there is not any restriction on the construction of the thermal print head with respect to the paper feed space. Further, the possibility of forming the driving circuit at an optional position enables reduction in size of the thermal print head.

Furthermore, the driving circuit and the heating resistors are electrically interconnected by wiring patterns of thin films, which are free from restrictions on the pitch of wiring lines and, hence, dimensional restrictions, without requiring wire bonding process, complex processes, the use of expensive equipments and materials for wire bonding. Particularly, the thermal print head has high reliability because the thermal print head does not include any IC chip and, hence any junction.

Still further, since the heating resistors and the active elements of the driving circuit are formed simultaneously through the same process on the same substrate, the manufacturing cost of the thermal print head remains substantially constant regardless of the design of the circuit, which is highly advantageous in the practical application of the thermal print head.

Particularly, when the substrate 1 is a silicon substrate, and the insulating layer 2 is a SiO_2 layer of a thickness in the range of 1 to 500 μm, preferably, 10 to 150 μm, heat accumulation in the vicinity of the heating resistors 2 can be controlled properly, and thereby print quality and printing speed are improved.

Although the present invention has been described with reference to a first embodiment thereof in which the active layers of the MOS FETs of the driving circuit are used as the heating resistors, the present invention is not limited thereto and, naturally, many variations and changes are possible therein. Further embodiments of the present invention will be described hereinafter. In the fol-

lowing description, those parts that are the same or corresponding to those of the first embodiment are designated by like reference characters throughout and the description thereof will be omitted to avoid duplication.

Second Embodiment (Fig. 2):

The gate electrodes 7 of FETs and heating resistors 21 are formed simultaneously of the same gate material. The lead electrodes of the heating resistors 21, and the respective lead electrodes 9 and 10 of the source region 4 and the drain region 5, similarly to those of the first embodiment, are formed simultaneously of the same electrode material.

Third Embodiment (Fig. 3):

A polycrystalline silicon layer 3 for forming the active layer 3c of FETs is used, similarly to that of the first embodiment shown in Fig. 1, for forming heating resistors 3B, and an insulating layer 8 is functions also as an oxidation resistant layer for the heating resistors 3B. Accordingly, any particular oxidation resistant layer, such as the oxidation resistant layers 12 of the first and second embodiments shown in Figs. 1 and 2, respectively, need not be formed over the heating resistors 3B, and only an abrasion resistant layer 13 is formed over the driving circuit and the heating resistors 3B.

Fourth Embodiment (Fig. 4):

Heating resistors 21, similarly to those of the second embodiment shown in Fig. 2, are formed of the same gate material forming the gate electrodes 7 of FETs, and an insulating layer 8 functions also as an oxidation resistant layer for the heating resistors 21. Accordingly, the fourth embodiment, similarly to the third embodiment shown in Fig. 3, does not need any particular oxidation resistant layer 12. The heating resistors, similarly to those of the conventional thermal print head, may be formed of Ta-SiO_2, Ta-Si, TaN or NiCr, and the heating resistors may be connected to the thin-film transistors, respectively, by a wiring pattern of the electrodes of the thin-film transistors.

In the foregoing embodiments, the heating resistors 3B are formed on the insulating layer 2, i.e., the thermal resistance layer, formed over the flat substrate to control heat accumulation in the vicinity of the heating resistors 3B properly, and thereby print quality can be improved to a satisfactory extent. However, for the further improvement of print quality, it is possible to form a convex SiO_2 layer as a second thermal resistance layer 22 under the heating resistors 3B as illustrated in Fig. 7 to enable the appropriate contact of the heating resistors 3B with the thermosensitive recording sheet. The convex second thermal resistance layer 22 is formed through a vacuum thin-film forming technique, such as a sputtering process.

When two or more thermal resistance layers are formed as mentioned above, preferably, the total thickness of the thermal resistance layers, similarly to those of the foregoing embodiments, is in the range of 1 to 500 μm. Accordingly, it is preferable that the total thickness of the thermal resistance layer 2 and the second thermal resistance layer 22 of the embodiment shown in Fig. 7 also is in the range of 1 to 500 μm. Therefore, the thickness of the second thermal resistance layer 22 is dependent on the thickness of the thermal resistance layer 2 formed over the substrate 1. However, the preferable thickness of the second thermal resistance layer 22 is in the range of zero to 350 μm. The parts of the embodiment shown in Fig. 7 like or corresponding to those of the foregoing embodiments are designated by like reference characters and the description thereof is omitted to avoid duplication.

As apparent from the foregoing description, the thermal print head according to the present invention comprises heating resistors and a driving circuit formed on the same substrate and interconnected by wiring patterns formed of a gate material and an electrode material, respectively, without requiring a wire bonding process. Therefore, the thermal print head production line is able to operate at a high productivity and the thermal print head of the present invention has a high reliability.

Furthermore, since the driving circuit comprises thin-film transistors and the height of the thin-film transistors on the substrate is very small (several microns or less), there is not any restriction on the disposition of the thermal print head relative to the platen, and the employment of the thin-film transistors is very advantageous to the reduction in size of the thermal print head.

Still further, since the thickness of the active layer of the thin-film transistors of the driving circuit is as small as 800 Å and hence the electron mobility μ is very high, the thin-film transistors, namely, driving devices, may be of a very small area, which also is advantageous to the reduction in size of the thermal print head.

Moreover, forming the active layer in a thin film is highly effective for improving the printing characteristics of the thermal print head in the practical application thereof as well as for the reduction in size of the thermal head. For example, the thin-film active layer reduces the on-resistance of the driver

device and, hence the power loss, and thereby the power efficiency is improved remarkably. Since the frequency characteristics of the FETs can be improved, high-speed printing and high-gradational printing are possible.

Still further, when the insulating substrate is formed of silicon having a high thermal conductivity and the thermal resistance layer is formed of SiO_2 over the surface of the insulating substrate, heat accumulation in the vicinity of the heating resistors can be controlled properly, an excessive amount of heat will not be accumulated in the thermal resistance layer and the insulating substrate, and blurs and irregular density in the printing are eliminated to improve the print quality.

Particularly, when the convex second thermal resistance layer is formed under the heating resistors, the state of contact between the heating resistors and the thermosensitive recording sheet is improved, and thereby the print quality is further improved.

Claims

I. A thermal print head containing super-thin polycrystalline silicon film transistors, characterized in:
heating resistors (3B, 2I) formed in a thin polycrystalline silicon layer (3) formed over a substrate (I); and a driving circuit comprising super-thin film transistors (4, 5, 6) each having a thin active layer - (3c) formed in said polycrystalline silicon layer (3).

2. A thermal print head as recited in claim I, characterized in that the thickness of the polycrystalline silicon layer (3) forming the respective active layers (3c) of said super-thin polycrystalline silicon film transistors (4, 5, 6) is in the range of 20 to 800 Å.

3. A thermal print head as recited in claim I or 2, characterized in that the material forming said heating resistors (3B) is the same as that forming the respective active layers (3c) of said super-thin polycrystalline silicon film transistors (4, 5, 6).

4. A thermal print head as recited in claim 1 or 2,, characterized in that said heating resistors (2I) and the respective gate electrodes (7) of said super-thin polycrystalline silicon film transistors (4, 5, 6) are formed of the same material.

5. A thermal print head containing super-thin polycrystalline silicon film transistors, comprising:
an insulating silicon substrate (I);
a thermal resistance layer (2) formed on at least a part of the surface of the insulating silicon substrate (I);
a thin polycrystalline silicon layer (3) formed on portions of the thermal resistance layer (2);
heating resistors (3B, 2I) formed in the thin polycrystalline silicon layer (3); and
a driving circuit comprising thin-film transistors (4, 5, 6) each having a thin active layer (3c), formed in the thin polycrystalline silicon layer (3).

6. A thermal print head as recited in claim 5, characterized in that the thickness of the polycrystalline silicon layer (3) forming the respective active layers (3c) of said thin-film transistors (4, 5, 6) is in the range of 20 to 800 Å.

7. A thermal print head as recited in claim 5 or 6, characterized in that a convex second thermal resistance layer (22) is formed between each said heating resistor (3B) and said insulating silicon substrate (I).

8. A thermal print head as recited in any one of claims I to 7, characterized in that an oxidation protection layer (I2) covers each of said active layers.

9. A thermal print head as recited in any one of claims I to 8, characterized in that a layer (I3) of abrasion resistant material is applied over the areas of said resistors (3B, 2I) and said driving circuits (4, 5, 6).

FIG. 1

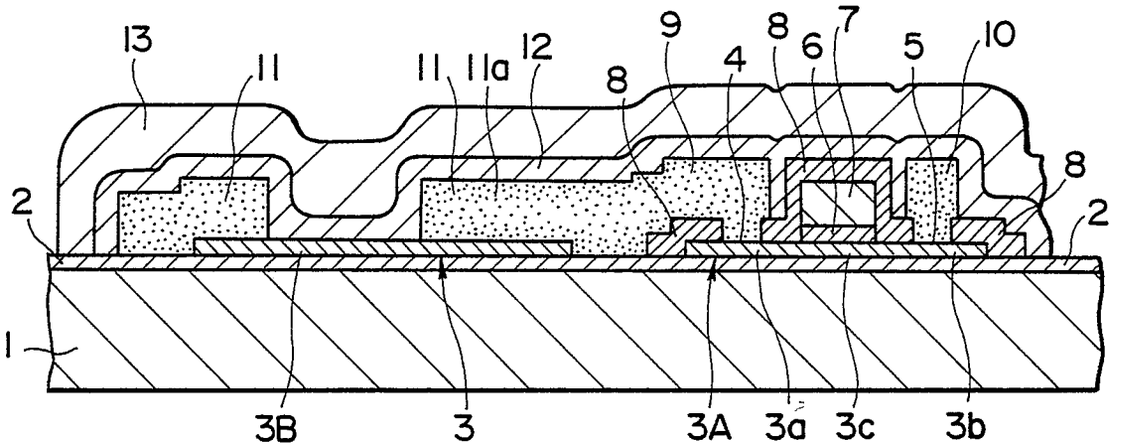

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FIG. 2

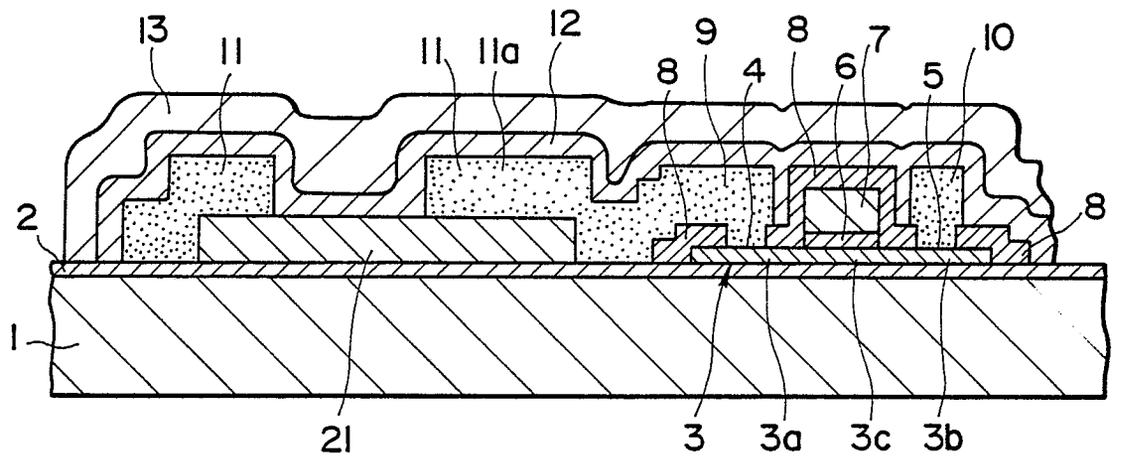

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FIG. 3

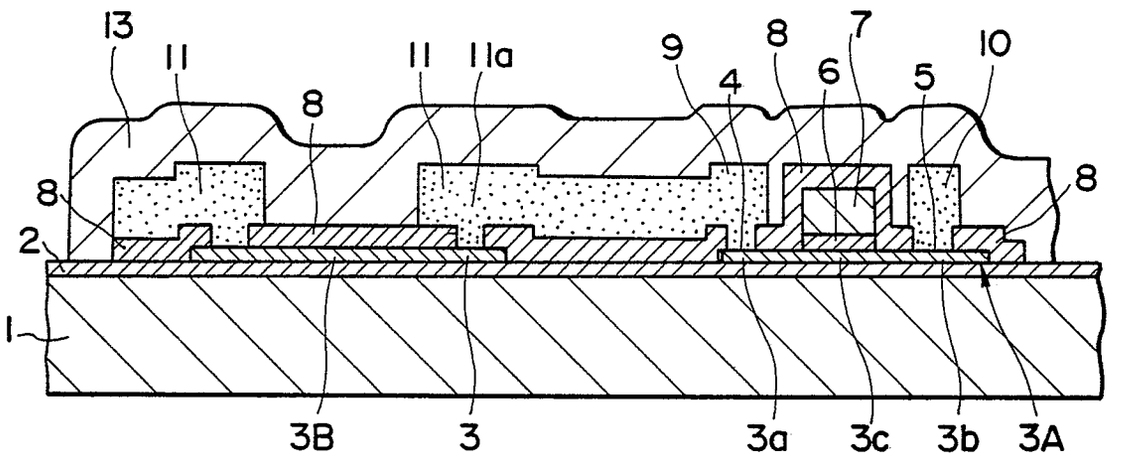

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FIG. 4

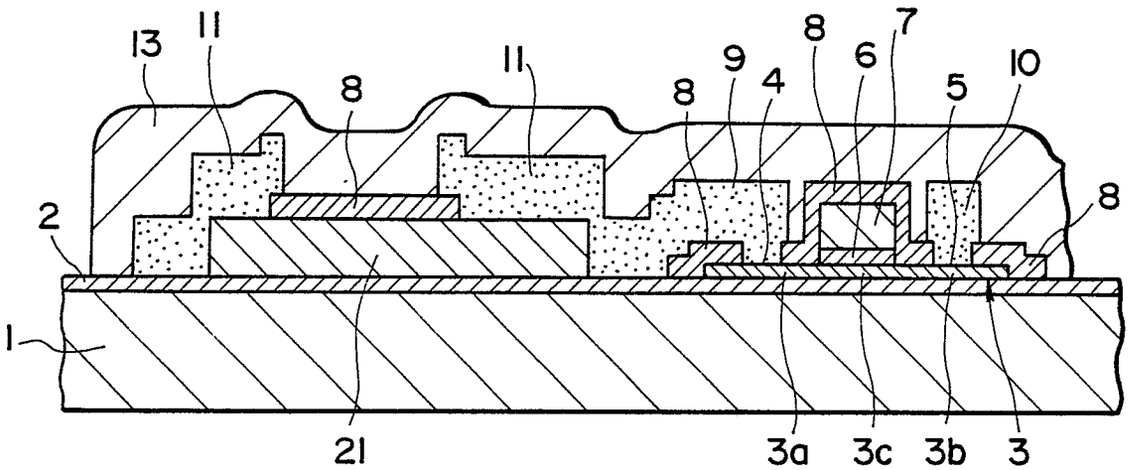

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FIG. 5

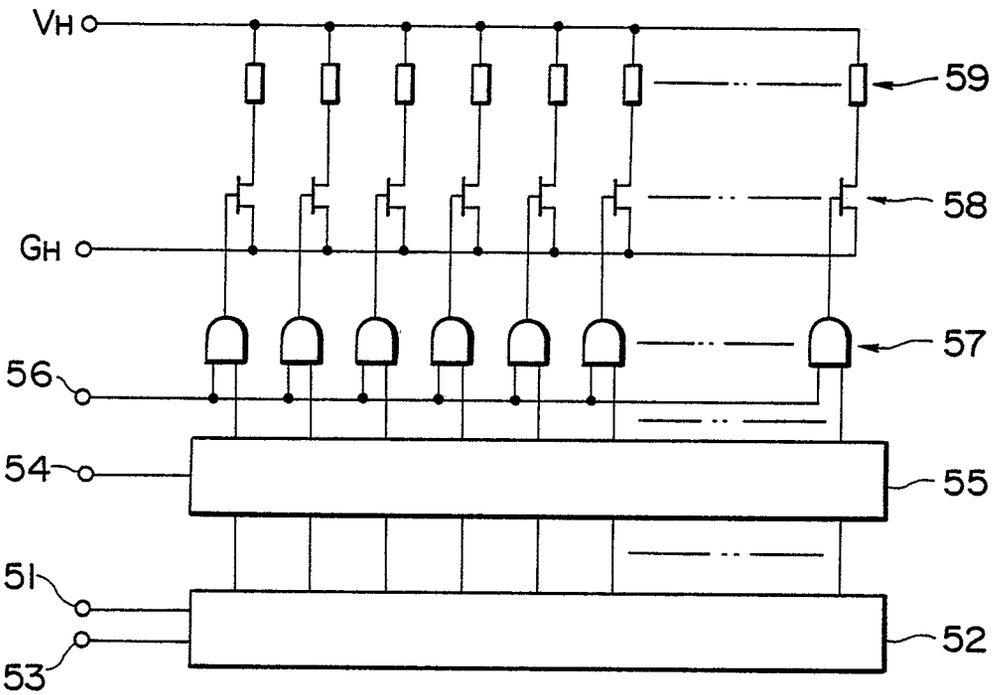


FIG. 6

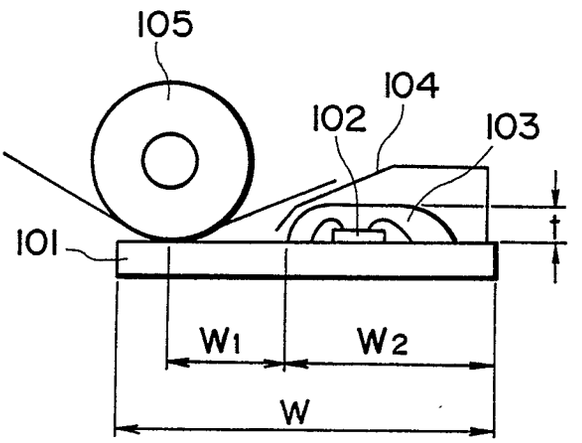


FIG. 7

