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(54) **Nozzle chamber with paddle vane and externally located thermal actuator**

Düsenkammer mit Paddelschaukel und externem thermischen Betätigungselement

Chambre de buse avec pagaie et actuateur thermique en dehors

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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 Elmjett 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 3683212 (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] EP-A-0506232 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.

[0010] Another prior art apparatus is disclosed in JP 4118241.

[0011] 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.

[0012] 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.

[0013] 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.

[0014] 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.

[0015] It would therefore be desirable if an efficient system for the mass production of ink jet print heads could be developed.

[0016] 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 pos-

sible unwanted attack by a sacrificial etchant.

[0017] 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.

[0018] 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

[0019] The present invention provides an ink jet nozzle arrangement in accordance with the claims which follow.

Brief Description of the Drawings

[0020] 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. 570 to Fig. 572 illustrate the basic operational principles of an embodiment;

Fig. 573 is a side perspective view of a single inkjet nozzle arrangement constructed in accordance with an embodiment;

Fig. 574 is a side perspective view of a portion of an array of a printhead constructed in accordance with the principles of an embodiment;

Fig. 575 provides a legend of the materials indicated in Fig. 576 to Fig. 585;

Fig. 576 to Fig. 585 illustrate sectional views of the manufacturing steps in one form of construction of an ink jet printhead nozzle;

Fig. 586 to Fig. 588 illustrate the operational principles of an embodiment;

Fig. 589 is a side perspective view of a single nozzle arrangement of an embodiment;

Fig. 590 illustrates a side sectional view of a single nozzle arrangement;

Fig. 591 and Fig. 592 illustrate operational principles of an embodiment;

Fig. 593 to Fig. 600 illustrate the manufacturing steps in the construction of an embodiment;

Fig. 601 illustrates a top plan view of a single nozzle;

Fig. 602 illustrates a portion of a single color printhead device;

Fig. 603 illustrates a portion of a three color printhead device;

Fig. 604 provides a legend of the materials indicated in Fig. 605 to Fig. 614; and

Fig. 605 to Fig. 614 illustrate sectional views of the manufacturing steps in one form of construction of an ink jet printhead nozzle.

Description

[0021] In an embodiment, there is provided a nozzle chamber having ink within it and a thermal actuator device interconnected to a paddle the thermal actuator device being actuated so as to eject from the nozzle chamber. An embodiment includes a particular thermal actuator structure which includes a series of tapered actuator heater arms for providing conductive heating of a conductive trace. The actuator arm is interconnected to a paddle by a slotted wall in the nozzle chamber. The actuator arm has a mating shape so as to mate substantially with the surfaces of the slot in the nozzle chamber wall.

[0022] Turning initially to Fig. 570 to Fig. 572, there is provided schematic illustrations of the basic operation of the device. A nozzle chamber 4001 is provided filled with ink 4002 by means of an ink inlet channel 4003 which can be etched through a wafer substrate on which the nozzle chamber 4001 rests. The nozzle chamber 4001 further includes an ink ejection aperture 4004 around which an ink meniscus forms.

[0023] Inside the nozzle chamber 4001 is a paddle type device 4007 which is interconnected to an actuator arm 4008 through a slot in the wall of the nozzle chamber 4001. The actuator arm 4008 includes a heater means eg. 4009 located adjacent to a post end portion 4010 of the actuator arm. The post 4010 being fixed to a substrate.

[0024] When it is desired to eject a drop from the nozzle chamber, as illustrated in Fig. 571, the heater means 4009 is heated so as to undergo thermal expansion. Preferably, the heater means itself or the other portions of the actuator arm 4008 are built from materials having a high bend efficiency.

[0025] A suitable material for the heater elements is a copper nickel alloy which can be formed so as to bend a glass material.

[0026] The heater means is ideally located adjacent the post end portion 4010 such that the effects of activation are magnified at the paddle end 4007 such that small thermal expansions near post 4010 result in large movements of the paddle end.

[0027] The heating 4009 and consequential paddle

movement causes a general increase in pressure around the ink meniscus 4005 which expands, as illustrated in Fig. 571, in a rapid manner. The heater current is pulsed and ink is ejected out of the nozzle 4004 in addition to flowing in from the ink channel 4003. Subsequently, the paddle 4007 is deactivated to again return to its quiescent position. The deactivation causes a general reflow of the ink into the nozzle chamber. The forward momentum of the ink outside the nozzle rim and the corresponding backflow results in a general necking and breaking off of the drop 4012 which proceeds to the print media. The collapsed meniscus 4005 results in a general sucking of ink into the nozzle chamber 4002 via the in flow channel 4003. In time, the nozzle chamber is refilled such that the position in Fig. 570 is again reached and the nozzle chamber is subsequently ready for the ejection of another drop of ink.

[0028] Turning now to Fig. 573 there is illustrated a view of a single nozzle arrangements of an embodiment. The arrangement of Fig. 573 has a number in the structures which aid and assist in the low energy operation of the paddle.

[0029] Firstly, the actuator 4008 includes a series of tapered heater sections eg. 4015 which comprise an upper glass portion (amorphous silicon dioxide) 4016 formed on top of a titanium nitride layers 4017. Alternatively a copper nickel alloy layer (hereinafter called cupronickel) can be utilized which will have a higher bend efficiency.

[0030] The titanium nitride layer 4017 is in a tapered form and, as such, resistive heating takes place near the post end portion 4010. Adjacent titanium nitride/glass portions are interconnected at block portion 4019 which also provides for a mechanical structural support for the actuator arm.

[0031] The heater means ideally includes a plurality of tapered portions 4015 which are elongated and spaced apart such that, upon heating, the bending force exhibited along the axis of the actuator arm is maximized. The slots between adjacent tapered portions allow for slight differential operation of each thermal actuator with respect to adjacent actuators.

[0032] The block portion 4019 is interconnected to an arm portion 4020. The arm 4020 is in turn connected to the paddle 4007 inside the nozzle chamber 4001 by means of a slot eg. 4022 formed in the side of the nozzle chamber 4001. The formation of the slot 4022 is designed generally to mate with the surfaces of the arm 4020 so as to minimise opportunities for the outflow of ink around this arm. The ink is held generally within the nozzle chamber 4001 via surface tension effects around the slot 4022.

[0033] When it is desired to actuate the arm 4008, a conductive current is passed through the titanium nitride layer 4017 via vias within the block portion 4010 connecting to a lower CMOS layer 4006 which provides for the necessary power and control circuitry for the nozzle arrangement. The conductive current results in heating of the nitride layer 4017 adjacent to the post portion 4010

which results in a general upward bending of the arm 4008 and the consequential ejection of ink out of the nozzle 4004. The ejected drop being printed on page in the usual manner for an inkjet printer as previously described.

[0034] Obviously, an array of ink ejection devices can be subsequently formed so as to create a single print-head. For example, in Fig. 574 there is illustrated an array views which comprises multiple ink ejection nozzle arrangements 4001 laid out in interleaved lines so as to form a printhead array. Of course, different types of arrays can be formulated including full color arrays etc.

[0035] An embodiment achieves a particular balance between utilisation of the standard semi-conductor processing material such as titanium nitride and glass in a MEMS process. Obviously the skilled person may make other choices of materials and design features where the economics are justified. For example, a copper nickel alloy of 50% copper and 50% nickel may be more advantageously deployed as the conductive heating compound as it is likely to have higher levels of bend efficiency. Also, other design structures may be employed where it is not necessary to provide for such a simple form of manufacture.

[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 a 0.5 micron, one poly, 2 metal CMOS process. This step is shown in Fig. 576. For clarity, these diagrams may not be to scale, and may not represent a cross section though any single plane of the nozzle. Fig. 575 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 nozzle chamber, the surface anti-wicking notch, and the heater contacts. This step is shown in Fig. 577.
3. Deposit 1 micron of sacrificial material (e.g. aluminum or photosensitive polyimide)
4. Etch (if aluminum) or develop (if photosensitive polyimide) the sacrificial layer using Mask 2. This mask defines the nozzle chamber walls and the actuator anchor point. This step is shown in Fig. 578.
5. Deposit 0.2 micron of heater material, e.g. TiN.
6. Deposit 3.4 microns of PECVD glass.
7. Etch both glass and heater layers together, using Mask 3. This mask defines the actuator, paddle, and nozzle chamber walls. This step is shown in Fig. 579.
8. Wafer probe. All electrical connections are complete at this point, bond pads are accessible, and the chips are not yet separated.
9. Deposit 10 microns of sacrificial material.
10. Etch or develop sacrificial material using Mask

4. This mask defines the nozzle chamber wall. This step is shown in Fig. 580.

11. Deposit 3 microns of PECVD glass.

12. Etch to a depth of (approx.) 1 micron using Mask 5. This mask defines the nozzle rim. This step is shown in Fig. 581.

13. Etch down to the sacrificial layer using Mask 6. This mask defines the roof of the nozzle chamber, and the nozzle itself. This step is shown in Fig. 582.

14. Back-etch completely through the silicon wafer (with, for example, an ASE Advanced Silicon Etcher from Surface Technology Systems) using Mask 7. 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. 583.

15. 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. 584.

16. 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.

17. 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.

18. Hydrophobize the front surface of the print heads.

19. Fill the completed print heads with ink and test them. A filled nozzle is shown in Fig. 585.

[0037] In an embodiment, there is provided a nozzle chamber having ink within it and a thermal actuator device interconnected to a panel the thermal actuator device being actuated so as to eject ink from the nozzle chamber. An embodiment includes a particular thermal actuator structure which includes a tapered heater structure arms for providing positional heating of a conductive heater layer row. The actuator arm is interconnected to a paddle by a slotted wall in the nozzle chamber. The actuator arm has a mating shape so as to mate substantially with the surfaces of the slot in the nozzle chamber wall.

[0038] Turning initially to Fig. 586 to Fig. 588, there is provided schematic illustrations of the basic operation of the device. A nozzle chamber 4101 is provided filled with ink 4102 by means of an ink inlet channel 4103 which can be etched through a wafer substrate on which the nozzle chamber 4101 rests. The nozzle chamber 4101 includes an ink ejection aperture 4104 around which an ink meniscus forms.

[0039] Inside the nozzle chamber 4101 is a paddle type device 4107 which is interconnected to an actuator arm 4108 through a slot in the wall of the nozzle chamber 4101. The actuator arm 4108 includes a heater means eg. 4109 located adjacent to a post end portion 4110 of the actuator arm. The post 4110 being fixed to a sub-

strate.

[0040] When it is desired to eject a drop from the nozzle chamber, as illustrated in Fig. 587, the heater means 4109 is heated so as to undergo thermal expansion. Preferably, the heater means itself or the other portions of the actuator arm 4108 are built from materials having a high bend efficiency.

[0041] A suitable material for the heater elements is a copper nickel alloy which can be formed so as to bend a glass material.

[0042] The heater means is ideally located adjacent the post end portion 4110 such that the effects of activation are magnified at the paddle end 4107 such that small thermal expansions near post 4110 result in large movements of the paddle end. The heating 4109 causes a general increase in pressure around the ink meniscus 4105 which expands, as illustrated in Fig. 587, in a rapid manner. The heater current is pulsed and ink is ejected out of the nozzle 4104 in addition to flowing in from the ink channel 4103. Subsequently, the paddle 4107 is deactivated to again return to its quiescent position. The deactivation causes a general reflow of the ink into the nozzle chamber. The forward momentum of the ink outside the nozzle rim and the corresponding backflow results in a general necking and breaking off of the drop 4112 which proceeds to the print media. The collapsed meniscus 4105 results in a general sucking of ink into the nozzle chamber 4102 via the in flow channel 4103. In time, the nozzle chamber is refilled such that the position in Fig. 586 is again reached and the nozzle chamber is subsequently ready for the ejection of another drop of ink.

[0043] Turning now to Fig. 589, there is illustrated a single nozzle arrangement 4120 of an embodiment. The arrangements includes an actuator arm 4121 which includes a bottom arm 4122 which is constructed from a conductive material such as a copper nickel alloy (hereinafter called cupronickel) or titanium nitride (TiN). The layer 4122, as will become more apparent hereinafter includes a tapered end portion near the end post 4124. The tapering of the layer 4122 near this end means that any conductive resistive heating occurs near the post portion 4124.

[0044] The layer 4122 is connected to the lower CMOS layers 4126 which are formed in the standard manner on a silicon substrate surface 4127. The actuator arm 4121 is interconnected to an ejection paddle which is located within a nozzle chamber 4128. The nozzle chamber includes an ink ejection nozzle 4129 from which ink is ejected an includes a convoluted slot arrangement 4130 which is constructed such that the actuator arm 4121 is able to move up and down whilst causing minimal pressure fluctuations in the area of the nozzle chamber 4128 around the slotted interconnect 4130.

[0045] Fig. 590 illustrates a sectional view through a single nozzle and illustrates more clearly the internal structure of the nozzle chamber which includes the paddle 4132 attached to the actuator arm 4121 by means of

arm 4133. Importantly, the actuator arm 4121 includes, as noted previously, a bottom conductive strip portion 4122. Additionally, a second top strip portion 4125 is also provided.

[0046] The utilization of a second layer 4125 of the same material as the first layer 4122 allows for more accurate control of the actuator position as will be described with reference to Fig. 591 and Fig. 592. In Fig. 591, there is illustrated the example where a high Young's Modulus material 4140 is deposited utilizing standard semiconductor deposition techniques and on top of which is further deposited a second layer 4141 having a much lower Young's Modulus. Unfortunately, the deposition is likely to occur at a high temperature. Upon cooling, the two layers are likely to have different coefficients of thermal expansion and different Young's Modulus. Hence, in ambient room temperature, the thermal stresses are likely to cause bending of the two layers of material as shown 4142.

[0047] By utilizing a second deposition of the material having a high Young's Modulus, the situation in Fig. 592 is likely to result wherein the material 4141 is sandwiched between the two layers 4140. Upon cooling, the two layers 4140 are kept in tension with one another so as to result in a more planar structure 4145 no matter what operation temperature. This principle is utilized in the deposition of the two layers 4122, 4125 of Fig. 589 to Fig. 590.

[0048] Turning again to Fig. 589 and Fig. 590, one important attribute of an embodiment includes the slotted arrangement 4130. The slotted arrangement results in the actuator arm 4121 moving up and down thereby causing the paddle 4132 to also move up and down resulting in the ejection of ink. The slotted arrangements 4130 results in minimum ink outflow through the actuator arm interconnection and also results in minimal pressure increases in this area. The base 4133 of the actuator arm is extended out so as to form an extended interconnect with the paddle surface thereto providing for better attachment. The face 4133 is connected to a block arm 4136 which is provided to provide a high degree of rigidity. The actuator arm 4136 and the wall of the nozzle chamber 4128 have a general corrugated nature so as to reduce any flow of ink through the interconnection. The exterior surface of the nozzle chamber adjacent the block portion 4136 has a rim eg. 4138 so to minimize wicking of ink outside of the nozzle chamber. A pit 4137 is also provided for this purpose. The pit 4137 being formed in the lower CMOS layers 4126. An ink supply channel 4139 is provided by means of back etching through the wafer to the back surface of the nozzle.

[0049] Turning now to Fig. 593 to Fig. 600 there will now be described the manufacturing steps utilizing the construction of a single nozzle in accordance with an embodiment

[0050] The manufacturing uses standard micro-electro mechanical techniques 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.

1. An embodiment starts with a double sided polished wafer complete with, say, a 0.2 micron 1 poly 2 metal CMOS process providing for all the electrical interconnect necessary to drive the inkjet nozzle.
2. As shown in Fig. 593, the CMOS wafer is etched 4150 down to the silicon layer 4127. The etching includes etching down to an aluminium CMOS layer 4151, 4152.
3. Next, as illustrated in Fig. 594, a 1 micron layer of sacrificial material 4155 is deposited. The sacrificial material can be aluminium or photosensitive polyimide.
4. The sacrificial material is etched in the case of aluminium or exposed and developed in the case of polyimide in the area of the nozzle rim 4156 and including a depressed paddle area 4157.
5. Next, a 1 micron layer of heater material (cupronickel or TiN) is deposited 4160.
6. A 3.4 micron layer of PECVD glass 4161 is then deposited.
7. A second layer 4162 equivalent to the first layer 4160 is then deposited.
8. All three layers 4160 - 4162 are then etched utilizing the same mask. The utilization of a single mask substantially reduces the complexity in the processing steps involved in creation of the actuator paddle structure and the resulting structure is as illustrated in Fig. 595. Importantly, a break 4163 is provided so as to ensure electrical installation of the heater portion from the paddle portion.
9. Next, as illustrated in Fig. 596, a 10 micron layer of sacrificial material 4170 is deposited.
10. The deposited layer is etched (or just developed if polyimide) utilizing a fourth mask which includes nozzle rim etchant holes 4171 block portion holes 4172 and post portion 4173.
11. Next a 10µm of PCVD glass is deposited so as to form the nozzle rim 4171, arm portions 4172 and post portions 4173.
12. The glass layer is then planarized utilizing chemical mechanical planarization (CMP) with the resulting structure as illustrated in Fig. 596.
13. Next, as illustrated in Fig. 596, a 3 micron layer of PECVD glass is deposited.
14. The deposited glass is then etched as shown in Fig. 597, to a depth of approximately 1µm so as to form nozzle rim portion 4181 and actuator interconnect portion 4182.
15. Next, as illustrated in Fig. 598, the glass layer is etched utilizing a 6th mask so as to form final nozzle rim portion 4181 and actuator guide portion 4182.
16. Next, as illustrated in Fig. 599, the ink supply

channel is back etched 4185 from the back of the wafer utilizing a 7th mask. The etch can be performed utilizing a high precision deep silicon trench etcher such as the STS Advanced Silicon Etcher (ASE). This step can also be utilized to nearly completely dice the wafer.

17. Next, as illustrated in Fig. 600 the sacrificial material can be stripped or dissolved to also complete dicing of the wafer in accordance with requirements.

18. Next, the printheads can be individually mounted on attached moulded plastic ink channels to supply ink to the ink supply channels.

19. The electrical control circuitry and power supply can then be bonded to an etch of the printhead with a TAB film.

20. Generally, if necessary, the surface of the printhead is then hydrophobized so as to ensure minimal wicking of the ink along external surfaces. Subsequent testing can determine operational characteristics.

[0051] Importantly, as shown in the plan view of Fig. 601, the heater element has a tapered portion adjacent the post 4173 so as to ensure maximum heating occurs near the post.

[0052] Of course, different forms of inkjet printhead structures can be formed. For example, there is illustrated in Fig. 602, a portion of a single color printhead having two spaced apart rows 4190, 4191, with the two rows being interleaved so as to provide for a complete line of ink to be ejected in two stages. Preferably, a guide rail 4192 is provided for proper alignment of a TAB film with bond pads 4193. A second protective barrier 4194 can also preferably be provided. Preferably, as will become more apparent with reference to the description of Fig. 603 adjacent actuator arms are interleaved and reversed.

[0053] Turning now to Fig. 603, there is illustrated a full color printhead arrangement which includes three series of inkjet nozzles 4194, 4196, one each devoted to a separate color. Again, guide rails 4198, 4199 are provided in addition to bond pads, eg. 4200. In Fig. 604, there is illustrated a general plan of the layout of a portion of a full color printhead which clearly illustrates the interleaved nature of the actuator arms.

[0054] One alternative 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. 605. For clarity, these diagrams may not be to scale, and may not represent a cross section though any single plane of the nozzle. Fig. 604 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 nozzle chamber, the surface anti-wicking notch, and the heater contacts. This step is shown in Fig. 606.

3. Deposit 1 micron of sacrificial material (e.g. aluminum or photosensitive polyimide)

4. Etch (if aluminum) or develop (if photosensitive polyimide) the sacrificial layer using Mask 2. This mask defines the nozzle chamber walls and the actuator anchor point. This step is shown in Fig. 607.

5. Deposit 1 micron of heater material (e.g. cupronickel or TiN). If cupronickel, then deposition can consist of three steps - a thin anti-corrosion layer of, for example, TiN, followed by a seed layer, followed by electroplating of the 1 micron of cupronickel.

6. Deposit 3.4 microns of PECVD glass.

7. Deposit a layer identical to step 5.

8. Etch both layers of heater material, and glass layer, using Mask 3. This mask defines the actuator, paddle, and nozzle chamber walls. This step is shown in Fig. 608.

9. Wafer probe. All electrical connections are complete at this point, bond pads are accessible, and the chips are not yet separated.

10. Deposit 10 microns of sacrificial material.

11. Etch or develop sacrificial material using Mask 4. This mask defines the nozzle chamber wall. This step is shown in Fig. 609.

12. Deposit 3 microns of PECVD glass.

13. Etch to a depth of (approx.) 1 micron using Mask 5. This mask defines the nozzle rim. This step is shown in Fig. 610.

14. Etch down to the sacrificial layer using Mask 6. This mask defines the roof of the nozzle chamber, and the nozzle itself. This step is shown in Fig. 611.

15. Back-etch completely through the silicon wafer (with, for example, an ASE Advanced Silicon Etcher from Surface Technology Systems) using Mask 7. 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. 612.

16. 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. 613.

17. 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.

18. 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.

19. Hydrophobize the front surface of the print heads.

20. Fill the completed print heads with ink and test

them. A filled nozzle is shown in Fig. 614.

Claims

1. An ink jet nozzle arrangement comprising:

a nozzle chamber (4002;4101) having a fluid ejection nozzle in a wall of said chamber;
a movable paddle vane (4007;4107) configured to cause ejection of fluid out of said chamber via said fluid ejection nozzle, said paddle vane being actuated by an actuator device; and

characterized by:

a thermal actuator device (4009;4109) located externally of said nozzle chamber and attached to said paddle vane.

2. An ink jet nozzle arrangement as claimed in claim 1, wherein said paddle vane is located within said chamber.

3. An ink jet nozzle arrangement as claimed in claim 1, wherein said paddle vane forms at least part of said wall of said chamber

4. An ink jet nozzle arrangement as claimed in any one of the preceding claims, wherein said thermal actuator device includes a lever arm having one end attached to said paddle vane and a second end attached to a substrate.

5. An ink jet nozzle arrangement as claimed in claim 4 wherein said thermal actuator operates upon conductive heating along a conductive trace and said conductive heating includes the generation of a substantial portion of said heat in the area adjacent said second end.

6. An ink jet nozzle arrangement as claimed in claim 5 wherein said conductive heating includes a thinned cross-section adjacent said second end.

7. An ink jet nozzle arrangement as claimed in any one of the preceding claims wherein said thermal actuator includes a first and a second layer.

8. An ink jet nozzle arrangement according to claim 7 wherein said first and said layers are fabricated by a deposition process, said first and second layers being formed of a material having similar thermal properties such that, upon cooling after deposition of said layers, said two layers act against one another so as to maintain said actuator substantially in a predetermined position.

9. An ink jet nozzle arrangement as claimed in claim 8 wherein said layers comprise substantially either a copper nickel alloy or titanium nitride.

10. An ink jet nozzle arrangement as claimed in any one of the preceding claims wherein said nozzle chamber includes an actuator access port in a second wall of said chamber.

11. An ink jet nozzle arrangement as claimed in claim 1, wherein said thermal actuator device includes a plurality of separate spaced apart elongated thermal actuator units.

12. An ink jet nozzle arrangement as claimed in claim 11 wherein said thermal actuator units are interconnected at a first end to a substrate and at a second end to a rigid strut member.

13. An inkjet nozzle arrangement as claimed in claim 12 wherein said rigid strut member is interconnected to a lever arm having one end attached to said paddle vane.

Patentansprüche

1. Tintenstrahldüsenanordnung, umfassend:

eine Düsenkammer (4002; 4101) mit einer Fluidausstoßdüse in einer Wand der Kammer;
eine bewegliche Paddelklappe (4007; 4107), die dazu ausgelegt ist, ein Ausstoßen von Fluid aus der Kammer über die Fluidausstoßdüse zu bewirken, wobei die Paddelklappe durch eine Stellgliedvorrichtung betätigt wird; und

gekennzeichnet durch:

eine thermische Stellgliedvorrichtung (4009; 4109), die sich außerhalb der Düsenkammer befindet und an der Paddelklappe angebracht ist.

2. Tintenstrahldüsenanordnung nach Anspruch 1, wobei sich die Paddelklappe innerhalb der Kammer befindet.

3. Tintenstrahldüsenanordnung nach Anspruch 1, wobei die Paddelklappe zumindest einen Teil der Wand der Kammer bildet.

4. Tintenstrahldüsenanordnung nach einem der vorhergehenden Ansprüche, wobei die thermische Stellgliedvorrichtung einen Hebelarm umfasst, der ein an der Paddelklappe angebrachtes erstes Ende und ein an einem Substrat angebrachtes zweites Ende aufweist.

5. Tintenstrahldüsenanordnung nach Anspruch 4, wobei das thermische Stellglied bei einer Leitungserwärmung entlang einer Leitungsbahn arbeitet und die Leitungserwärmung die Erzeugung eines wesentlichen Teils der Wärme in dem an das zweite Ende angrenzenden Bereich umfasst. 5
6. Tintenstrahldüsenanordnung nach Anspruch 5, wobei die Leitungserwärmung einen ausgedünnten Querschnitt angrenzend an das zweite Ende umfasst. 10
7. Tintenstrahldüsenanordnung nach einem der vorhergehenden Ansprüche, wobei das thermische Stellglied eine erste Schicht und eine zweite Schicht umfasst. 15
8. Tintenstrahldüsenanordnung nach Anspruch 7, wobei die erste und zweite Schicht durch einen Abscheidvorgang hergestellt werden, und die erste und zweite Schicht aus Materialien mit ähnlichen thermischen Eigenschaften gebildet sind, so dass bei Abkühlung nach der Abscheidung der Schichten die beiden Schichten aufeinander einwirken, um das Stellglied im Wesentlichen in einer vorbestimmten Position zu halten. 20
9. Tintenstrahldüsenanordnung nach Anspruch 8, wobei die Schichten im Wesentlichen eine Kupfer-Nickel-Legierung oder Titanitrid aufweisen. 30
10. Tintenstrahldüsenanordnung nach einem der vorhergehenden Ansprüche, wobei die Düsenkammer eine Zugangsöffnung für das Stellglied in einer zweiten Wand der Kammer umfasst. 35
11. Tintenstrahldüsenanordnung nach Anspruch 1, wobei die thermische Stellgliedvorrichtung mehrere separate, voneinander beabstandete längliche thermische Stellgliedeinheiten umfasst. 40
12. Tintenstrahldüsenanordnung nach Anspruch 11, wobei die thermischen Stellgliedeinheiten an einem ersten Ende mit einem Substrat und an einem zweiten Ende mit einem starren Stützelement verbunden sind. 45
13. Tintenstrahldüsenanordnung nach Anspruch 12, wobei das starre Stützelement mit einem Hebelarm verbunden ist, der ein Ende aufweist, das an der Paddelklappe angebracht ist. 50

Revendications

1. Agencement de buse à jet d'encre comprenant :
une chambre de buse (4002 ; 4101) ayant une

buse d'éjection de fluide dans une paroi de ladite chambre ;
une palette agitatrice mobile (4007 ; 4107) configurée pour provoquer une éjection de fluide à l'extérieur de ladite chambre via ladite buse d'éjection de fluide, ladite palette agitatrice étant actionnée par un dispositif actionneur ; et

caractérisé par :

un dispositif actionneur thermique (4009 ; 4109) situé à l'extérieur de ladite chambre de buse et relié à ladite palette agitatrice.

2. Agencement de buse à jet d'encre comme revendiqué dans la revendication 1, dans lequel ladite palette agitatrice est située à l'intérieur de ladite chambre. 25
3. Agencement de buse à jet d'encre comme revendiqué dans la revendication 1, dans lequel ladite palette agitatrice forme au moins une partie de ladite paroi de ladite chambre. 30
4. Agencement de buse à jet d'encre comme revendiqué dans l'une quelconque des revendications précédentes, dans lequel ledit dispositif actionneur thermique inclut un bras de levier ayant une extrémité reliée à ladite palette agitatrice et une seconde extrémité reliée à un substrat. 35
5. Agencement de buse à jet d'encre comme revendiqué dans la revendication 4, dans lequel ledit actionneur thermique fonctionne lors d'un chauffage conducteur le long d'une trace conductrice et ledit chauffage conducteur comprend la génération d'une partie substantielle de ladite chaleur dans la zone adjacente à ladite seconde extrémité. 40
6. Agencement de buse à jet d'encre comme revendiqué dans la revendication 5, dans lequel ledit chauffage conducteur inclut une section transversale amincie adjacente à ladite seconde extrémité. 45
7. Agencement de buse à jet d'encre comme revendiqué dans l'une quelconque des revendications précédentes, dans lequel ledit actionneur thermique comprend une première couche et une seconde couche. 50
8. Agencement de buse à jet d'encre selon la revendication 7, dans lequel ladite première et ladite seconde couches sont fabriquées par un procédé de dépôt, lesdites première et seconde couches étant formées d'un matériau ayant des propriétés thermiques similaires de telle sorte que, lors d'un refroidissement après le dépôt desdites couches, lesdites deux couches agissent l'une contre l'autre de manière à

maintenir ledit actionneur dans une position sensiblement prédéterminée.

9. Agencement de buse à jet d'encre comme revendiqué dans la revendication 8, dans lequel lesdites couches comprennent essentiellement soit un alliage de cuivre et de nickel, soit du nitrure de titane. 5
10. Agencement de buse à jet d'encre comme revendiqué dans l'une quelconque des revendications précédentes, dans lequel ladite chambre de buse inclut un orifice d'accès à l'actionneur dans une seconde paroi de ladite chambre. 10
11. Agencement de buse à jet d'encre comme revendiqué dans la revendication 1, dans lequel ledit dispositif actionneur thermique comprend une pluralité d'unités d'actionnement thermique allongées, espacées et séparées. 15
20
12. Agencement de buse à jet d'encre comme revendiqué dans la revendication 11, dans lequel lesdites unités d'actionnement thermique sont interconnectées à une première extrémité, à un substrat et à une seconde extrémité, à un élément d'entretoise rigide. 25
13. Agencement de buse à jet d'encre comme revendiqué dans la revendication 12, dans lequel ledit élément de compression rigide est interconnecté à un bras de levier ayant une extrémité reliée à ladite palette agitatrice. 30

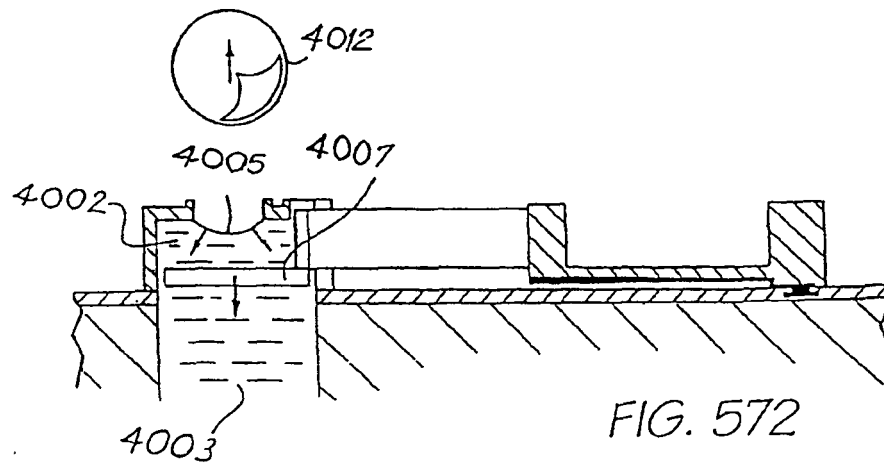
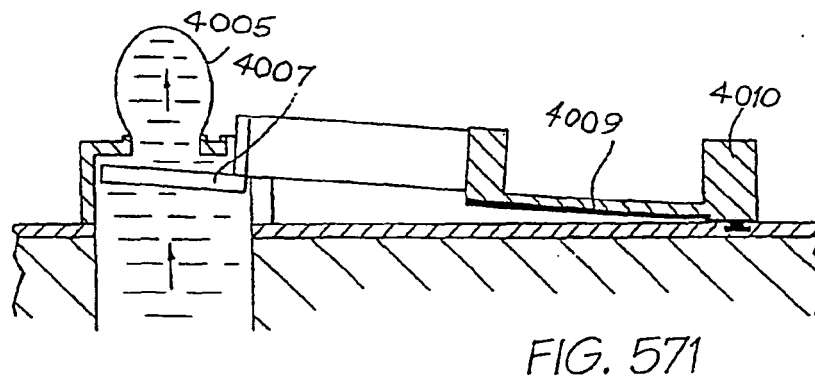
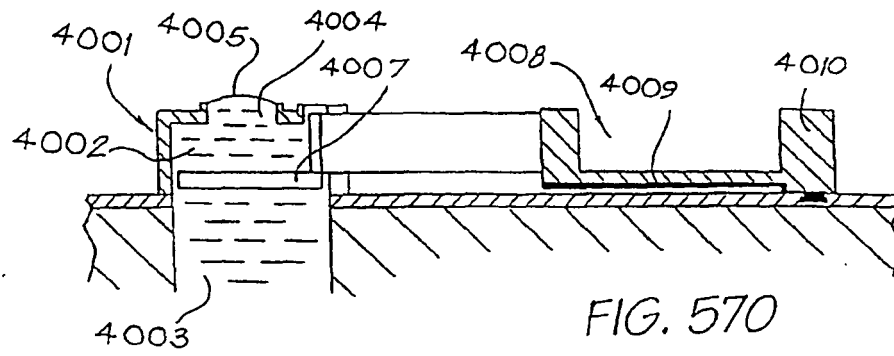
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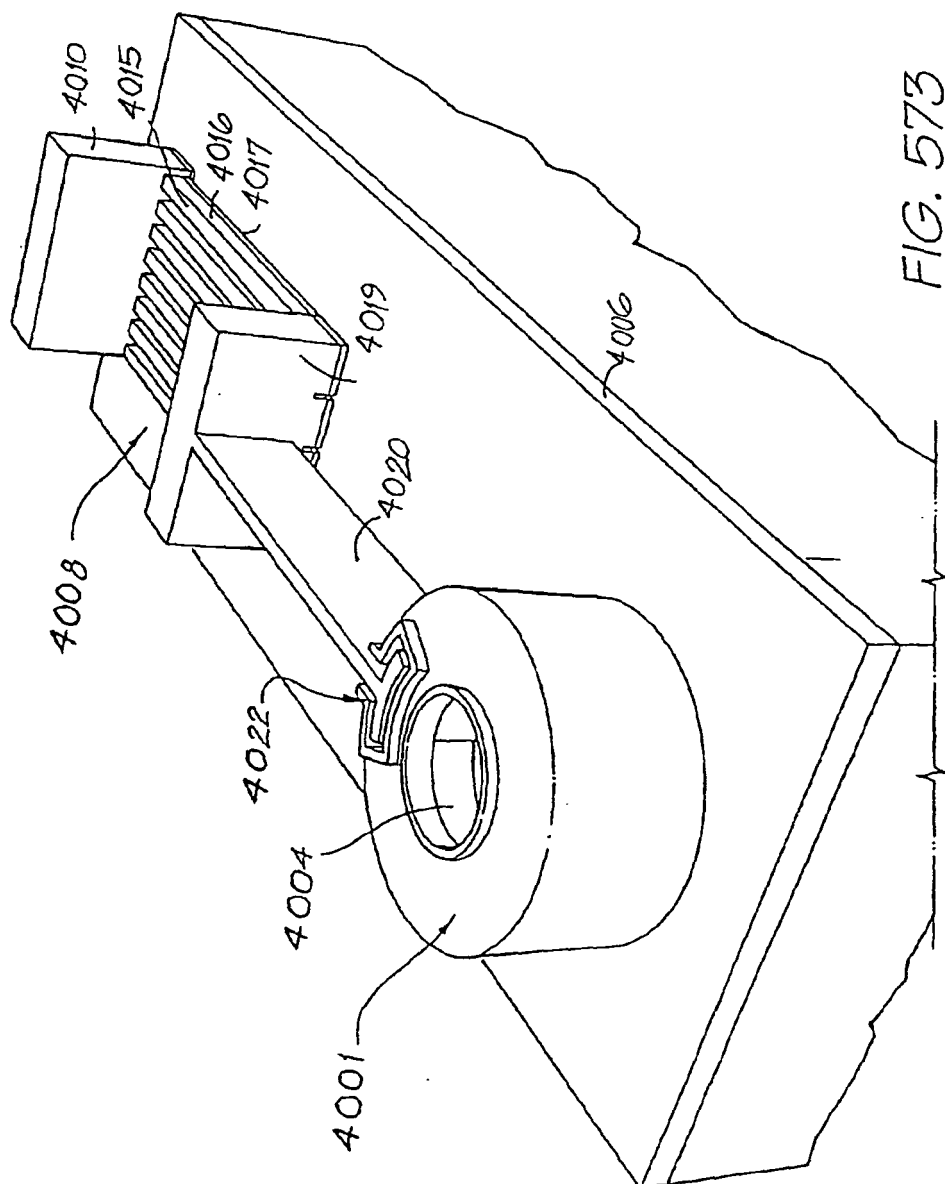
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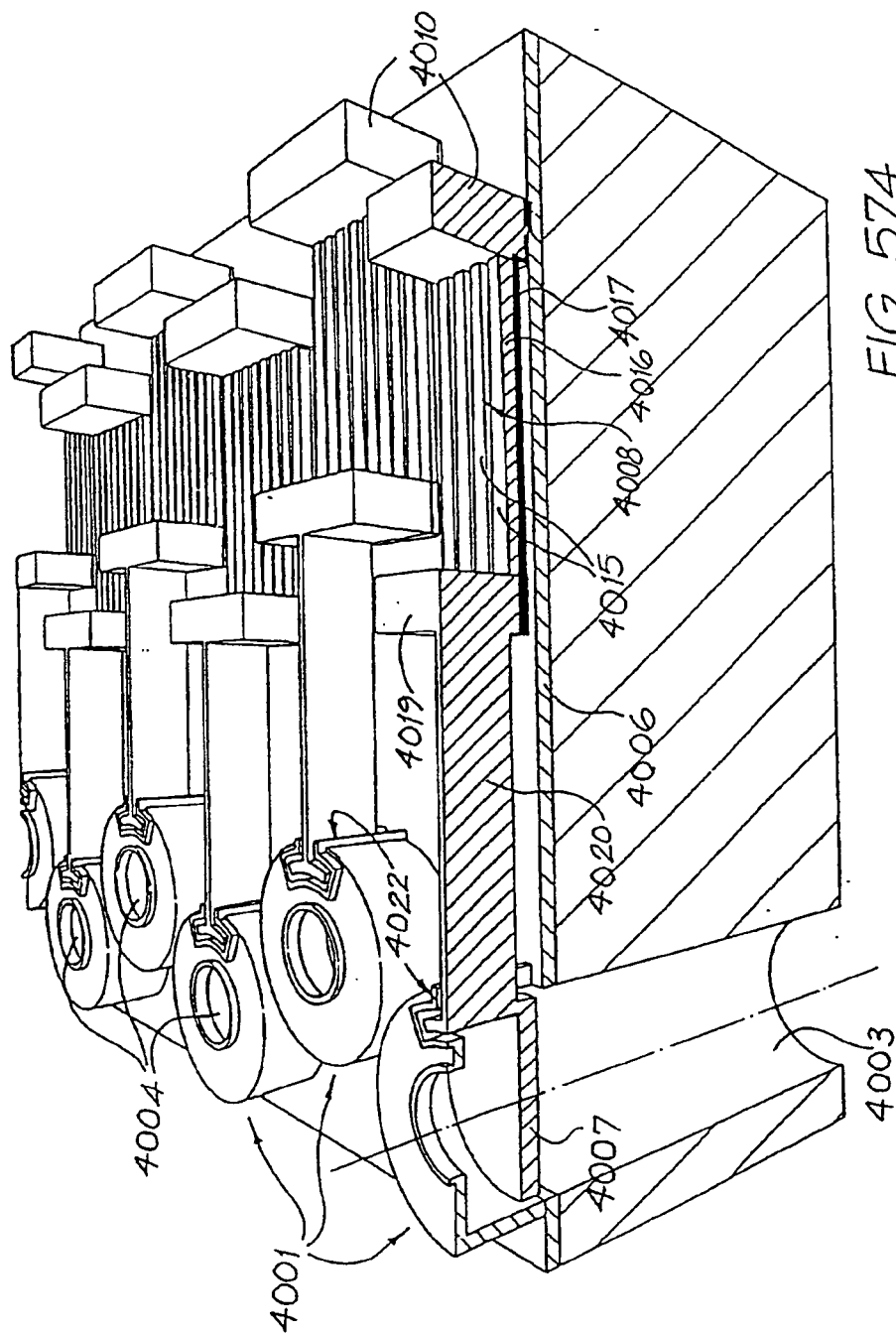
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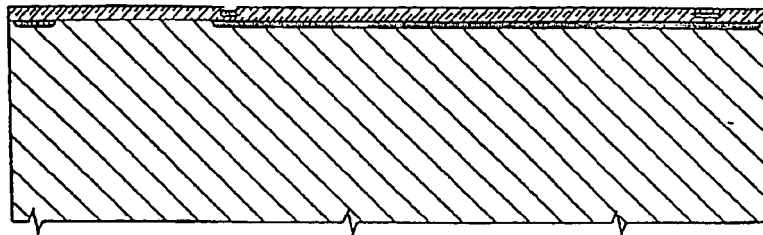
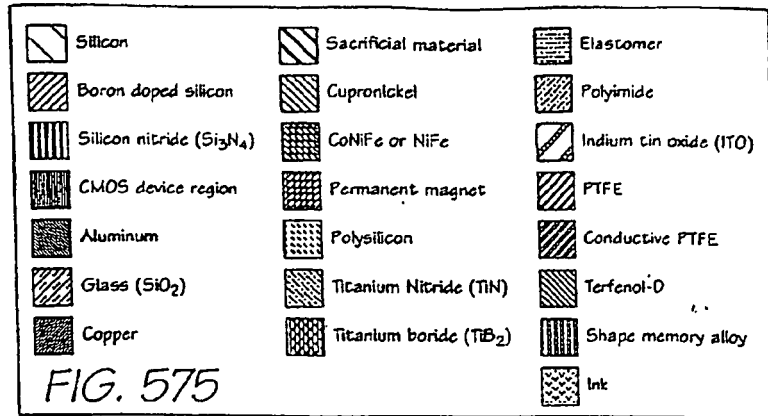


FIG. 576

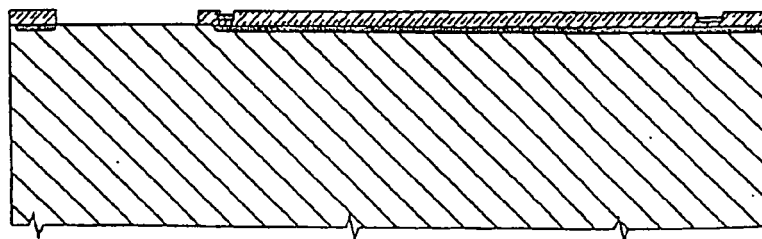


FIG. 577

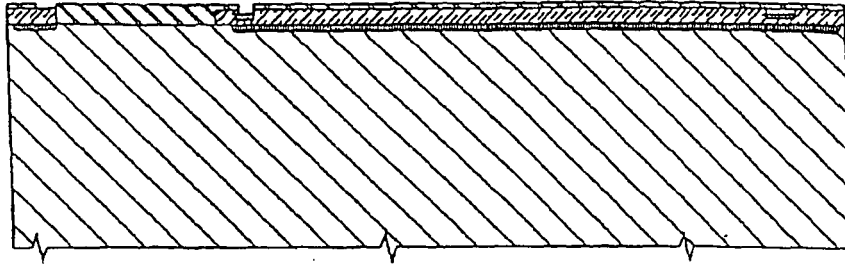


FIG. 578

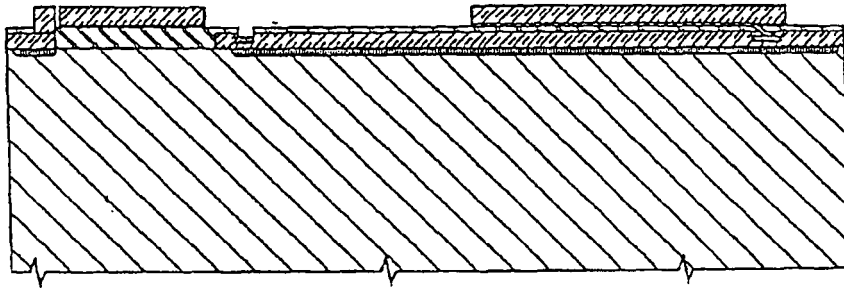


FIG. 579

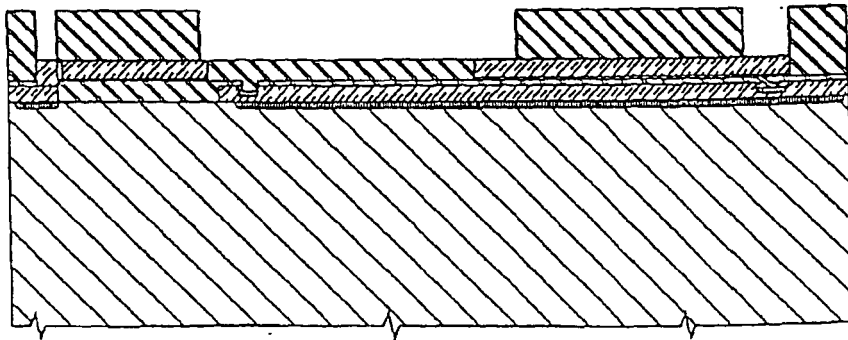


FIG. 580

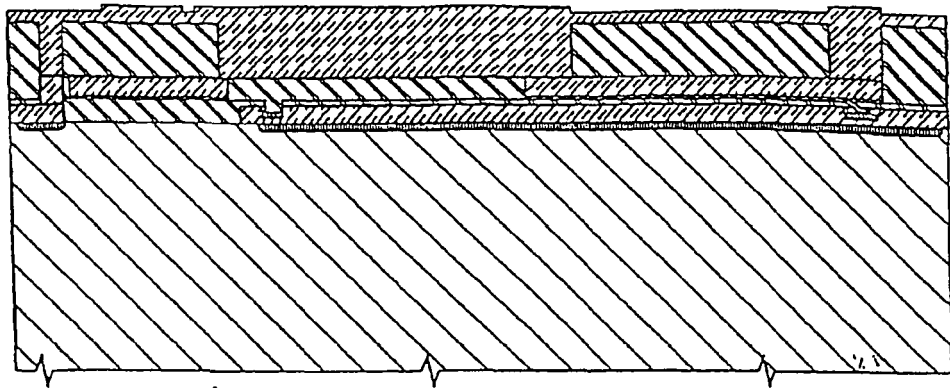


FIG. 581

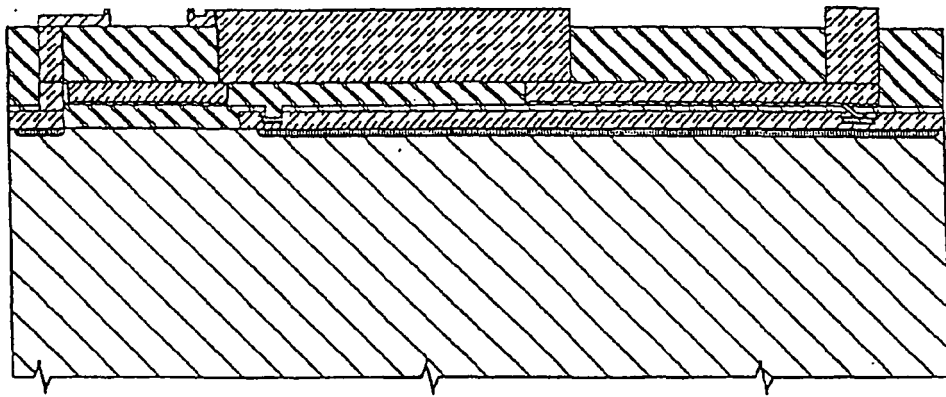


FIG. 582

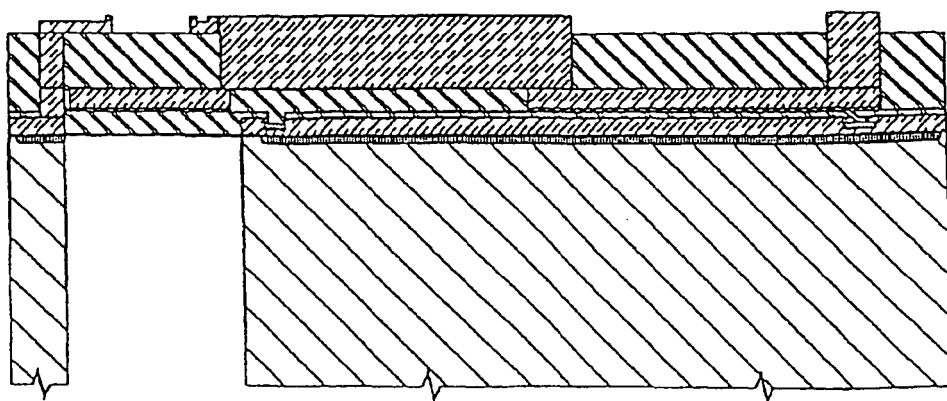


FIG. 583

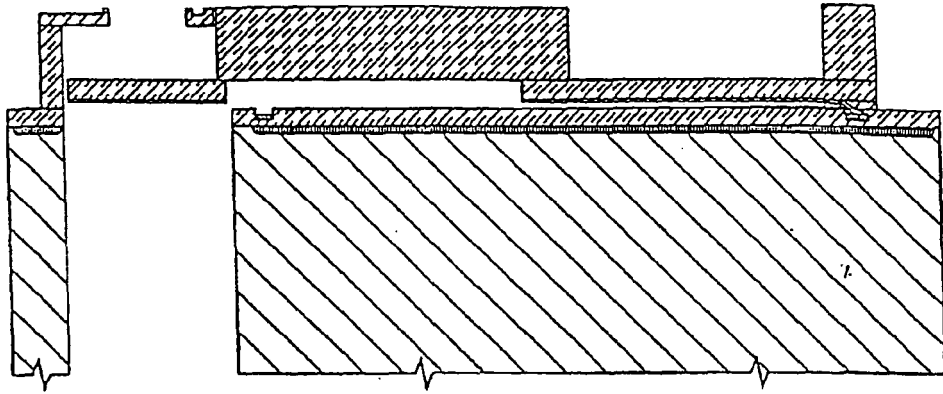


FIG. 584

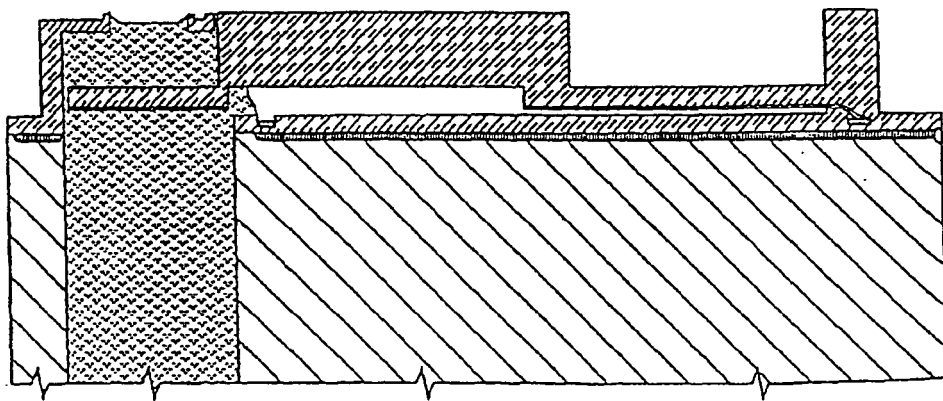


FIG. 585

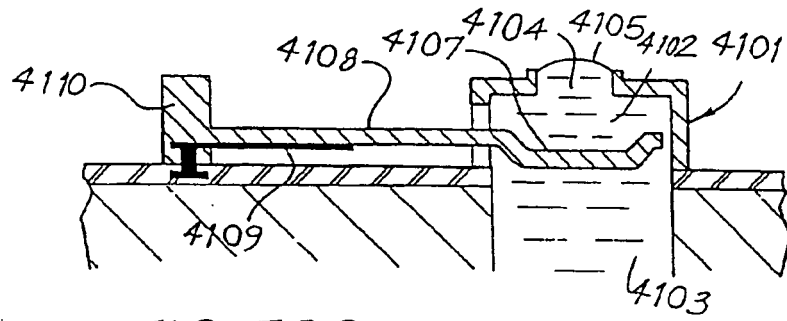


FIG. 586

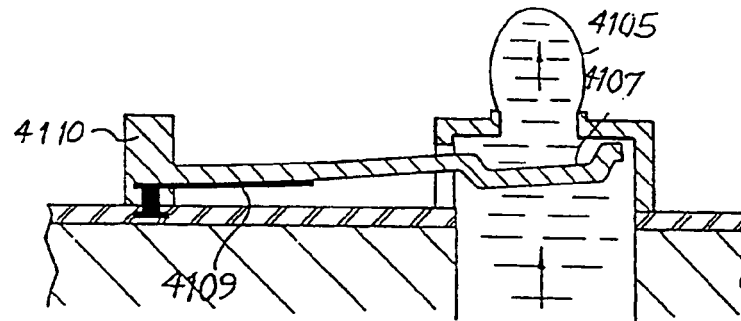


FIG. 587

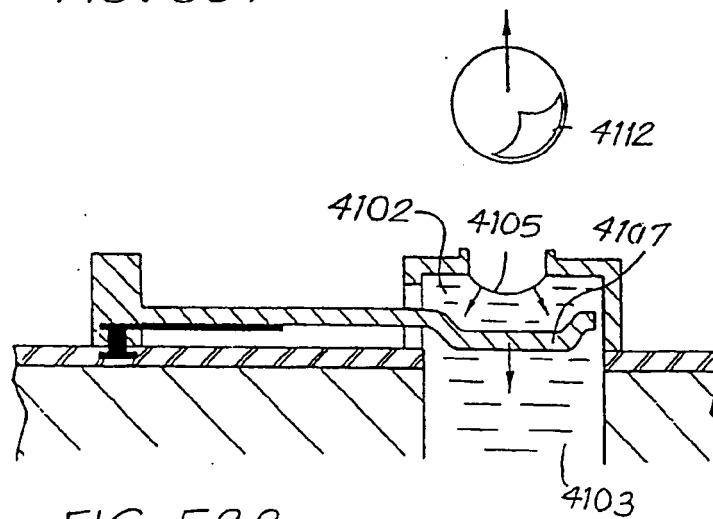
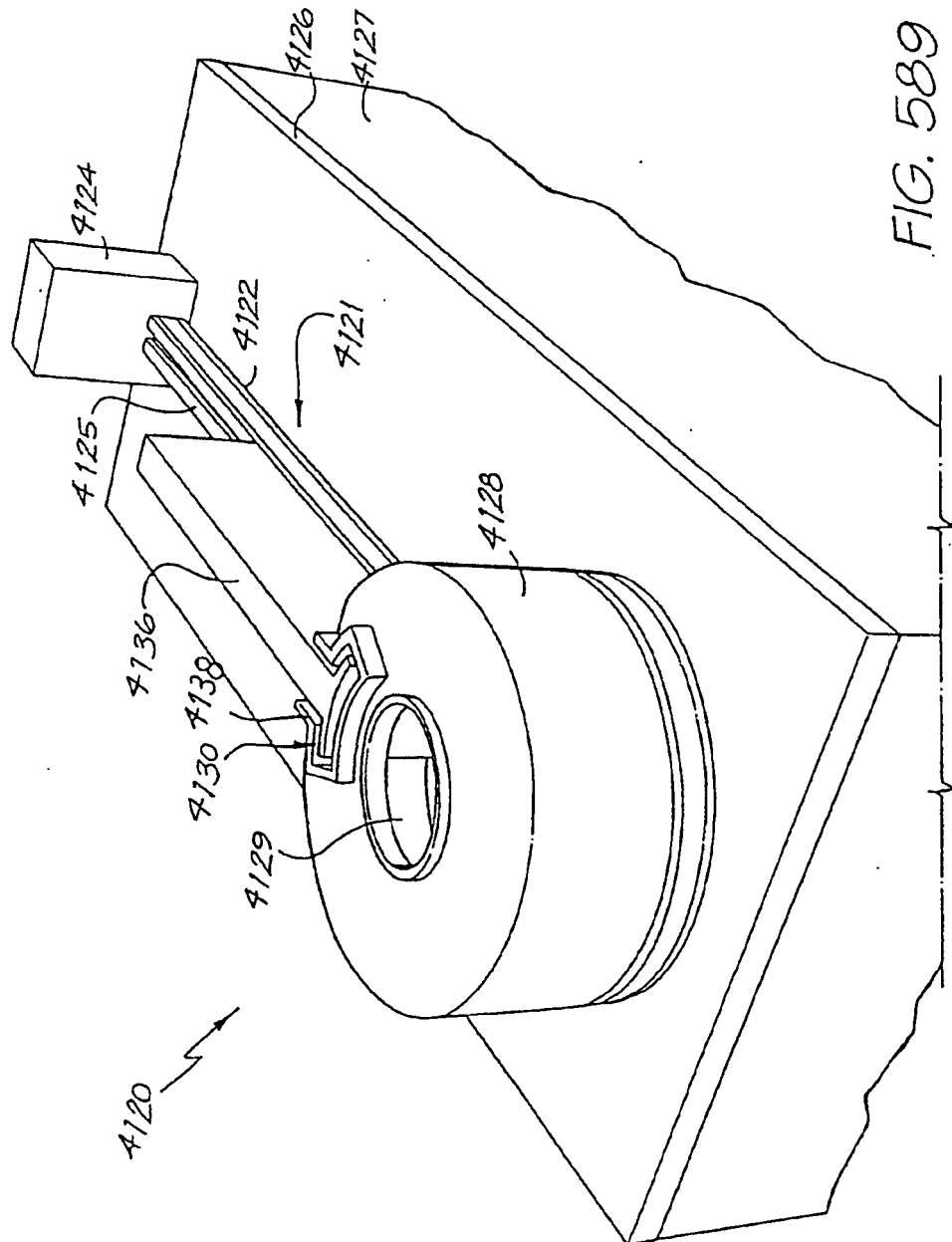
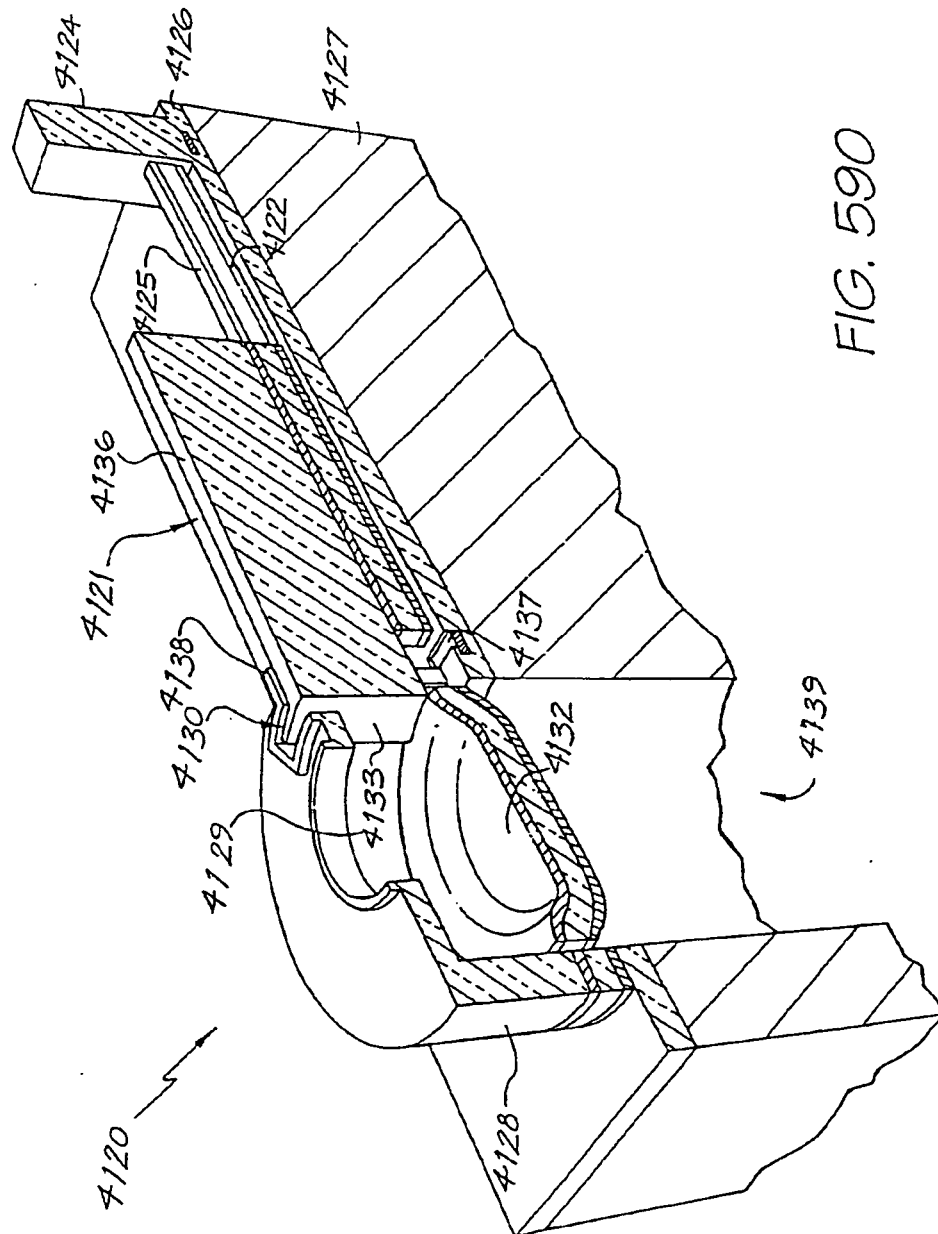


FIG. 588





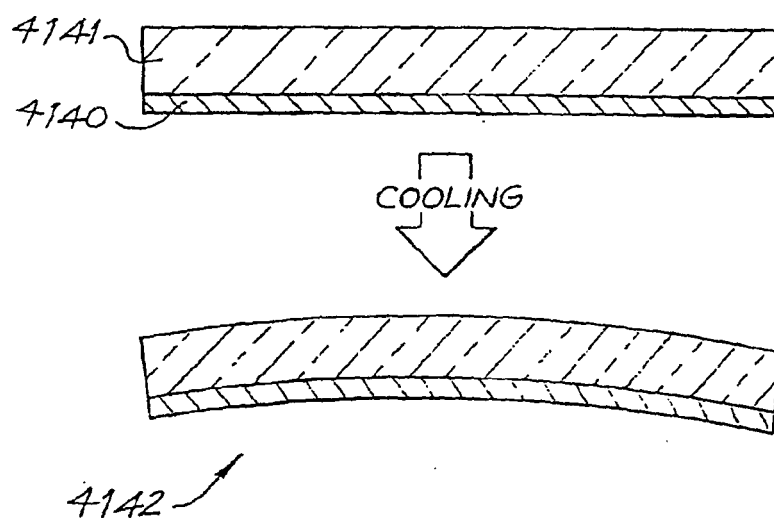


FIG. 591

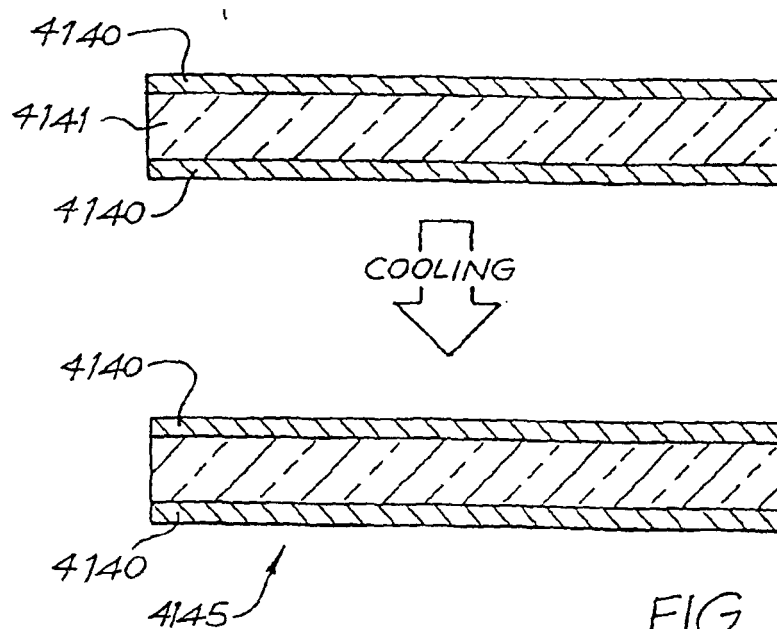


FIG. 592

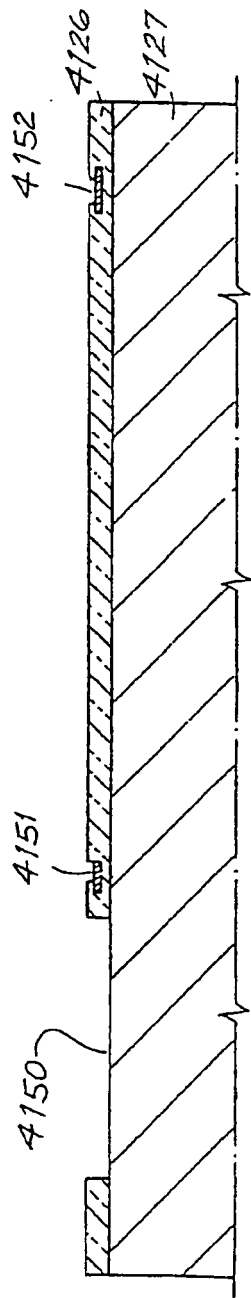


FIG. 593

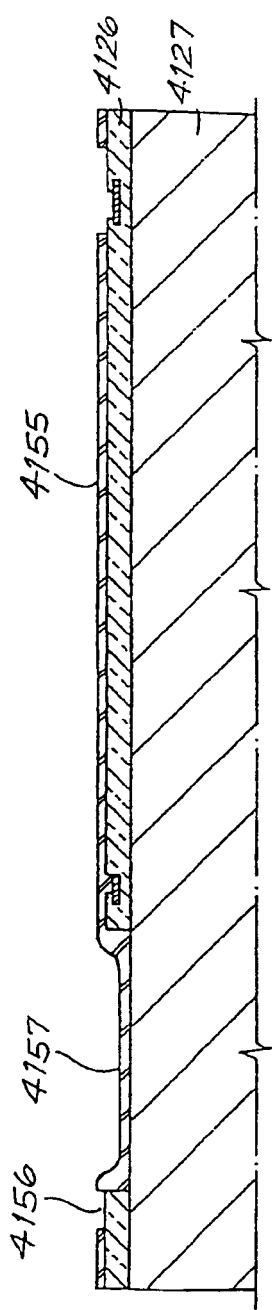


FIG. 594

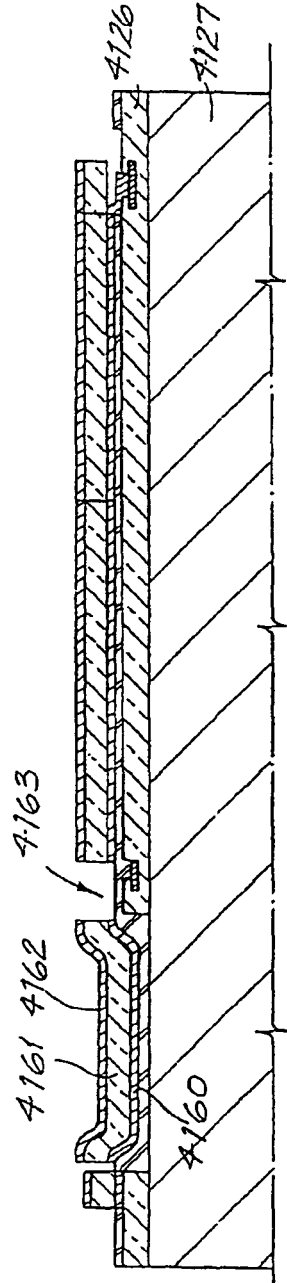


FIG. 595

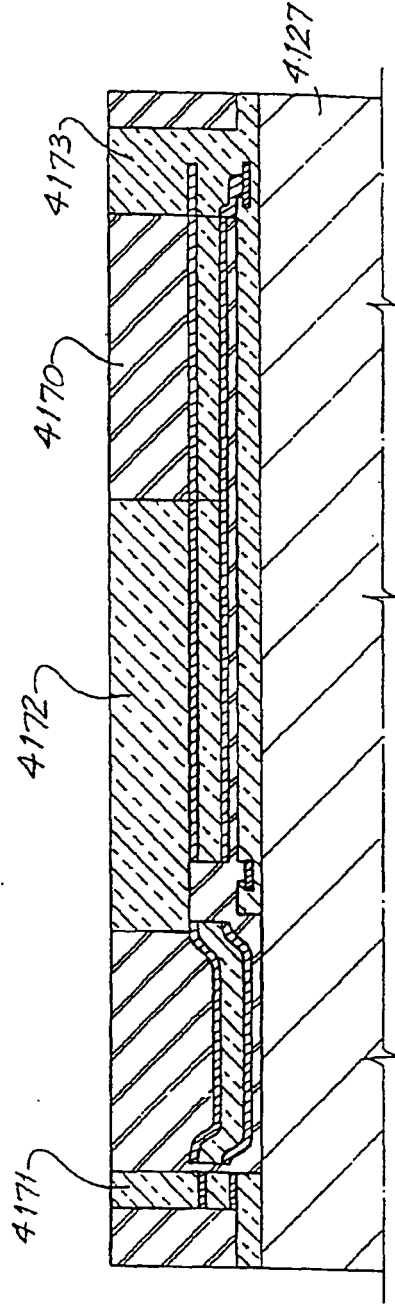


FIG. 596

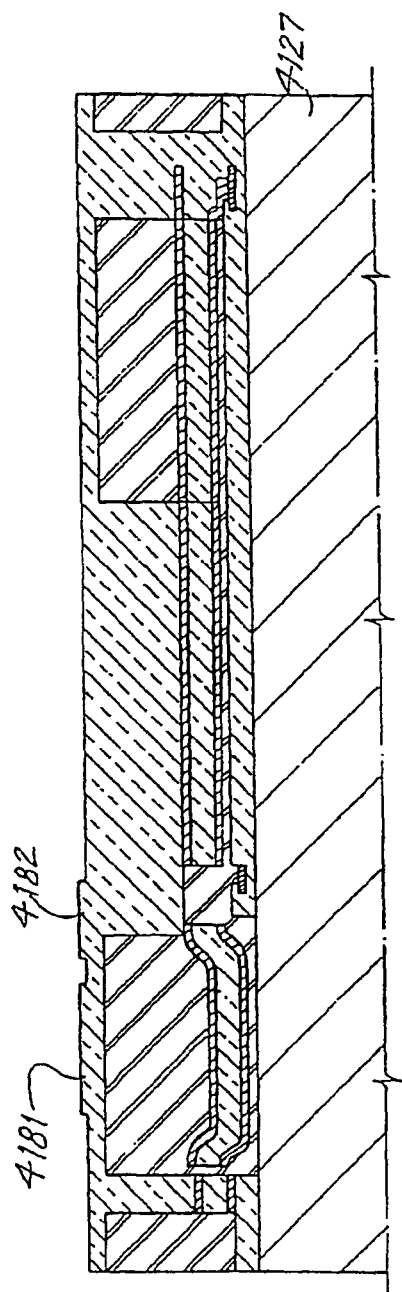


FIG. 597

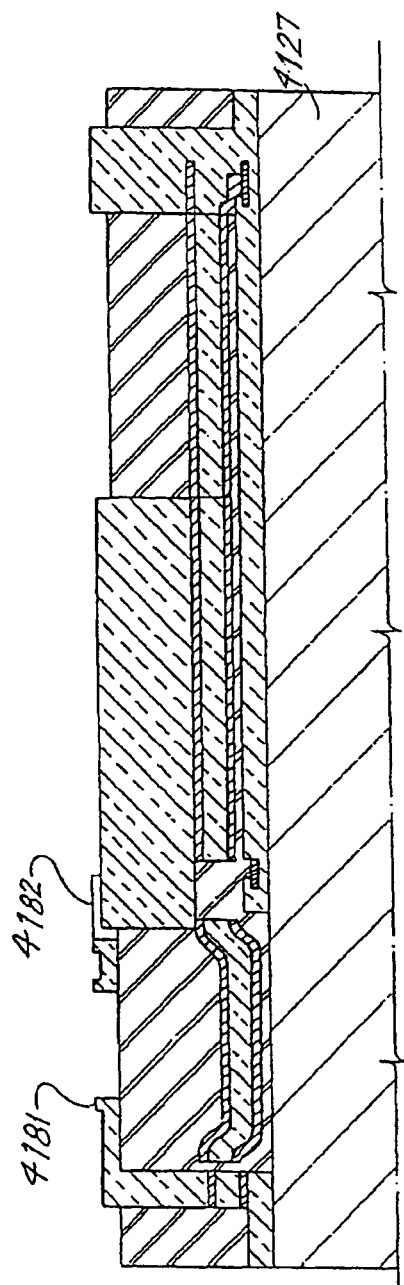


FIG. 598

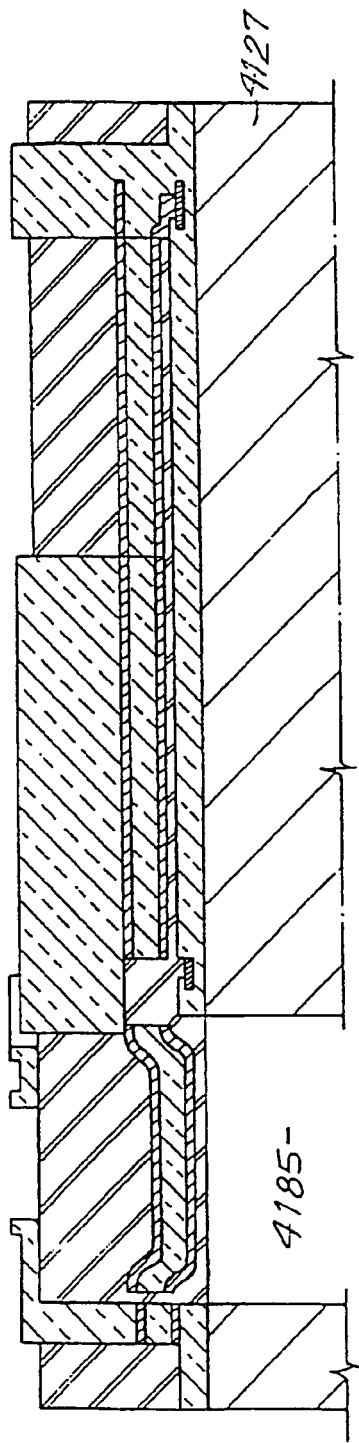


FIG. 599

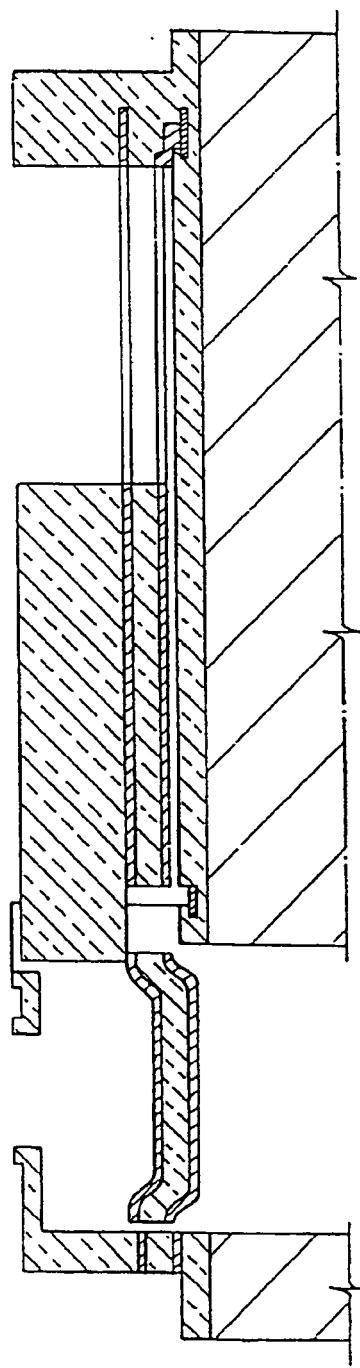


FIG. 600

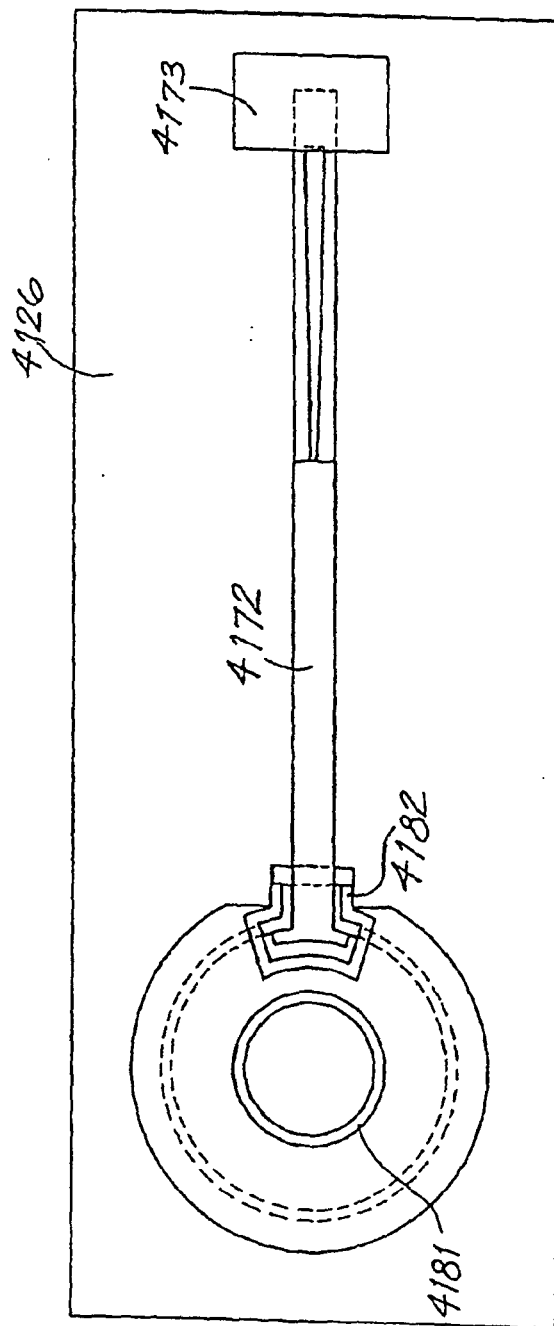


FIG. 601

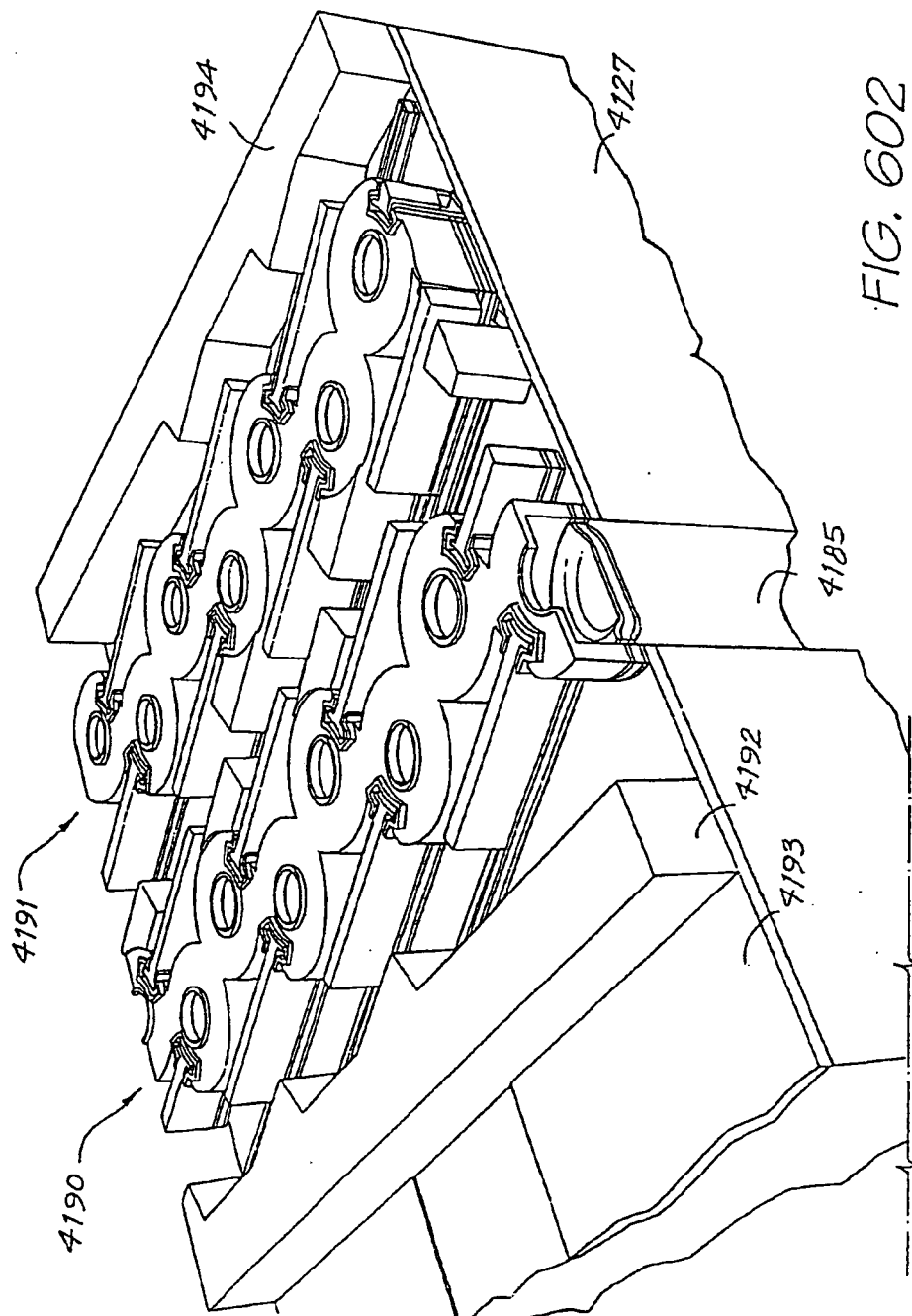


FIG. 602

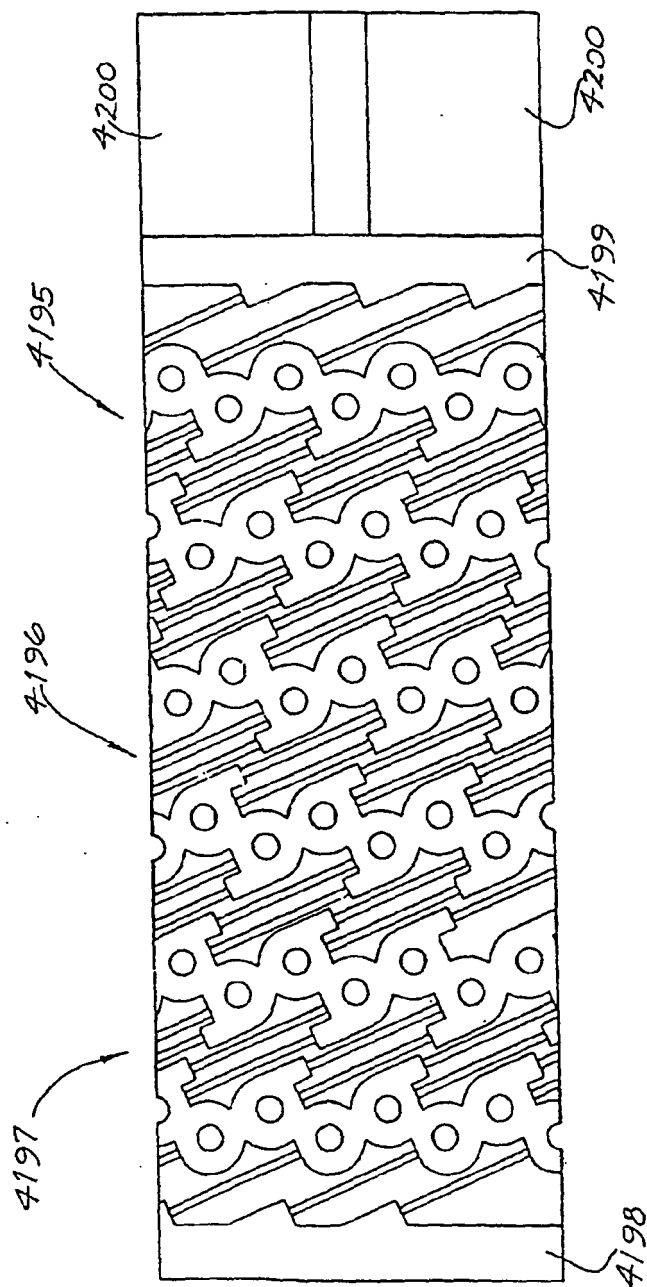


FIG. 603

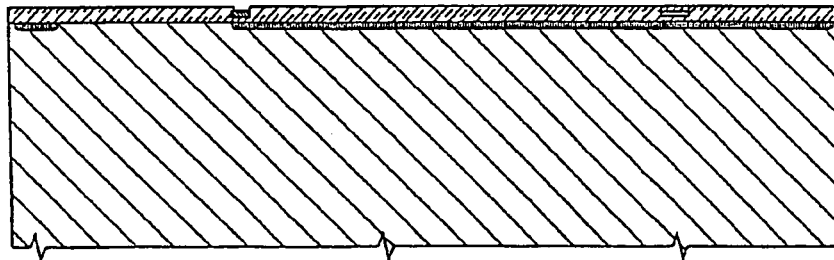
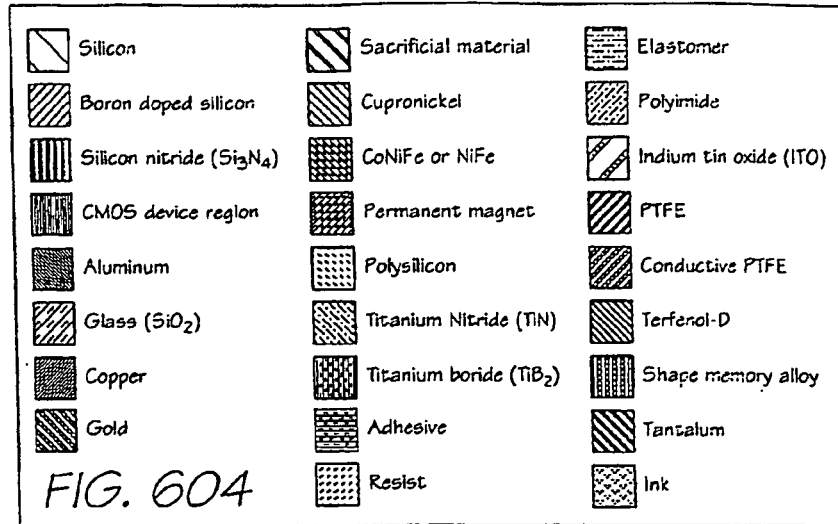


FIG. 605

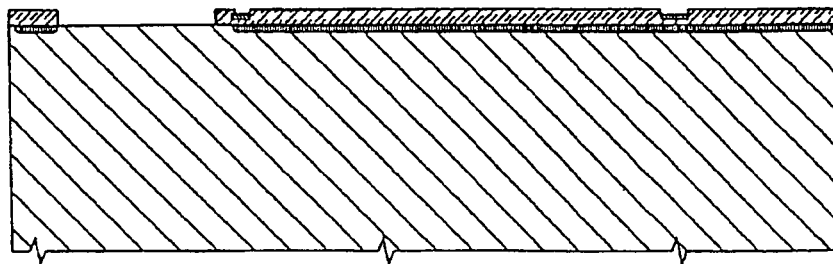


FIG. 606

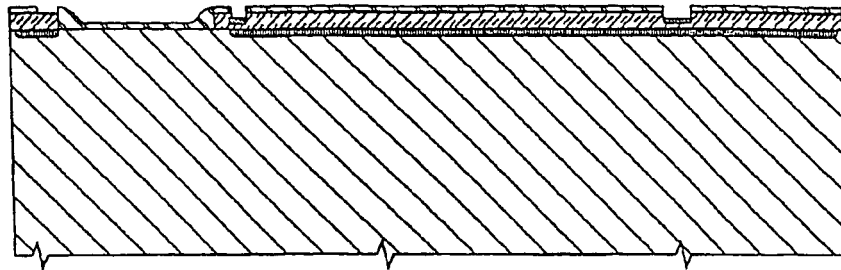


FIG. 607

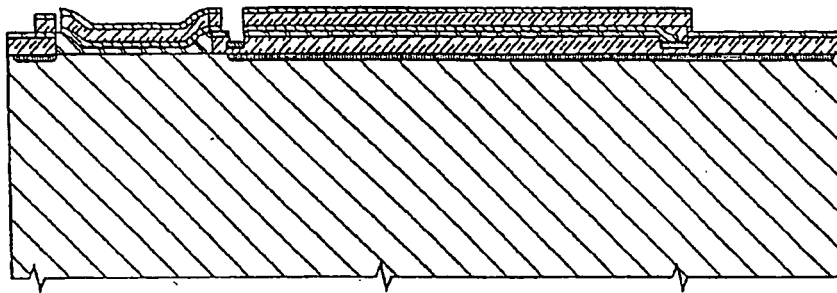


FIG. 608

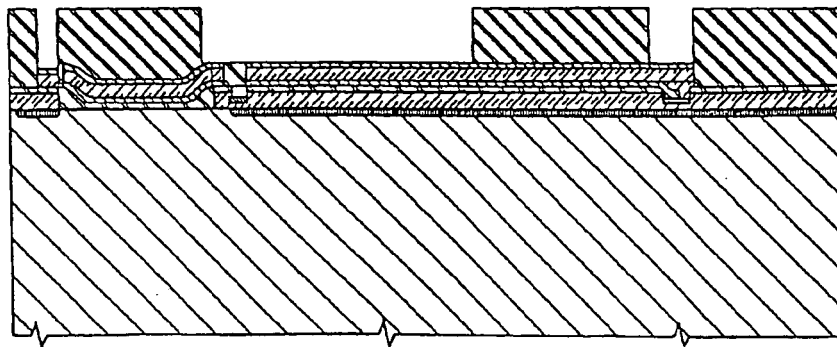


FIG. 609

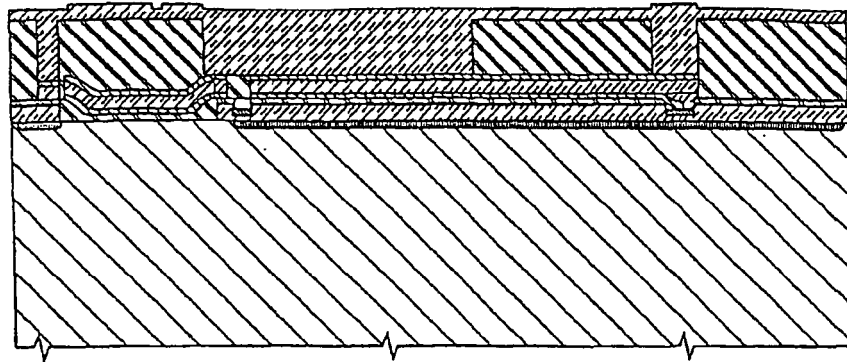


FIG. 610

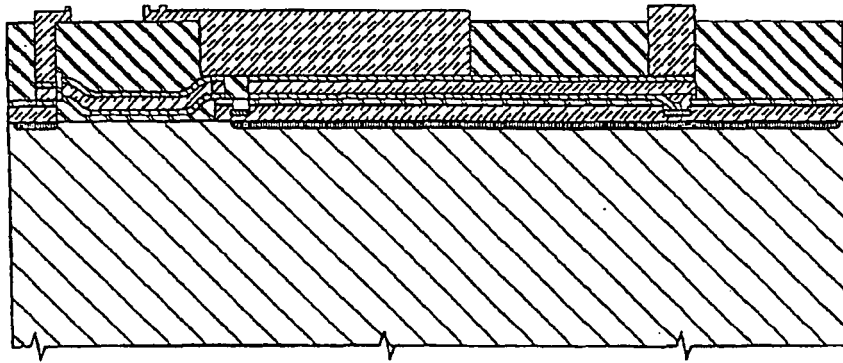


FIG. 611

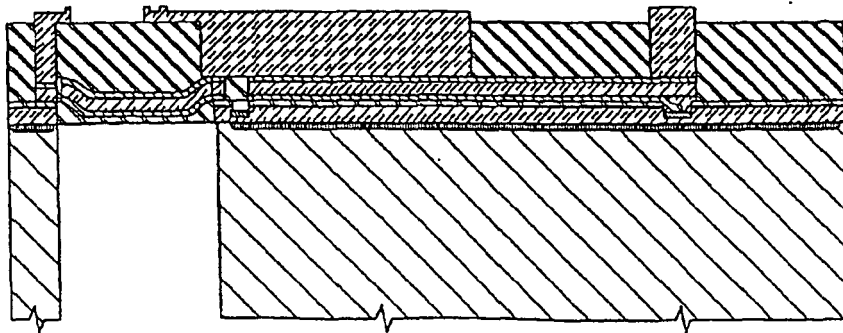


FIG. 612

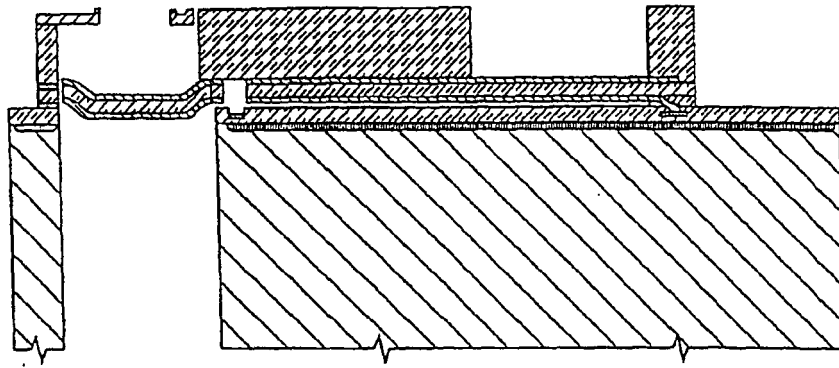


FIG. 613

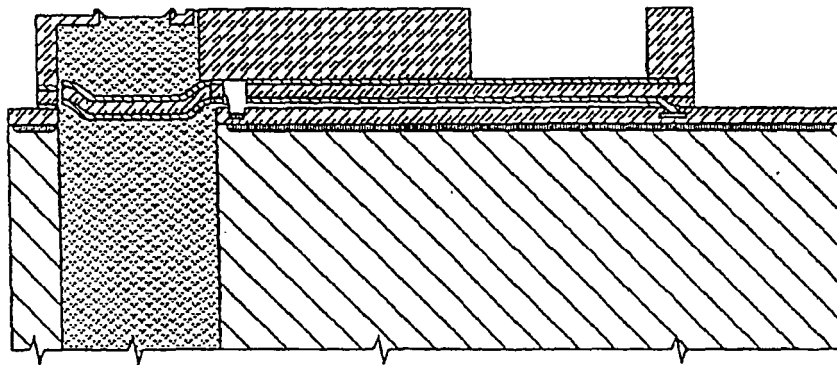


FIG. 614

REFERENCES CITED IN THE DESCRIPTION

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