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(54) **Title**: CHIP DEVICE FOR MONITORING AND REGULATING FLUID FLOW, AND METHODS OF MANUFACTURE THEREOF

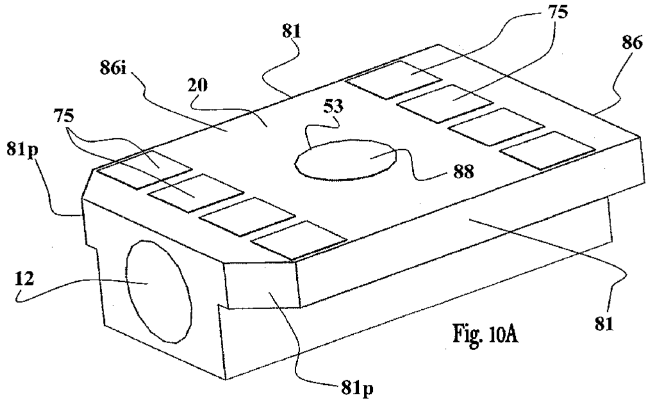


Fig. 10A

(57) **Abstract**: A device for monitoring fluid media, and methods of manufacture thereof are disclosed. The monitoring device may be implemented as a single monolithic unit made from a certain type of material without a separate packaging, and having a base element comprising at least one fluid port and at least one cavity or fluid flow path fluidly coupled to the at least one fluid port for enabling fluid exchange of fluid media therewith. The device comprises at least one sensing element associated with the cavity or fluid flow path and configured and operable for measuring at least one property or condition of fluid media introduced therein to, and generate measurement data or signals indicative thereof. Electrical contacts disposed on the base element of the device, and electrically coupled to the at least one sensing element are used for establishing electrical connection with the at least one sensing element.

CHIP DEVICE FOR MONITORING AND REGULATING FLUID FLOW, AND METHODS OF MANUFACTURE THEREOF

TECHNOLOGICAL FIELD

The present invention is generally in the field of micro-electro-mechanical fluidic systems. More particularly, the invention relates to a polymeric chip device for measurement and control of one or more conditions of a fluid.

BACKGROUND

This section is intended to introduce various aspects of art that may be related to various aspects of the present disclosure described and/or claimed below, and to facilitate a better understanding of the various aspects of the present disclosure. It should be therefore understood that these statements are to be read in this light, and not as admissions of prior art.

The fluidic micro-electro-mechanical (MEM) devices used nowadays usually incorporate sensors and/or actuators elements build using a combination of micro plastic and semiconductor (Silicon) technologies. In such devices, the sensors and/or actuators are usually implemented by semiconductor structures, and a fluid flow path of the device and their connections with fluid system, its packaging, and its mechanical/electrical interfaces are implemented by micro plastic fabrication techniques. In addition, electrical connectivity of such MEM devices with external systems is not implemented directly on the semiconductor die, and requires, *inter alia*, additional electrical interface involving wiring and electrical contacts, plastic structures, and printed circuit board (PCB).

These manufacture techniques requires accurate attachment of the semiconductor die to its plastic carrier to achieve electrical and mechanical connectivity to guarantee that pressure forces are correctly transmitted to the sensing elements, and obtain proper alignment between the fluid flow structures formed in the plastic packaging with the sensors and/or actuators implemented in the semiconductor die. This combination of manufacture techniques typically results in a costly, and considerably complex, fabrication process of the fluidic MEM devices.

Fluidic MEM devices fabrication techniques known from the patent literature are described in the following patent publications.

U.S. Patent No. 7,311,693 describes a drug delivery device with a pressurized reservoir in communication with a flow path to an outlet. The flow path includes two normally-closed valves and a flow restriction. A pressure measurement arrangement measures a differential fluid pressure between two points along the flow path which span at least part of the flow restriction, one of the points being between the valves. A controller selectively opens the valves to deliver a defined quantity of the liquid medicament to the outlet.

U.S. Patent No. 7,377,907 describes a portable insulin delivery device that supplies insulin in a pre-pressurized chamber, passes the insulin through a pressure-dropping labyrinth to a flow control valve. The valve is activated by a piezoelectric actuator. This allows for precise insulin delivery. An electronic package provides for programming of basal rates and bolus. A pressure sensor relays data concerning normal operation and pressure changes that indicate problems. The processor, keypad, displays power source, fluid pressure sensor and fluid flow control actuator are housed in a base unit. A removable cartridge unit houses the pre-pressurized fluid reservoir, flow path labyrinth, and flow control valve.

US Patent No. 7,318,351 describes a pressure sensor constructed of a plastic package. The plastic package incorporates in the same material a sensing diaphragm including tensile and compression regions. Deposited on the diaphragm are metal electrodes and a polymer film having piezoresistive properties. The electrodes and/or the polymer film are directly printed onto the plastic package without the use of a mask.

US Patent No. 7,375,404 describes a micro-electro-mechanical system (MEMS) device, along with means for its fabrication and operation for microfluidic and/or biomicrofluidic applications. The MEMS device includes a substrate, optional electrodes on the substrate, a patterned structure on the substrate, the patterned structure having a fluidic microchannel aligned with one or more of the optional electrodes, an encapsulation membrane covering the microchannel, and an optional reactive layer deposited over the electrode in the microchannel. MEMS devices of preferred embodiments permit a leak-tight seal to be formed around the microchannel and fluidic interconnects established for robust operation of fluidics-based processes. MEMS devices of other preferred embodiments permit reversible attachment and separation of the encapsulation membrane relative to the patterned structure.

GENERAL DESCRIPTION

Certain aspects of possible embodiments are presented hereinbelow merely to provide certain forms the embodiments might take. It is noted that these aspects are not intended to limit the scope of the presently disclosed subject matter. Indeed, the embodiments may encompass a variety of aspects that may not be set forth below.

The present invention is directed, in some embodiments, to a fluidic monolithic micro-electro-mechanical (MEM) device. More particularly, the present invention provides embodiments of fluidic MEM devices which functional components and packaging are implemented as a single massive undifferentiated unit (also referred to herein as a single polymeric chip, or SPC for short). This is different from conventional micro-electro-mechanical systems (MEMS) in which mechanical and electrical components are typically implemented in a semiconductor wafer and wherein separate packaging components are usually required to provide electrically connectivity to the semiconductor die and to properly align between the electro-mechanical elements implemented by the semiconductor die and fluid flow structure of the device.

Optionally, and in some embodiments preferably, the fluidic MEM device of the present invention is mostly, or entirely, fabricated from polymeric materials. The use of polymeric material in the fabrication of the fluidic MEM device is beneficial as it permits manufacture of the body/package and functional electro-mechanical components of the device by similar processes, and within the same fabrication framework. It was found by the inventors of the present invention that MEM devices fabricated from polymeric materials with, or without, non-polymeric materials, is substantially advantageous over MEM devices fabricated only from non-polymeric materials.

The advantages of such polymeric material implementations include, *inter alia*, allowing a mass production process of fully integrated monolithic polymeric devices (*e.g.*, within one piece of wafer) with conductive or semi-conductive materials for connection and transduction. As will be appreciated, the fabrication techniques described herein also advantageously provides fluidic MEM devices having high robustness, fracture durability, and biocompatibility.

In addition, as will be described and demonstrated hereinbelow, fabrication techniques of the fluidic MEM device according to some embodiment of the present invention allows embedding together the functional electro-mechanical components and the packaging of the fluidic MEM device into a single/monolithic piece/unit during the device fabrication. This is unlike conventional fabrication techniques of fluidic MEMS, typically made of Silicon, which must be separately packed inside another piece of material to provide fluidic alignment and sealing, and electrical connectivity to the device.

The elastic modulus of polymeric materials is typically two orders of magnitude lower than most metals or semiconductors. This, and other, properties of the polymeric material are advantageously employed in different embodiments of the present invention to incorporate into the fluidic MEM devices various sensing elements, flow restrictors, valves, and other functional elements, which are appreciably more accurate and of higher resolution. In addition, due to the ability of many polymeric materials to sustain very high strain, very large deflection of highly compliant polymeric microstructures can be achieved.

For example, and without being limiting, in some embodiments the fluidic MEM device comprises one or more pressure sensors, such as, but not limited to, strain gauge, capacitive gauge, piezoresistive gauge and suchlike. The elasticity of the polymeric materials from which the fluidic MEM device is manufactured allows implementing pressure sensors that are much more sensitive, relative to the metallic/semiconductor implementations of such sensors, thereby providing for higher measurement resolution. For example, and without being limiting, in some embodiments polymeric implementations of pressure sensors of the fluidic MEM device of the present invention are configured to measure fluid pressures in the range of about -5000 mmHg to about +5000 mmHg.

In various exemplary embodiments of the present invention the fluidic MEM device can comprise at least one element made from an electrically conductive polymer, such as, but not limited to, polypyrrole (PPy) or its derivatives. Also contemplated are other types of conductive polymers, including, without limitation, polyaniline (PANI), polythiophene, polyacetylene and poly-para-phenylene. Further contemplated for use according to some embodiments of the present invention are conductive polymeric composites, such as, but not limited to, a composite comprising electrically conductive particles and/or micro-particles and/or electrically conductive nano-particles (*e.g.*, silver (Ag), carbon nanotubes (CNTs)) and a conductive (*e.g.*, PPy or PANI) or non conductive polymer (*e.g.*, PDMS).

Embodiments of the fluidic MEM device of the present invention can be used in a variety of applications, such as, but not limited to, drug delivery systems, measurement of blood flow parameters (*e.g.*, flow rate, fluid pressure) and its components, inhalation, rhinomanometry, urine, infusion systems, and also in non-medical systems for monitoring other types of fluid media (*e.g.*, water, ink). The fluidic MEM devices disclosed herein are also usable in harsh environments, *e.g.*, environments that include dampness, wetness, damaging gases, heavy particulate matter, high G-forces, shocks, high temperatures, and other environmental conditions as well. Of course, the fluidic MEM devices disclosed herein may be also used in non-harsh environments.

For example, and without being limiting, the fluidic MEM device may be used (immersed) in liquid medicaments *e.g.*, in drug delivery devices or other medical devices. For instance, in some possible embodiment the fluidic MEM devices of the present invention are used in insulin pumps, elastomeric devices, intravenous (IV) infusion (*e.g.*, for measuring fluid pressure and/or flow rate and/or regulating the fluid flow), or as simple flow sensors in a syringe pump. The MEM devices may be also used to measure and/or control the flow in a nebulizer or any other gas medicament dispenser.

In some possible embodiments the fluidic MEM device is an implantable device.

The fluidic MEM device in some possible embodiment may be attached (*e.g.*, bonded) to a printed circuit board (PCB) *e.g.*, as a simple surface-mount device (SMD). Alternatively, in some possible embodiments, the fluidic MEM devices may be used as a PCB and SMD components can be attached (*e.g.*, bonded) to them.

In some possible embodiments the fluidic MEM device comprises polymeric structures usable as mechanical matching and/or locking and/or guiding and/or latching mechanism for connection with external devices and/or systems. The fluidic MEM device in some embodiments can have the ability to be plugged to, and thereupon operate with, an external system (plug and play device). In such embodiments the external system automatically recognizes the connection established with the fluidic MEM device and responsively begins to operate the device and exchange with it data and/or instruction signals.

In some possible embodiments the fluidic MEM device is configured and operable to control flow of a fluid material (*e.g.*, medicament administration) and/or measure conditions (*e.g.*, pressure and/or flow rate and/or temperature) of the fluid material. For example, and without being limiting, the fluidic MEM device may comprise one or more pressure sensors (absolute and/or differential). Each pressure sensor may comprise one or more membranes. Preferably, the absolute pressure sensors are implemented to employ either the atmospheric pressure (gauge pressure sensor) or a fixed reference pressure provided within a sealed chamber (sealed pressure sensor), as their reference pressure.

The device may also comprise one or more temperature sensors (*e.g.*, based on resistive transduction techniques) integrated therein. The temperature sensor is configured in some embodiments to measure fluid temperatures in the range of about -50 °C to about +150 °C.

Optionally, and in some embodiments preferably, the pressure sensors are made of polymeric membranes and/or plates having conductive materials deposited thereon to perform transduction (*e.g.*, resistive, capacitive or piezo-resistive). A fluid channel or cavity provide in the MEM device is used to enable the fluid media to interact with the membrane. In some embodiments the fluidic MEM device can comprise additional channels/cavities (or any other polymeric structure) configured to permit interaction of another side or portion of the membrane of the sensor with the fluid media, which can be a part of the packaging of the device in a way allowing to use the device as a flow sensor, differential flow sensors, and/or pressure sensor.

Alternatively or additionally, the fluidic MEM device may comprise one or more flow rate sensors. The flow rate sensors may utilize at least one restrictor formed in a fluid flow path of the device. Optionally, and in some embodiments preferably, the restrictors are polymeric channels of defined dimensions. The flow rate sensors are configured in some embodiments to measure fluid flow rates in the range of about 0.1 nano liters per hour to about 300 liters per hour.

The fluidic MEM device of the present invention may comprise other types of sensing elements for measuring and monitoring properties of the delivered fluid substance. For example, and without being limiting, the fluidic MEM device may comprise sensing elements for measuring electrical and/or chemical properties of the fluid (*e.g.*, electrical conductivity).

In some possible embodiments the fluidic MEM device comprises one or more valves. Optionally, and in some embodiments preferably, the valves are made of polymeric membrane and/or frame with a boss located at its center. The valves may be actuated mechanically (*e.g.*, using an external shiftable pin configured to controllably press a flow regulating structure implemented in the MEM device) and/or magnetically and/or electromagnetically (*e.g.*, using a deposited magnetic polymer or a magnetic layer/piece attached to the central boss). In some embodiments the polymeric membrane and/or frame of the valves can be used as mechanical suspension element and/or spring. The payload boss element of the valves may be coupled to the suspension elements so as to ensure suspension of the payload boss element above the opening to be sealed. In some embodiments the payload boss element of the valve is used as a sealer.

A reservoir (*e.g.*, a pressurized drug container) may be used to supply the device pressurized fluid with sufficient pressure to allow the correct flowing of the medicament from the reservoir to a patient. For example, and without being limiting, a pressurized reservoir used with the fluidic MEM device may be one of: an elastomeric device, a spring loaded device, a gravity device, any electrically powered device, any mechanically powered device, a syringe pump; or a peristaltic pump.

In some possible embodiments the fluidic MEM device comprises one or more elements made from non-polymeric materials (*e.g.*, comprising semiconductor materials and/or metals). For example, and without being limiting, semiconductor methods (*e.g.*, coating, evaporation, electroplating, liftoff, and suchlike) may be used to deposit conductive elements on (and/or in) the MEM device.

Accordingly, the fluidic MEM device may be used to measure the flow rate and/or pressure of a liquid, or gas, or nebulized substance (*e.g.*, drug). Control and/or measurement electronic units of the fluidic MEM device may be separated units, or integrated into the device.

In some possible embodiments the fluidic MEM device is manufactured to integrally include one or more electronic control modules applicable to receive and process measurement data/signals from the sensing elements of the device, generate control signals for actuating valves and/or any other possible actuators of the device, and exchange data and/or instructions with external systems.

In some possible embodiments the fluidic MEM device is manufactured using standard mold techniques. The fluidic MEM device may be manufactured utilizing other possible techniques, such as, but not limited to, 3D printing, micro scale molding, micro machining, nano and micro imprinting, hot embossing, injection molding, lithography, laser micromachining, etc.

In some embodiments fluid regulating elements are implemented in the MEM device by coupling a mechanical suspension element to the payload boss element. For example, a flexible/elastic membrane coupled to a fluid flow path of the device may be used as the suspension element (acting as a spring), and the payload boss element can be attached to the center of the membrane, such that the fluid flow path can be restricted, or entirely occluded, by pressing the boss element towards the flow path. The mechanical suspension element and/or the payload boss element, may be coupled to an external (electromagnetic or mechanical) actuating element configured to drive the payload boss to restrict/occlude the fluid flow path.

As will be appreciated by those skilled in the art, the fluidic MEM device may comprise microstructures and/or MEMS, and/or macrostructures. The MEM device can have an integrated polymeric packaging having integrated conductive pads, and/or pins, and/or wires, and/or tracks, and a connection system for connecting it to an external system and/or device. In some possible embodiments the total size of the MEM device is in a range of about 0.125 cubic millimeters to about 125 cubic centimeters, but smaller geometrical dimensions are also possible.

Optionally, and in some embodiments preferably, the fluidic MEM device is fabricated from wafers made at least in part of polymeric materials, which allows embedding the wafer level packaging of each fluidic MEM device on the wafer during the wafer fabrication. This is different from conventional fabrication techniques of MEM fluidic devices made of silicon, where each device (*i.e.*, die element) of the wafer must be separately packed inside another material by additional fabrication steps. This polymeric manufacture technique permits mass production of the fluidic MEM devices with all their electro-mechanical elements and fluid flow structures/components within a single piece of wafer material, and many other advantages as well, such as the ability to perform additional semiconductor fabrication processes (*e.g.*, lithography, metal deposition, electroforming, and etching), layer by layer fabrication, easy integration with semiconductors and electronics.

In some possible embodiments at least one of a top and bottom layer of the wafer is a complete flat surface. The dies structures within the wafer may be connected to each other by one or more bridges and/or gates, and/or connection layers. The wafer may be fabricated using any polymeric manufacture technique, such as, but not limited to, 3D printing, micro scale molding techniques, micro machining, nano and micro imprinting, hot embossing, injection molding, lithography, laser micromachining, etc.

The wafer can include one or more dies implementing the fluidic MEM device. In exemplary embodiments the wafer can comprise at least one layer/pattern comprising an electrically conducting material such as, but not limited to, gold (Au), Copper (Cu), Aluminum (Al), Platinum (Pt), Nickel (Ni), and/or alloy of a specified material. In other exemplary embodiments the conductive layers/patterns may be coated by one or more layers of electrically insulating materials (*e.g.*, PDMS, Parylene) to electrically isolate them from the fluid media or protect them from causes of degradation (*e.g.*, humidity, oxygen).

According to some embodiments, the wafer can have circular, rectangular, or any other geometrical shape of any dimension.

In some embodiments the wafer can comprise at least one layer/pattern comprising a conductive polymer, such as, but not limited to, polypyrrole (PPy) or its derivatives. Also contemplated are other types of conductive polymers, including, without limitation, polyaniline (PANI), polythiophene, polyacetylene and poly-para-phenylene. Further contemplated for use according to some embodiments of the present invention are conductive polymeric composite, such as, but not limited to, a composite comprising electrically conductive particle and/or micro particles and/or electrically conductive nanoparticles (*e.g.*, silver (Ag), carbon nanotubes (CNTs)) and a conductive (*e.g.*, PPy or PANI) or non-conductive polymer (*e.g.*, PDMS).

In some embodiments the wafer is constructed from two or more semi-finished semi-wafers such that each semi-wafer comprises dies of semi-finished devices which construction is completed by attaching (*e.g.*, ultrasonic welding, bonding, gluing) the semi-finished wafers one to the other. For example, the complete wafer may be constructed from two semi-finished wafers, each comprising certain flow and/or measuring and/or actuating elements designed to be joined and yield the MEM device by attaching the wafers one to the other. Conductive elements may be deposited on the dies in each semi-finished wafer configured to establish electrical connection between elements of the semi-finished wafers and/or with external devices/systems.

In some embodiments one or more metal layers are deposited and/or patterned onto the wafer using any suitable metal deposition technique, such as, but not limited to, sputtering, electroplating electroforming, printing, and printed circuit board (PCB) technology.

In some embodiments the mechanical elements may be fabricated with, or without, a supportive sacrificial layer, depending on the fabrication technique and the functionality of the mechanical element. For instance, if the fabrication process requires a sacrificial layer any mechanical element of the MEM device remains fixated/immobilized until the sacrificial layer is removed, (*e.g.*, mechanically, by pressurized air and/or water, chemical solution, temperature, melting, or any other technique) *i.e.*, membrane deformation will not be possible prior to the removal of the sacrificial layer. If the fabrication process doesn't require a sacrificial layer, the mechanical elements will be movable within the wafer immediately after fabrication, according to the design of the MEM device.

The wafer may comprise structural elements, which can be considered as part of the packaging of the fluidic MEM device structured therein.

In some embodiments the wafer can be configured such that the dies of the fluidic MEM devices within the wafer can be bonded directly to a printed circuit board (PCB) *e.g.*, as a standard surface-mount device (SMD).

One inventive aspect of the present invention relates to a device for monitoring fluid media. The device comprises a base element having at least one fluid port and at least one cavity or fluid flow path fluidly coupled to the at least one fluid port for enabling fluid exchange of fluid media therewith. Optionally, and some embodiments preferably, the base element is a monolithic unit made from a certain (same) type of material. At least one sensing element associated with the cavity or fluid flow path is used in the device for measuring at least one property or condition of fluid media introduced into the device, and for generating measurement data or signals indicative thereof. The device further comprises electrical contacts disposed on the base element, or other part of the device, and electrically coupled to the at least one sensing element.

In some embodiments the sensing element comprises two or more electrodes disposed inside the cavity or fluid flow path configured and operable to measure electrical conductivity of the fluid media. The sensing element may comprise a first pair of spaced apart electrodes for flowing a predefined electrical current through the cavity or fluid flow path when filled with the fluid media, and a second pair of spaced apart electrodes for measuring an electrical voltage induced by the predefined electrical current.

At least one membrane may be used in the device, the membrane is associated with the cavity or fluid flow path and configured and operable to elastically deform responsive to pressure conditions inside said cavity or fluid flow path. Optionally and in some embodiments preferably the at least one membrane is made from the same material from which the base element is made.

The at least one sensing element may comprise a transducing element disposed on at least one side of the membrane and being configured and operable to generate the measurement data or signals responsive to the pressure conditions. For example, and without being limiting, the at least one transducing element may comprise electrically conducting lines deposited on the membrane and forming a plurality of adjacently located predetermined patterns comprising at least one of rectangular-wave pattern, zigzag-like wavy pattern, and arc-shaped pattern. The patterns are preferably configured to maximize a length of the electrically conducting lines deposited on the membrane.

In some possible embodiments the fluid flow path comprises a constriction, and at least one membrane of the device is associated with the constriction and being configured and operable to elastically deform responsive to pressure conditions inside it. The device may comprise at least one membrane in a section of the fluid flow path not including the constriction. Alternatively or additionally, the device may comprise at least one membrane coupled to the constriction, and actuating means coupled to the membrane are used to controllably deform the membrane and to thereby regulate fluid passage through the constriction.

In some possible embodiments the device comprises at least one transducing element disposed on a surface area of the base element of the device not affected by the deformations of the at least one membrane. At least one of the transducing elements disposed on a surface area of the base element not affected by the deformations of the at least one membrane may be used as a temperature sensor. Optionally, and in some embodiments preferably, the transducing elements are configured and operable to implement a Wheatstone bridge circuitry.

The device may comprise at least one electrical circuitry mounted on the base element of the device and electrically coupled to one or more of the electrical contacts.

Optionally, and in some embodiment preferably, the electrical circuitry comprises a control unit configured and operable to receive and process the measurement data generated by the at least one sensing element and generate corresponding control signals for measuring and/or regulating the flow of the fluid media.

In some embodiment the device has a layered structure formed on the base element. The device may comprise a fluid path layer having the cavity or fluid flow path and configured and operable to sealably connect to the base element and establish fluid communication between the at least one fluid port and the cavity or fluid flow path, and an encapsulating layer having the at least one membrane and configured and operable to sealably connect the fluid path layer and align said at least one membrane with the cavity or fluid flow path to thereby enable the at least one membrane to interact with fluid media when introduced into said cavity or fluid flow path. The device may comprise an intermediate layer disposed between the flow path and encapsulating layers and comprising at least one slot, each slot being aligned with a membrane of the encapsulating layer and configured to receive fluid media from the cavity or fluid flow path of the flow path layer.

In a possible variant the device has a layered structure formed on the base element, where the base element comprises the at least one membrane, and wherein the device comprises a transition layer, having at least one fluid passage, each fluid passage being associated with a respective fluid port of the base element, and at least one slot, each slot being associated with a membrane of the base element, the transition layer configured and operable to sealably connect to the base element and fluidly communicate each fluid passage with its respective fluid port and align each slot with its respective membrane, and an encapsulating layer having the cavity or fluid flow path and configured and operable to sealably connect to the transition layer and fluidly communicate between the cavity or fluid flow path and the at least one fluid passage, thereby enabling passage of fluid media into the cavity or fluid flow path from the at least one fluid port in the base section via its respective fluid passage in the transition layer, and align the cavity or fluid flow path with the at least one slot, to thereby enable each membrane to interact with fluid media introduced into its respective slot via the cavity or fluid flow path. The device may comprise a fluid flow path in the encapsulating layer, where the fluid flow path having a constriction, and wherein at least one slot of the transition layer is in fluid communication with the constriction to enable its respective membrane to interact with fluid media introduced thereinto, and at least one other slot is in fluid communication with a non-constricted section of the fluid flow path to enable its respective membrane to interact with fluid media introduced thereinto. The device may comprise a fluid passage in the base element communicating between constricted and non-constricted regions of the fluid flow path. The fluid passage may comprise membrane configured and operable to an elastically deform responsive to pressure differences between the constricted and non-constricted regions of the fluid flow path, and the membrane having a transducing element configured and operable to generate measurement data or signals responsive to the deformations.

In some possible embodiment the encapsulating layer comprises at least one elastically deformable membrane having a flow regulating element configured and operable to engage a fluid passage of the transition layer to thereby alter fluid passage therethrough.

Optionally, and in some embodiments preferably, the device includes at lest one transduction element in the encapsulating layer.

The device may be configured and operable to be mounted on a PCB while establishing electrical contact with at least some of the electrical contacts of the device. Optionally, and in some embodiments preferably, the PCB comprises a cavity, and the at least one of the membranes of the device is adapted to deform towards or away said cavity of the PCB.

Optionally, and in some embodiments preferably, the device comprises quick connection means configured and operable to secure the device to an external device while establishing electrical connectivity therewith.

In another aspect therein provided_a fluid delivery system comprising at least one monitoring device as described hereinabove or hereinbelow, at least one fluid source for supplying the fluid media to the at least one monitoring device, and at least one fluid dispensing device for receiving fluid media from either the at least one monitoring device or the fluid source.

In yet another aspect there is provided a fluid delivery system comprising at least one monitoring device as described hereinabove or hereinbelow, at least one fluid source for supplying the fluid media to the monitoring device, at least one fluid dispensing device for receiving fluid media from either the at least one monitoring device or the fluid source, and a control unit coupled to the monitoring device and configured to receive and process the measurement data generated by the sensing element. The monitoring devices may be connected to each other in the system in series via their fluid ports. Alternatively, the monitoring devices are connected via their fluid ports to a fluid delivery line connecting between the fluid source and the fluid dispensing device.

In yet another aspect there is provided a method for constructing a flow control device. The method comprises constructing from a specific material a monolithic base structure comprising at least one fluid port and a cavity of a fluid flow path in fluid communication with the at least one fluid port for enabling exchange of fluid media therewith, constructing at least one sensing element associated with a cavity or fluid flow path of the device and configured and operable for measuring at least one property or condition of fluid media introduced thereinto and generating measurement data or signals indicative thereof, and forming on the device electrically conducting patterns for providing electrical connection to the at least one sensing element. The constructing of the base structure may comprise forming at least one membrane associated with the cavity or fluid flow path and configured and operable to elastically deform responsive to pressure conditions inside said cavity or fluid flow path, and wherein the at least one sensing element is at least partially structured on the membrane. The constructing of the base structure may comprise forming a constriction in the cavity or fluid flow path and forming at least one elastically deformable membrane associated with the constriction, and wherein at least one membrane associated with the constriction comprises a sensing element for measuring fluid pressure conditions in the constriction or mechanically coupled to an actuator for altering fluid passage through the constriction.

The method may comprise constructing a flow path layer comprising the cavity or fluid flow path, constructing an encapsulating layer comprising at least one elastically deformable membrane, wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the encapsulating layer, assembling a layered structures by sealably attaching the encapsulating layer to the flow path layer such that at least one membrane of the encapsulating layer is disposed over the cavity or fluid flow path of the flow path layer, and sealably attaching the layered assembly to the base structure such that fluid communication is established between the at least one fluid port of the base structure and the cavity or fluid flow path of the flow path layer.

Alternatively, the method may comprise constructing a flow path layer comprising the cavity or fluid flow path, constructing an intermediate layer comprising at least one slot, constructing an encapsulating layer comprising at least one elastically deformable membrane, wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the encapsulating layer, assembling a layered structure by sealably attaching the encapsulating layer to the intermediate layer such that at least one membrane of the encapsulating layer is disposed over at least one slot of the intermediate layer, and sealably attaching the intermediate layer to the flow path layer such that fluid communication is established between at least one slot of the intermediate layer and the cavity or fluid flow path of the flow path layer, and sealably attaching the layered assembly to the base structure such that fluid communication is established between the at least one fluid port of the base structure and the cavity or fluid flow path of the flow path layer.

The constructing of the base structure may comprise forming at least one membrane in the base structure, wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the base structure, the method may further comprise constructing a transition layer having at least one fluid passage and at least one slot formed therein, constructing an encapsulating layer having a cavity or fluid flow path, assembling a layered structure by sealably attaching the encapsulating layer to the transition layer such that fluid communication is established between the cavity or fluid flow path of the encapsulating layer and at least one fluid passage and at least one slot of the transition layer, and sealably attaching the layered structure to the base structure such that fluid communication is established between at least one slot of the transition layer and at least one fluid port of the base structure and such that at least one slot of the transition layer is positioned over at least one membrane of the base structure.

The constructing of the base structure may comprise forming at least one membrane in the base structure, wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the base structure. The method may further comprise constructing a transition layer having at least one fluid passage and at least one slot formed therein, constructing an encapsulating layer having a cavity or fluid flow path and at least one elastically deformable membrane having a flow regulating element, assembling a layered structure by sealably attaching the encapsulating layer to the transition layer such that fluid communication is established between the cavity or fluid flow path of the encapsulating layer and at least one fluid passage and at least one slot of the transition layer, and sealably attaching the layered assembly to the base structure such that fluid communication is established between at least one slot of the transition layer and at least one fluid port of the base structure, at least one slot of the transition layer is positioned over at least one membrane of the base structure, and the flow regulating element of at least one membrane of the encapsulating layer becomes engaged with a fluid passage of the transition layer.

In some embodiments the constructing of the encapsulation layer comprises forming the fluid flow path with a constriction, wherein the assembling of the layered structure comprises establishing fluid communication between the constriction of the encapsulating layer and at least one slot of the transition layer, where the at least one slot being associated with one of the membranes in the base structure. The constructing of the base structure may comprise forming a fluid passage in the base structure for communicating between constricted and non-constricted regions of the fluid flow path via respective slots of the transition layer, where the fluid passage comprising membrane configured and operable to elastically deform responsive to pressure differences between the constricted and non-constricted regions of the fluid flow path, and where the membrane is having a transducing element configured and operable to generate measurement data or signals responsive to said deformations.

Optionaly, and on some embodiment preferably, the constructing of the at least one sensing element comprises patterning electrically conducting structures on the at least one membrane. The patterning may comprise forming at least one resistive element on the membrane configured and operable to change electrical resistance thereof responsive to the deformations of the membrane. Alternatively or additionally, the patterning may comprise forming at least one capacitive element on the membrane configured and operable for changing electrical capacitance thereof responsive to the deformations of the membrane.

The method may comprise coating at least some of the electrically conducting patterns with one or more isolating layers.

In some embodiment the base structure, or layers of the device, are made from a polymeric material, and the electrically conducting patterns of the device are made by deposition of conductive material on the polymeric material.

In some applications the forming of at least one of the base structure and one or more of the sealably attached layers, utilizes one of the following techniques: injection molding, 3D printing, micro scale molding, micro machining, nano imprinting, micro imprinting, hot embossing, injection molding, lithography, and laser micromachining.

The constructing of the sensing element may utilize one of the following techniques: lithography, evaporation, liftoff, electrodeposition, electroforming, electroplating, electroless deposition and other IC techniques.

The method may comprise manufacturing an array of the flow control devices as dies of a wafer in a mass production process. The wafer may comprise alignment marks to facilitate wafer orientation and the forming of the electrically conducting patterns (*e.g.*, by lithography). The method may comprise sealing the wafer to prevent contamination by non-biocompatible materials (*e.g.*, during chemical processing - electroforming). The wafer may be circular or rectangular in shape, and can have a cutted edge usable to identify the wafer orientation. In some embodiments one face of the wafer is made substantially flat for forming the electrically conducting patterns thereon, and another face of the wafer is prepared for wafer dicing.

The method may comprise manufacturing in a mass production process a wafer stack comprising a plurality of said wafers stack one on top of the other. The method may comprise manufacturing in the mass production process a stack holder adapted to hold the wafer stack.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings. Features shown in the drawings are meant to be illustrative of only some embodiments of the invention, unless otherwise implicitly indicated. In the drawings like reference numerals are used to indicate corresponding parts, and in which:

Figs. 1A to **1D** are block diagrams schematically illustrating fluid delivery systems according to some possible embodiments, wherein **Fig. 1A** exemplifies general structure of a fluid delivery system, **Fig. 1B** demonstrates a fluid delivery system utilizing a concatenated arrangement of a plurality fluidic MEM devices, **Fig. 1C** depicts a fluid delivery system utilizing a plurality of fluidic MEM devices for monitoring a fluid streamed in a fluid stream line, and **Fig. 1D** exemplify a fluid delivery system using a fluidic MEM-device having a restrictor and configured to control and measure at least one condition of the delivered fluid;

Figs. 2A to **Fig. 2K** are block diagrams showing possible embodiments of the fluidic MEM device having a restrictor in its fluid flow path, wherein **Fig. 2A** exemplifies a fluidic MEM device comprising two valves and a differential pressure (DP) sensor, **Fig. 2B** exemplifies a fluidic MEM device comprising two valves, a differential pressure sensor, and a temperature sensor, **Fig. 2C** exemplifies a fluidic MEM device comprising a differential pressure sensor and a temperature sensor, **Fig. 2D** exemplifies a fluidic MEM device comprising two valves, two absolute pressure (AP) sensors, and a temperature sensor, **Fig. 2E** exemplifies a fluidic MEM device comprising two valves, a differential pressure sensor, and three absolute pressure sensors, **Fig. 2F** exemplifies a fluidic MEM device comprising two valves, a differential pressure sensor, three absolute pressure sensors, and a temperature sensor, **Fig. 2G** exemplifies a fluidic MEM device comprising three valves, a differential pressure sensor, and two absolute pressure sensors, **Fig. 2H** exemplifies a fluidic MEM device comprising four valves, a differential pressure sensor, three absolute pressure sensors, and a temperature sensor, **Fig. 2I** exemplifies a fluidic MEM device comprising two valves, a differential pressure sensor, and two absolute pressure sensors, **Fig. 2J** exemplifies a fluidic MEM device comprising two valves, a differential pressure sensor, three absolute pressure sensors, and a temperature sensor, and **Fig. 2K** exemplifies a fluidic MEM device comprising two valves, a differential pressure (DP) sensor and a conductivity sensor;

Figs. 3A to **3H** schematically illustrate a manufacture process of a fluidic MEM device according to some possible embodiments;

Figs. 4A to **4G** schematically illustrate possible embodiments of the fluidic MEM device having resistive/piezoresistive sensing element(s), wherein **Fig. 4A** shows a sectional view of a possible embodiment of the MEM device having a chamber/channel and a membrane, **Fig. 4B** demonstrates arrangement of conducting lines/electrodes of a resistive transducing element formed on the membrane and electrical contacts (pads) thereof, **Fig. 4C** demonstrates a transducing element implemented by an electrically conducting line arranged to form a rectangular wave pattern, **Fig. 4D** and **4E** demonstrate a transducing element implemented by an electrically conducting line arranged in a zigzag wavy pattern, **Fig. 4F** and **4G** demonstrate a transducing element implemented by an electrically conducting line arranged to form a circular pattern;

Figs. 5A to **5D** demonstrate possible arrangements of the transducing elements for implementing a Wheatstone bridge in the fluidic MEM device;

Figs. 6A to **6E** schematically illustrate tranducing sensing elements formed on the membrane of the MEM device according to some possible embodiments, wherein **Figs. 6A** and **6B** respectively show the membrane and electrodes of a capacitive tranducing element formed on it in a resting state and in a deformed state, **Fig. 6C** demonstrates a Rosette-like circular arrangement of a capacitive transducer on the membrane, **Fig. 6D** exemplifies a parallel plate capacitive transducing sensor element employing conductive surfaces, and **Fig 6E** exemplifies a MEM device having a capacitive transducer in a gas compartment of the device;

Figs. 7A and **7B** are sectional views of fluidic MEM device employing different types of differential pressure sensing elements according to possible embodiments, wherein **Fig. 7A** shows a MEM device having two chambers/channels used to implement the differential pressure sensor and **Fig. 7B** shows a MEM device usable for measuring differential pressure across a restrictor using two absolute pressure sensors;

Figs. 8A to **8I** are sectional views schematically illustrating a process suitable for fabricating a fluidic MEM device according to some possible embodiments;

Figs. 9A and **9B** schematically illustrate mechanical and electrical interfacing of the fluidic MEM device with an external device/system according to possible embodiments;

Figs. 10A to **10F** show a possible configuration of the fluidic MEM device and arrangements for quick connection/disconnection to/from external devices/systems, wherein **Fig. 10A** shows a perspective view of the MEM device, **Fig. 10B** shows a sectional view of the MEM device, and **Figs. 10C** to **10F** exemplify possible mechanisms for connecting the MEM device to external systems;

Figs. 11A to **11I** exemplify structures and constructions of various possible embodiments of the fluidic MEM device, and arrangements for quick connection/disconnection to/from external devices/systems, wherein **Fig. 11A** to **11C** show MEM device structure usable for measurement of fluid pressure and/or flow rate, **Fig. 11D** to **11F** show another MEM device structure usable for measurement of fluid pressure and/or flow rate, **Fig. 11G** shows a sectional view of a MEM device structure usable for flow control and for measurement of fluid pressure and/or flow rate, and **Fig. 11H** and **Fig. 11I** exemplify a possible mechanism for connecting the MEM device to external systems/dvices;

Figs. 12A and **12B** demonstrate attachment of a fluidic MEM device to a PCB according to possible embodiments, wherein Fig. **12A** is an exploded view and **Fig. 12B** is a sectional view of the MEM device and of the PCB;

Figs. 13A to **13C** show perspective, exploded and sectional, views, respectively, of a MEM device having electrical elements and/or circuitries attached to its body according to some possible embodiments;

Figs. 14A and **14B** show a MEM device configured according to some possible embodiments to measure electrical conductivity of a fluid, wherein **Fig. 14A** is a perspective view and **Fig. 14B** shows a based portion of the device; and

Figs. 15A to **15F** are perspective views demonstrating mass production of fluidic MEM devices using wafers according to some possible embodiments, wherein **Figs. 15A** to **15C** show rectangular wafers comprising arrays of MEM devices, **Figs. 15D** and **15E** show a circular wafer comprising an array of MEM devices, and **Fig. 15F** demonstrate a fabrication technique of a stack of wafers of MEM devices with a wafer holder assembly.

DETAILED DESCRIPTION OF EMBODIMENTS

One or more specific embodiments of the present disclosure will be described below with reference to the drawings, which are to be considered in all aspects as illustrative only and not restrictive in any manner. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. Elements illustrated in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the invention. This invention may be provided in other specific forms and embodiments without departing from the essential characteristics described herein.

The present invention provides structures, arrangements, and manufacture techniques, of fluidic MEM devices implemented as small sized chips (*e.g.*, having a length of about 1 to 50 mm, width of about 1 to 50 mm, and height of about 1 to 50 mm) having one or more fluid flow structures, sensing and/or actuating elements. The MEM device can be implemented as a monolithic device fabricated in a single process (*e.g.*, molding, 3D printing, micro scale molding techniques, micro machining, nano and micro imprinting, hot embossing, injection molding, lithography, laser micromachining, and suchlike) to include all required fluid flow and sensing/actuating structures. Optionally, and in some embodiments preferably, the fluidic MEM device is configured and operable to be directly connected to external devices/systems and instantly establish electrical and/or fluid connection therewith.

Figs. 1A to **1D** are block diagrams schematically illustrating fluid delivery systems according to some possible embodiments. General structure of a fluid delivery system **10a** is shown in **Fig. 1A**. In this non-limiting example the delivery system **10a** comprises a fluidic MEM/chip device **20** (also referred to herein as MEM device) used to communicate fluid media between two flow systems **4** via fluid ports **12** thereof. A control unit **13** electrically and/or mechanically coupled to the MEM device **20** through connectors **2c** (*e.g.*, conductive pads, mechanical locking matching mechanism for connecting the device to the external control unit **13** and/or external mechanical actuation mechanism of the valves) provided on the MEM device, is used to monitor and/or regulate the fluid flow through the MEM device **20**. As exemplified in **Figs. 1A** to **1C**, in possible embodiments control unit **13'** may be integrated in the MEM device **20**, and in this case the external control unit **13** may be removed if redundant.

Fig. 1B demonstrates a fluid delivery system **10b** utilizing a concatenated (serial) arrangement of a plurality fluidic MEM devices **20** serially connected to each other via their fluid ports **12** for monitoring and/or regulating the flow of the fluid media steamed from the flow system **4**. The MEM device **20** at each end of this concatenated arrangement may be connected to a respective flow system **4** via its free fluid port **12**. This arrangement of system **10b** is particularly useful for monitoring fluid pressure in different points of a tube/line/pipe/channel. For example, and without being limiting, between two consecutive measurement points there may be an additional flow system or element, such as a filter or pump or restrictor that effects the flow parameters. In some cases, due to properties of the fluid media, only the concatenated system arrangement

10b can be used for monitoring and regulating the flowed fluid *e.g.*, in medical applications wherein the monitored fluid media should not be steady, for instance if the fluid is blood, which should not be held steady in the system to prevent it from becoming clotted. Another advantage of the concatenated system arrangement **10b** is that there is less risk of air getting trapped within the system.

Fig. 1C shows a fluid delivery system **10c** utilizing a plurality of fluidic MEM devices **20'** for monitoring fluid media streamed into a fluid transfer line **8** by the fluid system **4**. In this non-limiting example each MEM device **20'** comprises a single fluid port **12** for communication of fluid media thereinto from the transfer line **8**. Thus, in this example the MEM devices **20'** are usable only for monitoring properties/conditions of the fluid media (*e.g.*, fluid pressure) streamed through the line **8**. In this system arrangement **10c** the flow system is less (or not at all) effected from the presence of the MEM device **20'**. This arrangement is usable in situations wherein the measurements should be double checked by introducing more than one sensing element, while not effecting the system, in order to achieve a more reliable and/or accurate measurements. Another advantage of the system arrangement **10c** is that it allows replacing one of the MEM devices **20'** while keeping the system **10c** operable to monitor the fluid media by the sensing elements of the other MEM device **20'**.

Fig. 1D depicts a fluid delivery system **10d** using a fluidic MEM-device **20** to monitor and/or regulate fluid media flowing between a fluid supply system **11** and a fluid delivery unit **14** (*e.g.*, a dispensing device). The MEM device **20** in this non-limiting example comprises a fluid flow regulating and monitoring arrangement **12q**, one or more sensing elements, and at least one fluid inlet **12i** and at least one fluid outlet **12u** (only one inlet and outlet depicted in **Fig. 1D**). The regulating and monitoring arrangement **12q** comprises a restrictor **12r** (*e.g.*, implemented by a constriction forming a slender fluid passage segment), and a controllable flow regulator (*e.g.*, flow control valve) **12v**. Fluid media supplied by the fluid reservoir **11** is introduced into the MEM device **20** via the at least one inlet **12i** and transferred to the delivery unit **14** via the at least one outlet **12u** of the fluidic MEM device **20**. The control unit **13**, electrically and mechanically (*e.g.*, by a locking matching mechanism) coupled to the fluidic MEM device **20** (*e.g.*, electrically via its contact pads), is used for monitoring and regulating the flow of the fluid media by processing measurement data/signals received front the sensing elements and generating control signals to change the state of the flow regulator **12v**.

In some embodiments the coupling of the MEM device **20** to the external control system **13** is both mechanical and electrical. For example, a locking/matching mechanism may be used to establish electrical connection with the external control unit **13** and/or mechanical connection with mechanical actuators used to operate the flow regulator **12v**.

The sensing elements provided in the MEM device **20** may be configured and operable for measuring one or more properties/ conditions of the fluid introduced thereinto via the at least one inlet **12i**. For example, and without being limiting, the MEM device **20** may comprise one or more pressure sensors **12s/12d** for measuring pressure of the fluid media passing through the MEM device **20** and generating measurement data/signals indicative thereof, and/or one or more temperature sensors **12t** for measuring temperature of the fluid media and/or one or more conductivity sensor and generating measurement data/signals indicative thereof. In particular, in this example the MEM device **20** comprises an absolute pressure sensor **12s**, a differential pressure sensor **12d**, an electrical conductivity sensor **12k**, and a temperature sensor **12t**. The pressure and temperature sensors are electrically coupled to the control unit **20** configured and operable to receive measurement data/signals from the sensor units, process and analyze (*e.g.*, determine fluid flow rate) the received data/signals, and generate control signals for setting the state of the flow regulator **12v** accordingly.

Figs. 2A to **2K** exemplify various possible embodiments of the fluidic MEM device **20**. In **Fig. 2A** the MEM device **20a** comprises a differential pressure sensor **12d** configured and operable to measure differential pressure between a fluid flow path **12p** upstream to the restrictor **12r** and a slender fluid passage inside the restrictor **12r**. In this non-limiting example two flow regulators are used to control the passage of the fluid through the MEM device **20a**; a first flow regulator **12v** located upstream to the flow restrictor **12r** and a second flow regulator **12v'** located downstream to the flow restrictor **12r**.

In some possible embodiments upstream (**12v**) and downstream (**12v'**) flow regulators are used in the MEM device to improve safety/reliability *e.g.*, if one flow regulator malfunctions the fluid flow can be still controlled by the second regulator. In addition, this configuration also permits measuring the fluid pressures in the input and output channels in states wherein there is no fluid flow in the device, by measuring the pressure when only one of the flow regulators is open. Furthermore, the use of such two flow regulators provides for safety controls *e.g.*, in situations wherein the input pressure has to be higher than the output pressure and/or where the input and output pressures should be within a predetermined safety range required by certain application needs.

Fig. 2B demonstrates a fluidic MEM device **20b** which configuration is substantially similar to that of MEM device **20a** shown in **Fig. 2A**, and further comprising a temperature sensor **12t** configured and operable to measure temperature of fluid passing through the fluid flow path of the restrictor **12r** and generate data/signals indicative thereof. In some possible embodiments measurement data received from the temperature sensor **12t** is used by the control unit (**13**) to compensate for temperature effects in the flow measurement data from the pressure sensor(s) **12d**. **Fig. 2C** demonstrates a MEM device **20c** which configuration is substantially similar to that of MEM device **20b** shown in **Fig. 2B**, but without the flow regulators **12v** *i.e.*, this configuration can be used in certain embodiments requiring only measurement/monitoring fluid conditions (*e.g.*, flow rate, pressure, temperature) without flow control/regulating.

The configuration of MEM device **20d** shown in **Fig. 2D** is substantially similar to MEM device **20b** shown in **Fig. 2B** but having two absolute pressure sensors **12s** instead of the differential pressure sensor **12d**. In this non-limiting example a first absolute pressure sensor **12s^** is configured and operable to measure fluid pressure in fluid flow path **12p** upstream to the fluid restrictor **12r** and generate measurement data/signals indicative thereof, and a second absolute pressure sensor **12s** is configured and operable to measure fluid pressure in a slender fluid passage formed inside the fluid restrictor **12r**, and generate measurement data/signals indicative thereof. This configuration of MEM device **20d** may be used in certain embodiments using the control unit **13** to determine fluid flow rate through the MEM device based of the measurement data received from the absolute pressure sensors **12s** and **12s^**.

It is noted that the use of absolute pressure sensors **12s** as exemplified in **Fig. 2D** may be used to implement additional device controls functionalities, such as, but not limited to: disconnection of input and output flow paths/channels, verification of absolute pressure in the input channel (the flow path between the inlet **12i** and the restrictor **12r**) and/or output channel (the flow path between the outlet **12u** and the restrictor **12r**) and within the MEM device **20**.

Figs. **2E** and **2F** exemplify possible embodiments wherein absolute pressure sensors **12s** are used together with a differential pressure sensor **12d** in MEM devices having a upstream flow regulator **12v** and an downstream flow regulator **12v'**. The configuration of MEM device **20e** shown in **Fig.** **2E** is substantially similar to that of MEM device **20a** shown in **Fig.** **2A** but further comprises the following absolute pressure sensors: a first absolute pressure sensor **12s** configured and operable to measure fluid pressure in a slender fluid flow path inside the fluid restrictor, and generate measurement data/signals indicative thereof; a second absolute pressure sensor **12s'** configured and operable to measure fluid pressure in a fluid flow path downstream to the flow restrictor **12r** (*i.e.*, between the restrictor **12r** and the downstream flow regulator **12v'**) and generate measurement data/signals indicative thereof; and a third absolute pressure sensor **12s''** configured and operable to measure fluid pressure in a fluid flow path downstream to the flow regulator **12v'** (*i.e.*, between the flow regulator **12v'** and the outlet **12u** of the device **20e**) and generate measurement data/signals indicative thereof.

The configuration of MEM device **20f** shown in **Fig.** **2F** is substantially similar to that of MEM device **20b** shown in **Fig.** **2B** but further comprising three absolute pressure sensors **12s**, as follows: a first absolute pressure sensor **12s**$^{\mathbf{x}}$ configured and operable to measure fluid pressure in the fluid flow path between the inlet **12i** of the device **20f** and the upstream flow regulator **12v** and generate measurement data/signals indicative thereof; a second absolute pressure sensor **12s'** configured and operable to measure fluid pressure in a fluid flow path downstream to the flow restrictor **12r**, and generate measurement data/signals indicative thereof; and a third absolute pressure sensor **12s''** configured and operable to measure fluid pressure in a fluid flow path downstream to the downstream flow regulator **12v'**, and generate measurement data/signals indicative thereof.

The configurations of the MEM devices **20e** and **20f** are particularly useful for improving resolution/precision of the fluid flow rate determined based on the absolute pressure measurement data, and for obtaining absolute pressure measurement data indicative of fluid pressure at the input channel, at the output channel, and across the restrictor **12r**, independent of the state of the flow regulators **12v** and **12v'**. It is noted that these configurations are also useful for double checking the determined fluid flow rate by comparing the measurement data obtained from the differential pressure sensor **12d** and to the measurement data obtained from the absolute pressure sensors **12s/12s**$^{\times}$, **12s'** and/or **12s"**.

Figs 2G and **2H** exemplify possible embodiments wherein one or more concatenated upstream flow regulators **12v** are used in the input channel and two or more concatenated downstream flow regulators **12v**' are used in the output channel of the MEM device, and absolute pressure is measured at the output channel and in between the pairs of concatenated upstream/downstream flow regulators. The configuration of MEM device **20g** shown in **Fig. 20G** is substantially similar to that of MEM device **20a** shown in **Fig. 2A**, but comprising two concatenated downstream flow regulators **12v'** between the flow restrictor **12r** and the outlet **12u** (instead of just one), and further comprising two absolute pressure sensors **12s**; a first absolute pressure sensors **12s'** configured and operable to measure fluid pressure in a fluid flow path between the two downstream flow regulators **12v'** and generate measurement data/signals indicative thereof, and a second absolute pressure sensors **12s"** configured and operable to measure fluid pressure in a downstream fluid flow path between the flow regulators **12v'** and the outlet **12u** of the device **20g** and generate measurement data/signals indicative thereof.

The configuration of MEM device **20h** shown in **Fig. 2H** is substantially similar to that of MEM device **20b** shown in **Fig. 2B**, but comprising two concatenated downstream flow regulators **12v'** between the flow restrictor **12r** and the outlet **12u** (instead of just one), two concatenated upstream flow regulators **12v** between the flow restrictor **12r** and the inlet **12i** (instead of just one), and further comprising three absolute pressure sensors **12s**. A first absolute pressure sensor **12s'** is configured and operable to measure fluid pressure in a fluid flow path between the two downstream flow regulators **12v'** and generate measurement data/signals indicative thereof, a second absolute pressure sensor **12s**$^{\times\wedge}$ is configured and operable to measure fluid pressure in a fluid flow path between the two upstream flow regulators **12v** and generate measurement data/signals indicative thereof, and a third absolute fluid pressure sensor **12s"** configured and operable to measure fluid pressure in a fluid flow path between the downstream flow regulators **12v'** and the outlet **12u** of the device **20h** and generate measurement data/signals indicative thereof.

Figs. 2I and **2J** exemplify possible embodiments having only the downstream flow regulators **12v'** in the output channel. As seen, the input channel between the inlet **12i** of the devices **20i** and **20j** and their restrictors **12r** do not include neither sensor units nor flow regulators. As seen, the configuration of MEM device **20i** shown in **Fig. 2I** is substantially similar to that of MEM device **20g** shown in **Fig. 2G**, but without the upstream flow regulator **12v**, and the configuration of MEM device **20j** shown in **Fig. 2J** is substantially similar to that of MEM device **20h** shown in **Fig. 2H**, but without the two concatenated upstream flow regulators **12v** and the absolute pressure sensor **12s**$^{\times\wedge}$ between them.

Fig. 2K demonstrates a MEM device **20k** with configuration substantially similar to that of MEM device **20a** shown in **Fig. 2A**, and further comprising an electrical conductivity sensor **12k** configured and operable to measure electrical conductivity in a part of the fluid flow path downstream to the restrictor **12r**. Of course, the conductivity sensor may be positioned in any other part of the fluid flow path *e.g.*, in the restrictor **12r** or in a part of the fluid flow path upstream to the restrictor **12r**. In some embodiments the measured conductivity is used to determine the type of fluid introduced into the MEM device **20k**. In addition the measured conductivity can also be useful to detect presence of air (or other gases) *i.e.*, if air is present in the fluid chamber/channel there is no electrical current passing through the conductivity sensor **12k**.

It is noted that temperature sensors **12t** of the MEM device may be placed anywhere along the fluid flow path of the MEM device, not limited to its restrictor **12r** section. Optionally, and in some embodiments preferably, the temperature sensors **12t** are situated at the restrictor **12r** for measuring the fluid temperature in the restrictor in order to calculate/verify the fluid flow rate. In certain applications it is important to monitor the fluid pressure inside the MEM device to prevent high pressure conditions thereinside. The system utilizing the MEM device may be thus configured to issue an alarm (*e.g.*, by the control unit **13**) whenever the measurement data obtained from the sensor elements indicates that the fluid pressure conditions in the MEM device are greater than some predetermined allowable pressure level.

Flow sensors for measuring flow rate of fluid media through the MEM device **20** may be implemented using one or more pressure sensors, the fluid channel **12p** and the restrictor **12r** formed therein. The flow of the fluid media is related to the pressure difference across the restrictor which can be measured using a differential sensor pressure **12d**, two gauge pressure sensors **AP**, or two sealed pressure sensors (will described herein below). Combinations of these pressure sensor elements can be use to implement additional and safety controls such as (*e.g.*, for detection of air/gas bubbles, output pressure out of range - if too high there could be an obstruction and if too low the delivery system could be disconnected, input pressure out of range - if too low relative to the output pressure there could be a reflow, and if too high could damage the MEM device and the fluid media may not be delivered according to specification).

The flow regulators **12v/12v'** in the different configurations shown in **Fig. 2** may be used to implement flow control schemes for the MEM device. The flow regulators can be controlled mechanically or electromagnetically by the external (or integrally embedded **13'**) control unit **13**, which may be configured and operable to measure the fluid flow rate through the MEM device and adjust the state of the flow regulators accordingly to regulate the amount of fluid media delivered through the device.

Figs. 3A to **3H** schematically illustrate a process for fabricating a fluidic MEM device (**20**) according to some embodiments. In **Fig. 3A** an initial substantially flat base layer **40a** is prepared from a base-material (*e.g.*, from a polymeric or any other suitable material) for deposition of layered structures/patterns thereon. The thickness of the base layer **40a** may generally be about 0.1 to 5 mm. In **Fig. 3B** one or more base-material patterns (*e.g.*, having total thickness of about 0.2 to 10 mm) are deposited on the base layer **40a** to provide a predetermined geometrical shape for a base structure **40b** of the device. Thereafter, a thin base-material layer **41a** is deposited above the base structure **40b** so as to define one or more fluid channels **12c** (only one fluid channel is shown in **Fig. 3**) having one or more restrictors **12r**, and providing a build-layer for formation of one or more membranes (**47m**, **48m** and **49m**, in **Fig. 3E**).

As seen, a restrictor **12r** may be implemented by a constriction forming a slender fluid passage by the one or more base-material patterns deposited in **Fig. 3B** on the base layer **40a**. The thickness of the thin layer **41a** may generally be about 0.01mm to 1.5 mm. In some embodiments, a sacrificial supportive layer (not shown in **Fig. 3**) is used for depositing the thin base-material layer **41a** above the base structure **40b**, which is thereafter removed to build the fluid channel **12c** and its restrictor **12r**. Alternatively, the design and fabrication process may be configured to allow the deposition of the thin base-material layer **41a** without a sacrificial layer.

In **Figs. 3A** to **3H** the MEM device is constructed to include a single fluid channel **12c** having a single restrictor **12r**. In possible embodiments the cross-sectional area of the fluid channel **12c** may be about 0.0005 mm^2 to 70 mm^2, and the cross-sectional area of its restrictor **12r** may be about 0.0002 mm^2 to 70 mm^2.

Next, as illustrated in **Fig. 3D**, electrically conductive and/or mechanically actuable (*i.e.*, mechanically operated), elements are deposited in one or more layers on top of the thin layer **41a** *e.g.*, by electroplating, electroforming, printing, evaporation, sputtering , or electroless plating, or electropolymerization. For example, and without being limiting, the elements deposited on the thin layer **41a** may comprise electrically conducting lines/contacts and/or flow regulators bosses, formed by depositing predetermined metallic patterns (*e.g.*, having thickness of about 0.0001 to 0.2 mm). **Fig. 3D** specifically exemplifies formation of two electrodes **47** and **48**, and an actuable boss **49**. In **Fig. 3E** one or more base-material patterns **41b** are deposited on top of the thin layer **41a** to form a predetermined pattern having one or more void areas **41v** (*i.e.*, areas over thin layer **41a** not covered by layer **41b**) defining the membranes of the MEM device. The one or more base-material patterns **41b** are deposited such that the electrically conductive/actuable elements **47**, **48** and **49**, are obtained in at least one of the void areas **41v**, or as exemplified in **Figs. 3E** and **3F**, electrodes **47** and **48** are obtained inside the void areas **41v** of membranes **47m** and **48m**, respectively, and actuable element **49** is obtained inside the void area **41v** of membranes **49m**. The thickness of the one or more base-material patterns **41b** surrounding the electrically conductive/actuable elements **47**, **48** and **49**, may be substantially of the same thickness as that of said electrically conductive/actuable elements **47**, **48** and **49**.

In **Fig. 3F** one or more base-material layers **41c** are deposited on top of the base-material patterns **41b**, and above/over the electrically conductive/actuable elements **47**, **48** and **49**, encapsulating the electrically conductive/actuable elements of the device, thereby isolating the conductive/actuable elements and finalizing the fabrication process of the MEM device. The thickness of the base-material patterns **41b** may generally be about 0.1 to 2 mm, and in some possible embodiments about 0.0002 to 2 mm. The MEM device can be used to measure and/or regulate fluid flowed through it fluid channel(s) **12c**. Horizontal arrowed lines shown in **Fig. 3F** illustrate passage of a fluid media streamed into the fluid channel **12c**. Zigzagged arrowed lines illustrate in **Fig. 3F** fluid pressure applied over the membranes **47m** and **48m** due to the passage of the streamed fluid.

A vertical rectangular-shaped arrow illustrates in **Fig. 3F** represent deformation of membrane **49m** downwardly by the actuable element **49** for regulating the fluid flow through the channel of the device by changing cross-sectional area of fluid flow path inside the restrictor **12r**. The different membranes **47m**, **48m** and **49m** are preferably made elastically (reversibly) deformable, for restoring their resting state shape whenever no actuating forces/fluid pressure conditions are being applied on them. Also as seen in **Fig. 3F**, a first pressure sensor implemented by membrane **47m** and its electrodes **47** is configured and operable to measure the fluid pressure in the fluid channel **12c**, and a second pressure sensor implemented by membrane **48m** and its electrodes **48** is configured and operable to measure the fluid pressure in the restrictor **12r**.

With reference to **Figs. 3G** and **3H**, in an alternative fabrication process the step of depositing of the electrically conductive and/or mechanically actuable elements (shown in **Fig. 3D**) is repeated a predetermined number of times within patterned grooves inside a previously deposited base-material **41e** (seen in **Fig. 3H**), the grooves substantially encompassing the deposited electrically conductive and/or mechanically actuable elements. In this way electrically conducting pillars (vias, *e.g.*, having height of about 0.001 to 2 mm) **47a**, **48a** and **49a**, are formed contained encapsulated within the one or more layers of the base-material patterns **41e**.

In the configuration demonstrated in **Figs. 3G** and **3H** larger conductive/actuable elements structures are prepared, which can be exploited electrically or mechanically, *e.g.*, to improve robustness, or different conductivity properties, or to yield more complex shapes. In some embodiments a sacrificial supportive material is used in the steps shown in **Fig. 3G**, which are later removed, *e.g.*, using lithography techniques. In the non-limiting example shown in **Fig. 3H** the base structure **40b** or the base-material patterns **41e** is used as both a structural material and a supportive material for the process.

It is important to note that the encapsulation of the MEM device by the layers **41c** in **Fig. 3F**, and/or **41e** in **Fig. 3H**, could be also carried out using a type of polymer different from that used for the base-material patterns **41b**, *e.g.*, Polydimethylsiloxane (PDMS), Parylene.

Figs. 4A to **4G** schematically illustrate possible embodiments of the fluidic MEM device having resistive/piezoresistive sensing element(s). With reference to **Fig. 4A**, wherein there is shown a cross-sectional view of a fluidic MEM device **50** fabricated as a single monolithic unit having a solid (massive) body **51** comprising electrical contact pads **55** deposited over an external surface area thereof to provide electrical connectivity with external devices/units and/or systems *e.g.*, for pressure measurement. The MEM device **50** comprises a fluid chamber or channel **51n** and a membrane **53** sealably mounted inside the chamber/ channel **51n** over an opening **51p** formed in one of the walls of the device.

As will be described and illustrated hereinbelow, the membrane **53** is preferably made sufficiently elastic to permit deformations thereof towards/into the opening **51p** responsive to fluid pressure conditions evolving inside the fluid chamber/channel **51n**. The contact pads **55** are electrically coupled to transducing elements of the sensing means (not shown in **Fig. 4A**) formed over the membrane **53** to thereby permit an external device/system (not shown) coupled to the MEM device **50** to obtain measurement data/signals from its sensor(s).

Fig. 4B demonstrates possible arrangement of electrically conducting lines of a resistive transducing element **52** formed on the membrane **53** of the MEM device **50**, and electrical contacts (pads) thereof. In this specific and non-limiting example, the transducing elements **56** formed on the membrane **53** comprises either resistive and/or piezo-resistive transducing elements **56c** mechanically coupled to the membrane **53** and electrically connected to the contact pads **55** of the MEM device for measuring at least one condition or property (*e.g.*, pressure) of a fluid introduced into, or passed through, the fluid chamber/ channel **51n** (*e.g.*, in response to deflection of the membrane **53**). For example, and without being limiting, the transducing elements **56c** may be prepared from an electrically conducting material, such as, but not limited to, Gold (Au), Copper (Cu), Platinum (Pt), Aluminum (Al), Nickel (Ni) or theirs alloy, deposited on the membrane surface *e.g.*, printing, sputtering, evaporation, electroforming.

As seen in **Fig. 4B** and further demonstrated in **Fig. 4C** the transducing element may be implemented by an electrically conducting line arranged to form a dense rectangular wave-like pattern to maximize the length of the electrically conducing lines **56** traversing the surface of the membrane **53** and thereby substantially improve the sensitivity of the resistive transducing element **52**.

For example, and without being limiting, in possible embodiments the thickness of the electrically conducing lines **56** may be about 0.0001 to 0.05 mm, and the distance between adjacently located electrically conducing lines **56** may generally be about 0.0001 to 0.1 mm. It is noted that while **Figs. 4B** and **4C** demonstrate rectangular configuration **56s** of rectangular wave like patterns formed by the electrically conducing lines **56**, other geometrical shapes are also possible, such as, but not limited to, circular, half-circle, elliptical, polygon, etc.

Figs. 4D and **4E** demonstrate arranging the electrically conducing lines **56** of the resistive transducing element **52** to form a plurality of zigzag (*e.g.*, sine-wave like or saw-shaped) patterns **56z**, according possible embodiments. The zigzag patterns **56z** of electrically conducing lines **56** are successively arranged in close proximity to maximize the length of the conducing lines **56** and the membrane area covered by resistive transducing element **52**. Each zigzag pattern **56z** may be electrically connected to an adjacently located zigzag pattern by a contact pad **56k**, to thereby electrically link the plurality of zigzag patterns **56z** to form a substantially long electrically conducting line so as to maximize the membrane area covered by the resistive transducing element **52** and improve its sensitivity. The thickness of the electrically conducting line **56**, and the distance between adjacently located zigzag patterns **56z** may be within the same ranges indicated above with reference to **Figs. 4B** and **4C**.

Fig. 4F and **4G** demonstrate a circular arrangement (*e.g.*, Rosette type) of the resistive transducing element **52**. In this non-limiting example the electrically conducting lines **56** form a plurality of adjacently located arc-shaped patterns **56p**, where each arc-shaped pattern **56p** is enclosed between, and electrically connected to, at least one inner arc-shaped pattern **56p** and at least one outer arc-shaped pattern **56p** (except for innermost and outermost arcs), thereby obtaining a substantially half circle geometrical shape of the resistive transducing element **52**. In this way the length of the electrically conducting line **56**, and the membrane area it covers, are significantly maximized so as to improve the sensitivity of the resistive transducing element **52**. The thickness of the electrically conducting line **56**, and the distance between adjacently located arc-shaped patterns **56p** may be within the same ranges indicated above with reference to **Figs. 4B** and **4C**. In a possible embodiment the radius **R** of the half-circle shape formed by the resistive transducing element **52** may be about 0.05 to 5 mm.

Figs. 5A to **5D** demonstrate possible arrangements of the resistive sensing elements for implementing a Wheatstone bridge circuitry in the fluidic MEM device. With reference to **Fig. 5A**, four resistive elements may be patterned over surface areas of the MEM device **20**, **R1**, **R2**, **R3** and **R4**. At least one element patterned over the deformable area of the membrane **53** (*e.g.*, **R1**) is used as a sensing element, while the other elements patterned on other parts of the MEM device **20** (non-deformable or low-deflection regions) of the membrane **53** are used as dummy elements. In this way temperature and other possible effects that may influence the measurements are compensated.

In the non-limiting example shown in **Fig. 5A** the sensing elements **R1** and **R2** are formed over the deformable area of the membrane and the dummy elements **R3** and **R4** are used for temperature compensation and zero offsetting. Placing the two sensing elements **R1** and **R2** over the deformable region of the membrane **53** improves (doubles) the sensitivity of the sensor. It is noted that in possible embodiments the dummy elements **R3** and **R4** may be located external to the MEM device (*e.g.*, in the control unit). The Wheatstone bridge connections can be completed external to the MEM device **20** using the circuitry configuration shown in **Fig. 5C**, or in some embodiments on the MEM device, as demonstrated in **Fig. 5D**.

In this way changes in the electrical resistance(s) of the sensing elements formed over the deformable regions of the membrane **53** may be measured using the Wheatstone bridge configuration **58** *e.g.*, shown in **Fig. 5B**, and the measured signals/data obtained from the Wheatstone bridge circuit **58** (**Vout**) may be used by the control unit (**13**) to determine the pressure of the fluid media streamed through (or contained in) the MEM device **20**. In possible embodiments the (dummy) sensing elements formed on the non-deformable (or low deflection) regions of the membrane **53** may be also used to implement a temperature sensor.

For example, the dummy resistors may be made from materials exhibiting specific resistance changes responsive to temperature changes (*e.g.*, Gold (Au), Copper (Cu), Platinum (Pt), Nickel (Ni), and suchlike), which may be used as resistance temperature detectors (RTD). Such dummy resistors are preferably placed in areas not affected by the membrane deformations (or of low deformation), such that the main effect of their resistance change is due to temperature. In this case external switching circuitry (not shown) can be used to allow reading only the electrical resistance of a single resistor. The resistor reading could be done by 2, 3 or 4, point reading technique according to the accuracy needed.

In some embodiments the control unit **13** may be configured to implement a switching module capable of measuring the resistance of each sensing element separately (*e.g.*, two terminals reading, three terminals reading or four terminals readings) according to the sensor configuration implemented in the MEM device **20**. Such configuration permits self-test capability and enables verifying the correct insertion of the MEM device in its connections slot. The control unit **13** may be also configured to manipulate the resistors connections and establish a desired Wheatstone measurement circuitry configuration according to the needed measurement data (*e.g.*, to implement a zero offset compensation scheme). The control unit may be also configured to present additional resistor elements into the measurement circuitry to establish a desired Wheatstone bridge configuration (*e.g.*, add parallel or serial resistors to one or more of the elements formed on the MEM device to balance the Wheatstone bridge).

Figs. 6A to **6C** schematically illustrate possible embodiments of capacitive tranducing sensing elements **52c** that may be formed on the surface of the membrane **53** of the MEM device **20**. **Figs. 6A** and **6B** are sectional views of a MEM device membrane showing the membrane **53** and high aspect ratio electrodes **57** of the tranducing element **52c** patterned on the membrane. **Fig. 6A** shows the membrane **53** in a resting state (*i.e.*, when pressure is not applied over it), having a plurality of electrode pairs (for the sake of simplicity only three such electrode pairs depicted in Figs. **6A** and **6B**), each comprising a reference electrode **57a** and a sensing electrode **57b** (generally referred to herein as electrode pair **57**). Total capacitance of the electrodes in the resting state, as measured via the contact pads (**55**), may be used as a reference for fluid pressure measurement. In **Fig. 6B** the membrane **53** is elastically deformed/deflected (due to application of fluid pressure) and the distance between the reference and sensing electrodes in one or more (*e.g.*, depending on the amount of applied pressure) of the electrode pairs is changed in response, thereby changing the total capacitance measurable via the contact pads. In this way a measure of the fluid pressure inside the chamber/ channel (**51n**) of the MEM device **20** may be obtained according to the capacitance measured between the contact pads of the MEM device **20**.

Fig. 6C schematically illustrates a possible electrode arrangement of a capacitive sensor element **52c** arranged over the membrane **53** of the MEM device **20** according to some possible embodiments. In this non-liming example a plurality of substantially round high aspect ratio electrode pairs are coaxially arranged on (or in) the membrane **53**. More particularly, in this non-limiting example each sensing electrode **57b** is arranged to form an open loop ("C"-like shape) structure enclosing/encircling a respective adjacently located reference electrode **57a** also having an open loop shape. The openings of the open loop shaped sensing electrodes **57b** are facing one side of the plane of the membrane **53** (in which the contact pad **55a** of the reference electrodes is disposed) for passage of electrically conducting lines connecting between the reference electrodes **57a** and the contact pad **55a**. Similarly, each reference electrode **57a** (except the last one, which is in a form of a complete circle) is also arranged in a form of an open loop ("C"-like shape) structure enclosing another pair of adjacently located sensing and reference electrodes. The openings of the open loop shaped reference electrodes **57a** are facing the other side of the plane of the membrane **53** (in which the contact pad **55b** of the sensing electrodes is disposed) for passage of electrically conducting lines connecting between the sensing electrodes **57b** and the contact pad **55b**.

As exemplified in Figs. **6A** and **6B**, the elastic deflection of the membrane **53** due to fluid pressure changes the distance between at least one of the open-loop adjacently located electrode pairs **57a** and **57b**, resulting in a measurable change in the capacitance of the capacitive sensor element **52c**. It is understood that the high aspect ratio sensing (**57b**) and reference (**57a**) electrodes are substantially parallel to each other, and that the measured capacitance of the sensing element in the resting state of the membrane refers to zero pressure difference between the two sides of the membrane **53**. It is also understood that the concentric adjacently located electrode pairs may be arranged to form various different open-shaped geometrical shapes, not necessarily round/circular *e.g.*, elliptical, triangular, rectangular, polygon, and suchlike, *mutatis mutandis*, and that the electrode pairs may be arranged such that the sensing electrode **57b** is enclosed by the open-shape structure of the reference electrode **57a**.

The high aspect ratio electrode pairs **57** may be fabricated from, but not limited to, Gold (Au), Copper (Cu), Nickel (Ni), Aluminum (Al), or Platinum (Pt), or combinations thereof (*e.g.*, applied by electrodeposition, electroforming, electroplating, electroless deposition). In some embodiments a thin adhesion improving layer (*e.g.*, made of Chrome (Cr) and/or Titanium (Ti)) is used to improve the adhesion of the metal electrodes, conducting lines and/or contacts, to the polymer surface of the MEM device.

In addition, a surface treatment to the polymer surface of the MEM device may used to improve adhesion of the metal electrodes, conducting lines and/or contacts, thereto *e.g.*, by oxygen plasma. The aspect ratio (the ratio between the height and the width) of the electrodes **57** in some embodiments may be about 1 to 50, and the distance between each electrode pair **57** may be about 0.001 to 0.02 mm.

It is noted that electrically conducting lines **56**, and/or the electrodes **57**, of the sensing elements exemplified hereinabove may be formed on either the inner side (*i.e.*, inside the fluid chamber/channel **51n** of the MEM device) or the outer side of the membrane **53**. In such embodiments wherein the conducting lines **56** and/or electrodes **57** are formed on the inner side of the membrane **53** they may be coated by one or more layers of electrically insulating materials (*e.g.*, PDMS, Parylene C) to electrically isolate them from the fluid media inside the chamber/channel and protect them from causes of degradation (*e.g.*, humidity, oxygen).

Fig. 6D shows a sectional view of a MEM device **50a** having a body **51f** and a capacitive sensor element **52g** with parallel plates configuration. As seen, in this non-limiting example only one of the electrodes is placed on (or in) the membrane **53**. Particularly, the sensing electrode **57x** is arranged on (or in) the membrane **53** of the device, and the reference electrode **57y** is placed on (or in) a surface area inside the chamber/ channel **55f** of the MEM device, opposite to the membrane **53**. In this configuration a gap ***g*** formed between the reference and sensing electrodes is defined by the geometrical dimensions of the chamber/ channel **55f** of the MEM device **50a**.

Fig 6E exemplifies a MEM device **50e** having a capacitive pressure sensor **52u**. The MEM device **50e** comprises a hollow body **51q** having a fluid chamber/channel **55f** for holding/streaming fluid media, and a gas compartment **55t** filled with gas (*e.g.*, air). An elastically deflectable membrane **53** sealably separates between the fluid chamber/channel **55f** and the compartment **55t**. One side of the membrane **53** is thus facing the fluid chamber/channel **55f**, and contacts the fluid media in it, and its other side is facing the gas compartment **55t**.

The capacitive pressure sensor **52u** comprises two parallel electrically conducting plates/surfaces, a first electrically conducting surface **57q** is provided on a surface of the membrane **53** facing the gas compartment **55t**, and a second electrically conducting surface **57q** is provided on an inner surface of the compartment **55t** that is facing, and opposite to, the membrane **53**, such that a gap **g** (*e.g.*, of about 0.0005 to 0.1 mm) is obtained between the parallel electrically conducting surfaces **57q** and **57t**.

When pressure conditions evolve inside the chamber/ channel **55f** of the MEM device **50a** the membrane **53** is deflected due to pressure difference between the two sides of the membrane **53**. In the deflected state of the membrane **53** the high aspect ratio electrodes are not parallel. As the sensing electrode **57q** is deformed responsive to the membrane deflection (reference electrode **57t** does not deform), resulting in change of the dielectric gap **g** and corresponding change in the measurable capacitance of the sensor element **52g**. The electrodes **57q** and **57t** may be fabricated from Gold (Au), Copper (Cu), Nickel (Ni), Aluminum (Al), or Platinum (Pt), or combinations thereof (*e.g.*, applied by electrodeposition, electroforming, electroplating, electroless deposition). In some embodiments a thin adhesion improving layer *e.g.*, made of Titanium (Ti) and/or Chrome (Cr), is applied to the surface of the MEM device to increase the adhesion of the metal electrodes, conducting line and/or contacts, thereto. In addition, a surface treatment may be applied to the polymer surface of the device to improve the adhesion of the electrodes, conducting lines and/or contacts, thereto *e.g.*, by oxygen plasma.

In some possible embodiments the surface area (conductive layers) of each one of the electrodes **57q** and **57t** is about 0.5 to 50 mm². Optionally, and in some embodiments preferably, the distance **g** between the electrodes **57q** and **57t** in the resting state of the membrane **53** is about 0.0005 to 0.1 mm, for providing a suitable measurable capacitance range of the sensor element **52g**. Optionally, and in some embodiments preferably, the electrodes **57q** and **57t** are coated by one or more dielectric insulating material (*e.g.*, PDMS, Parylene C) to prevent electrical contact with the fluid media passed through/contained in the MEM device or protect them from causes of degradation (*e.g.*, humidity, oxygen).

In some embodiments the electrodes **57q** and **57t** are not coated by an electrically insulating material and thus in touch/electrical contact with the fluid media inside the chamber/ channel **55f**. In this case, the sensor element **52g** can be used to measure the electrical conductivity of the fluid media inside the MEM device.

The pressure sensor elements descried heretofore are types of absolute gauge pressure sensors (except for capacitive pressure sensor **52u** in **Fig. 6E**) configured to measure the pressure relative to atmospheric pressure. The pressure sensors described hereinbelow are types of differential pressure sensors (*i.e.*, that measure the difference between two pressures each applied over one side of the membrane). **Figs. 7A** and **7B** are sectional views of fluidic MEM devices according to possible embodiments configured to implement differential pressure sensor elements.

Fig. 7A shows a sectional-view of a MEM device **50b**, according to possible embodiments, having a body **51g** and a sensor element **52e** configured to measure differential fluid pressure. In this non-limiting example the MEM device **50b** comprises two substantially parallel chambers/channels, **55x** and **55y** with a communicating bore **55p** between them. The bore **55p** between the chambers/ channels **55x** and **55y** is sealed by the membrane **53** of the device **50b**, so as to prevent fluid communication between them. In case a pressure difference evolves between the two chambers/channels **55x** and **55y**, the membrane **53** is (elastically) pressed and deformed by the higher fluid pressure in one of the chambers/channels towards the other chamber/channel having the lower pressure conditions, resulting in deflection of the transducing element **57v** and/or **57u** formed thereon, and responsively in a change in data/signal measured by the sensor element **52e**. The transducing elements **57v** and/or **57u** may be a type of resistive elements as described hereinabove.

While **Fig. 7A** exemplifies use of two transducing elements **57v** and/or **57u** located on opposite sides of the membrane (transducing element **57v** is associated with chamber **55x** and transducing element **57u** is associated with chamber **55y**), it is understood that one transducing element may be used on one of the sides of the membrane **53**, or embedded in it. The conductive transduction layers **57v** and **57u**, and their respective signal transmission lines may be encapsulated within the membrane **53** and electrically insulated from the fluid (liquid and/or gas) inside the chambers.

Fig. 7B shows a sectional view of fluidic MEM device **60** employing two absolute pressure sensors **52a** and **52b** (*e.g.*, implemented using any of above-described transducing elements), and a restrictor **66**. As seen, one of the absolute pressure sensors **52a** is associated with a fluid flow path **65** of the device **60**, while the other absolute pressure sensors **52b** is associated with a slender fluid passage section **66** of the restrictor. In this way, fluid flow rate may be determined based on a pressure difference between the two absolute pressure sensors **52a** and **52b**. A flow channel **65** of the MEM device **60**, and the restrictor **66** formed therein, can be built within the same fabrication process of the device body **61** with its membranes **66a** and **66b**, and its contacts **65a** (*e.g.*, using the fabrication technique illustrated in **Fig. 3**).

Optionally, and in some embodiments preferably, in the different embodiments described hereinabove and hereinbelow, all the transduction elements (*e.g.*, sensing electrodes) and their respective conductive lines are electrically isolated (*e.g.*, by PDMS or Parylene).

Figs. 8A to **8I** show sectional views schematically illustrating a process suitable for fabricating a fluid MEM device according to some embodiments. In **Fig. 8A** one or more layers comprising an initial polymeric pattern **73** and sacrificial substance pattern **71** are deposited on a substrate **77**. As shown in **Fig. 8B**, additional layers comprising sacrificial substance **71** patterns and polymeric substance **73** patterns are successively applied one on top of the other using predefined patterns, to thereby construct a predetermined structure for the MEM device. The sacrificial substance patterns **71** and the polymeric substance pattern **73** in each layer may be (but not necessarily) complementary to each other such that each layer of the structure encompasses a complete cross-sectional area of the MEM device, without holes or voids. The structure obtained for the MEM device preferably comprises all the structures/elements of the MEM device, such as, but not limited to, the locking/latching mechanism, and interfacing means (*e.g.*, fluid inlet/outlet).

In **Fig. 8C** a top thin polymeric layer **73y** is applied over the multilayered structure. The thin polymeric layer **73y** is used to implement membrane(s) of the MEM device. Optionally, as exemplified in **Fig. 8D**, a surface treatment **73t** (*e.g.*, by oxygen plasma) may be applied to the top polymeric layer **73y** to improve adhesion thereto of any successively applied layer(s). In some embodiment one or more thin adhesion improving layers (*e.g.*, made from Chrome (Cr) or Titanium (Ti)), are used to improve adhesion of the metallic electrically conducting lines and/or electrodes to the polymeric surface of the device.

Next, as shown in **Fig. 8E**, electrically conducting lines **78** are patterned on membrane portions (**73m**, in **Fig. 8I**) of the top polymeric layer **73y**, and electric contacts (pads) **76** can be deposited on top of non-deformable (or low deflection) regions of the thin polymeric layer **73y** *e.g.*, in a single layer applied outside the membrane portions top polymeric layer **73y** (the conducting lines and contact pads are also referred to herein as electrically conductive patterns). After applying the electrically conductive patterns **76/78**, one or more additional polymeric patterns/layers **79** may be applied over at least a portion of the electrically conductive patterns **76/78**, as seen in **Fig. 8H** that encapsulates the MEM device structure while enabling access to the contact pads of the MEM device.

The fabrication process may be finalized by removal of the substrate **77** and sacrificial substance patterns **71**, to thereby empty the chamber **71v** and release the membrane **73m**, as demonstrated in **Fig. 8I**. In this non-limiting example the obtained MEM device structure comprises a fluid chamber/channel **71v**, an elastically deformable membrane **73m** with electrically conductive structure **78** patterned thereon, a fluid inlet (or outlet) **73i**, and externally accessible contact pads **76**.

In an alternative embodiment, exemplified in **Fig. 8F**, after applying the electrically conductive patterns shown in **Fig. 8E**, and before completing the device encapsulation shown in **Fig. 8H**, additional electrically conducting patterns **78a** may be applied over the electrically conducting lines **78** and/or connections pads to thereby form conductive pillars for viases and/or high aspect ratio electrodes, *e.g.*, by electroplating, or electroless plating, or electropolymerization. In yet another possible alternative embodiment, seen **Fig. 8G**, a polymeric foil **73f** comprising the electrically conductive patterns **76/78** (*e.g.*, conducting lines, connection pads, and/or the transducer) may be attached (*e.g.*, by adhesion) on top of the top polymeric layer **73y**.

The sacrificial substance can be made from a type of Photoresist material (*e.g.*, SU8, AZ 4562), water-soluble polymers (*e.g.*, polyethylene glycol (PEG), or suchlike, and the polymeric material can be made from PDMS, ABS, PVC, Polyethylene (PE), PEEK, Polycarbonate (PC), Polyetherimide (PEI), Polysulfone (PSU), Polypropylene (PP), Polyurethane (PU), or the like. The sacrificial and polymeric material patterns may be applied one on top of the other by 3D printing or lithography, for example. The electrically conducting patterns may be made, for example, from Gold (Au), Copper (Cu), Nickel (Ni), Aluminum (Al), Platinum (Pt), and they may be applied on the top polymeric layer **73y**, for example, by electrodeposition, electroforming, electroplating, or electroless deposition. In some embodiment a thin adhesion layer (*e.g.*, made of Chrome (Cr) or Titanium (Ti)) is deposited on the membrane surface to increase the adhesion of the metal lines/contacts to the surface of the device. In addition, a surface treatment may be applied to the polymer surface of the device to improve the adhesion of the metal lines and/or contacts thereto *e.g.*, by oxygen plasma.

In some embodiments (*e.g.*, employing some 3D printing techniques) the sacrificial layers **71** are not needed.

Figs. 9A and **9B** schematically illustrate mechanical and electrical interfacing of the fluidic MEM device **20** with an external device/system according to possible embodiments.

Fig. 9A schematically illustrates a quick connector mechanism **30** of the fluidic MEM device **20** according to some possible embodiments. As described hereinabove, the MEM device **20** according to the various embodiments of the present invention does not require packaging as the entire MEM device **20** is manufactured using similar processes, and within the same fabrication framework, as of the flow restrictor, flow regulators, pressure and temperature sensors. In this non-limiting example the quick connection of mechanism **30** is established by a latching slot (or cavity) **36** adapted to snugly receive the MEM device **20** by pushing it thereinto, as exemplified by dashed lines and arrows in **Fig. 9A**. The quick connection mechanism **30** comprises a latching/locking mechanism **32** configured and operable to secure the MEM device **20** inside the slot **36**, and/or a matching mechanism **31** for assuring that the MEM device **20** fitted into the slot **36** is properly oriented.

Fig. 9B exemplifies another quick connector mechanism **37** with mechanical matching and locking designed to enable quick connection to an external device/system **33** and establishing electrical connectivity therewith. In this non limiting example a fitting socket **33c** is provided in the external device **33** that allows locking the MEM device into the socket **33c** while providing the needed connectivity with the external device **33**. The MEM device **20** may comprise a protruding edge **26** in one end thereof designed to be received inside a cavity (at **33c**) formed by a shoulder-shaped member **33s** of the socket. After introducing the protruding edge **26** of the MEM device into the cavity of the socket **33c** the MEM device **20** is pressed towards a base section **33b** of the socket and locked thereinside as butt end (at a side opposite to the protruding edge **26**) thereof is pressed against a retaining member **33t** (at a side opposite to the cavity) of the socket **33c**. The MEM device **20** thus becomes locked inside the socket **33c** while electrical connection is established between contacting pads **25a** of the MEM device **20** and corresponding contact pads **25b** provided in the base section **33b** of the socket. The quick connection mechanism **37** may comprise means providing sealable fluid connection between the MEM device **20** and the external device **33**.

As exemplified in **Fig. 1D**, the external devices and/or systems **35** can comprise one or more reservoirs (**11**), or fluid supply lines coming from them, connectable to the inlet (**12i**) of the MEM device **20**, one or more delivery/dispensing units (**14**), or liquid delivery lines coming from them, connectable to the outlet (**12u**) of the MEM device **20**, and external (or integrated) control units (**13**) electrically coupled to the MEM device **20**. The electrical connection to the external control unit **13** includes matching electrical connections for reading the temperature, conductivity and/or pressure sensors (*e.g.*, **1-1'** and **2-2'**), and connectors for actuating the flow regulators (**12v**) either mechanically, electromagnetically or electrostatically (*e.g.*, **3-3'** and **4-4'**).

The MEM device **20** can include in some embodiments matching, and/or locking, and/or latching mechanisms (*e.g.*, Luer locks, not shown in **Figs. 9A** and **9B**) configured and operable to establish fluid sealable communication between the MEM device **20** and external devices and/or systems **35**.

Figs. 10A and **10B** show a possible configuration of the fluidic MEM device **20** according to possible embodiments configured to measure pressure of fluid media. In this non-limiting example the MEM device **20** is made of a substantially rectangular body **86** having a fluid port **12** at each side thereof, for passage of fluid media through the channel **61** passing along the body of the MEM device **20**. An interfacing face **86i** of the MEM device **20** comprises an array of contact pads **75** for establishing electrical connection between the MEM device **20** and external devices/systems, a deformable membrane **53**, and transducing element(s) **88** formed on (or in) the membrane **53** and electrically coupled to the contact pads **75** for measuring fluid pressure inside the channel **61**. The interfacing side **86i** of the MEM device **20** also comprises two grubbing ears **81** laterally protruding in opposite sideway directions of the device. The grubbing ears **81** may comprise facets **81p** formed at one end thereof for matching the MEM device **20** to respective mechanical connection means of an external device/system, as will be exemplified below.

With reference to Fig. **10B**, a pass-through bore **61b** connecting between the fluid channel **61** and the interfacing face **86i** of the device is sealed by the membrane **53** covering the opening of the bore **61b**, such that fluid media introduce into the channel **61** can interact with the membrane **53** through the bore **61b**. The contact pads **75** provide electrical connection to the transducing element(s) **88** formed on the membrane **53** for measuring the fluid pressure inside the channel **61**. The fluid ports **12** may be configured to implement quick connectors (*e.g.*, Luer locks) to allow sealable and quick connection of the MEM device **20** to external device/system.

In some possible embodiments the fluid channel **61** may comprise a restrictor **61r** implemented by a constriction **61c** formed in the fluid channel **61** usable for implementing a differential flow sensor using a single gauge pressure sensor **88**. For example, if the fluid media is introduced into the MEM device via the non-constricted side of the device, as demonstrated by dashed arrowed line **61a**, and there are environmental pressure conditions at the outlet **61v** of the device, then the same pressure conditions occur across the restrictor **61r** and within the non-constricted portion of the fluid channel **61**. As there are same pressure conditions on the two sides of the membrane **53** a differential fluid pressure measurement is obtained by the sensor element **88**.

Figs. 10C to **10F** exemplify possible mechanisms for connecting the MEM device to external devices/systems. In Figs. **10C** the MEM device **20** is shown in operational settings attached to an external device/system **35**. The MEM device **20** is attached to a docking assembly **87** having a support plate **87p** with two fastening structures **87e** formed on a top side thereof and configured to receive and hold the grubbing ears **81** of the MEM device **20**, and a PCB **83** attached to a bottom side of the support plate **87p** and configured to establish electrically connection with the contact pads **75** of the MEM device **20** upon attachment thereof to the external device **35**.

Fig. 10D shows an exploded perspective view of the docking assembly **87**. A slot **89s** formed in the support plate **87p** accommodates a latching mechanism **89** configured to lock the MEM device **20** in its operational setting between the fastening structures **87e**. The latching mechanism **89** comprises a depressible tongue **89p** configured to be reversibly depressed into the slot **89s** while the MEM device **20** is slid along the surface of the support plate **87p** towards the fastening structures **87e**, as shown by arrow **85**. As seen in **Fig. 10C**, upon fully inserting the MEM device **20** between the fastening structures **87e** the depressible tongue **89p** emerge upwardly from the slot **89s** and locks the MEM device immobilized in its operational state therein. A push button **89g** provided in the latching mechanism **89** can be used to move the depressible tongue **89p** into the slot **89s** for releasing the MEM device **20** from the docking assembly **87**.

Also seen in **Fig. 10D**, an array of upwardly projecting electrical contacts **83c** provided on the PCB **83** configured for placement in pass-through bores **20** formed in the support plate **87p**, to thereby establish electrical connection with the contact pads **75** of the MEM device **20** upon placement in operational state in the docking assembly.

Referring now to **Figs. 10E** and **10F**, exemplifying another docking assembly **87'** according to a possible embodiment wherein two deflectable clamps **87t** are used for holding the MEM device **20** immobilized in an operational state on the support plate **87p** between two lateral holders **87q**. In this embodiment the lateral holders **87q** are configured to retain the corners of the grubbing ears **81** of the MEM device **20** at its leading end (with respect to direction of insertion therebetween) in matching cavities, and thereafter the MEM device is pressed towards the support plate **87p** and clamped by the clamps **87t** as it is fitted between the holders **87q** and the clamps **87t** are "snapped"/lock over the trailing ends of the grubbing ears **81**. In this state the contact pads **75** of the MEM device **20** establish electrical connection with the contactors array **83c'** of the PCB **83**. In some embodiments the contactors array **83c'** are implemented by a type of spring loaded connectors, configured to allow the connectors to move up and down to thereby facilitate in keeping MEM device in place secured to the support plate **87p**. The MEM device **20** can be released from the docking assembly by pulling the clamps **87t** and lifting the MEM device from the holders **87q**.

In possible embodiments the PCB **83** may include additional contact and circuitries, as may be needed by the external device/system **35** (*e.g.*, control units, Wheatstone bridge elements, power source, and suchlike).

Figs. 11A to **11C** show a fluidic MEM device **20** structure usable according to possible embodiments for measurement of fluid pressure and/or flow rate. The MEM device **20** in this non-limiting example is a multilayered structure comprising a base structure **20s** a flow path layer **20t**, a fluid chambers layer **20u** (also referred to herein as intermediate layer), and a membrane layer **20v** (also referred to herein as encapsulating layer). The MEM device further includes a laterally projecting lip **20w** comprising a plurality of contact pads configured to provide electrical connectivity to sensing and/or actuating elements of the MEM device **20**, and to circuitries and/or other elements (*e.g.*, control module) embedded in the MEM device **20**.

With reference to **Fig. 11B** showing a sectional view of the MEM device **20**, the base portion **20s** of the device comprises internal flow structures configured to receive fluid media via a fluid inlet **12i** thereof, communicate the received fluid media to elements residing in the other layers, receive back the fluid media from the other layers and discharge it via a fluid outlet **12u** thereof. The fluid inlet **12i** and outlet **12u** of the MEM device **20** may be configured as sealable quick connection structures (*e.g.*, Luer lock) to permit quick connection to fluid supplying means (*e.g.*, drug reservoir) and to a fluid delivery system (*e.g.*, drug delivery/dispensing device).

Referring now to Figs. **11B** and **11C**, the base structure **20s** comprises a receive channel **12f** in fluid communication with the inlet **12i** and gradually tapering therefrom towards a small opening **84a** at the upper surface of the base structure **20s**, and a transfer channel **12m** in fluid communication with the outlet **12u** and gradually tapering therefrom towards another small opening **84b** at the upper surface of the base structure **20s**. The flow path layer **20t**, stacked on top of the base structure **20s**, comprises two corresponding holes **80a** and **80b** (seen in **Fig. 11C**) configured to be aligned and overlap the small openings **84a** and **84b** in the upper surface of the base structure **20s**. A slot formed in the flow path layer **20t** connects between the two holes **80a** and **80b**, thereby forming a fluid flow path of the MEM device **20**. The fluid flow path may comprise two sections having different cross-sectional areas, a first section serving as the fluid channel **12p** communicates with the first hole **80a**, and a second section having a smaller cross-sectional area and serving as the restrictor **12r** communicates between the fluid channel **12p** and the second hole **80b**. A tapering constriction may be formed between the fluid channel **12p** and the restrictor **12r**.

The fluid chambers layer **20u** stacked on top of the flow path layer **20t** comprises two slots **82a** and **82b** having tapered profiles configured to form fluid chambers in the layer. Each slot has a slender portion passing along the bottom side of the fluid chambers layer **20u**, and a wide (enlarged) portion passing along the upper side of the layer. The first slot **82a** is aligned with a section (or entire length) of the fluid channel **12p** formed in the flow path layer **20t** such that its slender portion communicates with the fluid channel **12p**, and the second slot **82b** is aligned with a section (or entire length) of the restrictor **12r** such that its slender portion communicates with the restrictor **12r**.

The flow structures of the MEM device **20** are sealed by the uppermost membrane layer **20v** configured with two elastically deflectable membranes **53a** and **53b**, each having a respective transducing sensing element, **88a** and **88b**, patterned thereon. The location of the membranes **53a** and **53b** in the membrane layer **20v** places each membrane over a respective fluid chamber implemented by the slots **82a** and **82b** such that the fluid pressures applied by the fluid media introduced into the chambers can be sensed by the respective transducing sensing elements **88a** and **88b**, as the fluid media in the chambers interacts with the respective membranes, and measured via the contact pads **75** of the MEM device **20**.

In this way, fluid media introduced into the MEM device **20** through its inlet **12i** is transferred via receive channel **12f** into the fluid channel **12p**, its restrictor and the fluid chambers formed by the slots **82a** and **82b**, and therefrom discharged via the transfer channel **12m** and outlet **12u**. The measurement data/signals obtained from the transducing sensing element **88a** is thus indicative of the pressure conditions inside the slot **82a** and the fluid channel **12p** coupled to it, and the measurement data/signals obtained from the transducing sensing element **88b** is indicative of the pressure conditions inside the slot **82b** and the restrictor **12r** coupled to it. The control unit (**13**) can use the measurement data to determine the fluid flow rate through the MEM device **20**.

The MEM device **20** illustrated in **Figs. 11A** to **11C** may be manufactured using the same materials and techniques described hereinabove. In some possible embodiments the different layers of the MEM device **20** may be separately prepared in different manufacture procedures, and thereafter sealably glued or welded to each other to form the desired MEM device structure illustrated in Figs. **11A** to **11C**. The cross-sectional area of the fluid flow path **12p** formed in the layer **20t** may be in some embodiment about 0.0001 to 25 mm^2, and the cross-sectional area of its restrictor **12r** may be about 0.0001 to 24.9 mm^2. Volume of the each fluid chamber formed by the tapered slots **82a** and **82b** in layer **20u** may be in some embodiments about 0.001 to 125 mm^3.

In some embodiments a layered structure is constructed by sealably attaching the fluid chambers layer **20u** to the flow path layer **20t** such that fluid communication is established between the slot **82a** and the fluid flow path **12p**, and between the slot **82b** and the restrictor **12r**, and attaching the membrane layer **20v** to the fluid chambers layer **20u** such that the membrane **53a** is placed over the slot **82a**, and the membrane **53b** is placed over the slot **82b**. The layered assembly is then attached to the base structure **20s** such that fluid communication is established between the opening **84a** and the fluid flow path **12p**, and between the opening **84b** and the restrictor **12r**.

In some possible embodiments the MEM device is constructed without the fluid chambers layer **20u**. In this case a layered structure may be assembled by sealably attaching the membrane layer **20v** directly to the flow path layer **20t** such that membrane **53a** is position directly over the fluid flow path, and the membrane **53b** is positioned directly over the restrictor **12r**.

Figs. 11D to **11F** show another configuration of a fluidic MEM device **20** structure usable according to possible embodiments for measurement of fluid pressure and/or flow rate. In this embodiment the MEM device **20** is also a multilayered structure comprising a base structure **20z**, an intermediate fluid chambers layer **20y** (also referred to herein as transition layer), and a top fluid flow path layer **20x** (also referred to herein as encapsulating layer). The MEM device further includes a laterally projecting lip **20w** having a plurality of contact pads (**75**) configured to provide electrical connectivity to sensing and/or actuating elements of the MEM device **20**, and to circuitries and/or other elements (*e.g.*, control module) embedded in the MEM device **20**. A cavity **93** provided in the bottom side of the base structure **20z** includes two openings **93a** and **93b** communicating with respective internal sensor compartments (**94a** and **94b**, in **Fig. 11F**) of the device.

As seen in **Fig. 11E** showing an exploded view of the MEM device, a longitudinal channel formed at the bottom side of the fluid flow path layer **20x** implements the fluid flow path **12p** and its restrictor **12r**. In this case the channel has a certain predetermined depth into the flow path layer **20x** to allow sealing it by the intermediate fluid chambers layer **20y** and the base sstructure. The intermediate layer **20y** comprises two pass-through bores **80a** and **80b** for communicating fluid media between the flow structures of the base structure **20z** and of the fluid flow path layer **20x**.

Referring now to **Fig. 11F**, in the intermediate layer **20y**, a first pass-through bore **80a** aligned with, and overlapping the, upper opening **84a** of the receive channel **12f** in the base structure **20z** is used to communicate fluid media received via the inlet **12i** to the fluid flow path **12p** formed in the flow path layer **20x**, and a second pass-through bore **80b** aligned with, and overlapping the, upper opening **84b** of the transfer channel **12f** in the base structure **20z** is used to communicate fluid media from the restrictor **12r** formed in the flow path layer **20x** to the outlet **12u** of the device.

The intermediate layer **20y** comprises two slots **82a** and **82b** having tapered profiles configured to form fluid chambers in the layer. Each slot has a slender portion passing along the upper side of the intermediate layer **20y**, and a wide (enlarged) portion passing along the bottom side of the layer. The first slot **82a** is aligned with a section (or entire length) of the fluid channel **12p** formed in the flow path layer **20x** such that its slender portion communicates with the fluid channel **12p**, and the second slot **82b** is aligned with a section (or entire length) of the restrictor **12r** such that its slender portion communicates with the restrictor **12r**. This structure thus enables communicating fluid passing through the fluid channel **12p** and its restrictor **12r** into the respective chambers formed by the slots **82a** and **82b** in the intermediate layer **20y**.

The base structure **20z** comprises sensor compartments incorporating sensing elements of the device. A first compartment **94a** provided in the base structure **20z** is connected to the opening **93a** in the bottom cavity **93** and covered by a membrane layer **53a** having a transducing element **88a** formed thereon, and a second compartment **94b** provided in the base structure **20z** is connected to the opening **93b** in the bottom cavity **93** and covered by a membrane layer **53b** having a transducing element **88b** formed thereon. The membranes **53a** and **53b** are preferably implemented by thin top layer of the base structure **20z**. As seen in Fig. **11F**, the membranes **53a** and **53b** are in contact with the chambers formed in the intermediate layers **20y** by the slots **82a** and **82b**, respectively. Thus, the measurement data/signals obtained from transducing element **88a** is indicative of pressure conditions in the first chamber formed in the intermediate layer **20y** by the slot **82a**, and in the fluid flow path **12p** fluidly coupled to it, and the measurement data/signals obtained from transducing element **88b** is indicative of pressure conditions in the second chamber formed in the intermediate layer **20y** by the slot **82b**, and in the restrictor **12r** fluidly coupled to it.

In this configuration, if the opening **93a** in the bottom cavity **93** is sealed with specific pressure conditions inside the sensor compartment **94a**, then the pressure sensor implemented by the transducing element **88a** is a sealed pressure sensor (*i.e.*, similar to a gauge pressure sensor except that it measures pressure relative to some fixed pressure rather than the ambient atmospheric pressure). Similarly, if the opening **93b** in the bottom cavity **93** is sealed with specific pressure conditions inside the sensor compartment **94b**, then the pressure sensor implemented by the transducing element **88b** is a sealed pressure sensor. In case the openings **93a** and **93b** are open such that there are atmospheric pressure conditions inside the sensor compartments **94a** and **94b**, the sensor elements implemented by the transducing elements **88a** and **88b** are regular gauge sensors.

The MEM device **20** shown in **Figs. 11D** to **11F** may further comprise a differential pressure sensor **95**. The differential pressure sensor **95** may be implemented using a "U"-shaped differential pressure sensor cavity **95c** residing in the base structure **20z**, where top opening **95a** of one of its arms is sealably closed by thin membrane **91a** formed by a top layer of the base structure **20z**, while the top opening **95b** of the other arm is open to communicate fluid media with restrictor **12r** through the second chamber formed in the intermediate layer **20y** by the slot **82b**. In this way, the upper side of the membrane **91a** is in contact with the first chamber formed in the intermediate layer **20y** by the slot **82a**, and thus the pressure conditions in the fluid flow path **12p** are applied on it. On the other hand, the pressure conditions inside the cavity **95c**, and that are applied on the bottom part of the membrane **91a**, are the same as in the restrictor **12r**. Thus, deformations of the membrane **91a** corresponds to the pressure difference between the fluid flow path **12p** and its restrictor **12r**, and accordingly, the measurement data/signals obtained from the transducing element **96a** of membrane **91a** is indicative of the pressure difference along the fluid channel.

Accordingly, in operation the “U-Shape” channel **95c** is filled with the fluid media. If liquid media is used with the MEM device, then air contained within the cavity **95c** can be removed through the channel **95n** communicating between the two arms of the "U"-shaped cavity **95c**. Alternatively, in some embodiments, the cavity **95c** is filled with an uncompressible fluid/gel so that the pressure can be completely transmitted to the bottom side of the membrane **95a** (as **95b** remain opened to the restrictor pressure) *e.g.*, the fluid or gel within the cavity **95c** may be sealed by the same coating process used to apply the membrane of the sensing element.

In possible embodiments the opening **95b** of the "U"-shaped cavity may be sealed by a thin membrane (not shown), while the opening **95a** of the other arm is maintained open (not shown) to communicate fluid media with the fluid flow path **12p** through the first chamber formed in the intermediate layer **20y** by the slot **82a**. Accordingly, in such embodiments the pressure applied over the upper side of the membrane will be the pressure in the restrictor **12r**, while the pressure applied over the bottom side of the membrane will be pressure in the fluid flow path **12p**.

The use of such differential sensor allows to significantly reduce the precision needed for the flow control (*e.g.*, to about 1% with the differential pressure sensor while using absolute pressure sensors requires precision of about 0.05%). Of course, as the absolute pressure that needs to be measured is increased the accuracy requirements of the absolute pressure sensors are also increased.

Fig. 11G shows a sectional view of a MEM device **20** structure according to possible embodiments having flow regulators **98a** and **98b**. The MEM device shown in **Fig. 11G** is also a multilayered structure comprising a base structure **20z**, an intermediate fluid chambers layer **20y** (also referred to herein as transition layer), and a top fluid flow path layer **20x** (also referred to herein as encapsulating layer). The structure of the layers may be substantially similar to the layers of the MEM device shown in **Figs. 11D** to **11F**, but not necessarily. The flow regulators **98a** and **98b** may each be implemented using a thin membrane **98m** sealably separating between overlapping upper cavity **98u** and lower cavity **98w**, formed in the fluid flow path layer **20x**, where the lower cavities **98w** of each flow regulator are in fluid communication with their respective pass-through bore **80a** and **80b**. A piston **98p** attached to the bottom side of the membranes **98m** is usable to restrict (or completely occlude/seal) the passage through the opening **84a/b** to the fluid channel **12p** and restrictor **12r** by actuating mechanical pressure (*e.g.*, using electromagnetic or mechanical actuator) over the upper side of the membrane **98m**.

More particularly, in this embodiment fluid media from the receive channel **12f** is delivered into the fluid flow path **12p** through the lower cavity **98w**. Thus, as the piston **98p** of the flow regulator **98a** is pushed by the respective membrane **98m** downwardly towards the top opening **84a** of the receive channel **12f** the fluid flow passage to the lower cavity **98w** is restricted, or becomes fully blocked once the top opening **84a** is sealed by the piston **98p**. Similarly, as the piston **98p** of the flow regulator **98b** is pushed by the respective membrane **98m** upwardly towards the opening **80b** of the transfer channel **12f** the fluid flow passage to the lower cavity **98w** is restricted, or becomes fully blocked once the top opening **84b** is sealed by the piston **98p**.

In a normally-open configuration, once the actuating pressure over the membrane is removed, the original state of the membranes **98m** is restored, and the pistons **98p** are retracted upwardly, thereby releasing the fluid flow restriction over the fluid passage and allowing passage of fluid media to/from the fluid channel of the device. Optionally, and in some embodiments preferably, a normally closed configuration is used, as exemplified in **Fig. 11G**, wherein actuating means (not shown) are used to push downwardly the membranes **98m** and their respective pistons **98p** to permit fluid communication to the lower cavities **98w** of the flow regulators. Such normally closed configurations of the flow regulators prevent reflow from the output channel to the input channel in case the input pressure falls below the output pressure.

The MEM device of **Fig. 11G** may be manufactured in a two step process comprising (i) polymer fabrication, and (ii) conductive/sensing layers deposition (*e.g.*, using integrated circuits (IC) technology). Considering the dimension of a MEM device (*e.g.*, about 1 cm^3), in mass production of the MEM devices the manufacture may be carried out as follows (i) first, the base structure **20z (Fig. 11E)**, fluid flow path layer **20x** and the intermediate fluid chambers layer **20y** are manufactured with their flow structures, (ii) the conducive layers (lines, contact pads **75** and transducing elements) are deposited on the base structure **20z**, and (iii) the flow path layer **20x** is sealably adhered/welded on top of the fluid chambers layer **20y** (in some embodiments the flow path layer **20x** and the fluid chamber layer **20y** are manufactured as a single unit), which are then sealably adhered/welded on top of the base structure **20z** . As seen in **Fig. 11E** the lip **20w** (with contact pads **75**) laterally projects from the base structure **20z** to facilitate connection to the conducting elements (lines, transducing elements) on the base structure **20z.**

In some embodiment a layered structure is assembled by sealbly attaching the flow path layer **20x** to the fluid chambers layer **20y** such that fluid communication is established between the fluid flow path in the flow path layer **20x** and the hole **80a** and slot **82a** in the fluid chambers layer **20y**, and between the restrictor **12r** in the flow path layer and the hole **80a** and slot **82a** in the fluid chambers layer **20y**. The layered structure is then attached to the base structure **20z** such that the slots in the fluid chambers layer **20y** are placed over their respective membranes in the base structure **20z** (slot **82a** is placed over membrane **53a/91a** and slot **82b** is placed over membrane **53b**).

Figs. 11H and **11I** exemplify a possible mechanism for quick connection of the MEM device **20** to external systems **35**. In this non-limiting example the docking assembly **87** is designed to receive the MEM device **20** by sliding its projecting lip **20w** inside a connector assembly **83c** mounted on the PCB **83**. As the lip inserted into the connector **83c** it is locked and immobilized by a deflectable clamp **87k**, and electrical connectivity is established between the contact pads **75** and the PCB **83**, allowing the external device to read measurement signals/data from the MEM device and/or provide actuating signals for changing the state of flow regulating elements of the device. This locking system can better hide the contacts of the external electronic when the MEM device is not inserted (*e.g.*, can easily protect the electrical contact of the external electronic from sprinkles of water).

Fig. 12A is an exploded view exemplifying a possible embodiment wherein the MEM device **20** is attached to a printed circuit board **83** having contact pads **75q** and a cavity **83b**. With reference to **Fig. 12B**, showing a sectional view of the fluidic MEM device **20** attached to the PCB **83**. In this non-limiting example the side surface of the MEM device comprising the membrane **53** with a sensing element (not shown) and the contact pads **75** is attached to the surface of the PCB **83**. In order to permit deflection of membrane **53** the MEM device **20** is attached to the PCB **83** (*e.g.*, by contact bonding **83t**) by placing the deformable membrane **53** over the cavity **83b**.

In some embodiments the MEM device is bonded to a PCB, as exemplified in **Fig. 12** described above *e.g.*, as a standard SMD component. In other possible embodiments SMD components are bonded to the MEM device, as exemplified in **Figs. 13A** to **13C**. In particular, after the metallization process is completed, a polymeric wafer comprising an array of dies of MEM devices **20** (shown in **Fig. 14**) can be seen as PCB where electronic components/circuitries can be attached (*e.g.*, passive components, SMD chips, ASIC, battery, integrated antenna, etc.).

With references to **Figs. 13A** to **13C**, electronic circuitries (*e.g.*, ASICS) **130** may be mechanically connected (*e.g.*, glued) to the MEM device 20 and electrically connected to respective pads **75c** provided on the MEM device **20** *e.g.*, using wire-bonding (the circuitries **130** may be implemented with a power harvesting unit, read-out circuits and/or RF transmitter/receiver). Thereafter, the electronic circuitries **130** may be covered with an insulating layer (*e.g.*, epoxy resin – not shown). In this non-limiting example contact pads **75b** provided in MEM device **20** are used to connect a power source (*e.g.*, battery), in case the circuitries **130** is not implemented as a power harvesting unit. Additional electrical/electronic elements **131** may be also electrically connected (*e.g.*, standard SMD components such as resistors, capacitors, integrated RF antenna, etc.) to the MEM device **20** by means of the contact pads **75a** provided thereon.

Figs. 14A and **14B** show a MEM device **140** configured according to some possible embodiments to measure electrical conductivity of fluid media. With reference to **Fig. 14A**, MEM device **140** generally comprises a base plate **149** and a hollow body **145** constructed over a predefined portion of the base plate **149**. A fluid channel/chamber **145a** provided in the hollow body **145** is accessible for fluid media entry thereinto via a fluid port **145p**. In some embodiments the fluid port **145p** is used as an inlet, and another fluid port (not shown) provide at the other end of the hollow body **145** is used as an outlet.

A portion **149p** of the base plate **149** not occupied by the hollow body **145** is provided with an array of electrical contact pads, each electrically coupled by an electrically conducting line with a respective electrode disposed inside the fluid channel/chamber **145a**. In some embodiment two contacts, and two respective electrodes are used for measuring electrical conductivity of the fluid in the channel/chamber **145a**. In this non-limiting example four contact pads, **141**, **142**, **143** and **144**, are provided on the uncovered portion **149p** of the plate **149**, and four conducting lines **141a**, **142a**, **143a** and **144a**, are respectively used to connect each contact pad to a respective electrode **141c**, **142c**, **143c** and **144c**, inside the chamber/channel **145a**. In this configuration the contact pads **141**, **142**, **143** and **144**, are used to connect the MEM device to **140** to an external device (*e.g.*, control unit), and the respective electrode **141c**, **142c**, **143c** and **144c**, in direct contact with fluid media in the chamber/channel **145a** are used to measure electrical conductivity of the fluid.

Referring now to **Fig. 14B** showing the base portion/plate **149** of the device **140**, without the hollow body **145**, the electrical conductivity of the fluid inside the chamber/channel may be measured by applying an alternating current (AC) **I** between the outer electrodes **144c** and **141c** (being closer to the lateral sides of the device) and at the same time measuring the electrical voltage **V** obtained over the inner electrodes **143c** and **142c** (located between the outer electrodes). The AC current **I** passing through the fluid (shown by dotted-dashed line) and the measured voltage **V** can be then used to calculate the electrical conductance **G** based on the equality **G** = **I** / **V**. The conductivity *c* can be then calculated based on the cell constant K as follows: *c* = K*G. The cell constant K depends from geometric parameters of the channel/chamber **145a** and of the electrodes, and it can be either calculated or calibrated. Because the conductivity is temperature dependent the temperature sensor can be used from the external control to compensate temperature effects.

In multilayered MEM device construction approaches exemplified in **Figs. 11A** to **11G** the attachment (*e.g.*, welding) between the different layers and the base structure can be carried out at die level or at wafer level**. Figs. 15A** and **15B** demonstrates a possible manufacture of the MEM device in a rectangular wafer **100** comprising an array of dies **101** of the MEM devices. As shown in **Fig. 15B**, dies of MEM device **101** adjacently located in the wafer **100** may be connected to each other by connecting pins **102** (or by connection layers).

Fig. 15C shows a wafer **100** according to possible embodiments comprising electrical/electronic elements (*e.g.*, SMD) electrically connected to the dies **101** at wafer level. As seen, each die **101** in the wafer **100** comprises a small MEM device serving a PCB with integrated sensing elements and control capabilities and connections to external fluid supply/delivery systems.

Figs. 15D and **15E** show a circular wafer configuration **110** each comprising an array of dies **101** of the MEM devices. As seen in **Fig. 15E**, alignment structures **111** may be formed in the wafer **110** for facilitating automated mass production fabrication process.

Fig. 15F demonstrates a fabrication technique of a stack **118** of wafers **110**, each comprising an array of dies **101** of the MEM devices. The stack **118** is held in a stack holder **113** adapted to receive the wafers in slots. In this non-limiting example, the wafer stack **118** and the holder **113** are built together within the same manufacture process employing any suitable production technique, such as 3D printing. This production technique can thus provide a more efficient and time saving manufacture process. In addition, as the wafer stack **118** and its holder **113** are fabricated as one unit they can be transported easily and without additional staking operations. In some embodiments the stack holder **113** comprises one or more protection layers for the first and last wafers **110** in the stack.

As described hereinabove and shown in the associated Figs., the present invention provides structures and manufacture techniques of fluid MEM device usable for monitoring and regulating flow of a fluid media. While particular embodiments of the invention have been described, it will be understood, however, that the invention is not limited thereto, since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. As will be appreciated by the skilled person, the invention can be carried out in a great variety of ways, employing more than one technique from those described above, all without exceeding the scope of the invention.

CLAIMS

1. A device for monitoring fluid media comprising:

a base element having at least one fluid port and at least one cavity or fluid flow path fluidly coupled to said at least one fluid port for enabling fluid exchange of fluid media therewith, said base element being a monolithic unit made from a certain type of material;

at least one sensing element associated with said cavity or fluid flow path and configured and operable for measuring at least one property or condition of fluid media introduced thereinto and generate measurement data or signals indicative thereof; and

electrical contacts disposed on said base element of the device and electrically coupled to said at least one sensing element.

2. The device according to claim 1 wherein the sensing element comprises two or more electrodes disposed inside the cavity or fluid flow path configured and operable to measure electrical conductivity of the fluid media.

3. The device according to claim 2 wherein the sensing element comprises a first pair of spaced apart electrodes for flowing a predefined electrical current through the cavity or fluid flow path when filled with the fluid media, and a second pair of spaced apart electrodes for measuring an electrical voltage induced by said predefined electrical current.

4. The device of any one of the preceding claims comprising at least one membrane associated with the cavity or fluid flow path and configured and operable to elastically deform responsive to pressure conditions inside said cavity or fluid flow path.

5. The device of claim 4 wherein the at least one membrane is made from the same material from which the base element is made.

6. The device of claim 4 or 5 wherein the at least one sensing element comprises a transducing element disposed on at least one side of the membrane and being

configured and operable to generate the measurement data or signals responsive to the pressure conditions.

7. The device of claim 6 wherein the at least one transducing element comprises electrically conducting lines deposited on the membrane and forming a plurality of adjacently located predetermined patterns comprising at least one of rectangular-wave pattern, zigzag-like wavy pattern, and arc-shaped pattern, said patterns configured to maximize a length of the electrically conducting lines deposited on the membrane.

8. The device of any one of the preceding claims wherein the fluid flow path comprises a constriction, and wherein least one membrane of the device is associated with said constriction and being configured and operable to elastically deform responsive to pressure conditions inside it.

9. The device of claim 8 comprising at least one membrane in a section of the fluid flow path not including the constriction.

10. The device of claim 8 or 9 comprising at least one membrane coupled to the constriction, and actuating means coupled to said membrane and configured and operable to controllably deform said membrane to thereby regulate fluid passage through the constriction.

11. The device of any one of the preceding claims comprising at least one transducing element disposed on a surface area of the base element of the device not affected by the deformations of the at least one membrane.

12. The device of claim 11 wherein at least one of the transducing elements disposed on a surface area of the base element not affected by the deformations of the at least one membrane is used as a temperature sensor.

13. The device of claim 11 or 12 wherein the transducing elements are configured and operable to implement Wheatstone bridge circuitry.

14. The device of any one of the preceding claims comprising at least one electrical circuitry mounted on the base element of the device and electrically coupled to one or more of the electrical contacts.

15. The device of claim 14 wherein the electrical circuitry comprises a control unit configured and operable to receive and process the measurement data generated by the at least one sensing element and generate corresponding control signals for regulating flow of the fluid media.

16. The device of any one of claims 4 to 15 wherein the device has a layered structure formed on the base element, and wherein the device comprises:

a fluid path layer having the cavity or fluid flow path and configured and operable to sealably connect to the base element and establish fluid communication between the at least one fluid port and the cavity or fluid flow path; and

an encapsulating layer having the at least one membrane and configured and operable to sealably connect the fluid path layer and align said at least one membrane with the cavity or fluid flow path to thereby enable the at least one membrane to interact with fluid media when introduced into said cavity or fluid flow path.

17. The device of claim 16 comprising an intermediate layer disposed between the flow path and encapsulating layers and comprising at least one slot, each slot being aligned with a membrane of the encapsulating layer and configured to receive fluid media from the cavity or fluid flow path of the flow path layer.

18. The device of any one of claims 4 to 15 wherein the device has a layered structure formed on the base element, said base element comprising the at least one membrane, and wherein the device comprises:

a transition layer, having at least one fluid passage, each fluid passage being associated with a respective fluid port of the base element, and at least one slot, each slot being associated with a membrane of the base element, said transition layer configured and operable to sealably connect to the base element and fluidly communicate each fluid passage with its respective fluid port and align each slot with its respective membrane; and an encapsulating layer having the cavity or fluid flow path and configured and operable to sealably connect to the transition layer and fluidly communicate between the cavity or fluid flow path and the at least one fluid passage, thereby enabling passage of fluid media into the cavity or fluid flow path from the at least one fluid port in the base section via its respective fluid passage in the transition layer, and align the cavity or fluid flow path with the at least one slot, to thereby enable each membrane to interact with fluid media introduced into its respective slot via the cavity or fluid flow path.

19. The device of claim 18 comprising a fluid flow path in the encapsulating layer, said fluid flow path having a constriction, and wherein at least one slot of the transition layer is in fluid communication with said constriction to enable its respective membrane to interact with fluid media introduced thereinto, and at least one other slot is in fluid communication with a non-constricted section of the fluid flow path to enable its respective membrane to interact with fluid media introduced thereinto.

20. The device of claim 19 comprising a fluid passage in the base element communicating between constricted and non-constricted regions of the fluid flow path, said fluid passage comprising membrane configured and operable to an elastically deform responsive to pressure differences between said constricted and non-constricted regions of the fluid flow path, said membrane having a transducing element configured and operable to generate measurement data or signals responsive to said deformations.

21. The device of any one of claims 18 to 20 wherein the encapsulating layer comprises at least one elastically deformable membrane having a flow regulating element configured and operable to engage a fluid passage of the transition layer to thereby alter fluid passage therethrough.

22. The device of any one of claims 18 to 21 having at lest one transduction element on the encapsulating layer.

23. The device of any one of the preceding claims configured and operable for mounting on a PCB while establishing electrical contact with at least some of the electrical contacts of the device.

24. The device of claim 23 wherein the PCB comprises a cavity, and wherein at least one of the membranes of the device being adapted to deform towards or away said cavity of the PCB.

25. The device of any one of the preceding claims comprising quick connection means configured and operable to secure the device to an external device while establishing electrical connectivity therewith.

26. A fluid delivery system comprising at least one monitoring device of claim 15, at least one fluid source for supplying the fluid media to the at least one monitoring device, at least one fluid dispensing device for receiving fluid media from either the at least one monitoring device or the fluid source.

27. A fluid delivery system comprising at least one monitoring device of any one of claims 1 to 25, at least one fluid source for supplying the fluid media to the monitoring device, at least one fluid dispensing device for receiving fluid media from either the at least one monitoring device or the fluid source, and a control unit coupled to the monitoring device and configured to receive and process the measurement data generated by the sensing element.

28. A fluid delivery system according to claim 26 or 27 wherein the monitoring devices are connected to each other in series via their fluid ports.

29. A fluid delivery system according to claim 22 or 23 wherein the monitoring devices are connected via their fluid ports to a fluid delivery line connecting between the fluid source and the fluid dispensing device.

30. A method to construct a flow control device comprising:

constructing from a specific material a monolithic base structure comprising at least one fluid port and a cavity of a fluid flow path in fluid communication with the at least one fluid port for enabling exchange of fluid media therewith;

constructing at least one sensing element associated with a cavity or fluid flow path of the device and configured and operable for measuring at least one property or condition of fluid media introduced thereinto and generating measurement data or signals indicative thereof; and

forming on said device electrically conducting patterns for providing electrical connection to said at least one sensing element.

31. The method of claim 30 wherein constructing of the base structure comprises forming at least one membrane associated with the cavity or fluid flow path and configured and operable to elastically deform responsive to pressure conditions inside said cavity or fluid flow path, and wherein the at least one sensing element is at least partially structured on the membrane.

32. The method of claim 30 or 31 wherein the constructing of the base structure comprises forming a constriction in the cavity or fluid flow path and forming at least one elastically deformable membrane associated with said constriction, and wherein at least one membrane associated with the constriction comprises a sensing element for measuring fluid pressure conditions in the constriction or mechanically coupled to an actuator for altering fluid passage through the constriction.

33. The method of claim 30 comprising:

constructing a flow path layer comprising the cavity or fluid flow path;

constructing an encapsulating layer comprising at least one elastically deformable membrane, wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the encapsulating layer;

assembling a layered structures by sealably attaching the encapsulating layer to the flow path layer such that at least one membrane of the encapsulating layer is disposed over the cavity or fluid flow path of the flow path layer; and

sealably attaching the layered assembly to the base structure such that fluid communication is established between the at least one fluid port of the base structure and the cavity or fluid flow path of the flow path layer.

34. The method of claim 30 comprising:

constructing a flow path layer comprising the cavity or fluid flow path;

constructing an intermediate layer comprising at least one slot;

constructing an encapsulating layer comprising at least one elastically deformable membrane, wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the encapsulating layer;

assembling a layered structure by sealably attaching the encapsulating layer to the intermediate layer such that at least one membrane of the encapsulating layer is disposed over at least one slot of the intermediate layer, and sealably attaching the intermediate layer to the flow path layer such that fluid communication is established between at least one slot of the intermediate layer and the cavity or fluid flow path of the flow path layer; and

sealably attaching the layered assembly to the base structure such that fluid communication is established between the at least one fluid port of the base structure and the cavity or fluid flow path of the flow path layer.

35. The method of claim 30 wherein constructing of the base structure comprises forming at least one membrane in the base structure and wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the base structure, the method further comprising:

constructing a transition layer having at least one fluid passage and at least one slot formed therein;

constructing an encapsulating layer having a cavity or fluid flow path;

assembling a layered structure by sealably attaching the encapsulating layer to the transition layer such that fluid communication is established between the cavity or fluid flow path of the encapsulating layer and at least one fluid passage and at least one slot of the transition layer; and

sealably attaching the layered structure to the base structure such that fluid communication is established between at least one slot of the transition layer and at least one fluid port of the base structure and such that at least one slot of the transition layer is positioned over at least one membrane of the base structure.

36. The method of claim 30 wherein constructing of the base structure comprises forming at least one membrane in the base structure and wherein the at least one sensing element associated with at least one membrane and the electrically conducting patterns are constructed on the base structure, the method further comprising:

constructing a transition layer having at least one fluid passage and at least one slot formed therein;

constructing an encapsulating layer having a cavity or fluid flow path and at least one elastically deformable membrane having a flow regulating element;

assembling a layered structure by sealably attaching the encapsulating layer to the transition layer such that fluid communication is established between the cavity or fluid flow path of the encapsulating layer and at least one fluid passage and at least one slot of the transition layer; and

sealably attaching the layered assembly to the base structure such that fluid communication is established between at least one slot of the transition layer and at least one fluid port of the base structure, at least one slot of the transition layer is positioned over at least one membrane of the base structure, and the flow regulating element of at least one membrane of the encapsulating layer becomes engaged with a fluid passage of the transition layer.

37. The method of any one of claims 35 to 36 wherein the constructing of the encapsulation layer comprises forming the fluid flow path with a constriction, and wherein the assembling of the layered structure comprises establishing fluid communication between the constriction of the encapsulating layer and at least one slot of the transition layer, said at least one slot being associated with one of the membranes in the base structure.

38. The method of claim 37 wherein the constructing of the base structure comprises forming a fluid passage in the base structure for communicating between constricted and non-constricted regions of the fluid flow path via respective slots of the transition layer, said fluid passage comprising membrane configured and operable to elastically deform responsive to pressure differences between said constricted and non-constricted regions of the fluid flow path, said membrane having a transducing element configured and operable to generate measurement data or signals responsive to said deformations.

39. The method of any one of claims 31 to 38 wherein the constructing of the at least one sensing element comprises patterning electrically conducting structures on the at least one membrane.

40. The method of claim 39 wherein the patterning comprises forming at least one resistive element on the membrane configured and operable to change electrical resistance thereof responsive to the deformations of the membrane.

41. The method of claim 40 wherein the patterning comprises forming at least one capacitive element on the membrane configured and operable for changing electrical capacitance thereof responsive to the deformations of the membrane.

42. The method of any one of claims 30 to 41 comprising coating at least some of the electrically conducting patterns with one or more isolating layers.

43. The method of any one of claims 30 to 42 wherein the base structure, or layers of the device, are made from a polymeric material, and wherein electrically conducting patterns of the device are made by deposition of conductive material on the polymeric material.

44. The method of any one of claim 30 to 43 wherein forming at least one of the base structure and one or more of the sealably attached layers, utilizes one of the following techniques: injection molding, 3D printing, micro scale molding, micro machining, nano imprinting, micro imprinting, hot embossing, injection molding, lithography, and laser micromachining.

45. The method of any one of claims 30 to 44 wherein the constructing of the sensing element utilizes one of the following techniques: lithography, evaporation, liftoff, electrodeposition, electroforming, electroplating, electroless deposition and other IC techniques.

46. The method of any one of claims 30 to 45 comprising manufacturing an array of the flow control devices as dies of a wafer in a mass production process.

47. The method of claim 46 wherein the wafer comprises alignment marks to facilitate wafer orientation and the forming of the electrically conducting patterns.

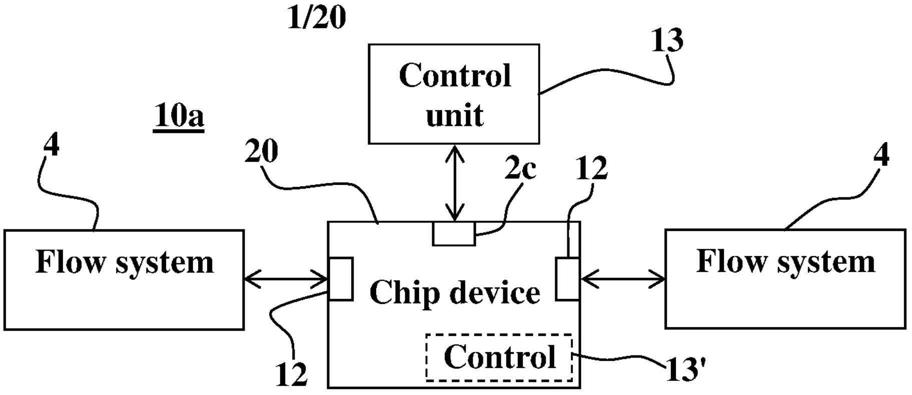
48. The method of any one of claims 46 to 47 comprising sealing the wafer to prevent contamination of the internal flow paths or cavities by non biocompatible materials that may be used during the fabrication process.

49. The method of any one of claims 46 to 48 wherein at least one face of the wafer is made substantially flat for forming the electrically conducting patterns thereon, while keeping the wafer mechanically prepared for wafer dicing.

50. The method of any one of claims claim 46 to 49 comprising manufacturing in the mass production process a wafer stack comprising a plurality of said wafers stack one on top of the other.

51. The method of claim 50 comprising manufacturing in the mass production process a stack holder adapted to hold the wafer stack.

Fig. 1A



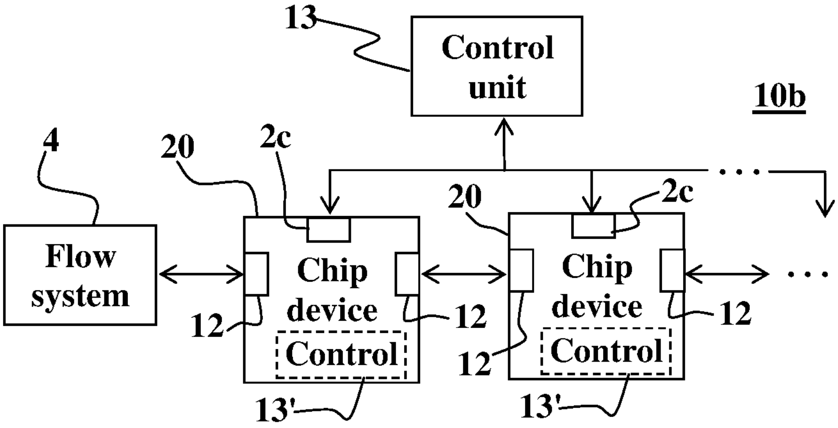
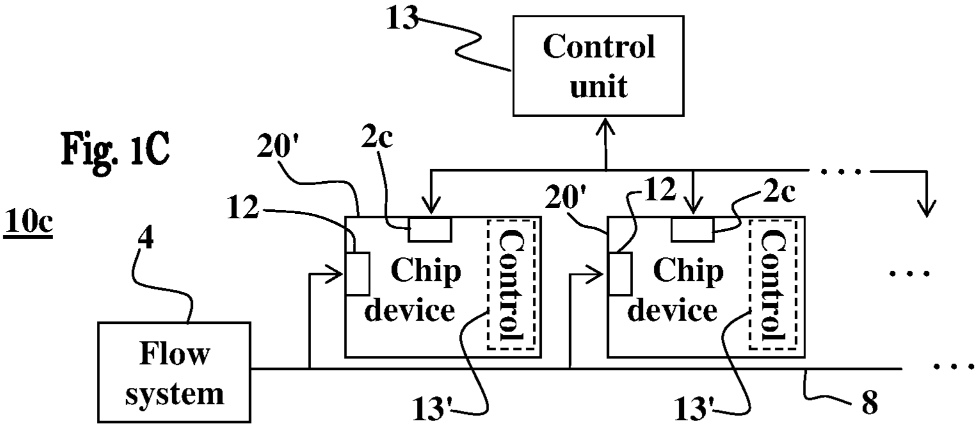


Fig. 1B

Fig. 1C



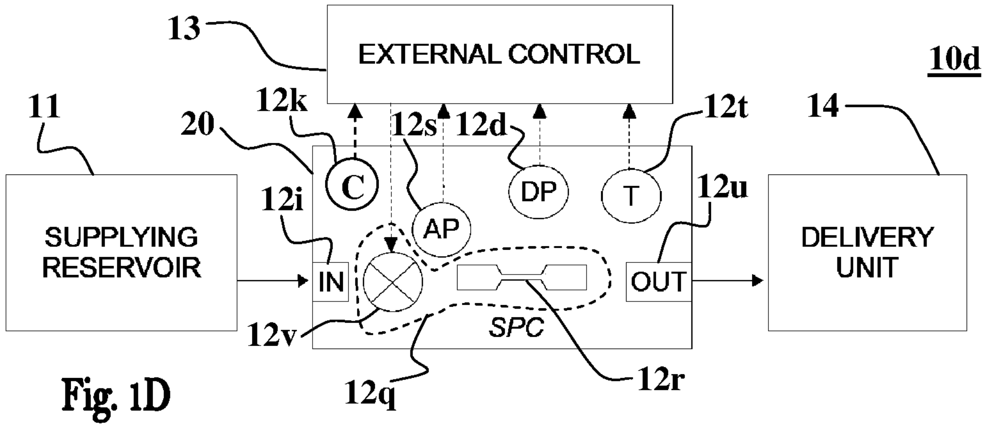


Fig. 1D

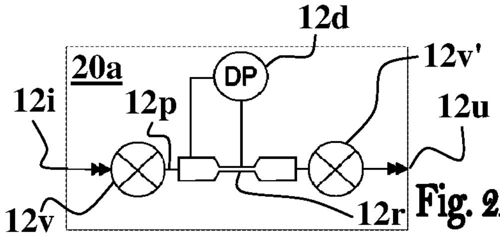


Fig. 2A

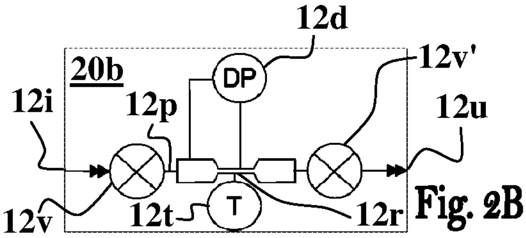


Fig. 2B

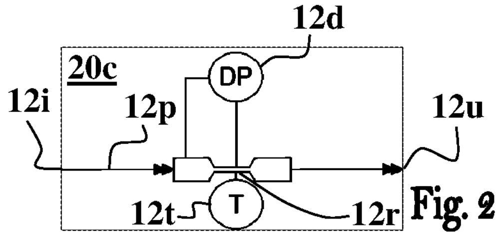


Fig. 2C

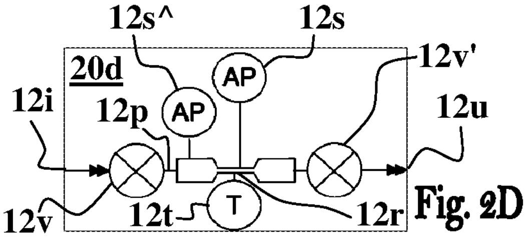


Fig. 2D

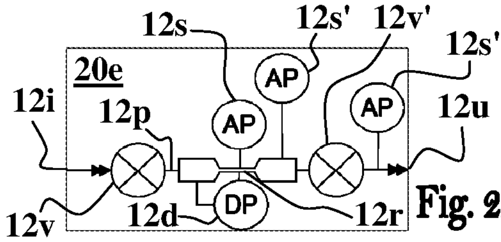


Fig. 2E

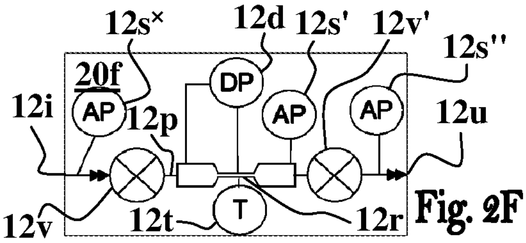


Fig. 2F

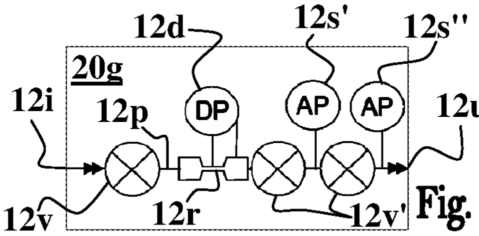


Fig. 2G

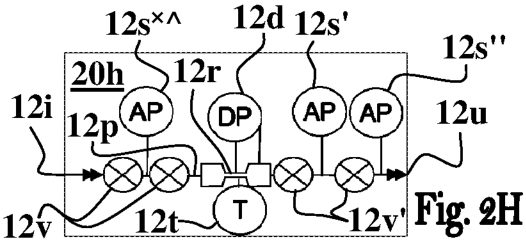


Fig. 2H

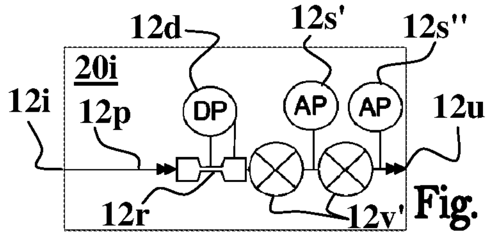


Fig. 2I

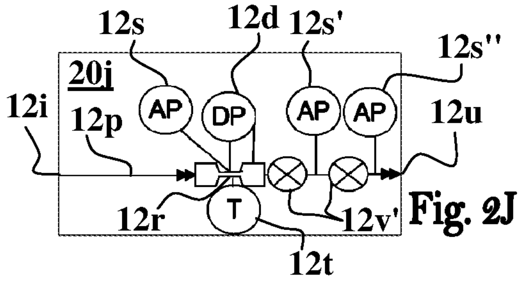


Fig. 2J

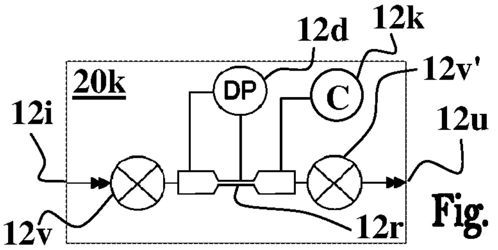


Fig. 2K

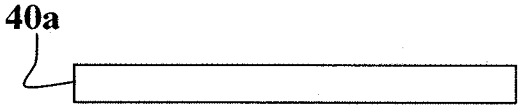


Fig. 3A

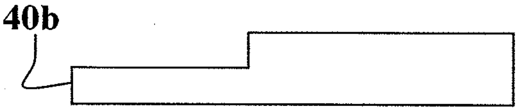


Fig. 3B

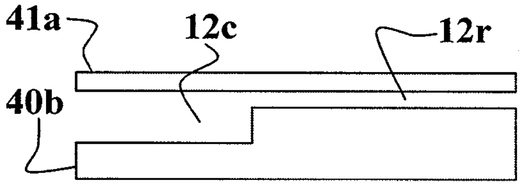


Fig. 3C

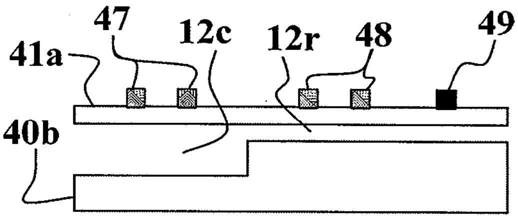


Fig. 3D

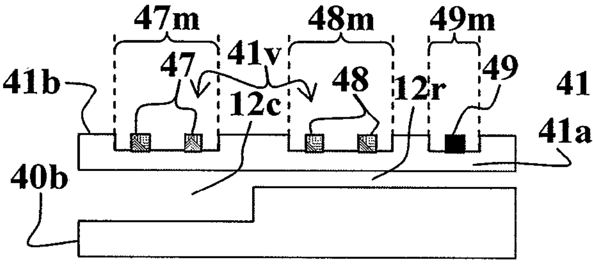


Fig. 3E

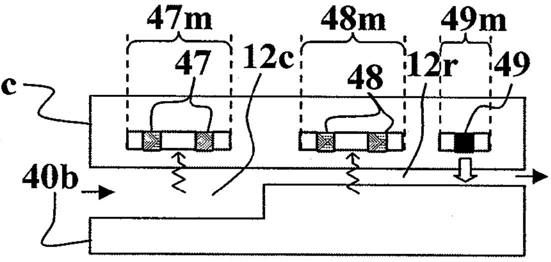


Fig. 3F

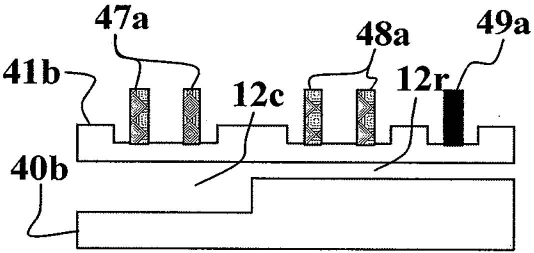


Fig. 3G

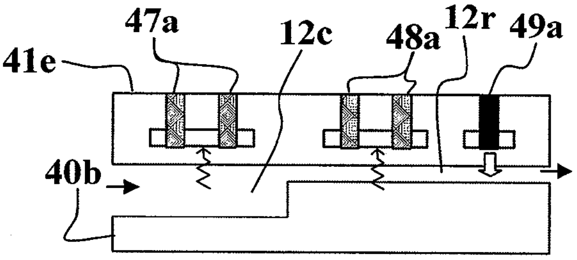


Fig. 3H

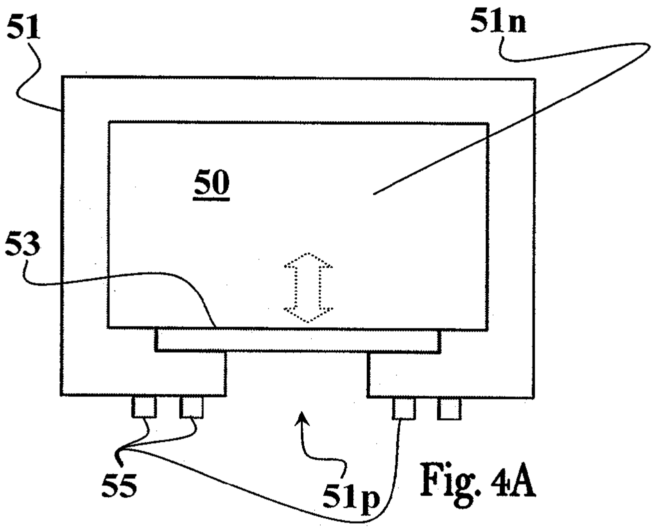


Fig. 4A

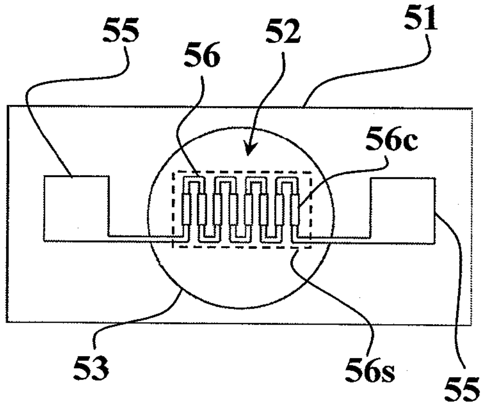


Fig. 4B

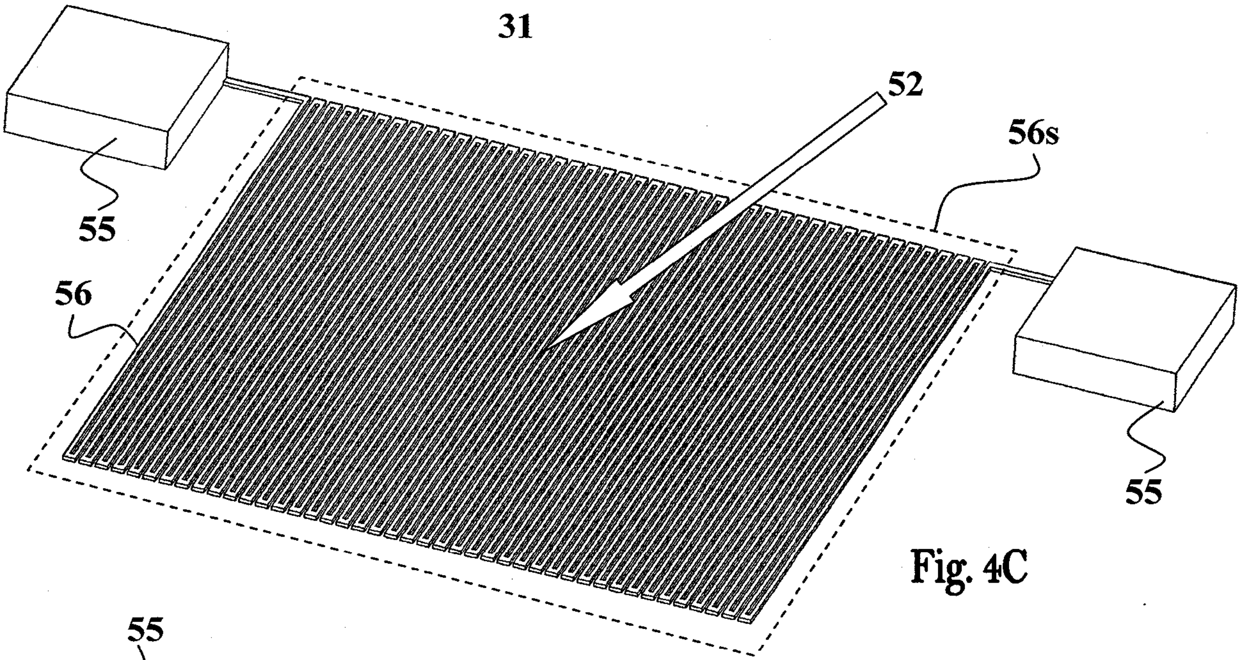


Fig. 4C

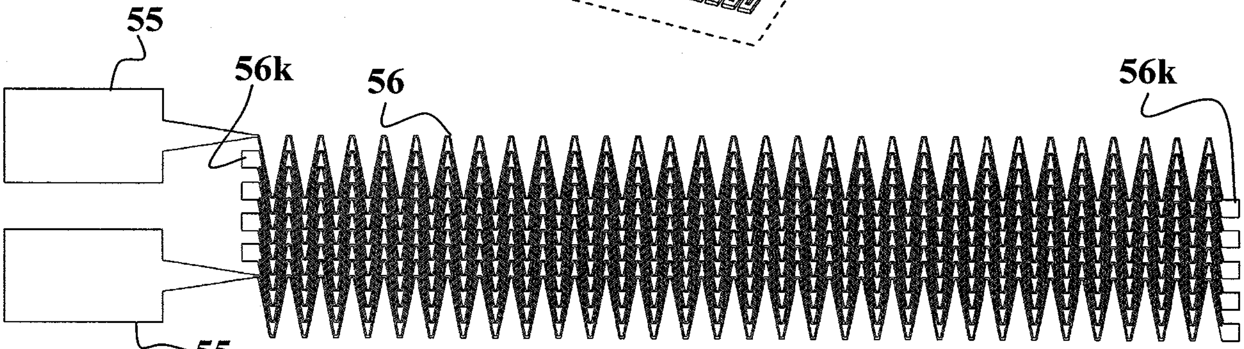


Fig. 4D

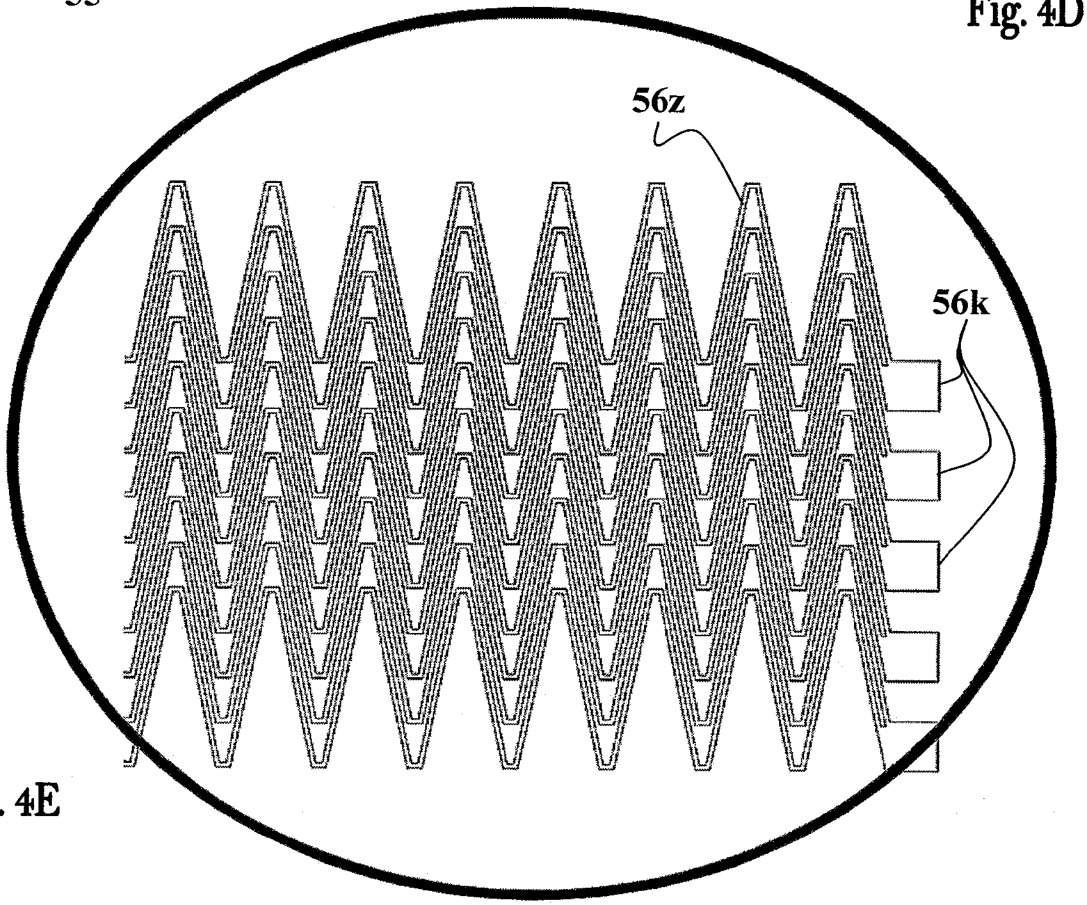


Fig. 4E

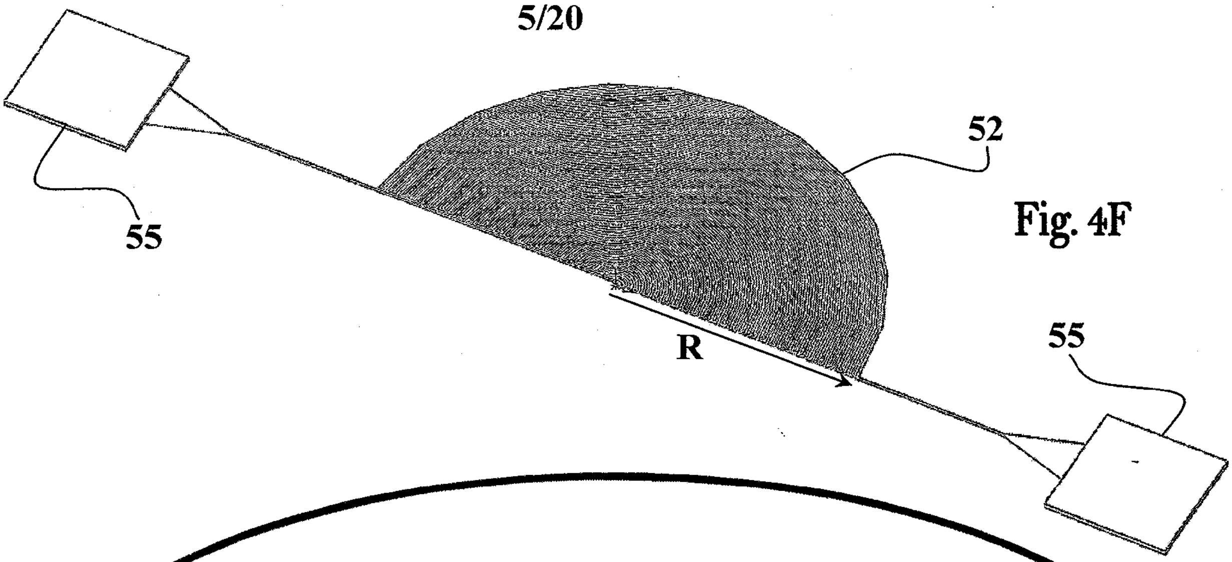


Fig. 4F

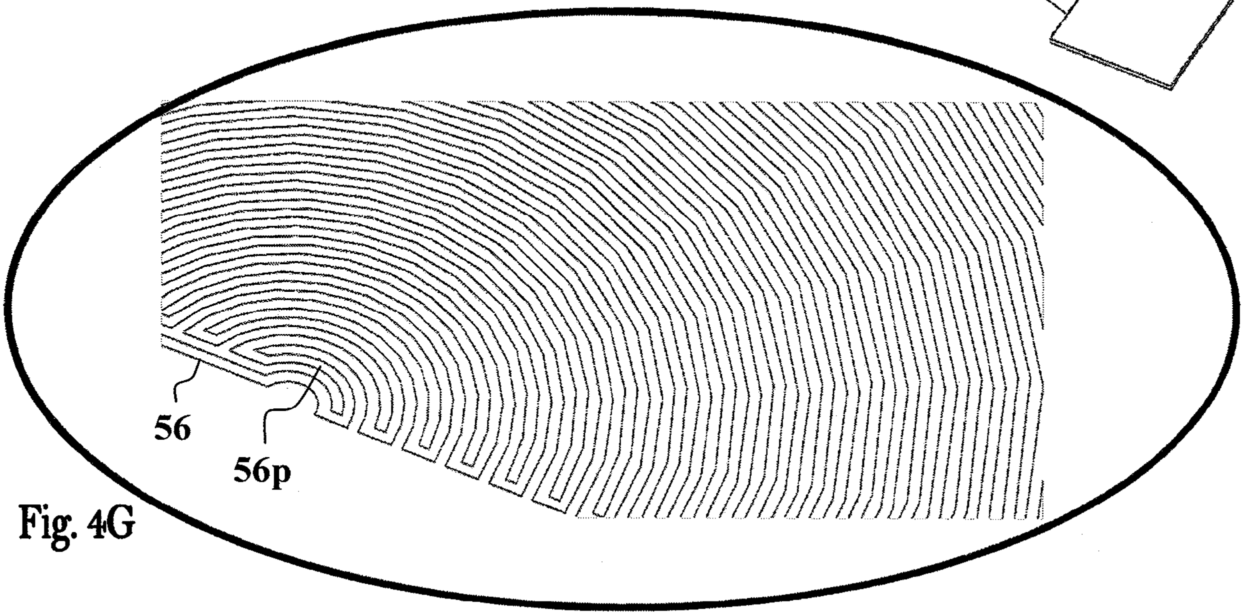


Fig. 4G

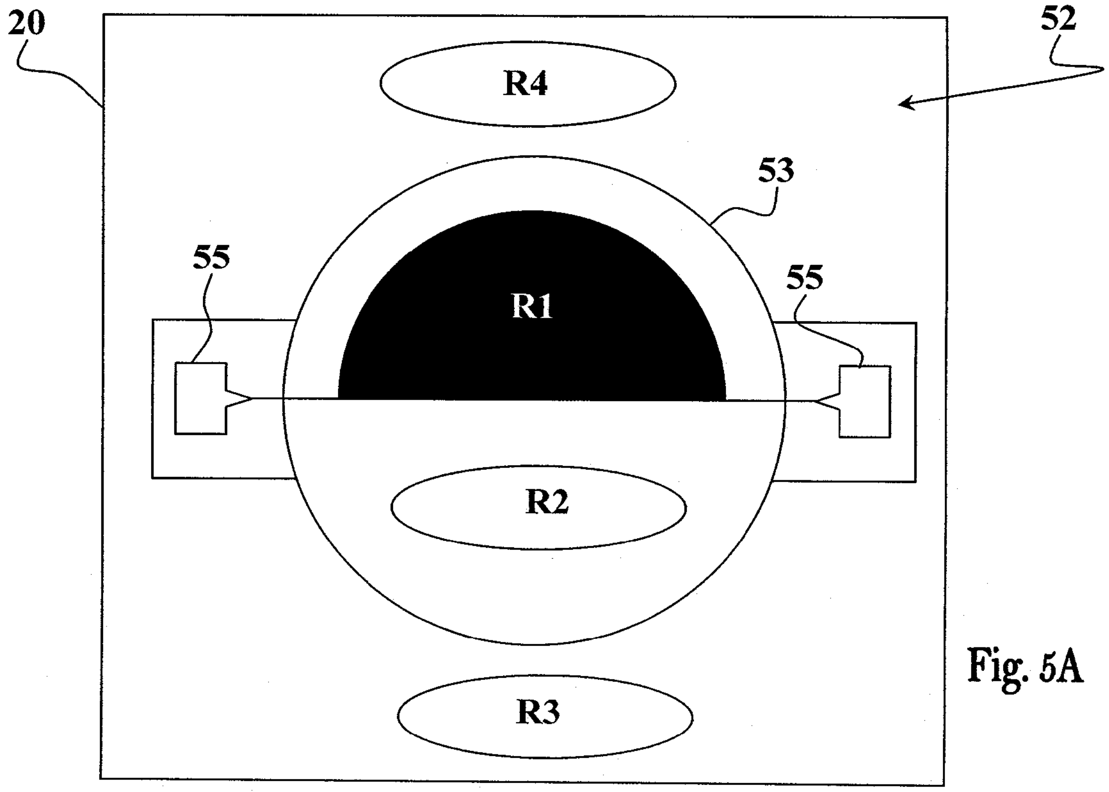


Fig. 5A

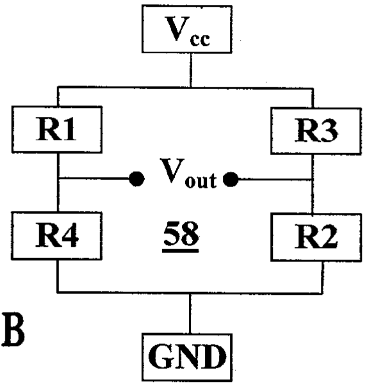


Fig. 5B

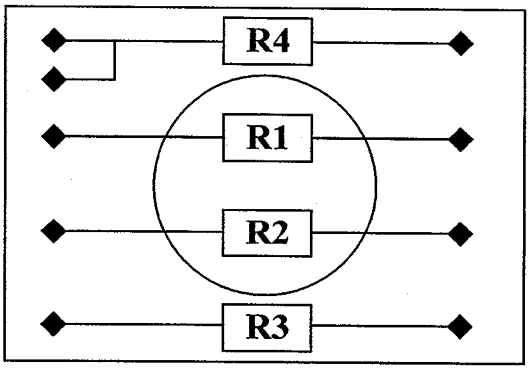


Fig. 5C

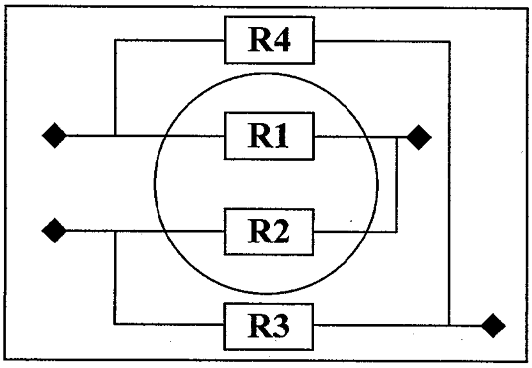


Fig. 5D

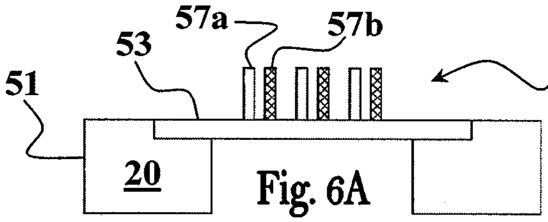


Fig. 6A

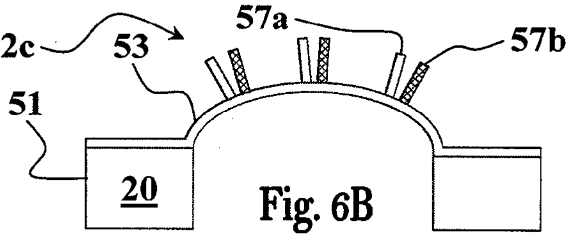


Fig. 6B

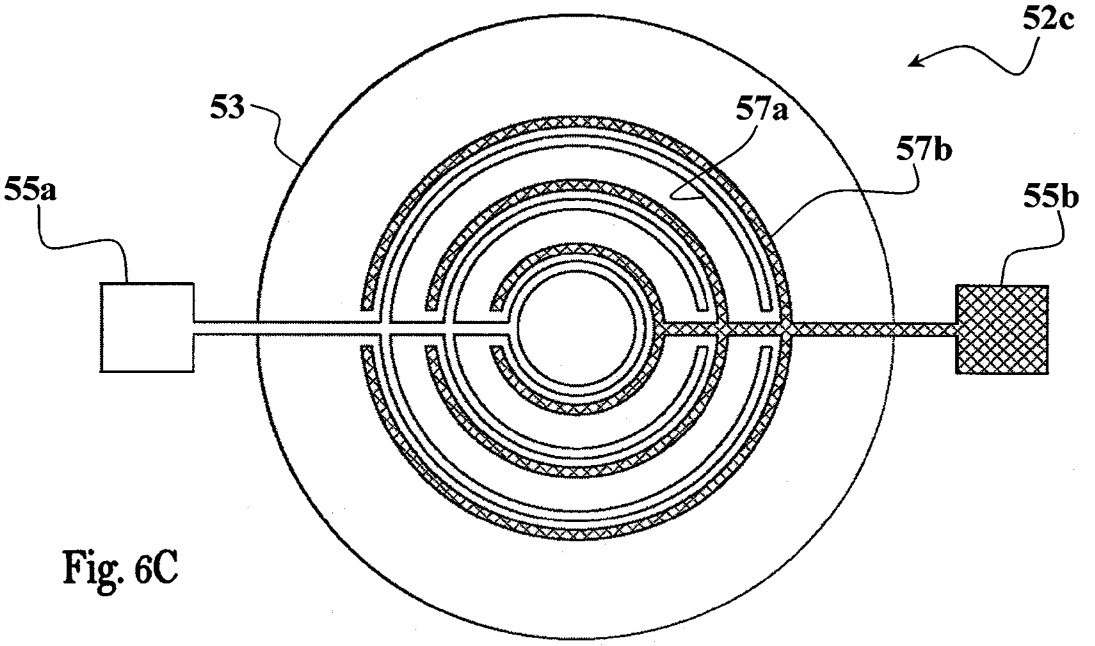


Fig. 6C

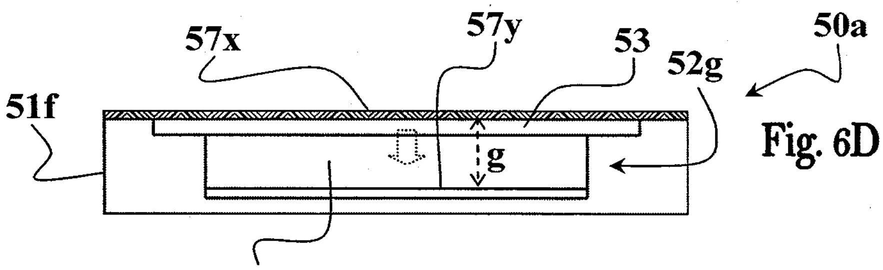


Fig. 6D

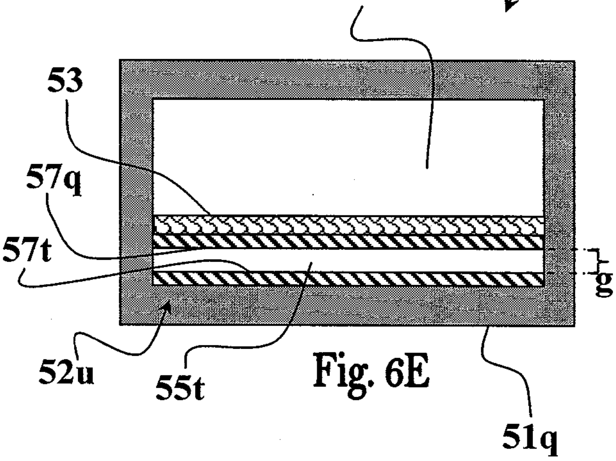


Fig. 6E

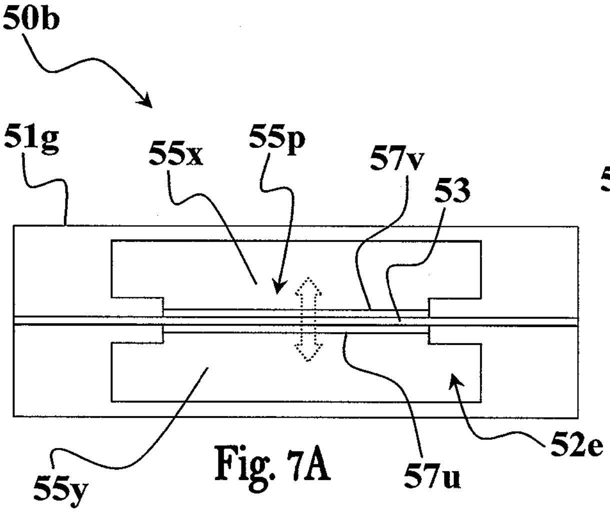


Fig. 7A

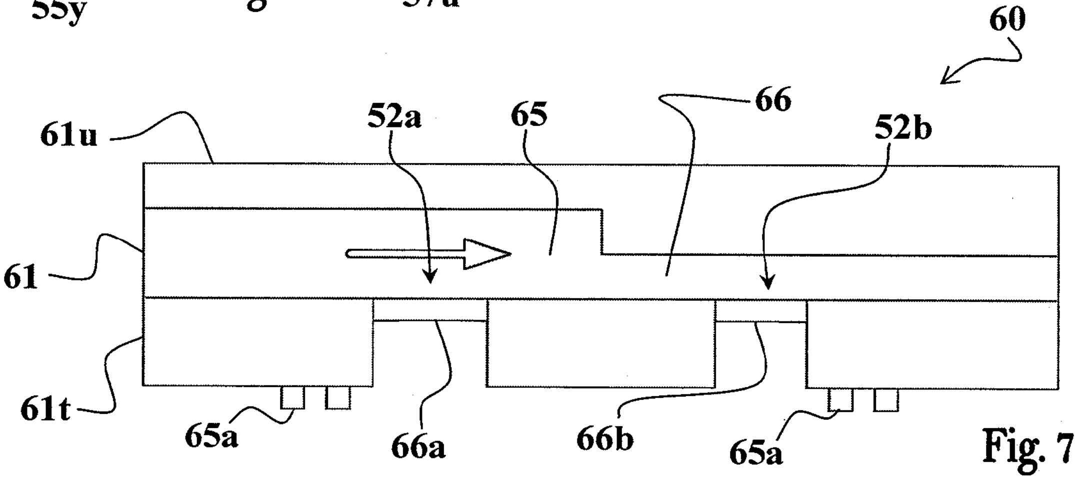


Fig. 7B

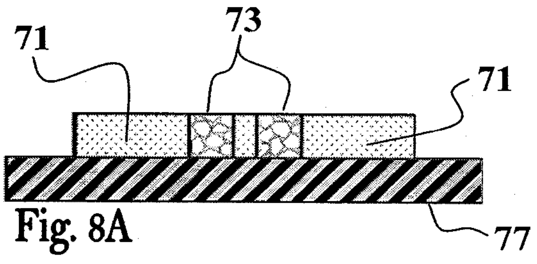


Fig. 8A

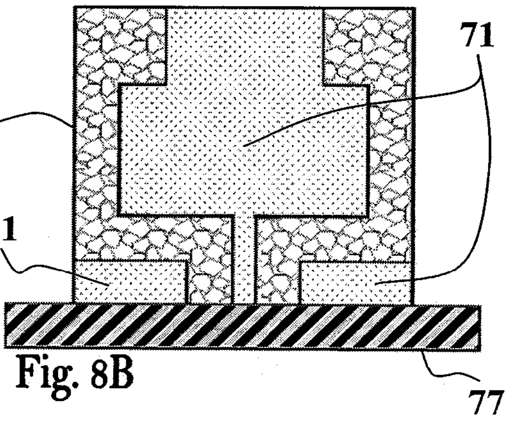


Fig. 8B

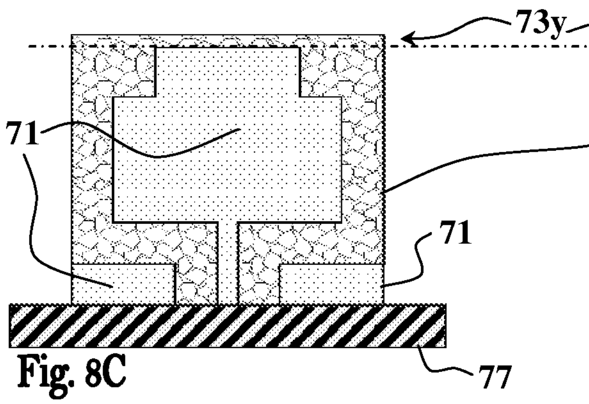


Fig. 8C

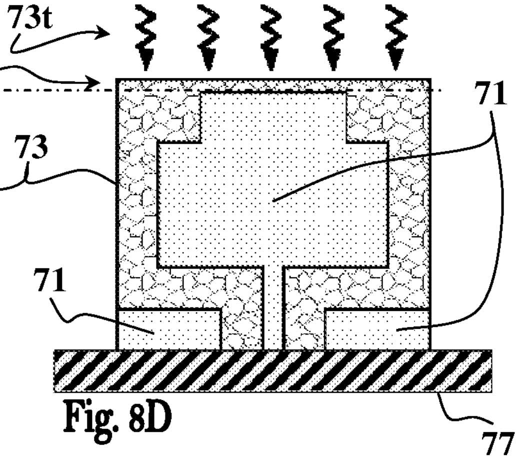


Fig. 8D

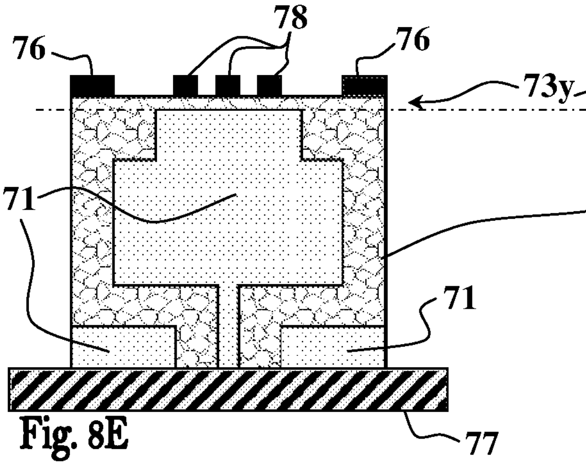


Fig. 8E

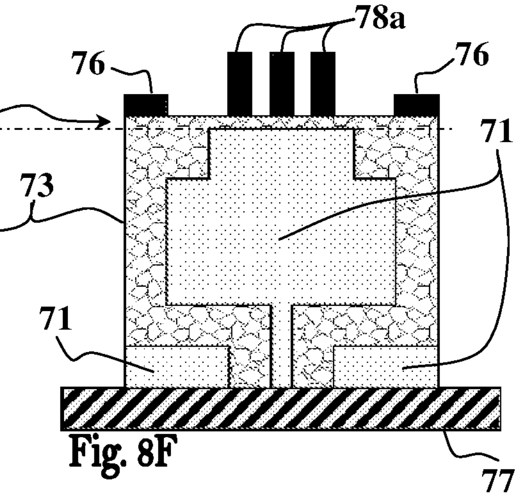


Fig. 8F

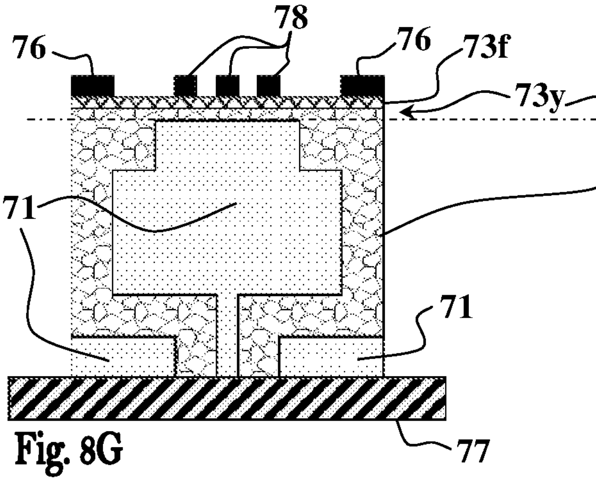


Fig. 8G

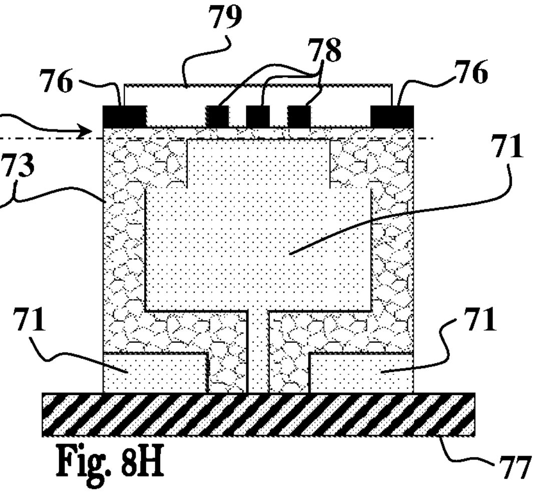


Fig. 8H

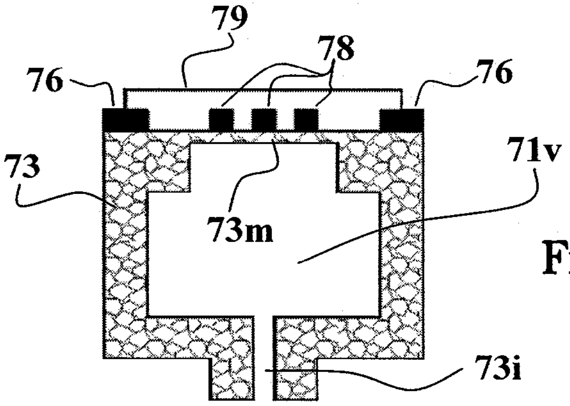


Fig. 8I

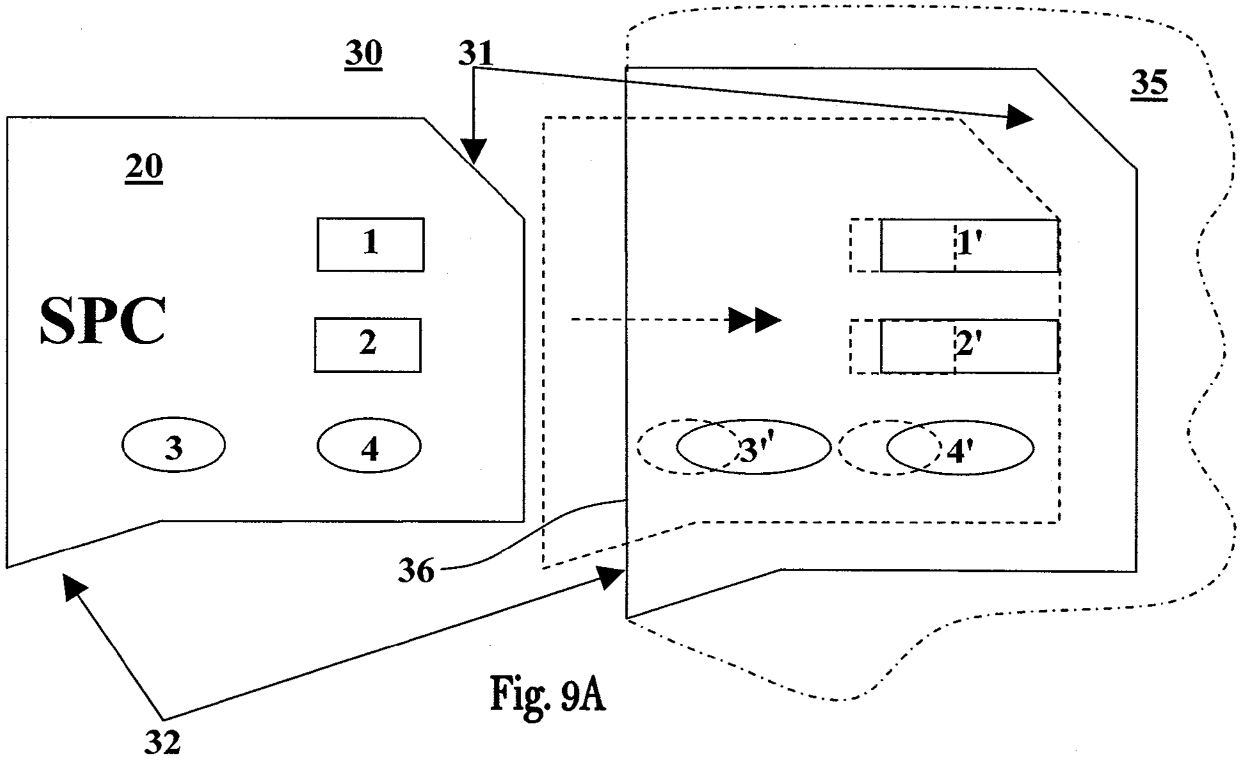


Fig. 9A

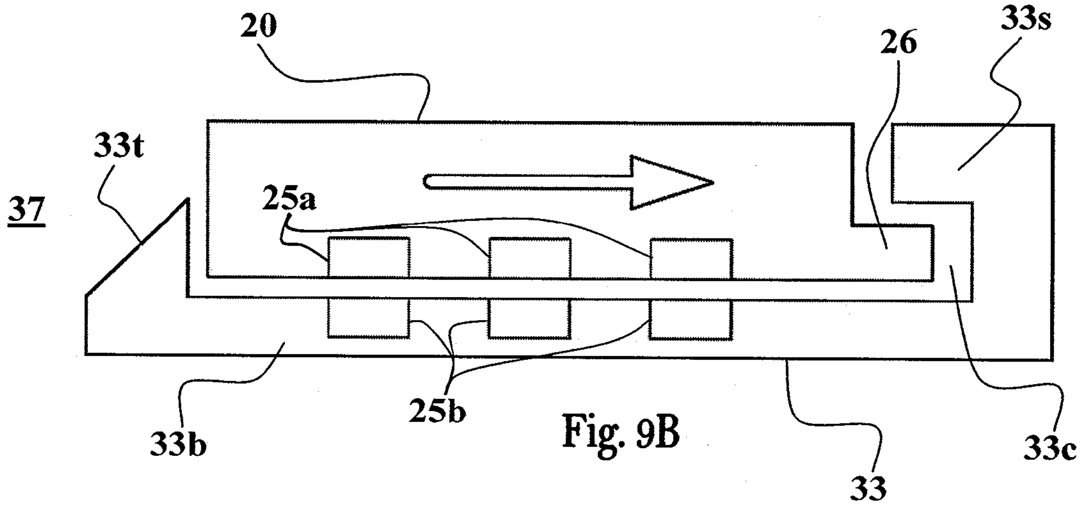


Fig. 9B

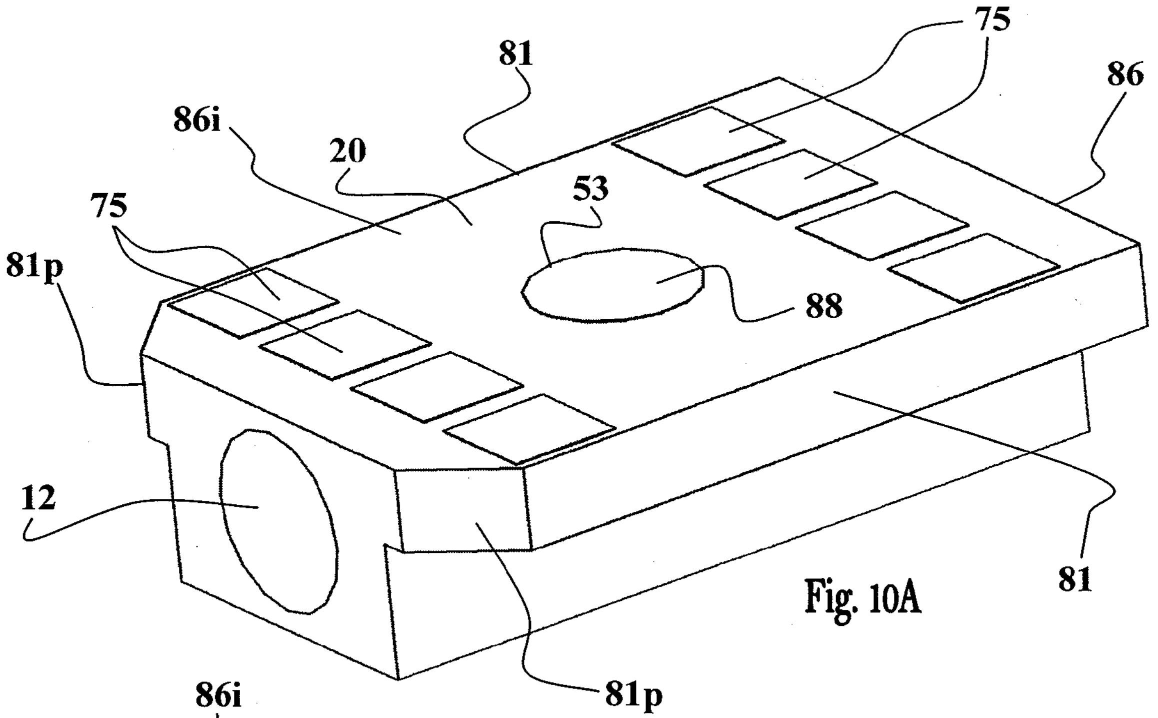


Fig. 10A

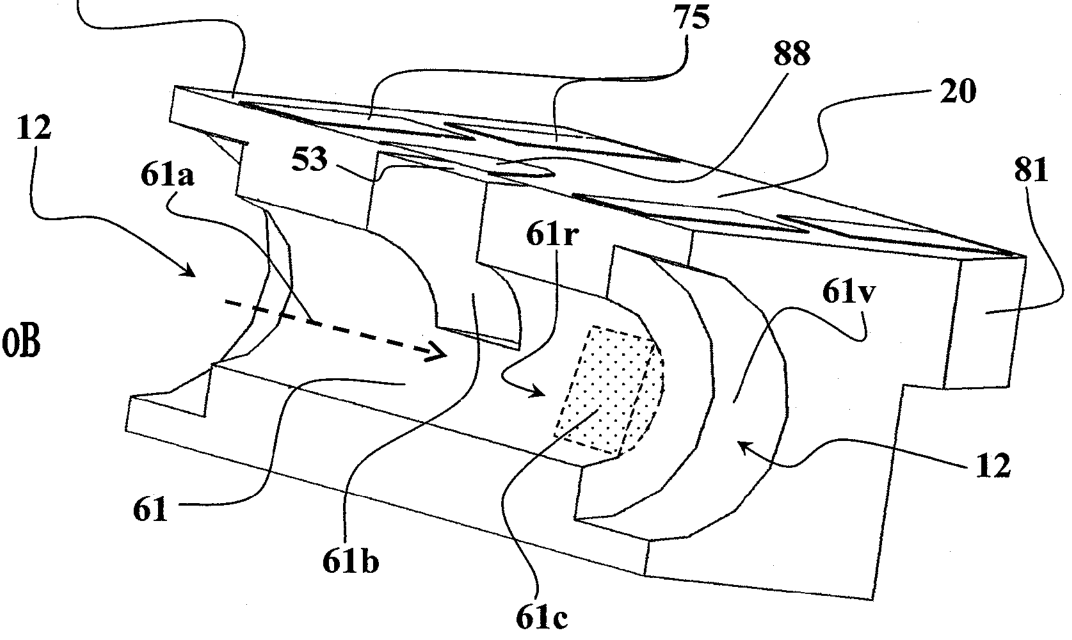


Fig. 10B

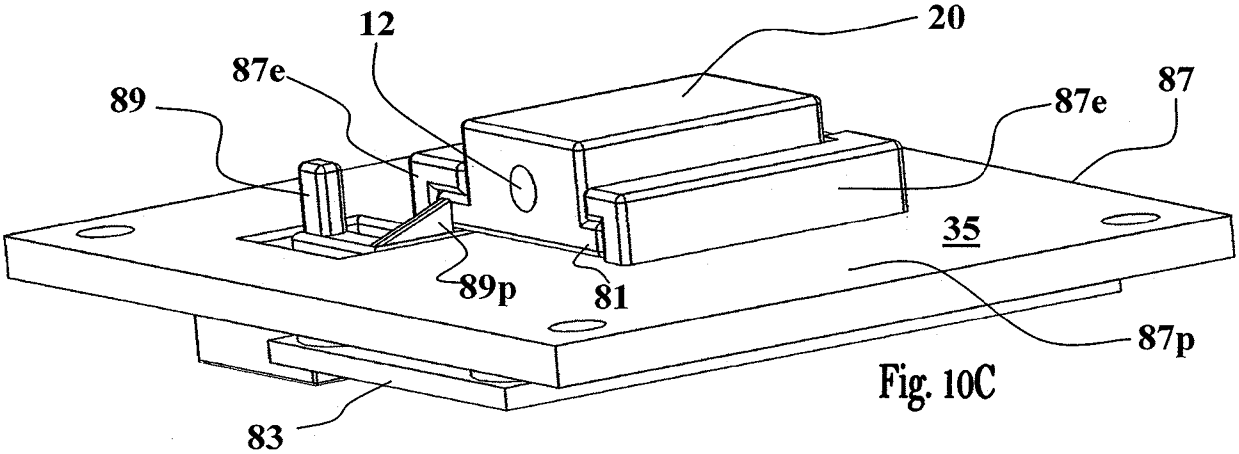


Fig. 10C

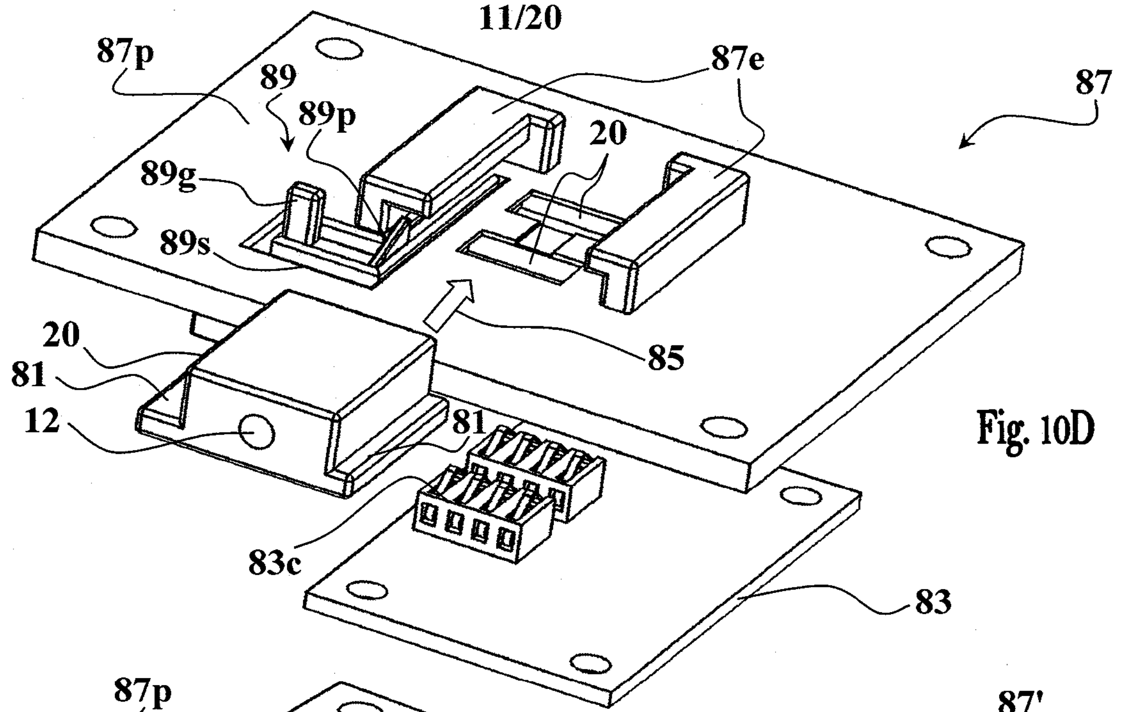
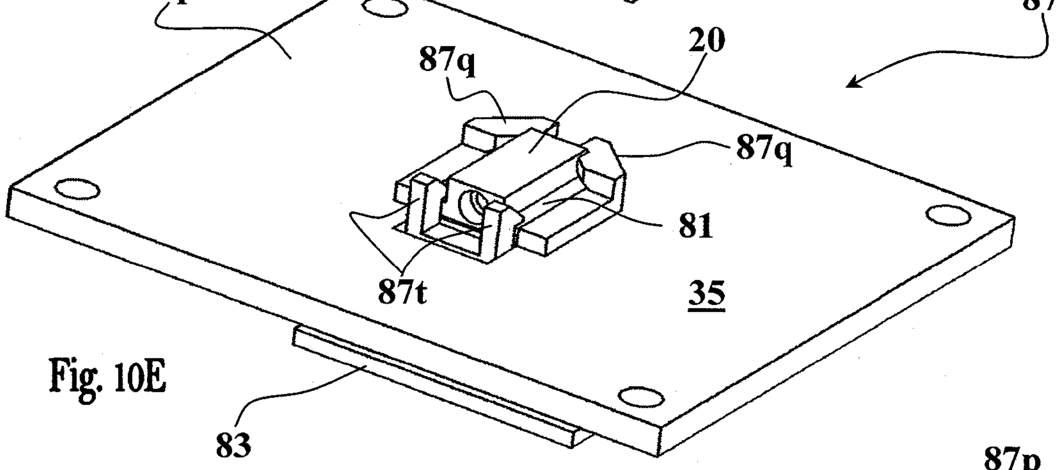


Fig. 10D



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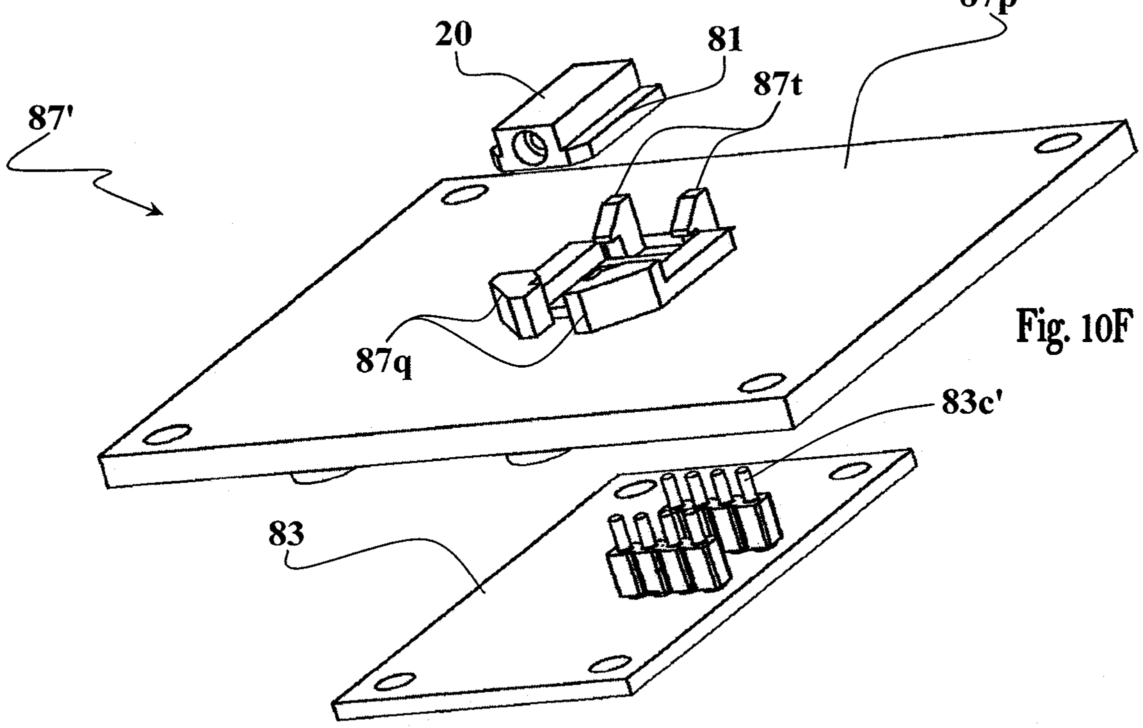

Fig. 10F

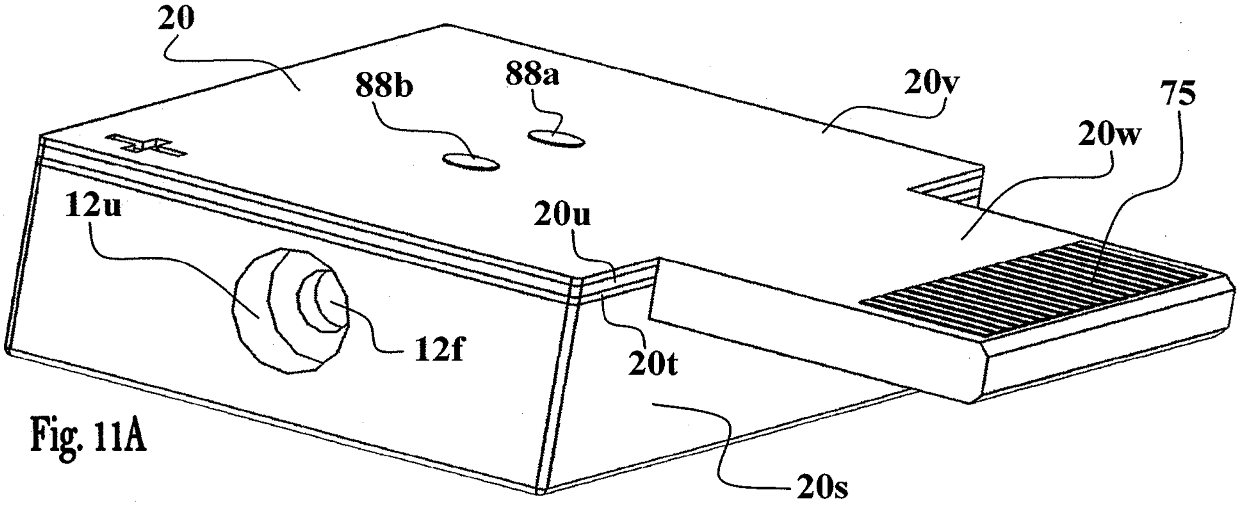

Fig. 11A

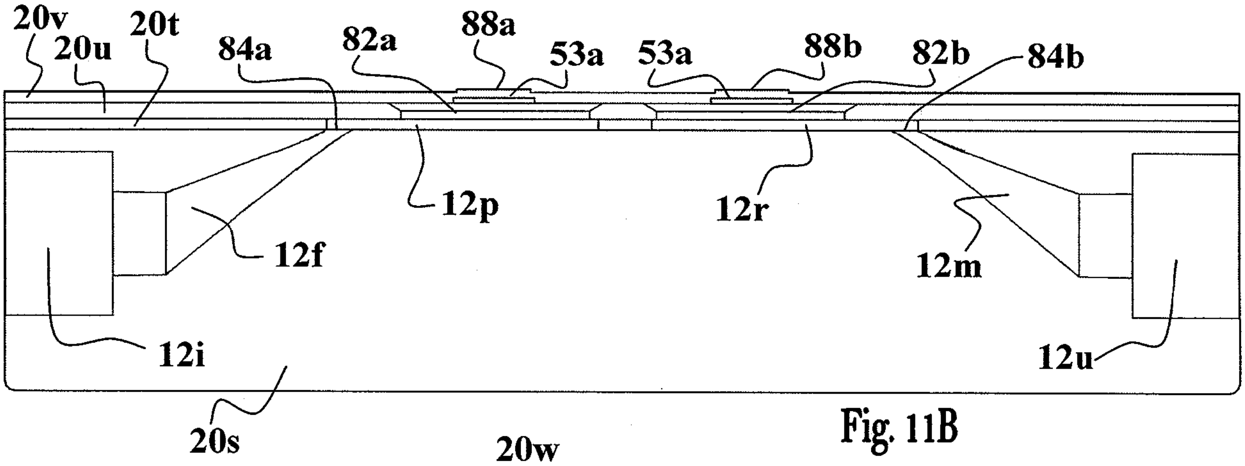

Fig. 11B

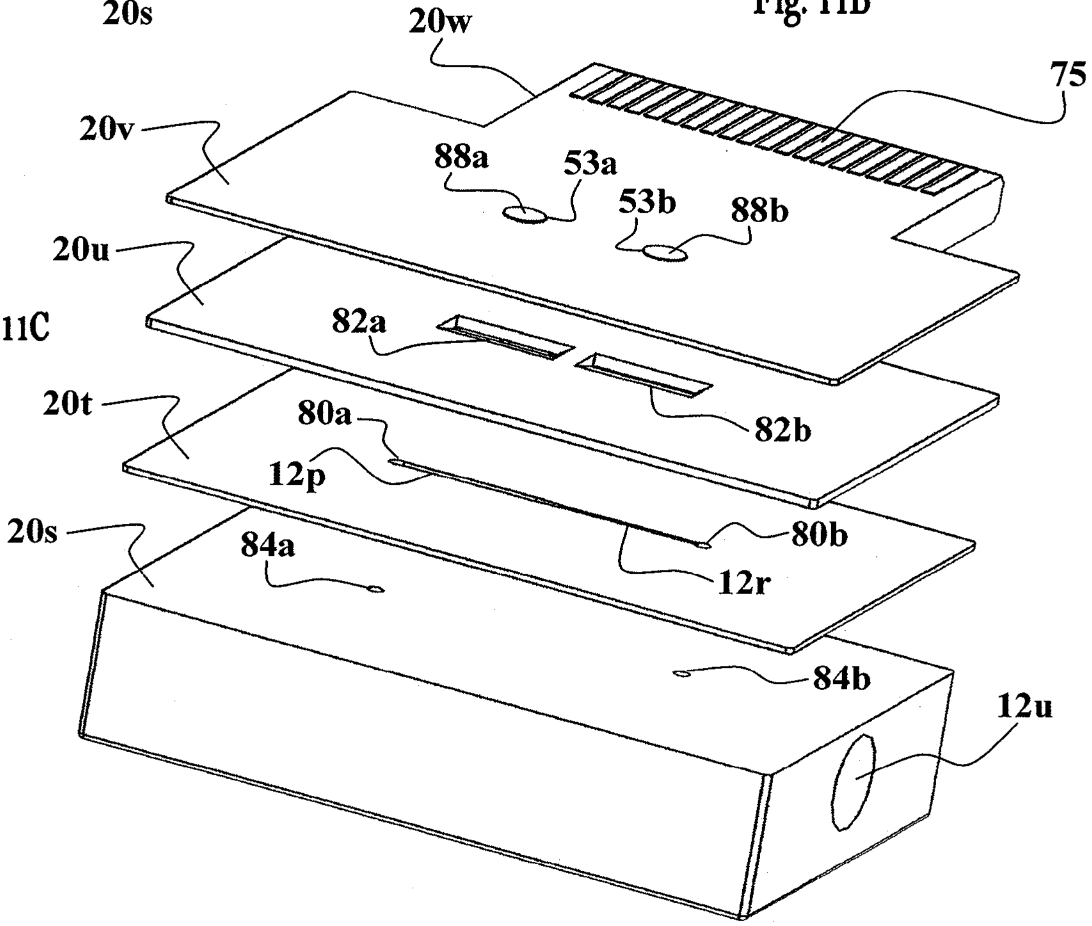

Fig. 11C

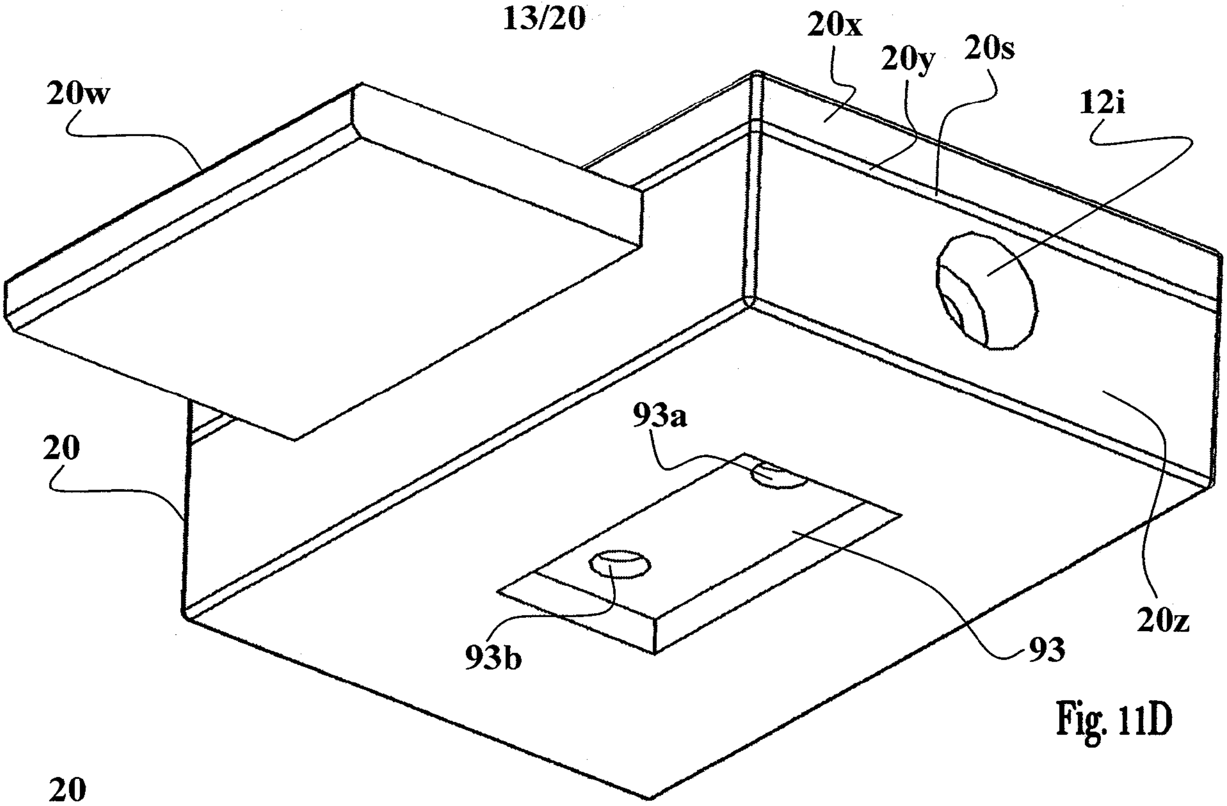

Fig. 11D

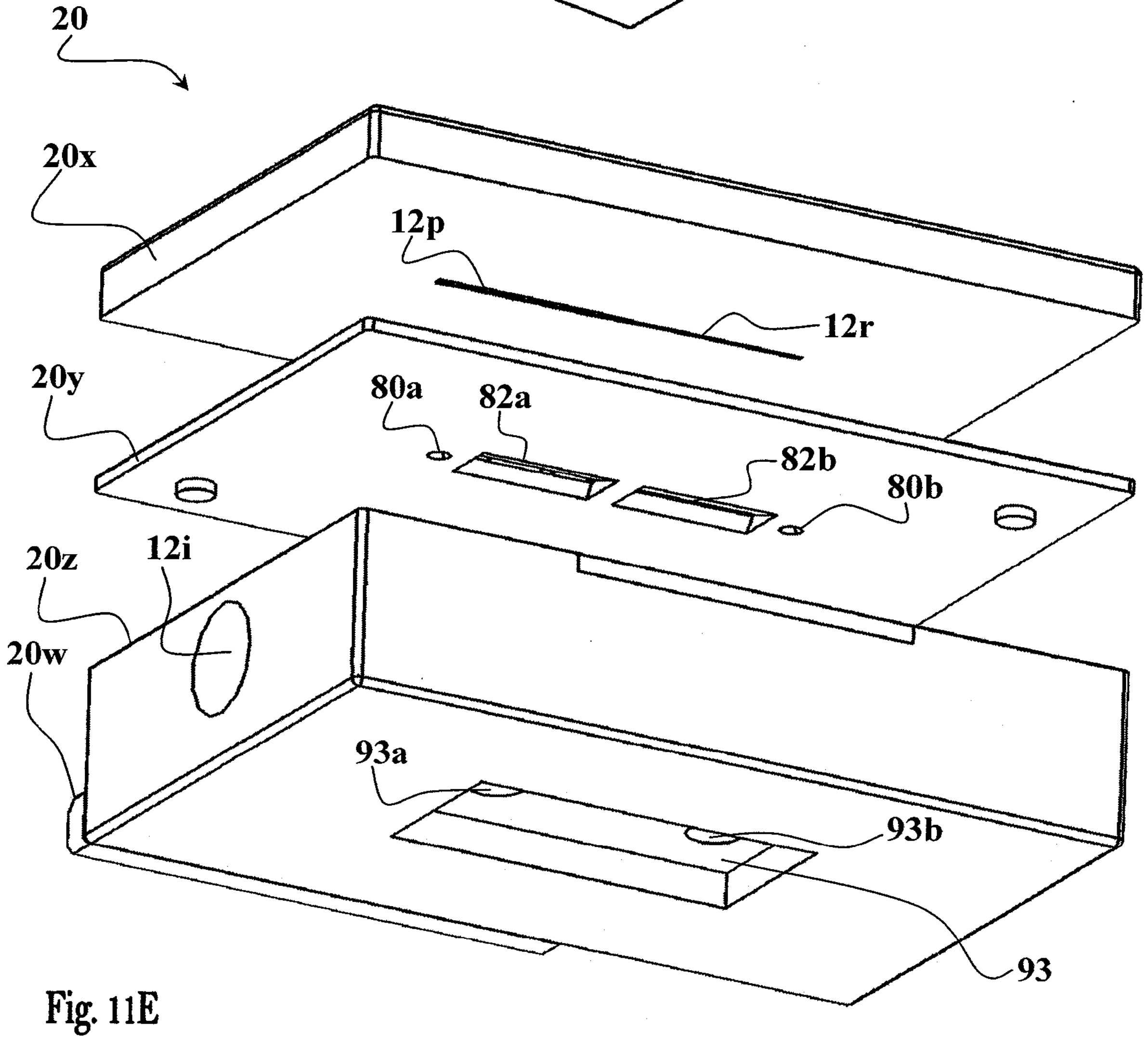

Fig. 11E

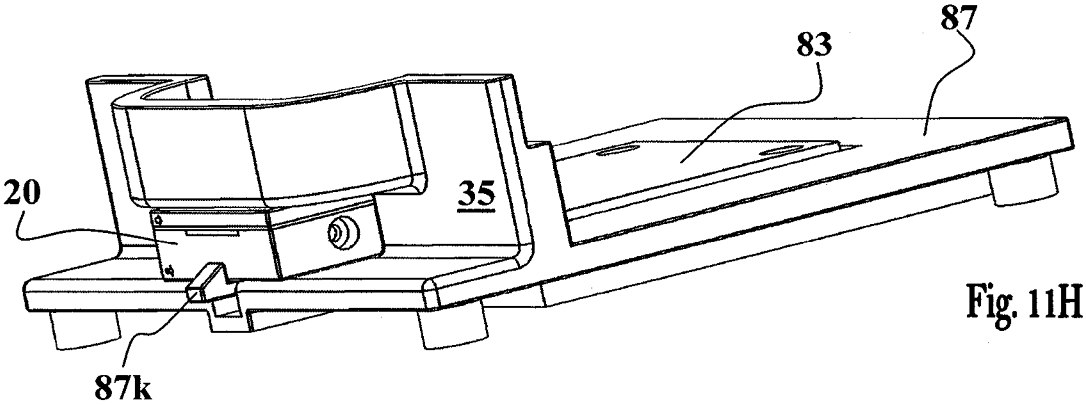

Fig. 11H

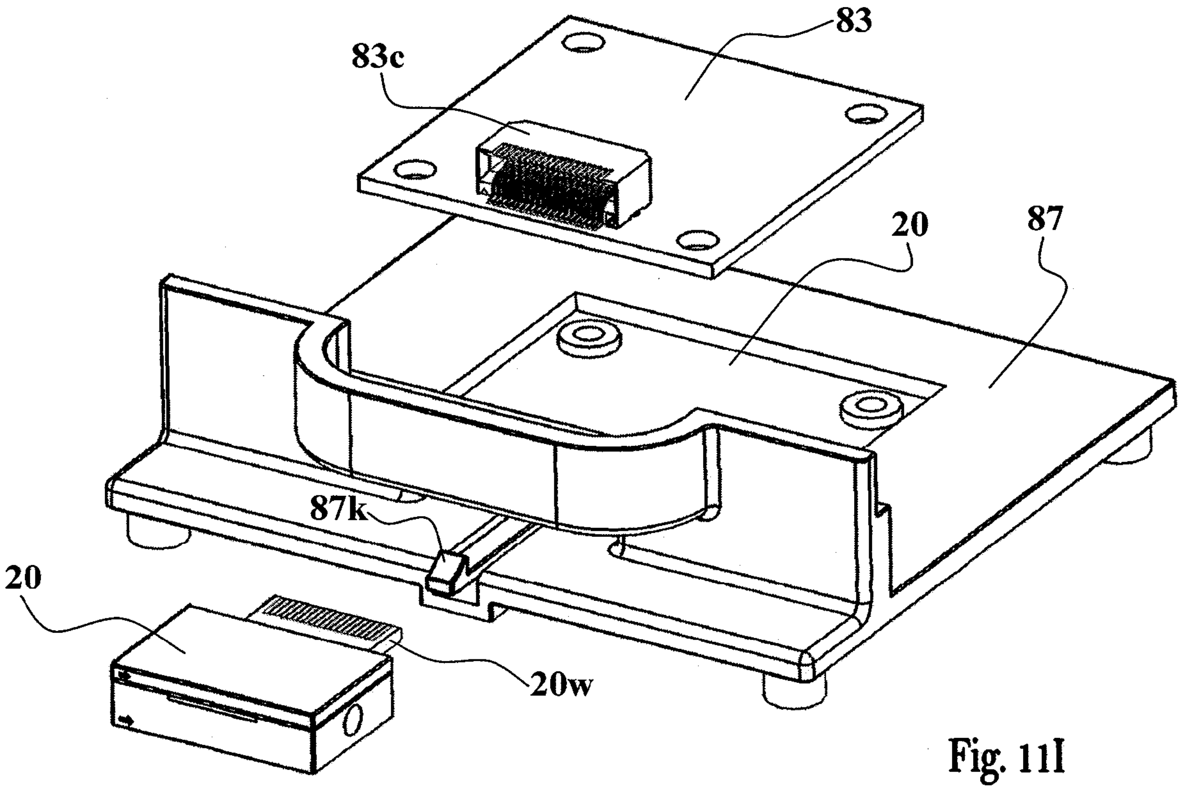

Fig. 11I

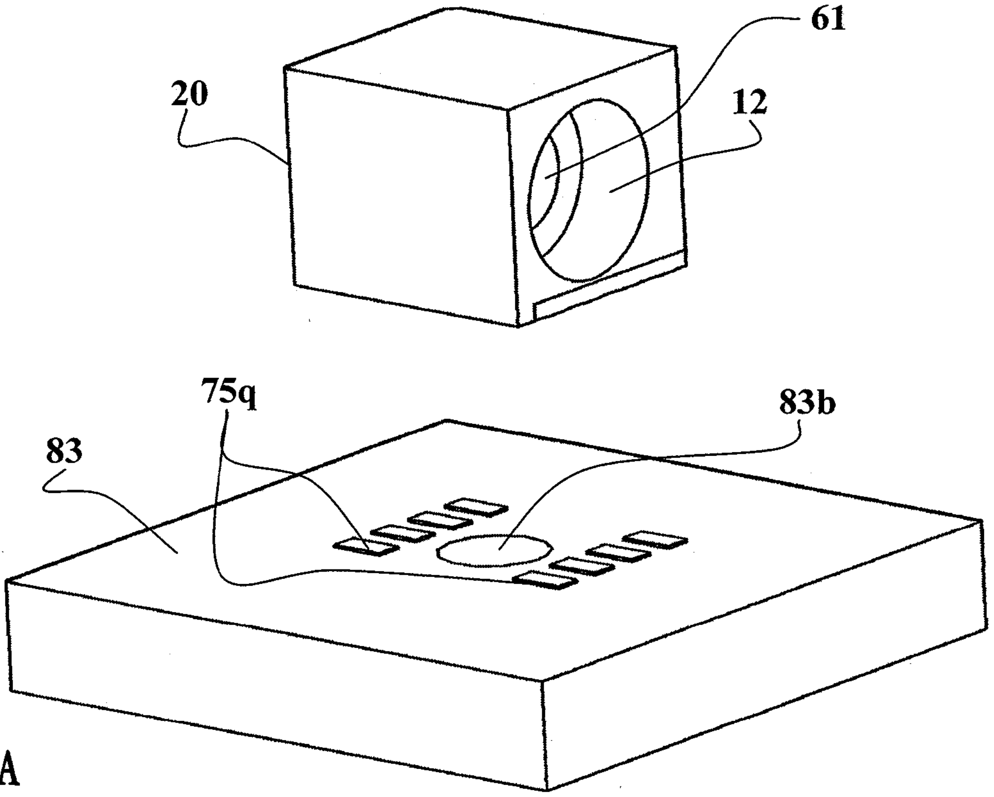

Fig. 12A

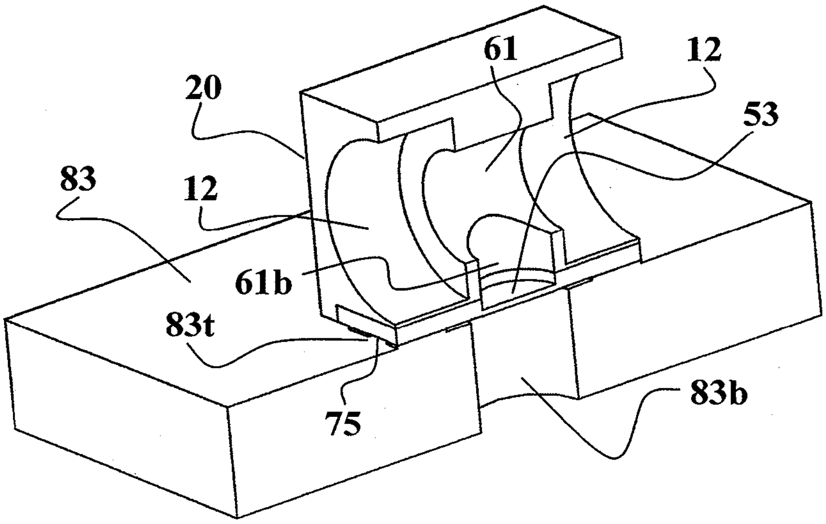

Fig. 12B

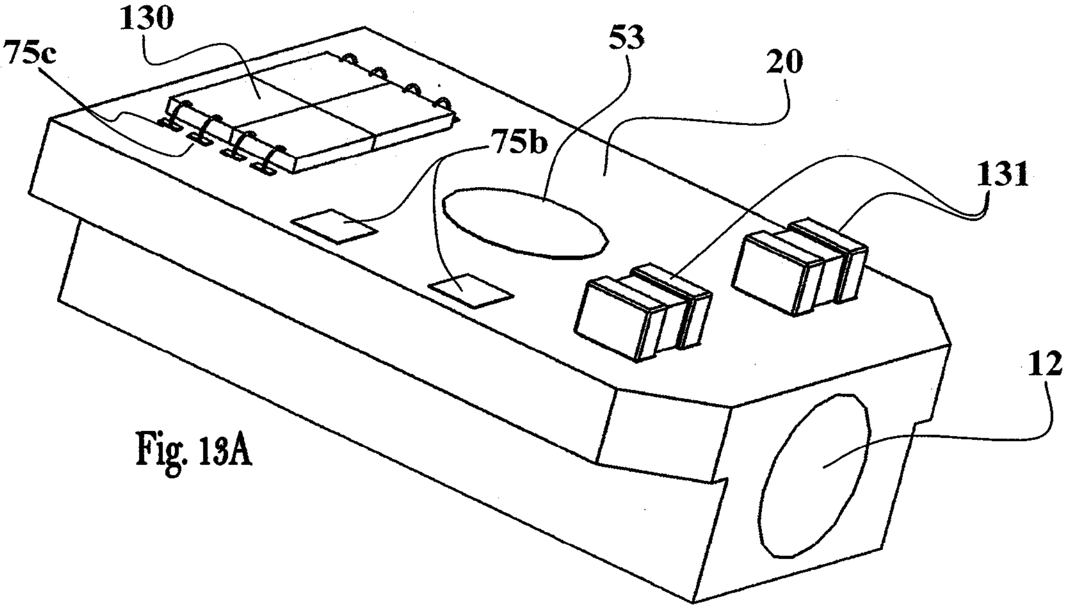

Fig. 13A

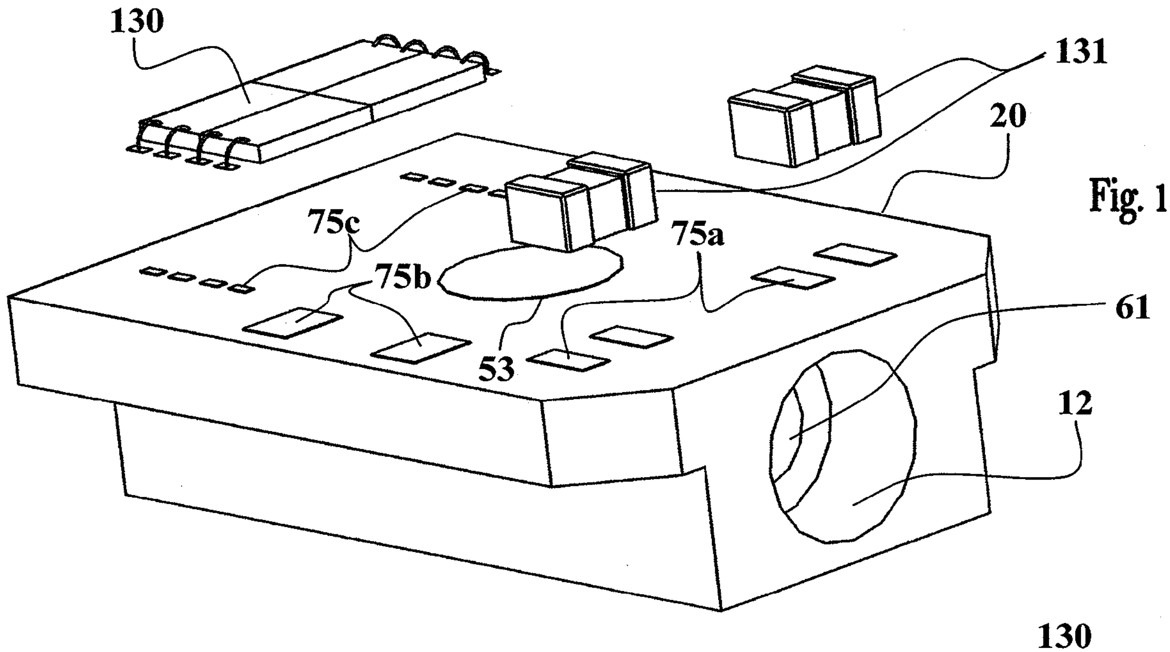

Fig. 13B

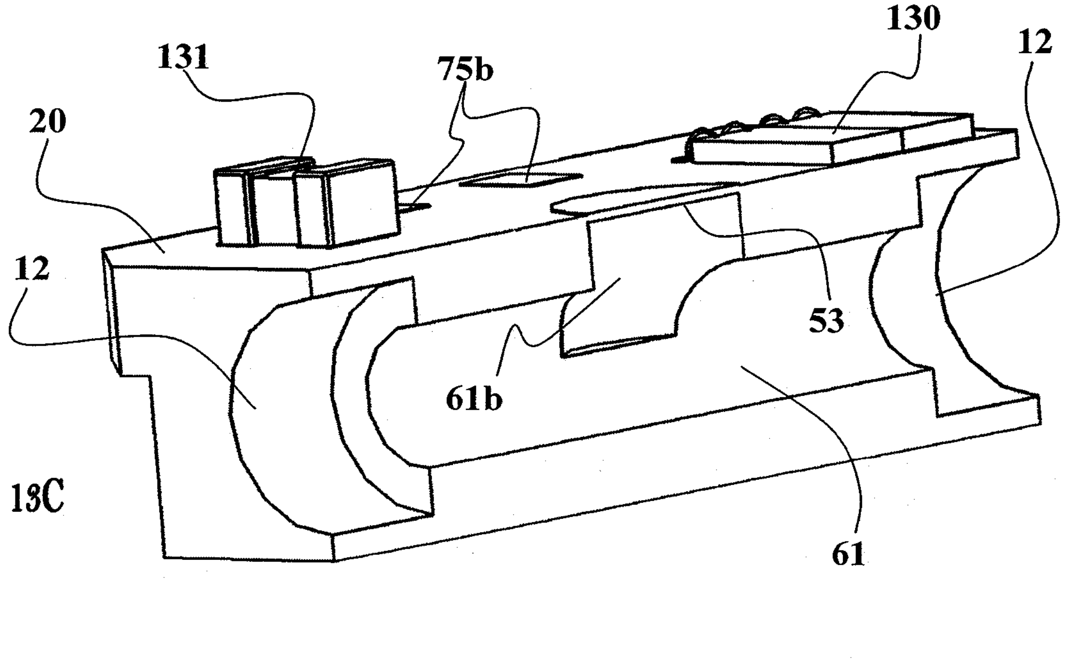

Fig. 13C

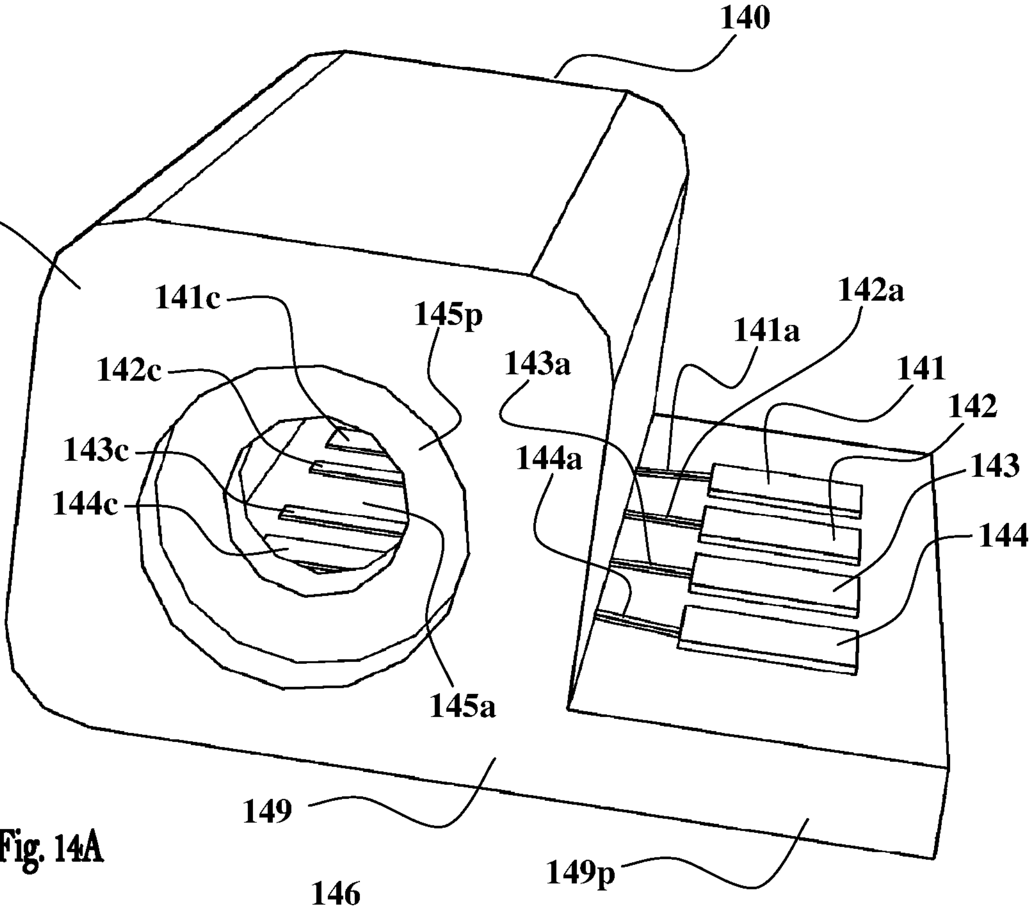

Fig. 14A

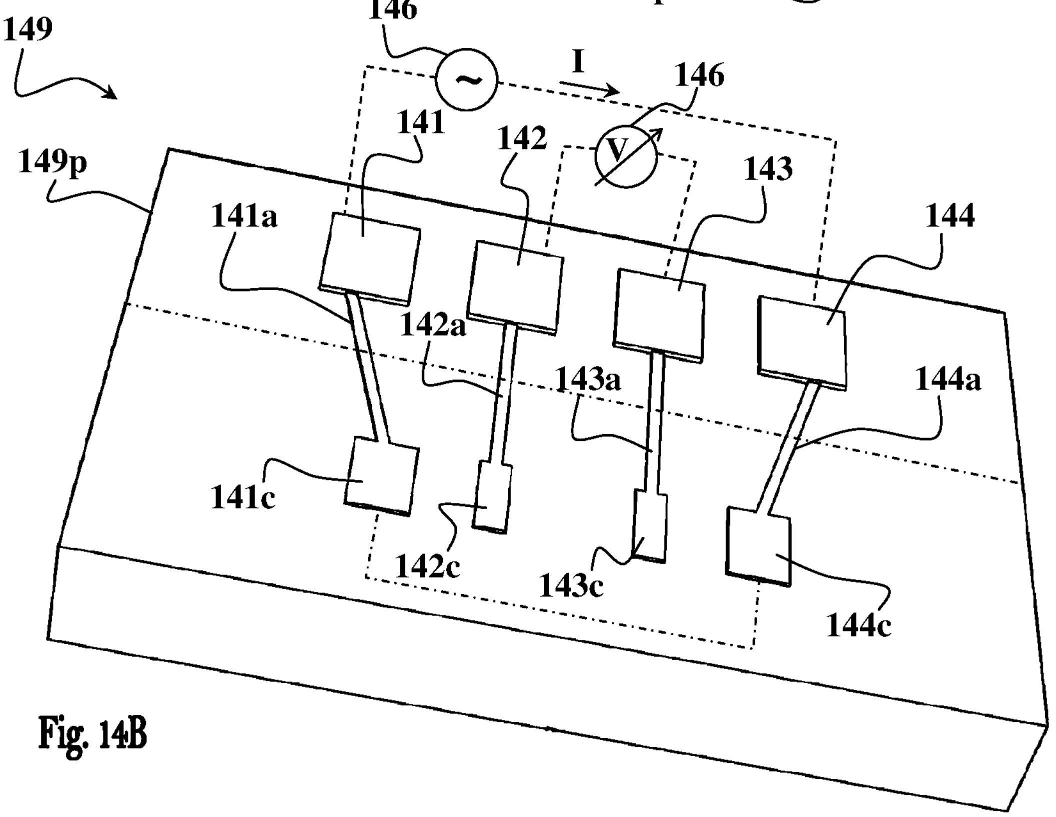

Fig. 14B

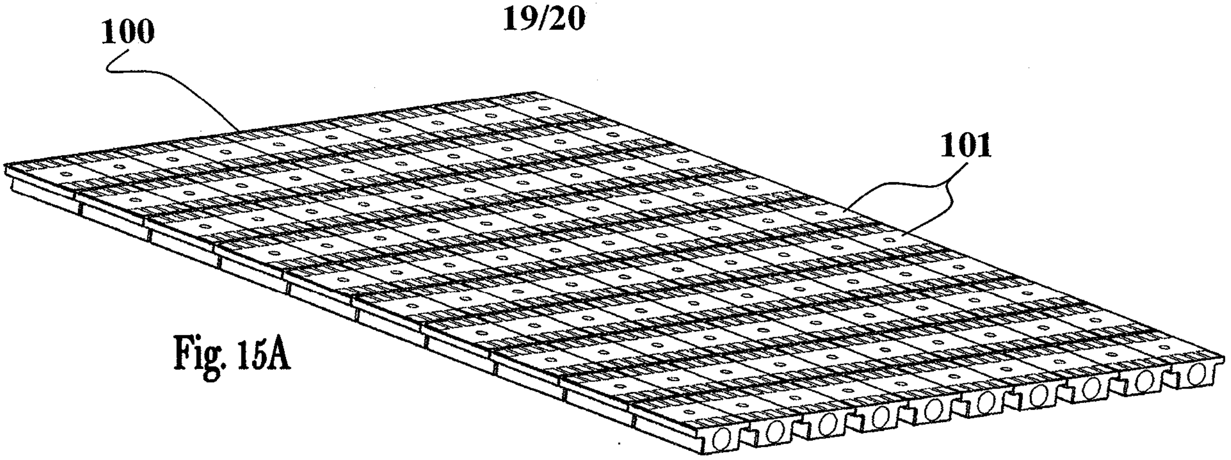

Fig. 15A

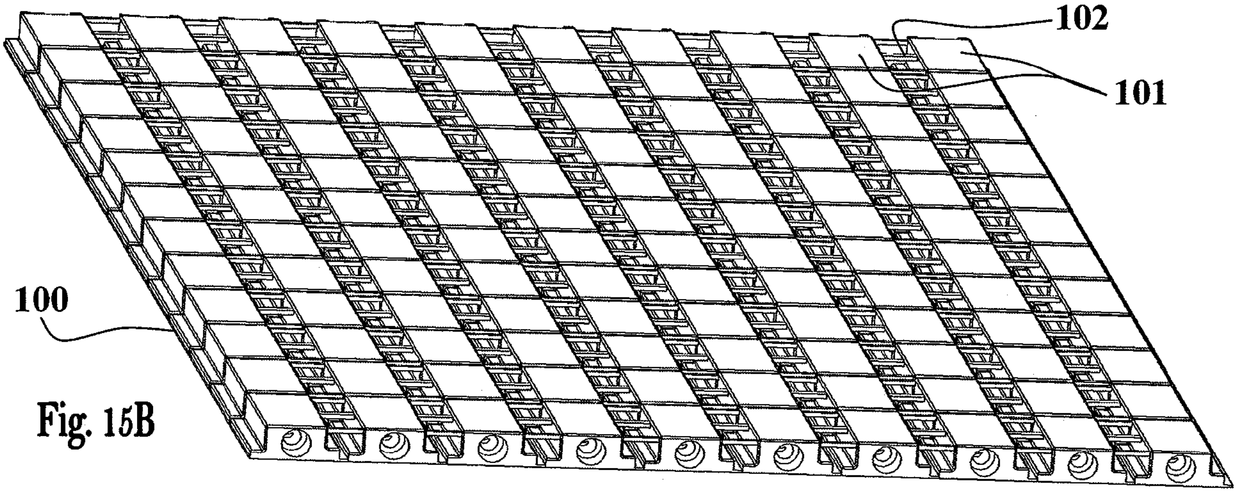

Fig. 15B

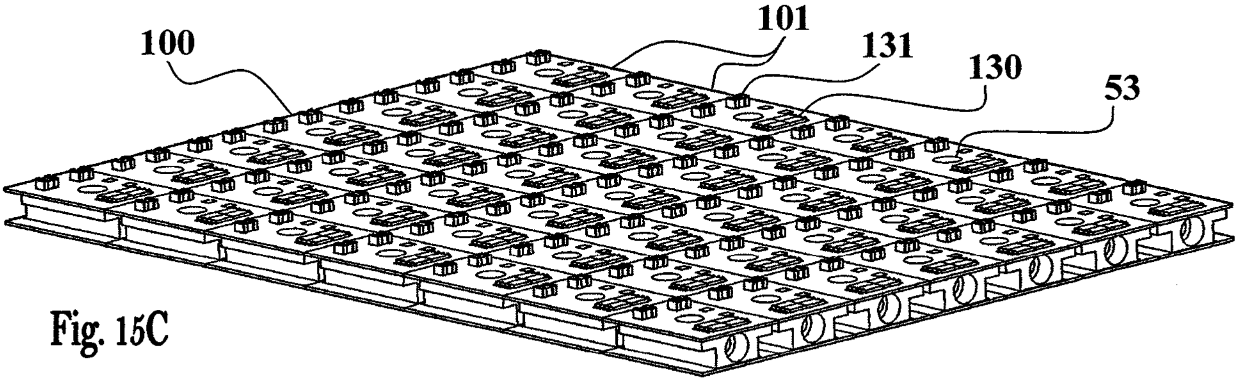

Fig. 15C

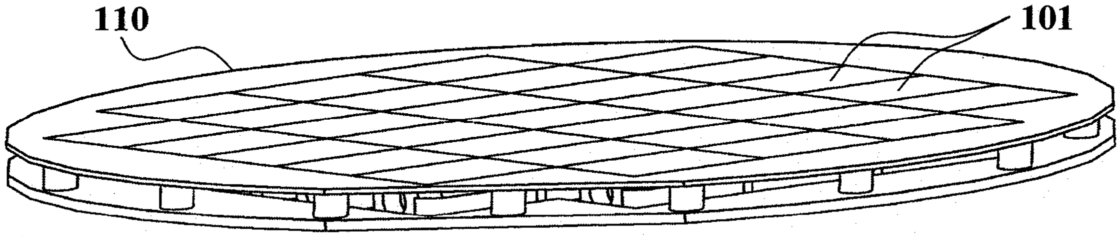

Fig. 15D

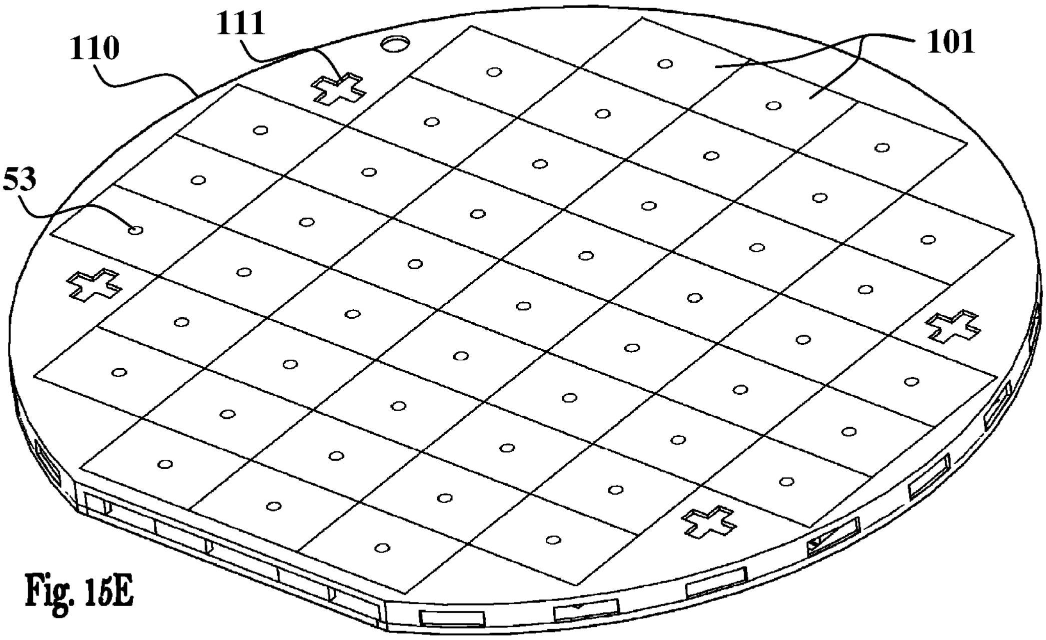

Fig. 15E

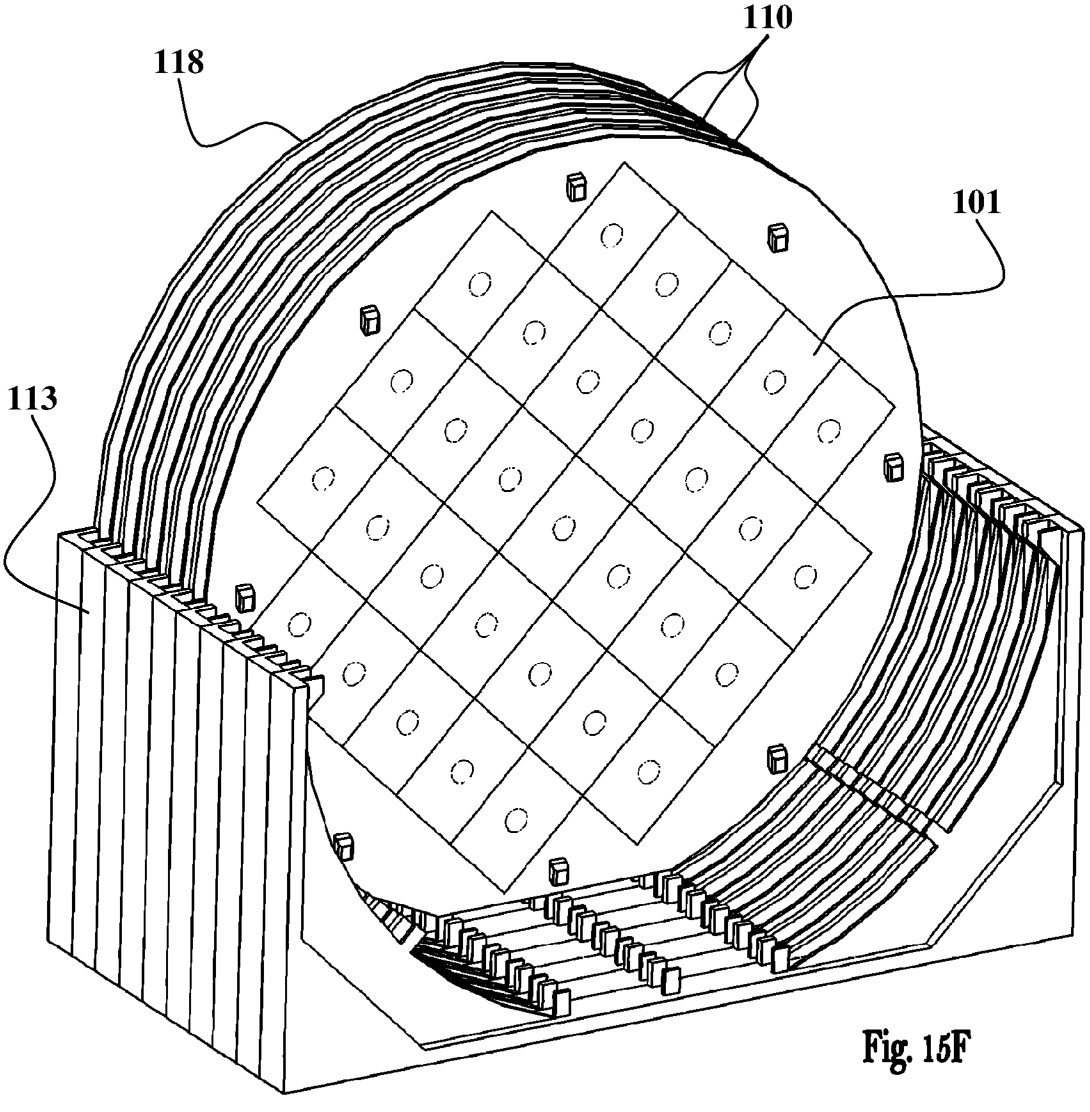

Fig. 15F

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2015/050111

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2015.01) G01L 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (2015.01) G01L 9/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Databases consulted: THOMSON INNOVATION, Esp@cenet, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002053242 A1 Tai et al. 09 May 2002 (2002/05/09) (The whole documents especially abstract, Figs 1, 5, 6, 8, 11, paragraphs 6, 7, 23-26, 34, 47, 48).	1,30,31
Y	(The whole documents especially abstract, Figs 1, 5, 6, 8, 11, paragraphs 6, 7, 23-26, 34, 47, 48).	2-29,32-51
X	US 2007028683 A1 Ionescu-Zanetti. 08 Feb 2007 (2007/02/08) (The whole documents especially abstract, Fig. 8, paragraphs 37, 41).	1,30,31
Y	(The whole documents especially abstract, Fig. 8, paragraphs 37, 41).	2-29,32-51
Y	US 7250775 B1 Collins et al. 31 Jul 2007 (2007/07/31) (Figs. 1, 2a-2b, col. 5 lines 14-26, col. 7 lines 27-55, Figs. 6, 7).	2

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search 07 Jul 2015	Date of mailing of the international search report 07 Jul 2015
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	Authorized officer NIMER Emad Telephone No. 972-2-5657801

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2002097303 A1 Gulvin et al. 25 Jul 2002 (2002/07/25) (Figs. 1-4, par. 23).	2,7
Y	US 7108354 B2 Gulvin et al. 19 Sep 2006 (2006/09/19) (Figs. 1-6, 8-14).	2
Y	US 2002127736 A1 Chou et al. 12 Sep 2002 (2002/09/12) (Fig. 28, par. 245).	8-10,14-29,32-51
Y	US 2002117517 A1 Unger et al. 29 Aug 2002 (2002/08/29) (Fig. 11B, paragraphs 239, 241, 242, 253, 254).	8-10,14-29,32-51
Y	US 2004209354 A1 Mathies et al. 21 Oct 2004 (2004/10/21) (Figs. 1A-1E, 3).	8-10,14-29,32-51
Y	US 2010018584 A1 Bransky et al. 28 Jan 2010 (2010/01/28) (Figs 5, 6, 8, 9, 11, 16, 18).	8-10,14-29,32-51
Y	US 2009129952 A1 Patrascu et al. 21 May 2009 (2009/05/21) (Abstract, Fig. 7).	8-10,14-29,32-51
Y	US 2005279635 A1 Chow et al. 22 Dec 2005 (2005/12/22) (Abstract, Fig. 3B, 3C, 4B).	14-29
Y	US 2009317298 A1 McAvoy et al. 24 Dec 2009 (2009/12/24) (Abstract, Fig. 4, paragraphs 354, 382, 384, 385).	14-29
Y	US 2013217598 A1 Ludwig et al. 22 Aug 2013 (2013/08/22) (Fig. 32, 36 paragraphs 79, 425, 427-429).	14-29
Y	US 2004086427 A1 Childers et al. 06 May 2004 (2004/05/06) (Figs. 1-3).	14-29
Y	US 2007224084 A1 Holmes et al. 27 Sep 2007 (2007/09/27) (Fig. 1, par. 95).	14-29
Y	WO 03000416 A2 Bohm et al. 03 Jan 2003 (2003/01/03) (Fig. 19 A, page 46 line 29-page 48 line 16).	16-29,33-51
Y	US 6857449 B1 Chow. 22 Feb 2005 (2005/02/22) (Abstract, Figs. 1A-C, col. 3 lines 40-51, col. 4 lines 11-22, col. 5 lines 5-22, col. 6 lines 46-col.7 line 65).	16-29,33-51

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2015/050111

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003116738 A1 O'Connor et al. 26 Jun 2003 (2003/06/26) (Figs. 1A, 3A, 4A, 5A, 6A, 8).	16-29,33-51

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2015/050111

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
US 2002053242 A1	09 May 2002	US 2002053242 A1	09 May 2002
		US 6782755 B2	31 Aug 2004
		AU 7928901 A	21 Jan 2002
		EP 1307720 A1	07 May 2003
		WO 0204907 A1	17 Jan 2002
US 2007028683 A1	08 Feb 2007	US 2007028683 A1	08 Feb 2007
US 7250775 B1	31 Jul 2007	US 7250775 B1	31 Jul 2007
US 2002097303 A1	25 Jul 2002	US 2002097303 A1	25 Jul 2002
		US 6572218 B2	03 Jun 2003
		EP 1226945 A1	31 Jul 2002
		JP 2002240285 A	28 Aug 2002
US 7108354 B2	19 Sep 2006	US 2005285902 A1	29 Dec 2005
		US 7108354 B2	19 Sep 2006
US 2002127736 A1	12 Sep 2002	US 2002127736 A1	12 Sep 2002
		US 7258774 B2	21 Aug 2007
		AU 1138902 A	15 Apr 2002
		EP 1322936 A2	02 Jul 2003
		US 2002123033 A1	05 Sep 2002
		US 7678547 B2	16 Mar 2010
		US 2008050283 A1	28 Feb 2008
		US 8992858 B2	31 Mar 2015
		WO 0229106 A2	11 Apr 2002
		WO 0229106 A3	11 Jul 2002
US 2002117517 A1	29 Aug 2002	US 2002117517 A1	29 Aug 2002
		US 6951632 B2	04 Oct 2005

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		AU 2002248149 A1	12 Aug 2002
		EP 1345698 A2	24 Sep 2003
		EP 1345698 A4	17 May 2006
		US 2005224351 A1	13 Oct 2005
		WO 02060582 A2	08 Aug 2002
		WO 02060582 A3	03 Apr 2003
		WO 02060582 A9	30 May 2003
------------------------------------	------------------------------------	------------------------------------	------------------------------------
US 2010018584 A1	28 Jan 2010	US 2010018584 A1	28 Jan 2010
		EP 2307137 A2	13 Apr 2011
		IL 210932 D0	28 Apr 2011
		WO 2010013238 A2	04 Feb 2010
		WO 2010013238 A3	15 Apr 2010
------------------------------------	------------------------------------	------------------------------------	------------------------------------
US 2004209354 A1	21 Oct 2004	US 2004209354 A1	21 Oct 2004
		US 7445926 B2	04 Nov 2008
		AU 2003303594 A1	29 Jul 2004
		CA 2512071 A1	22 Jul 2004
		CN 1791509 A	21 Jun 2006
		CN 100537219 C	09 Sep 2009
		CN 101613660 A	30 Dec 2009
		CN 101613660 B	15 May 2013
		EP 1594694 A2	16 Nov 2005
		EP 1594694 A4	20 Jan 2010
		EP 2404676 A1	11 Jan 2012
		JP 2011234728 A	24 Nov 2011
		JP 5250669 B2	31 Jul 2013
		JP 2006512092 A	13 Apr 2006
		KR 20050088476 A	06 Sep 2005
		KR 20110097934 A	31 Aug 2011
		US 2006073484 A1	06 Apr 2006

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		US 2009060797 A1	05 Mar 2009
		US 2010224255 A1	09 Sep 2010
		WO 2004061085 A2	22 Jul 2004
		WO 2004061085 A3	21 Oct 2004
		ZA 200504838 A	29 Mar 2006
US 2009129952 A1	21 May 2009	US 2009129952 A1	21 May 2009
		US 8353682 B2	15 Jan 2013
		AT 471457 T	15 Jul 2010
		DE 602008001547 D1	29 Jul 2010
		EP 2071189 A1	17 Jun 2009
		EP 2071189 B1	16 Jun 2010
US 2005279635 A1	22 Dec 2005	US 2005279635 A1	22 Dec 2005
		AU 745644 B2	28 Mar 2002
		AU 9205298 A	16 Mar 1999
		CA 2300075 A1	04 Mar 1999
		CA 2300075 C	28 Sep 2004
		EP 1007954 A1	14 Jun 2000
		EP 1007954 A4	28 Jun 2006
		US 5989402 A	23 Nov 1999
		US 6582576 B1	24 Jun 2003
		US 6827831 B1	07 Dec 2004
		WO 9910735 A1	04 Mar 1999
US 2009317298 A1	24 Dec 2009	US 2009317298 A1	24 Dec 2009
		US 7842248 B2	30 Nov 2010
US 2013217598 A1	22 Aug 2013	US 2013217598 A1	22 Aug 2013
		WO 2013119719 A1	15 Aug 2013

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
US 2004086427 A1	06 May 2004	US 2004086427 A1	06 May 2004
		US 7932098 B2	26 Apr 2011
		AU 2003287411 A1	07 Jun 2004
		CA 2504544 A1	21 May 2004
		CN 1732045 A	08 Feb 2006
		CN 100377787 C	02 Apr 2008
		EP 1558908 A2	03 Aug 2005
		JP 2006504974 A	09 Feb 2006
		KR 20050057683 A	16 Jun 2005
		MX PA05004470 A	23 Nov 2005
		TW 200419147 A	01 Oct 2004
		TW I247884 B	21 Jan 2006
		WO 2004042367 A2	21 May 2004
		WO 2004042367 A3	29 Jul 2004
US 2007224084 A1	27 Sep 2007	US 2007224084 A1	27 Sep 2007
		US 8741230 B2	03 Jun 2014
		AU 2006244617 A1	16 Nov 2006
		AU 2006244617 B2	18 Apr 2013
		CA 2610294 A1	16 Nov 2006
		CN 101535499 A	16 Sep 2009
		EP 1883341 A2	06 Feb 2008
		EP 1883341 A4	10 Sep 2014
		IL 187272 D0	09 Feb 2008
		IL 187272 A	30 Jun 2014
		IL 232544 D0	30 Jun 2014
		JP 2008544214 A	04 Dec 2008
		JP 2012127978 A	05 Jul 2012
		JP 2013029525 A	07 Feb 2013
		KR 20110041578 A	21 Apr 2011
		KR 101322943 B1	29 Oct 2013

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		KR 20080036550 A	28 Apr 2008
		KR 101381331 B1	04 Apr 2014
		KR 20130041993 A	25 Apr 2013
		KR 20130131485 A	03 Dec 2013
		KR 20140098856 A	08 Aug 2014
		KR 20150046355 A	29 Apr 2015
		MX 2007013985 A	22 Feb 2008
		NZ 564141 A	25 Feb 2011
		NZ 590930 A	30 Nov 2012
		NZ 599522 A	29 Nov 2013
		NZ 603604 A	28 Feb 2014
		NZ 603613 A	28 Feb 2014
		US 2006264782 A1	23 Nov 2006
		US 7635594 B2	22 Dec 2009
		US 2006264781 A1	23 Nov 2006
		US 7888125 B2	15 Feb 2011
		US 2010081144 A1	01 Apr 2010
		US 8283155 B2	09 Oct 2012
		US 2008009766 A1	10 Jan 2008
		US 8679407 B2	25 Mar 2014
		US 2006264780 A1	23 Nov 2006
		US 8841076 B2	23 Sep 2014
		US 2006264779 A1	23 Nov 2006
		US 2006264783 A1	23 Nov 2006
		US 2010074799 A1	25 Mar 2010
		US 2011104826 A1	05 May 2011
		US 2012052561 A1	01 Mar 2012
		US 2013115685 A1	09 May 2013
		US 2014222447 A1	07 Aug 2014
		US 2014329259 A1	06 Nov 2014
		US 2015099311 A1	09 Apr 2015

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		WO 2006121510 A2	16 Nov 2006
		WO 2006121510 A3	09 Apr 2009
		WO 2007111651 A2	04 Oct 2007
		WO 2007111651 A3	14 May 2009
WO 03000416 A2	03 Jan 2003	WO 03000416 A2	03 Jan 2003
		WO 03000416 A3	04 Dec 2003
		AU 2002310500 A1	08 Jan 2003
		AU 2002310501 A1	08 Jan 2003
		AU 2002326314 A1	08 Jan 2003
		AU 2003223530 A1	27 Oct 2003
		AU 2003224906 A1	27 Oct 2003
		CA 2451035 A1	03 Jan 2003
		CA 2451201 A1	03 Jan 2003
		CA 2451314 A1	16 Jan 2003
		CA 2451753 A1	03 Jan 2003
		EP 1406765 A1	14 Apr 2004
		EP 1406765 A4	01 Dec 2004
		EP 1407257 A1	14 Apr 2004
		EP 1407257 A4	24 Nov 2004
		EP 1412087 A1	28 Apr 2004
		EP 1412087 A4	09 Mar 2005
		EP 1412729 A2	28 Apr 2004
		EP 1412729 A4	09 Mar 2005
		EP 1499439 A1	26 Jan 2005
		EP 1499439 A4	25 May 2005
		EP 1499440 A1	26 Jan 2005
		EP 1499440 A4	25 May 2005
		JP 2004532992 A	28 Oct 2004
		JP 4080996 B2	23 Apr 2008
		JP 2004534229 A	11 Nov 2004

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		JP 4166690 B2	15 Oct 2008
		JP 2005502448 A	27 Jan 2005
		JP 2005514187 A	19 May 2005
		JP 2008249720 A	16 Oct 2008
		US 2003059949 A1	27 Mar 2003
		US 6808683 B2	26 Oct 2004
		US 2003059345 A1	27 Mar 2003
		US 7041257 B2	09 May 2006
		US 2003170146 A1	11 Sep 2003
		US 7153699 B2	26 Dec 2006
		US 2003007898 A1	09 Jan 2003
		US 7179423 B2	20 Feb 2007
		US 2004091398 A1	13 May 2004
		US 7211442 B2	01 May 2007
		US 2003194353 A1	16 Oct 2003
		US 7258839 B2	21 Aug 2007
		US 2007298171 A1	27 Dec 2007
		US 7686967 B2	30 Mar 2010
		US 2002195343 A1	26 Dec 2002
		US 2002197733 A1	26 Dec 2002
		US 2003015425 A1	23 Jan 2003
		US 2003077570 A1	24 Apr 2003
		US 2005036920 A1	17 Feb 2005
		US 2006027524 A1	09 Feb 2006
		US 2006134696 A1	22 Jun 2006
		US 2006263264 A1	23 Nov 2006
		US 2007054408 A1	08 Mar 2007
		US 2007148777 A1	28 Jun 2007
		WO 03000417 A2	03 Jan 2003
		WO 03000417 A3	27 Feb 2003
		WO 03000418 A2	03 Jan 2003

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2015/050111

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		WO 03000418 A3	13 Mar 2003
		WO 03000422 A1	03 Jan 2003
		WO 03001192 A1	03 Jan 2003
		WO 03001192 A9	26 Feb 2004
		WO 03004275 A1	16 Jan 2003
		WO 03004275 A9	29 Jan 2004
		WO 03025115 A1	27 Mar 2003
		WO 03086630 A1	23 Oct 2003
		WO 03086631 A1	23 Oct 2003
US 6857449 B1	22 Feb 2005	US 6857449 B1	22 Feb 2005
		US 6167910 B1	02 Jan 2001
		US 6321791 B1	27 Nov 2001
		US 2002023684 A1	28 Feb 2002
		US 6494230 B2	17 Dec 2002
		US 6648015 B1	18 Nov 2003
US 2003116738 A1	26 Jun 2003	US 2003116738 A1	26 Jun 2003
		US 6739576 B2	25 May 2004