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(54) **Ink jet nozzle with slotted sidewall and moveable vane**

Tintenstrahldüse mit geschlitzter Seitenwand und beweglichem Flügel

Buse de jet d'encre avec fente dans une paroi de côté et aile mobile

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- **PATENT ABSTRACTS OF JAPAN vol. 013, no. 320 (M-853), 20 July 1989 (1989-07-20) & JP 01 105746 A (RICOH CO LTD), 24 April 1989 (1989-04-24)**

Description

Field of Invention

[0001] The present invention relates to the field of ink jet printing systems.

Background of the Art

[0002] Many different types of printing have been invented, a large number of which are presently in use. The known forms of print have a variety of methods for marking the print media with a relevant marking media. Commonly used forms of printing include offset printing, laser printing and copying devices, dot matrix type impact printers, thermal paper printers, film recorders, thermal wax printers, dye sublimation printers and ink jet printers both of the drop on demand and continuous flow type. Each type of printer has its own advantages and problems when considering cost, speed, quality, reliability, simplicity of construction and operation etc.

[0003] In recent years, the field of ink jet printing, wherein each individual pixel of ink is derived from one or more ink nozzles has become increasingly popular primarily due to its inexpensive and versatile nature.

[0004] Many different techniques of ink jet printing have been invented. For a survey of the field, reference is made to an article by J Moore, "Non-Impact Printing: Introduction and Historical Perspective", Output Hard Copy Devices, Editors R Dubeck and S Sherr, pages 207 - 220 (1988).

[0005] Ink Jet printers themselves come in many different types. The utilisation of a continuous stream ink in ink jet printing appears to date back to at least 1929 wherein US Patent No. 1941001 by Hansell discloses a simple form of continuous stream electro-static ink jet printing.

[0006] US Patent 3596275 by Sweet also discloses a process of a continuous ink jet printing including the step wherein the ink jet stream is modulated by a high frequency electro-static field so as to cause drop separation. This technique is still utilised by several manufacturers including Elmjet and Scitex (see also US Patent No. 3373437 by Sweet et al)

[0007] Piezo-electric ink jet printers are also one form of commonly utilised ink jet printing device. Piezo-electric systems are disclosed by Kyser et. al. in US Patent No. 3946398 (1970) which utilises a diaphragm mode of operation, by Zolten in US Patent 3683272 (1970) which discloses a squeeze mode of operation of a piezo electric crystal, Stemme in US Patent No. 3747120 (1972) discloses a bend mode of piezo-electric operation, Howkins in US Patent No. 4459601 discloses a Piezo electric push mode actuation of the ink jet stream and Fischbeck in US 4584590 which discloses a sheer mode type of piezo-electric transducer element.

[0008] Recently, thermal ink jet printing has become an extremely popular form of ink jet printing: The ink jet printing techniques include those disclosed by Endo et al in GB 2007162 (1979) and Vaught et al in US Patent 4490728. Both the aforementioned references disclosed ink jet printing techniques rely upon the activation of an electrothermal actuator which results in the creation of a bubble in a constricted space, such as a nozzle, which thereby causes the ejection of ink from an aperture connected to the confined space onto a relevant print media. Printing devices utilising the electro-thermal actuator are manufactured by manufacturers such as Canon and Hewlett Packard.

[0009] EP0506232 discloses a valve for a drop on demand ink jet printer employing a lever seal in a housing to control the frequency and quantity of ink delivered to a printing material such as paper. Lever and housing of the chamber are unitary. There is no slit. Ejection is achieved by static pressure.

[0010] WO9418010 discloses a printhead for an ink jet printer includes a chamber for containing marking fluid fed to the head in use. A plurality of orifices open from the chamber, a marking fluid being emitted in use through the orifices. A corresponding plurality of actuators are provided. Each actuator comprises an arm having at one end means for selectively opening and closing a respective orifice; a magnetic circuit of which the arm forms a side; and one or more coils for selectively inducing a magnetic flux in the circuit in order to move the arm between a position in which it closes the respective orifice and a position in which it opens the orifice.

[0011] Neither of the documents discloses a movable vane that causes ejection of ink.

[0012] As can be seen from the foregoing, many different types of printing technologies are available. Ideally, a printing technology should have a number of desirable attributes. These include inexpensive construction and operation, high speed operation, safe and continuous long term operation etc. Each technology may have its own advantages and disadvantages in the areas of cost, speed, quality, reliability, power usage, simplicity of construction operation, durability and consumables.

[0013] Many ink jet printing mechanisms are known. Unfortunately, in mass production techniques, the production of ink jet heads is quite difficult. For example, often, the orifice or nozzle plate is constructed separately from the ink supply and ink ejection mechanism and bonded to the mechanism at a later stage (Hewlett-Packard Journal, Vol. 36 no 5, pp33-37 (1985)). These separate material processing steps required in handling such precision devices often adds a substantially expense in manufacturing.

[0014] Additionally, side shooting ink jet technologies (U.S. Patent No. 4,899,181) are often used but again, this limit the amount of mass production throughput given any particular capital investment.

[0015] Additionally, more esoteric techniques are also often utilised. These can include electroforming of nickel stage (Hewlett-Packard Journal, Vol. 36 no 5, pp33-37 (1985)), electro-discharge machining, laser ablation

(U.S. Patent No. 5,208,604), micro-punching, etc.

[0016] The utilisation of the above techniques is likely to add substantial expense to the mass production of ink jet print heads and therefore add substantially to their final cost.

[0017] It would therefore be desirable if an efficient system for the mass production of ink jet print heads could be developed.

[0018] Further, during the construction of micro electromechanical systems, it is common to utilize a sacrificial material to build up a mechanical system, within the sacrificial material being subsequently etched away so as to release the required mechanical structure. For example, a suitable common sacrificial material includes silicon dioxide which can be etched away in hydrofluoric acid. MEMS devices are often constructed on silicon wafers having integral electronics such as, for example, using a multi-level metal CMOS layer. Unfortunately, the CMOS process includes the construction of multiple layers which may include the utilization of materials which can be attacked by the sacrificial etchant. This often necessitates the construction of passivation layers using extra processing steps so as to protect other layers from possible unwanted attack by a sacrificial etchant.

[0019] In micro-electro mechanical system, it is often necessary to provide for the movement of objects. In particular, it is often necessary to pivot objects in addition to providing for fulcrum arrangements where a first movement of one end of the fulcrum is translated into a corresponding measurement of a second end of the fulcrum. Obviously, such arrangements are often fundamental to mechanical apparatuses.

[0020] Further, When constructing large integrated circuits or micro-electro mechanical systems, it is often necessary to interconnect a large number of wire to the final integrated circuit device. To this end, normally, a large number of bond pads are provided on the surface of a chip for the attachment of wires thereto. With the utilization of bond pads normally certain minimal spacings are utilized in accordance with the design technologies utilised. Where are large number of interconnects are required, an excessive amount of on chip real estate is required for providing bond pads. It is therefore desirable to minimize the amount of real estate provided for bond pads whilst ensuring the highest degree of accuracy of registration for automated attachment of interconnects such as a tape automated bonding (TAB) to the surface of a device.

Summary of the invention

[0021] The present invention relates to ink jet printing and in particular, discloses an ink jet nozzle arrangement in accordance with the claims which follow.

Brief Description of the Drawings

[0022] Notwithstanding any other forms which may fall within the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 332 illustrates a perspective view of an ink jet nozzle arrangement in accordance with an embodiment;

Fig. 333 illustrates the arrangement of Fig. 332 when the actuator is in an activated position;

Fig. 334 illustrates an exploded perspective view of the major components of an embodiment;

Fig. 335 provides a legend of the materials indicated in Fig. 336 to Fig. 347; and

Fig. 336 to Fig. 347 illustrate sectional views of the manufacturing steps in one form of construction of an ink jet printhead nozzle.

Description

[0023] In an embodiment, there is provided an ink jet printing system wherein each nozzle has a nozzle chamber having a slotted side wall through which is formed an actuator mechanism attached to a vane within the nozzle chamber such that the actuator can be activated to move the vane within the nozzle chamber to thereby cause ejection of ink from the nozzle chamber.

[0024] Turning now to the figures, there is illustrated in Fig. 332 an example of an ink jet nozzle arrangement 3301 as constructed in accordance with an embodiment. The nozzle arrangement includes a nozzle chamber 3302 normally filled with ink and an actuator mechanism 3303 for actuating a vane 3304 for the ejection of ink from the nozzle chamber 3302 via an ink ejection port 3305.

[0025] Fig. 332 is a perspective view of the ink jet nozzle arrangement of an embodiment in its idle or quiescent in position. Fig. 333 illustrates a perspective view after actuation of the actuator 3303.

[0026] The actuator 3303 includes two arms 3306, 3307. The two arms can be formed from titanium di-boride (TiB_2) which has a high Young's modulus and therefore provides a large degree of bending strength. A current is passed along the arms 3306, 3307 with the arm 3307 having a substantially thicker portion along most of its length. The arm 3307 is stiff but for in the area of thinned portion 3308 and hence the bending moment is concentrated in the area 3308. The thinned arm 3306 is of a thinner form and is heated by means of resistive heating of a current passing through the arms 3306,3307. The arms 3306, 3307 are interconnected to electrical circuitry via connections 3310, 3311.

[0027] Upon heating of the arm 3306, the arm 3306 is expanded with the bending of the arm 3307 being concentrated in the area 3308. This results in movement of the end of the actuator mechanism 3303 which proceeds through a slot in the wall nozzle chamber 3302. The bending further causes movement of vane 3304 so as to increase the pressure of the ink within the nozzle chamber and thereby cause its subsequent ejection from ink ejection nozzle 3305. The nozzle chamber 3302 is refilled via an ink channel 3313 (Fig. 334) formed in the wafer substrate 3314. After movement of the vane 3304, so as to cause the ejection of ink, the current to arm 3306 is turned off which results in a corresponding back movement of the end vane 3304. The ink within nozzle chamber 3302 is then replenished by means of wafer ink supply channel 3313 which is attached to an ink supply formed on the back of wafer 3314. The refill can be by means of a surface tension reduction effects of the ink within nozzle chamber 3302 across ink ejection port 3305.

[0028] Fig. 334 illustrates an exploded perspective view of the components of the ink jet nozzle arrangement.

[0029] Referring now specifically to Fig. 334, an embodiment can be constructed utilising semiconductor processing techniques in addition to micro machining and micro fabrication process technology (MEMS) and a full familiarity with these technologies is hereinafter assumed.

[0030] For a general introduction to a micro-electro mechanical system (MEMS) reference is made to standard proceedings in this field including the proceeding of the SPIE (International Society for Optical Engineering) including volumes 2642 and 2882 which contain the proceedings of recent advances and conferences in this field.

[0031] The nozzles can preferably be constructed by constructing a large array of nozzles on a single silicon wafer at a time. The array of nozzles can be divided into multiple print heads, with each print head itself having nozzles grouped into multiple colours to provide for full colour image reproduction. The arrangement can be constructed via the utilisation of a standard silicon wafer substrate 33-14 upon which is deposited an electrical circuitry layer 3316 which can comprise a standard CMOS circuitry layer. The CMOS layer can include an etched portion defining pit 3317. On top of the CMOS layer is initially deposited a protective layer (not shown) which comprise silicon nitride or the like. On top of this layer is deposited a sacrificial material which is initially suitably etched so as to form cavities for the portion of the thermal actuator 3303 and bottom portion of the vane 3304, in addition to the bottom rim of nozzle chamber 3302. These cavities can then be filled with titanium di-boride. Next, a similar process is used to form the glass portions of the actuator. Next, a further layer of sacrificial material is deposited and suitably etched so as to form the rest of the vane 3304 in addition to a portion of the nozzle chamber walls to the same height of vane 3304.

[0032] Subsequently, a further sacrificial layer is deposited and etched in a suitable manner so as to form the rest of the nozzle chamber 3302. The top surface of the nozzle chamber is further etched so as to form the nozzle rim rounding the ejection port 3305. Subsequently, the sacrificial material is etched away so as to release the construction of an embodiment. It will be readily evident to those skilled in the art that other MEMS processing steps could be utilized.

[0033] Preferably, the thermal actuator and vane portions 3303 and 3304 in addition to the nozzle chamber 3305 are constructed from titanium di-boride. The utilisation of titanium di-boride is standard in the construction of semiconductor systems and, in addition, its material properties, including a high Young's modulus, is utilised to advantage in the construction of the thermal actuator 3303.

[0034] Further, preferably the actuator 3303 is covered with a hydrophobic material, such as Teflon, so as to prevent any leaking of the liquid out of the slot 3319.

[0035] Further, as a final processing step, the ink channel can be etched through the wafer utilising a high anisotropic silicon wafer etchers. This can be done as an anisotropic crystallographic silicon etch, or an anisotropic dry etch. A dry etch system capable of high aspect ratio deep silicon trench etching such as the Surface Technology Systems (STS) Advance Silicon Etch (ASE) system is recommended for volume production, as the chip size can be reduced over a wet etch. The wet etch is suitable for small volume production where a suitable plasma etch system is not available. Altema-tively, but undesirably, ink access can be around the sides of the print head chips. If ink access is through the wafer higher ink flow is possible, and there is less requirement for high accuracy assembly. If ink access is around the edge of the chip, ink flow is severely limited, and the print head chips must be carefully assembled onto ink channel chips. This latter process is difficult due to the possibility of damaging the fragile nozzle plate. If plasma etching is used, the chips can be effectively diced at the same time. Separating the chips by plasma etching allows them to be spaced as little as 35 micron apart, increasing the number of chips on a wafer.

[0036] One form of detailed manufacturing process which can be used to fabricate monolithic ink jet print heads operating in accordance with the principles taught by the present embodiment can proceed utilizing the following steps:

1. Using a double sided polished wafer, complete drive transistors, data distribution, and timing circuits using a 0.5 micron, one poly, 2 metal CMOS process. Relevant features of the wafer at this step are shown in Fig. 336. For clarity, these diagrams may not be to scale, and may not represent a cross section though any single plane of the nozzle. Fig. 335 is a key to representations of various materials in these manufacturing diagrams, and those of other cross referenced ink jet configurations.
2. Etch oxide down to silicon or aluminum using Mask 1. This mask defines the ink inlet, the heater contact vias, and the edges of the print head chips. This step is shown in Fig. 337.
3. Deposit 1 micron of sacrificial material (e.g. aluminum)
4. Etch the sacrificial layer using Mask 2, defining

the nozzle chamber wall and the actuator anchor point. This step is shown in Fig. 338.
5. Deposit 1 micron of heater material, for example titanium nitride (TiN) or titanium diboride (TiB2).
6. Etch the heater material using Mask 3, which defines the actuator loop and the lowest layer of the nozzle wall. This step is shown in Fig. 339.
7. Wafer probe. All electrical connections are complete at this point, bond pads are accessible, and the chips are not yet separated.
8. Deposit 1 micron of titanium nitride.
9. Etch the titanium nitride using Mask 4, which defines the nozzle chamber wall, with the exception of the nozzle chamber actuator slot, and the paddle. This step is shown in Fig. 340.
10. Deposit 8 microns of sacrificial material.
11. Etch the sacrificial material down to titanium nitride using Mask 5. This mask defines the nozzle chamber wall and the paddle. This step is shown in Fig. 341.
12. Deposit a 0.5 micron conformal layer of titanium nitride and planarize down to the sacrificial layer using CMP.
13. Deposit 1 micron of sacrificial material.
14. Etch the sacrificial material down to titanium nitride using Mask 6. This mask defines the nozzle chamber wall. This step is shown in Fig. 342.
15. Deposit 1 microns of titanium nitride.
16. Etch to a depth of (approx.) 0.5 micron using Mask 7. This mask defines the nozzle rim. This step is shown in Fig. 343.
17. Etch down to the sacrificial layer using Mask 8. This mask defines the roof of the nozzle chamber, and the nozzle itself. This step is shown in Fig. 344.
18. Back-etch completely through the silicon wafer (with, for example, an ASE Advanced Silicon Etcher from Surface Technology Systems) using Mask 9. This mask defines the ink inlets which are etched through the wafer. The wafer is also diced by this etch. This step is shown in Fig. 345.
19. Etch the sacrificial material. The nozzle chambers are cleared, the actuators freed, and the chips are separated by this etch. This step is shown in Fig. 346.
20. Mount the print heads in their packaging, which may be a molded plastic former incorporating ink channels which supply the appropriate color ink to the ink inlets at the back of the wafer.
21. Connect the print heads to their interconnect systems. For a low profile connection with minimum disruption of airflow, TAB may be used. Wire bonding may also be used if the printer is to be operated with sufficient clearance to the paper.
22. Hydrophobize the front surface of the print heads.
23. Fill the completed print heads with ink and test them. A filled nozzle is shown in Fig. 347.

Claims

1. An ink jet nozzle arrangement comprising:

   a nozzle chamber (3302) having a slotted sidewall in a first surface and an ink ejection port (3305) defined in a second surface thereof;
   an ink supply channel interconnected to said nozzle chamber for the supply of ink to said nozzle chamber;
   a moveable vane (3304) located within said nozzle chamber and being moveable so as to cause the ejection of ink from said nozzle chamber; and
   an actuator located (3303) outside said nozzle chamber and interconnected to said moveable vane through said slotted sidewall.

2. An ink jet nozzle as claimed in claim 1 wherein said moveable vane, in its quiescent position, is located substantially adjacent a first end of said slot and said actuator is actuated to move said moveable vane from said first end of said slot to a second end of said slot.

3. An inkjet nozzle arrangement as claimed in claim 1 or 2 wherein said actuator comprises a thermal actuator which is actuated by means of an electric current passed through the thermal actuator resulting in resistive heating of said actuator.

4. An ink jet nozzle arrangement as claimed in claim 3 wherein said thermal actuator is constructed of a conductive material having a high Young's modulus.

5. An ink jet nozzle arrangement as claimed in claim 3 wherein said thermal actuator includes a first (3306) and second arm (3307), said first arm undergoing resistive heating to thereby cause said first arm to bend resulting in actuation by said thermal actuator.

6. An ink jet nozzle arrangement as claimed in claim 5 wherein the first arm has a thinned cross-section relative to the second arm,

7. An ink jet nozzle arrangement as claimed in claim 5 wherein said arms are attached to a substrate at one end.

8. An ink jet nozzle arrangement as claimed in any one of the preceding claims wherein said actuator device operates in an ambient atmosphere.

9. An ink jet nozzle arrangement as claimed in any of the preceding claims wherein the portions of said actuator located adjacent the exterior of said slotted side wall are coated with a hydrophobic material.

10. An ink jet nozzle arrangement as claimed in any of the preceding claims wherein said arrangement is formed on a silicon wafer and said ink supply channel is formed by etching a channel through said silicon wafer.

Patentansprüche

1. Tintenstrahldüsenanordnung, umfassend:

eine Düsenkammer (3302) mit einer durchbrochenen Seitenwand in einer ersten Oberfläche und einer Tintenausstoßöffnung (3305), die in einer zweiten Oberfläche von dieser ausgebildet ist;
einen mit der Düsenkammer verbundenen Tintenzufuhrkanal, um der Düsenkammer Tinte zuzuführen;
eine bewegbare Lamelle (3304), die in der Düsenkammer angeordnet ist und so bewegt werden kann, dass das Ausstoßen von Tinte aus der Düsenkammer herbeigeführt wird; und
ein Stellorgan (3303), das außerhalb der Düsenkammer angeordnet ist und mit der bewegbaren Lamelle durch die durchbrochene Seitenwand hindurch verbunden ist.

2. Tintenstrahldüsenanordnung nach Anspruch 1, wobei die bewegbare Lamelle in ihrer Ruheposition im Wesentlichen angrenzend an ein erstes Ende des Durchbruchs angeordnet ist, und das Stellorgan betätigt wird, um die bewegbare Lamelle vom ersten Ende des Durchbruchs zu einem zweiten Ende des Durchbruchs zu bewegen.

3. Tintenstrahldüsenanordnung nach Anspruch 1 oder 2, wobei das Stellorgan ein thermisches Stellorgan umfasst, das mittels eines elektrischen Stroms betätigt wird, der durch das thermische Stellorgan geschickt wird, was zu einer widerstandsbedingten Erwärmung des Stellorgans führt.

4. Tintenstrahldüsenanordnung nach Anspruch 3, wobei das thermische Stellorgan aus einem leitfähigen Material mit einem hohen Elastizitätsmodul aufgebaut ist.

5. Tintenstrahldüsenanordnung nach Anspruch 3, wobei das thermische Stellorgan einen ersten (3306) und einen zweiten Arm (3307) umfasst, wobei der erste Arm eine widerstandsbedingte Erwärmung durchmacht, um **dadurch** seine Verbiegung hervorzurufen, was zu einer Betätigung durch das thermische Stellorgan führt.

6. Tintenstrahldüsenanordnung nach Anspruch 5, wobei der erste Arm relativ zum zweiten Arm gesehen einen dünner ausgelegten Querschnitt hat.

7. Tintenstrahldüsenanordnung nach Anspruch 5, wobei die Arme an einem Ende an einem Trägermaterial angebracht sind.

8. Tintenstrahldüsenanordnung nach einem der vorhergehenden Ansprüche, wobei die Stellorganvorrichtung in einer Umgebungsatmosphäre arbeitet.

9. Tintenstrahldüsenanordnung nach einem der vorhergehenden Ansprüche, wobei die angrenzend an den Außenbereich der durchbrochenen Seitenwand befindlichen Abschnitte des Stellorgans mit einem hydrophoben Material beschichtet sind.

10. Tintenstrahldüsenanordnung nach einem der vorhergehenden Ansprüche, wobei die Anordnung auf einem Siliziumwafer gebildet ist und der Tintenzufuhrkanal durch Ätzen eines Kanals durch den Siliziumwafer gebildet ist.

Revendications

1. Agencement de buse à jet d'encre comprenant :

une chambre de buse (3302) comprenant une paroi latérale à fente dans une première surface et un orifice d'éjection d'encre (3305) défini dans une seconde surface de celle-ci ;
un canal d'alimentation en encre interconnecté à ladite chambre de buse pour l'alimentation en encre de ladite chambre de buse ;
une ailette mobile (3304) située à l'intérieur de ladite chambre de buse et étant mobile de façon à provoquer l'éjection de l'encre de ladite chambre de buse ; et
un actionneur (3303) situé à l'extérieur de ladite chambre de buse et interconnecté à ladite ailette mobile à travers ladite paroi latérale à fente.

2. Buse à jet d'encre selon la revendication 1, dans laquelle ladite ailette mobile, dans sa position de repos, est située de manière sensiblement voisine d'une première extrémité de ladite fente et ledit actionneur est actionné pour déplacer ladite ailette mobile de ladite première extrémité de ladite fente à une seconde extrémité de ladite fente.

3. Agencement de buse à jet d'encre selon la revendication 1 ou 2, dans lequel ledit actionneur comprend un actionneur thermique qui est actionné au moyen d'un courant électrique qui passe à travers l'actionneur thermique, ayant pour conséquence un échauffement résistif dudit actionneur.

4. Agencement de buse à jet d'encre selon la revendication 3, dans lequel ledit actionneur thermique est construit en un matériau conducteur ayant un module de Young élevé.

5. Agencement de buse à jet d'encre selon la revendication 3, dans lequel ledit actionneur thermique comprend un premier (3306) et un second (3307) bras, ledit premier bras subissant l'échauffement résistif pour amener ainsi ledit premier bras à plier, ayant pour conséquence l'actionnement par ledit actionneur thermique.

6. Agencement de buse à jet d'encre selon la revendication 5, dans lequel le premier bras présente une coupe transversale amincie par rapport au second bras.

7. Agencement de buse à jet d'encre selon la revendication 5, dans lequel lesdits bras sont fixés sur un substrat à une extrémité.

8. Agencement de buse à jet d'encre selon l'une quelconque des revendications précédentes, dans lequel ledit dispositif actionneur fonctionne dans une atmosphère ambiante.

9. Agencement de buse à jet d'encre selon l'une quelconque des revendications précédentes, dans lequel les parties dudit actionneur situées de manière voisine de l'extérieur de ladite paroi latérale à fente sont revêtues d'un matériau hydrophobe.

10. Agencement de buse à jet d'encre selon l'une quelconque des revendications précédentes, dans lequel ledit agencement est formé sur une tranche de silicium et ledit canal d'alimentation en encre est formé par gravure d'un canal dans ladite tranche de silicium.

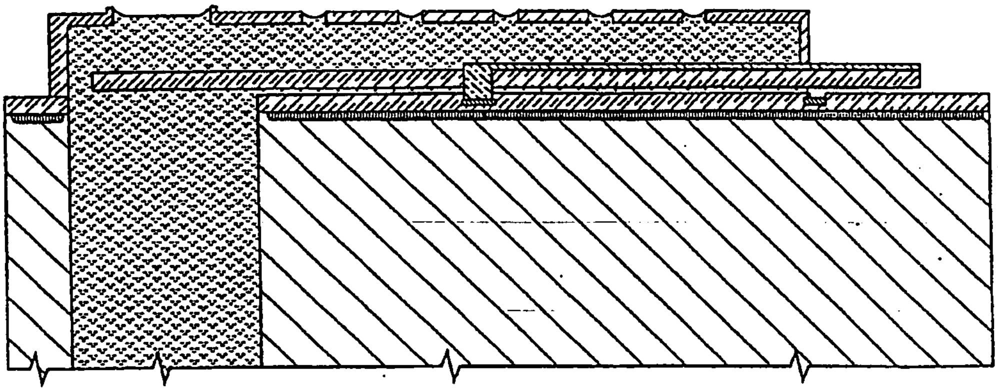

FIG. 331

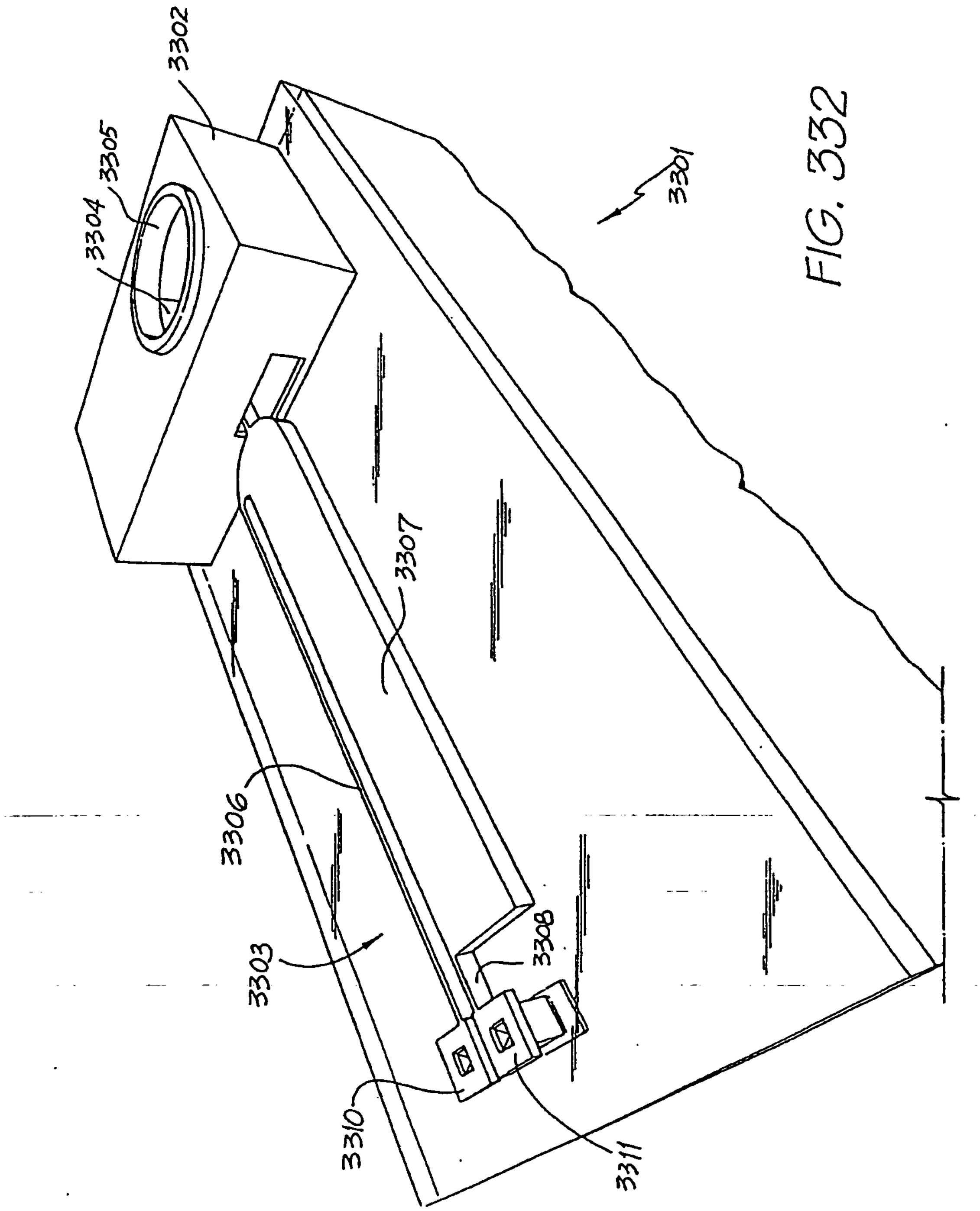

FIG. 332

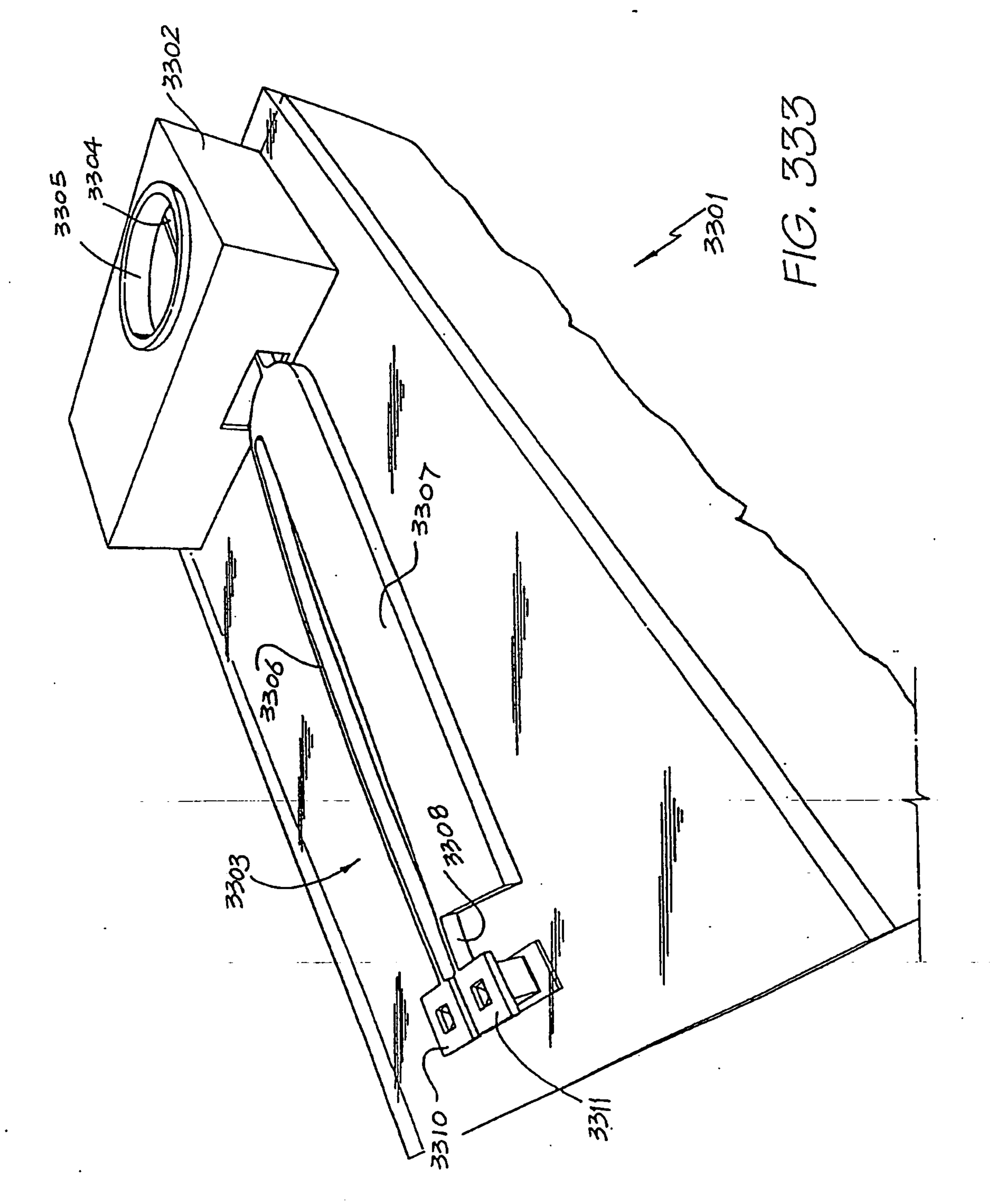

FIG. 333

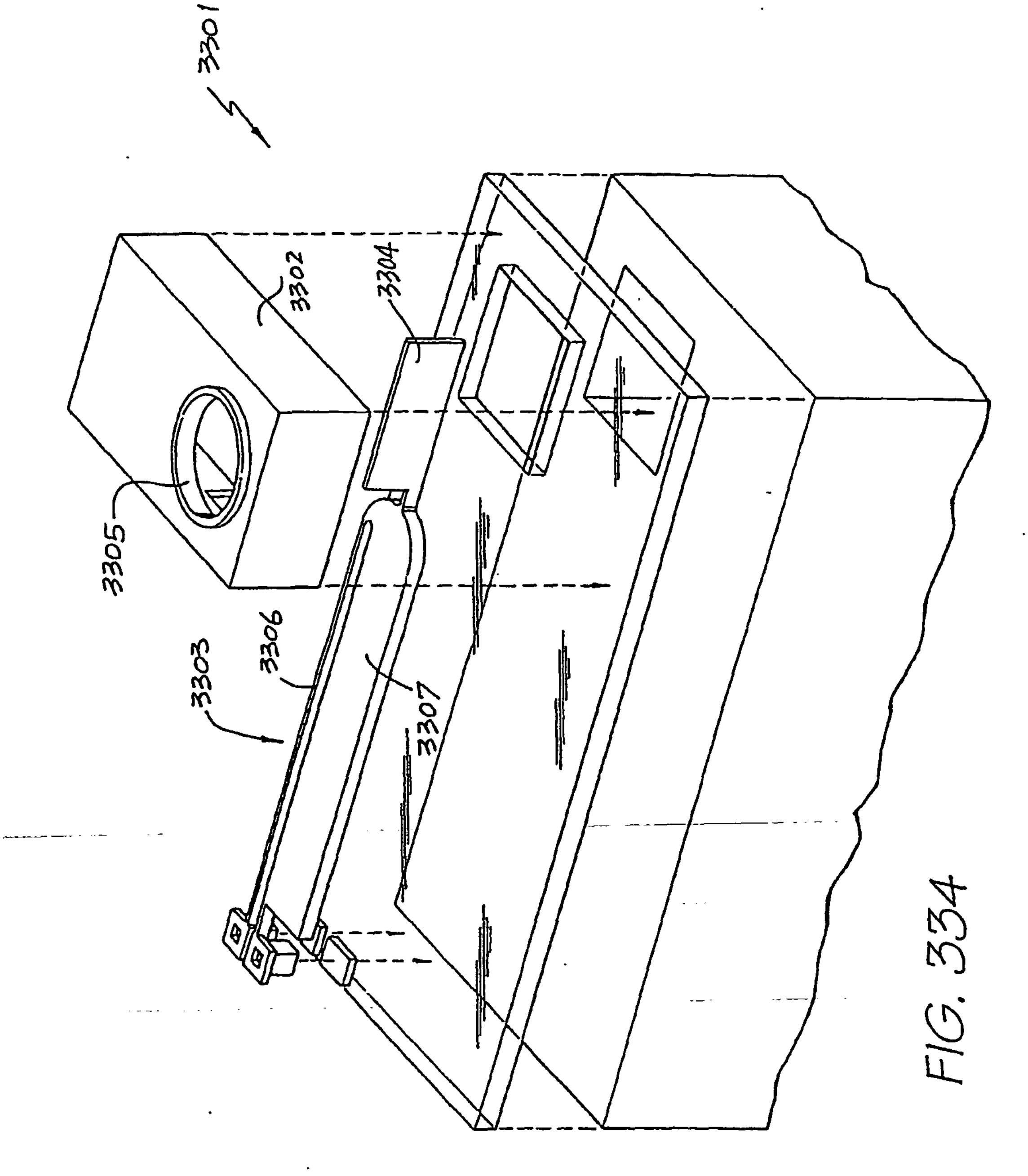

FIG. 334

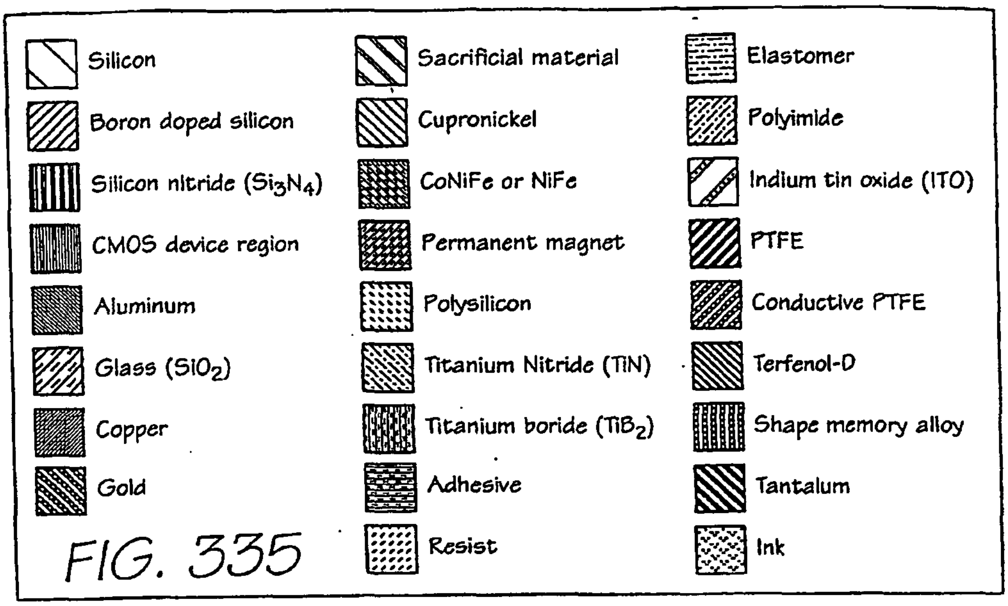

FIG. 335

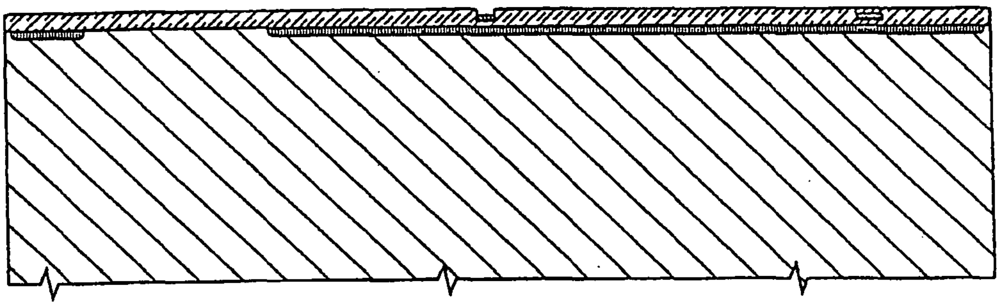
FIG. 336

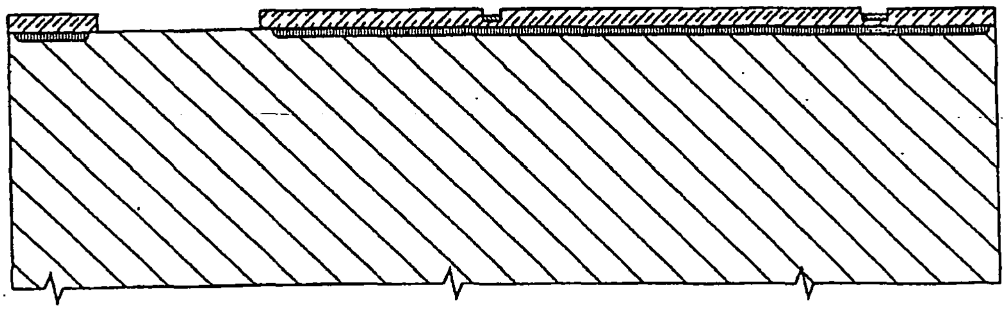
FIG. 337

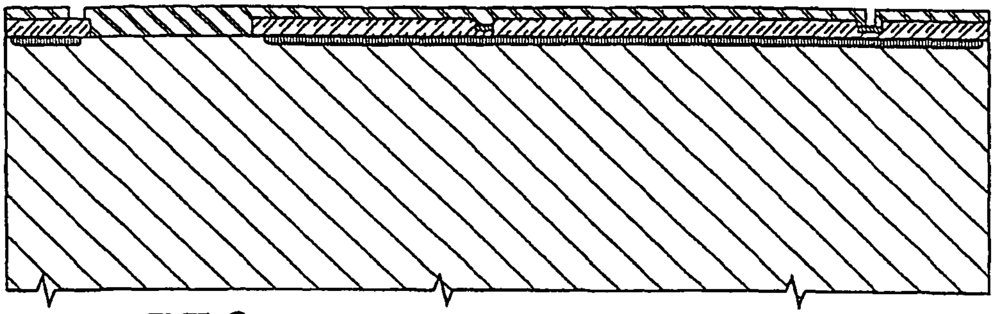

FIG. 338

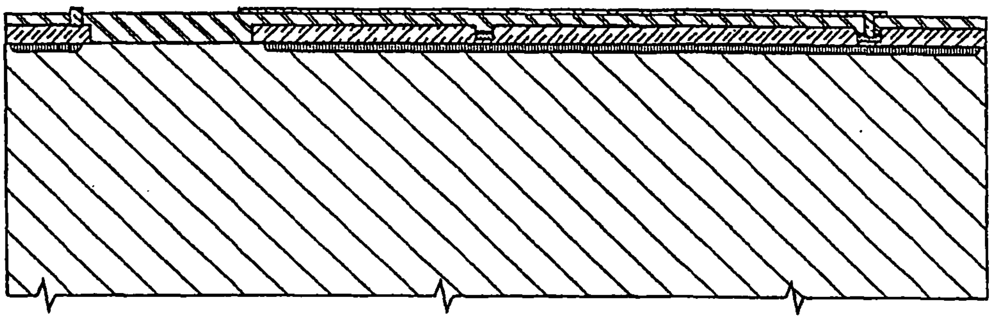

FIG. 339

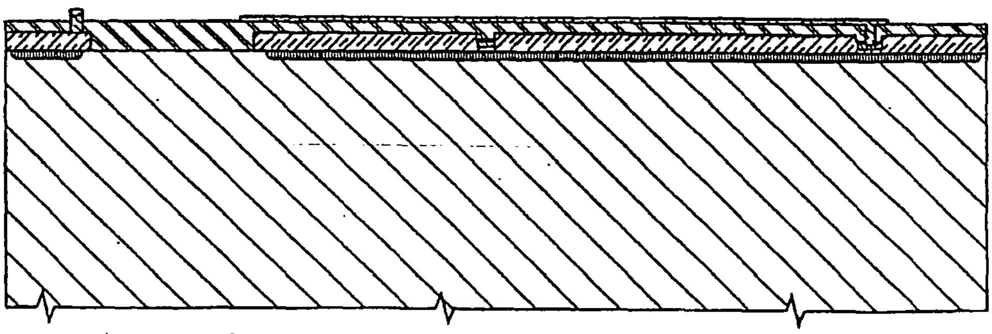

FIG. 340

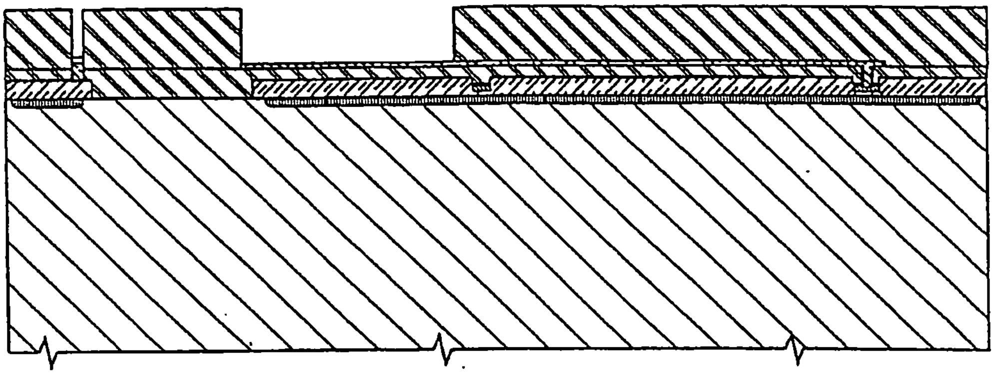

FIG. 341

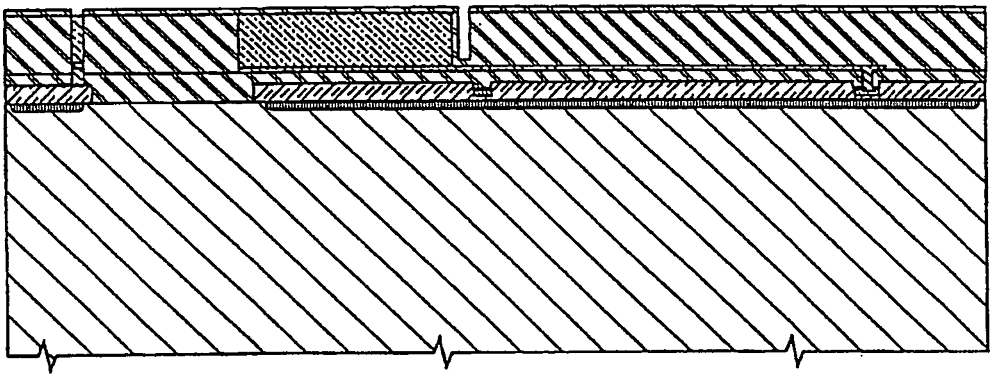

FIG. 342

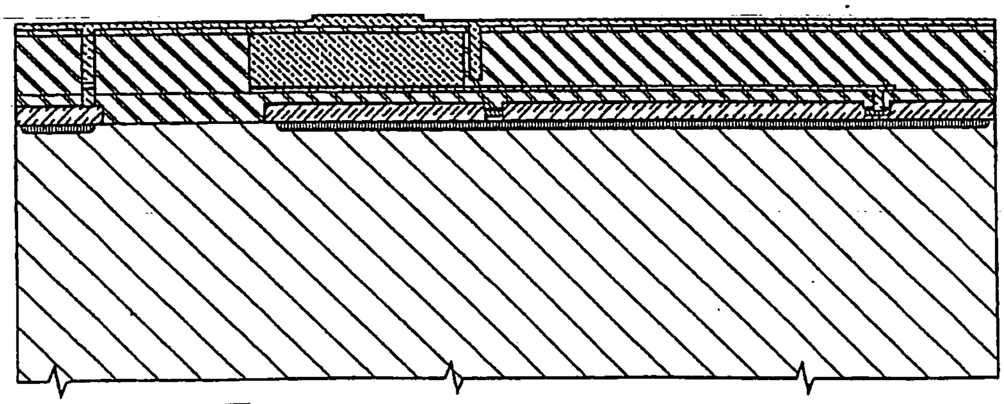

FIG. 343

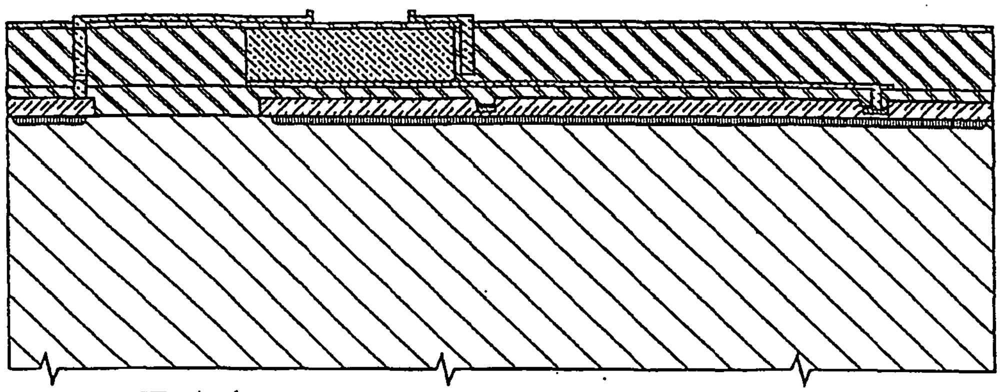
FIG. 344

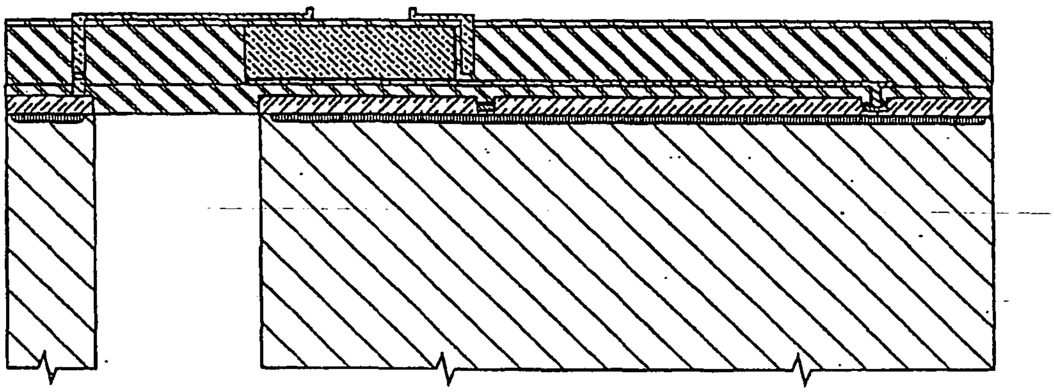
FIG. 345

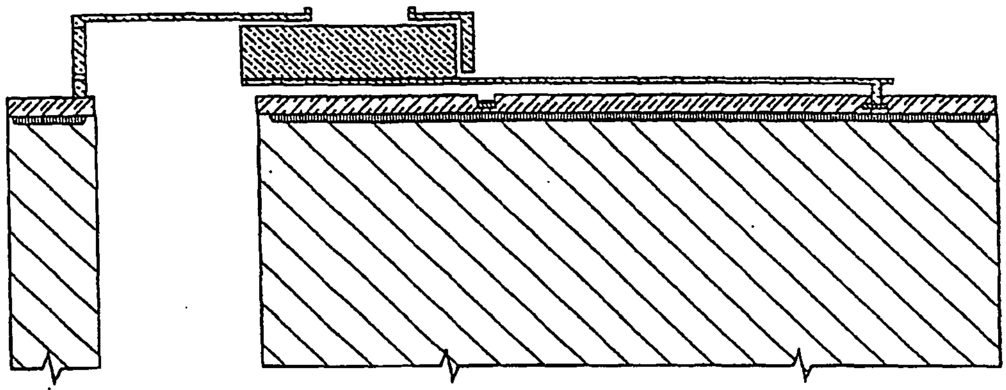

FIG. 346

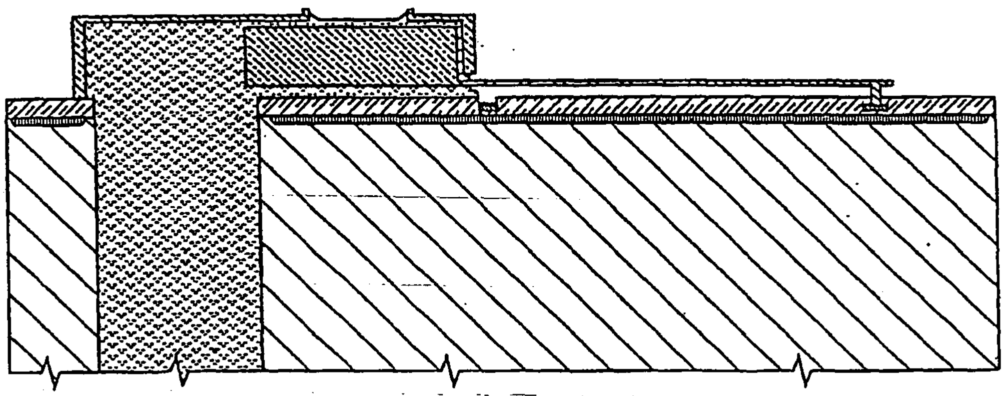

FIG. 347

REFERENCES CITED IN THE DESCRIPTION

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