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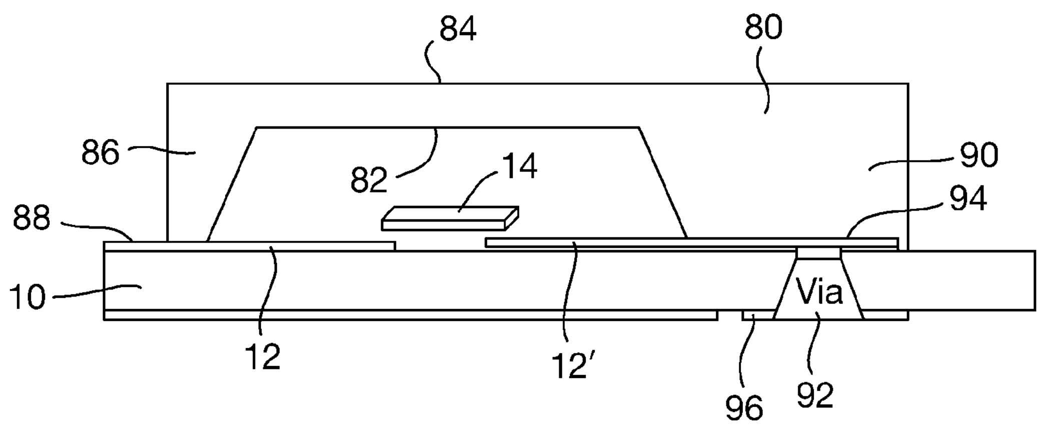
(54) **MEMS switches and the packaging thereof**

(57) A packaged RF or other MEMS device wherein a package in which the device is contained is at least partially optically transparent.

Fig.15.



EP 2 323 154 A1

Description

[0001] This invention relates to micro electro-mechanical system (MEMS) switches. In particular it relates to radio frequency (RF) MEMS switches, which may be particularly suitable for use in compact phase-shifting switching arrays for example for phased-array antennas and in some aspects also to other MEMS devices, not necessarily RF.

[0002] Prior art MEMS switches can suffer from poor insertion loss when operated at high (e.g. microwave) radio frequencies. The performance of nominally-identical switches can vary widely, in both direct-contact (ohmic) and indirect-contact (capacitative) types in which at least one of the contacting pads of the switch has a layer of dielectric material on its surface.

[0003] We have concluded that the source of this problem lies in the contacting surfaces of the switch not being presented to each other in a consistent manner from switch to switch, or even in successive operations of the same switch. This may be the result of contamination between contacting surfaces and/or the alignment of the contacts themselves. This has the result that instead of the surfaces contacting and conforming to each other over substantial areas, there is instead contact only over a relatively small area, in an extreme case approximating to just point or line contact. Poor contact such as this case can be particularly detrimental in a capacitative switch.

[0004] According therefore to one aspect of the invention there is provided a MEMS switch comprising a pair of contact-making surfaces, at least one of which is moveable relative to the other to open or close the switch, a said surface being carried by a flexible element, and actuator means configured to effect said relative movement, the arrangement being such that when the switch is closed the flexible element is deformed to conform the contacting surface defined thereon to the other contacting surface.

[0005] By "switch" we mean a device in which a pair of contacting surfaces can be opened or closed: there may be more than one pair of such contacts in a single device, (e.g. in multi-pole single terminal switches), and/or one contact may be shared between two other contacts e.g. in a double terminal switch.

[0006] In one form of this aspect of the invention a said contacting surface may be on a first portion of the flexible element which is attached to a further portion of the flexible element, internal stresses in the flexible element having been chosen so as to control the shape of the first portion and/or its angular disposition relative to the further portion.

[0007] In another form, a said contacting surface may be on a first portion of the flexible element which is attached to a further portion of the flexible element, the flexible element comprising at least two layers of different coefficients of thermal expansion chosen so as to control the shape of the first portion and/or its angular disposition relative to the further portion.

[0008] In a further form, a said contacting surface may be on a first portion of the flexible element which is attached to a further portion of the flexible element, the flexible element comprising at least two layers which have been formed at different elevated temperatures so as to control at ambient temperature the shape of the first portion and/or its angular disposition relative to the further portion.

[0009] These three forms can be used singly or in any combination.

[0010] Preferably the contact-making surface of the flexible element presents a deformable at least partially concave shape towards the other contact-making surface when spaced therefrom.

[0011] When the contact-making surfaces are spaced apart, the said surface on the first portion of the flexible element which maybe parallel to or inclined towards the other contacting surface from its point of attachment to the further portion of the flexible element.

[0012] The first portion may be attached to the further portion at a fold or hinge line.

[0013] The fold or hinge line may comprise a line of weakness which is disposed on the opposite side of said construction from a layer which tends to impart said concave shape to the first portion.

[0014] The shape of the flexible element may inflect between the first and further portions.

[0015] The actuator means may comprise a first part deflectable thermally, electrostatically or electromagnetically relative to a further actuator part so as to effect said relative movement.

[0016] The first actuator part may be disposed on the flexible element.

[0017] Alternatively, the actuator means may be moveable relative to the flexible element.

[0018] The actuator means may be adapted to apply a closing force along a line of action which passes through the contacting surfaces.

[0019] The actuator means may be supported from a fixed structure separately from the flexible element.

[0020] The actuator means may comprise at least one cantilever beam having a part which overlaps the flexible element to effect said relative movement.

[0021] The flexible element may comprise a cantilever beam.

[0022] Thus, in one embodiment the actuator means may comprise cantilever beams extending on each side of the flexible element, end parts of the cantilever beam being joined together to form the overlapping part.

[0023] The cantilever beams of the actuator means and the flexible element may be substantially co-planar except for the overlapping portion.

[0024] A said cantilever beam may have a curved cross-section perpendicular to its longitudinal axis.

[0025] The switch may be contained in a package which is at least partially transparent to permit inspection of the switch, in particular of the state of the contacts during manufacture or subsequently when in use.

[0026] This packaging feature is of wider applicability than just for MEMS switches. For example, it can be used in the effective packaging of an optoelectronic component which hitherto would have been left exposed on the circuit substrate.

[0027] Thus, another aspect of the invention provides a packaged MEMS device wherein a package in which the device is contained is at least partially optically transparent.

[0028] The package may comprise a transparent glass cover.

[0029] There may be a separate wall structure which spaces the glass cover from a circuit substrate.

[0030] The wall structure may be of glass or an oxide of silicon.

[0031] The cover may be frit-bonded to the wall structure.

[0032] There may be a via extending through the circuit substrate beneath the wall structure to form an electrical connection to the device.

[0033] Also or alternatively there may be a via through the wall structure to form an electrical connection to a conductor on the substrate.

[0034] The invention also provides a method of packaging a MEMS device comprising mounting the device on a circuit substrate, preparing a perimeter area around the device to receive a wall structure of a cover, and securing a perimeter wall of a transparent cover to the perimeter area.

[0035] The method may include securing a perimeter wall structure to the perimeter area, and then securing a transparent lid to the wall structure.

[0036] The method may include providing a via through the circuit substrate beneath the wall structure and/or a via through the wall structure to form an electrical connection to a conductor on the substrate.

[0037] In another aspect the invention provides a method of manufacturing a MEMS switch comprising a beam element shaped to present a contacting surface to another contacting surface to close the switch, the method comprising determining the shape of the beam by controlling residual stress in the material thereof.

[0038] The beam element may comprise a plurality of layers, at least one of which has a compressive residual stress and at least one of which has a tensile residual stress.

[0039] The layer with compressive residual stress may be of silicon nitride and the layer with tensile stress may be of silicon oxide.

[0040] In another embodiment, the beam element may be of layered construction, a first layer comprising a plurality of spaced metal areas separated by a dielectric material, the method including planarising the dielectric material so that the metal areas and the dielectric material provide an uninterrupted surface, and depositing a further layer of dielectric material on that surface.

[0041] The method may include forming the dielectric material between the metal areas by depositing a layer of the material on the metal layers so that it intrudes into the space between them, and then removing that layer except for the material between the metal areas by said planarisation.

[0042] In this embodiment, the dielectric material may be of silicon oxide.

[0043] The invention now will be described merely by way of example with reference to the accompanying drawings, wherein:

Figure 1 shows a prior art MEMS switch;

Figure 2 and 3 show MEMS switches according to the invention;

Figure 4, 5, 6 and 7 show further switches according to respective embodiments of the invention;

Figure 8 illustrates a problem with prior art switches;

Figures 9 and 10 show portions of switches according to the invention;

Figure 11 shows further switches according to embodiments of the invention;

Figure 12 shows part of the manufacture of switches according to the invention;

Figures 13 and 14 show further switches according to embodiments of the invention.

Figures 15 and 16 show switch packages according to the invention, and

Figure 17 shows the manufacture of the switch of figure 15.

Figure 1 shows diagrammatically a prior art normally-open MEMS switch. So far as relevant here, it comprises a substrate 10 on which is mounted a switch contact 12. A flexible cantilever beam 14 is mounted on the substrate via structure 16. The free end 18 of the cantilever has an undersurface 19 constituting the other switch contact. The beam 14 is moveable towards the substrate 10 by a pair of electrodes 20, one on the substrate the other on the beam. When a voltage is applied across them, sufficient electrostatic force is generated to deflect the beam and close the switch. The switch here is of the normally-open type, the natural resilience of the beam 14 holding the contact portion 18 normally spaced from the contact 12.

[0044] The MEMS switch is manufactured by the deposition of successive layers of material on the substrate, and the selective removal of some of them so as to leave spaces (e.g. the space between the beam 14 and the substrate 10). The techniques are known to those skilled in the art and are based on those used in the manufacture of integrated circuits, and so will not be described further here except so far as relevant to the invention.

[0045] The beam 14 in particular typically consists of a multi-layer structure of a nitride layer sandwiched between two metal layers, discrete parts of one of which layers operate respectively as an actuator electrode and as a switch contact surface.

[0046] The beam 14 is shown as having a shape which illustrates the problem with prior art switches. Whilst the portion 22 of the beam proximal to the mounting structure 16 has an acceptable shape, the end portion 18 is undesirably tilted upwards, resulting in a poor contact with the switch surface 12. Indeed the area of contact may be so small as to be little more than line contact. This is unacceptable, especially if the switch is capacitative rather than ohmic, where a consistent area of contact is critical for repeatable performance from switch to switch and, for a particular switch, for each switching operation.

[0047] We have concluded that a likely cause of this problem is uncontrolled residual stress in the multi-layer structure of the beam, and have devised two basic approaches to alleviating it. These approaches are illustrated in figures 2 and 3: both have the objective of causing the flexible end portion 18 of the beam 14 to conform its contacting surface 19 to the corresponding surface of the switch contact 12.

[0048] In figure 2, the beam 14 is manufactured (e.g. by a method such as described hereafter) so that its end portion 18 presents a concave shape to the switch contact 12. Preferably it is concave both viewed from the side as illustrated, and when viewed end-on, i.e. in cross-section relative to the longitudinal axis of the beam 14. When the end portion 18 is so shaped, the closing force applied by the electrodes 20 causes it to flatten on to (i.e. conform to) the surface of the switch contact 12, thereby ensuring a large enough area of contact for effective operation. The end portion 18 is tilted downwards relative to its point of attachment 24 to the proximal portion 22 of the beam, so that the tip of the beam touches the contact 12 first, and the remainder of the undersurface 19 of portion 18 is progressively brought into contact with it as the beam is depressed. This form of beam is suitable for actuation by electrodes positioned so far described, and is also suitable for use in the alternative approach illustrated in Figure 3.

[0049] In Figure 3, the switch is closed by a force applied directly to the end portion 18 along a line of action 26 which passes through the contacting surfaces of that portion and the switch contact 12. This ensures that even if the end portion 18 is tilted upward as in figure 3, it is pushed down onto the switch contact 12 and, due to its concave shape, spreads itself into conformity with it. Indeed, this solution can be applied even if the portion 18 is convex towards the switch contact 12, provided that the force is applied via a plate-like element large enough effectively to cover all of the end portion 18 and to spread its surface 19 into conformity with the surface of the switch contact. In this embodiment, and usefully also in that of figure 2, the connection 24 between the portions 18 and 22 of the beam 14 is in the form of a fold or hinge line, to facilitate the conformance of the end portion 18 to the surface of the switch contact 12 after the connection 24 has come into contact with that surface.

[0050] Figure 4 shows another embodiment of an indirectly-actuated switch. By indirect actuation we mean an arrangement in which the actuating force is applied other than on a line of action which passes through the contacting switch surfaces. In contrast direct actuation is where the line of action of the actuating force passes through these surfaces.

[0051] In figure 4, and also in subsequent figures, parts already described have the same reference numerals. This embodiment differs from that of figure 2 in that there are two flexible contact-making portions 18, 18' carried transversely of the longitudinal extent of the beam on a concave intermediate part 28 via folds 24, 24'. When the switch is closed, the portions 18, 18' connect two separate switch contacts 12, 12'; thereby the RF signal flows only in the beam portions 18, 28, and does not have to be taken through the proximal portion 22 of the beam where it may be subject to interference from the beam-actuation circuitry.

[0052] The end portions 18, 18' are concave both viewed from the side as at 30, and from the end as at 32. This assists in causing them to deform reliably into conformance with the surface of switch contacts 12, 12', provided that care is taken to ensure that the stiffening effect of the compound curvature 30, 32 does not reduce the compliance of the portion 18, 18' below that necessary for conformance of their undersurfaces 19, 19' to the surfaces of switch contacts 12, 12'. Although shown as concave, the shape of the intermediate portion 28 is not critical, provided that it is adequately stiff so that deformation takes place primarily in the portions 18, 18', and the portion 28 remains spaced from the switch contacts 12, 12' at least until the switching surfaces 19, 19' have been conformed thereto.

[0053] The embodiment of figure 5 is an example of a directly actuated MEMS switch according to the invention. In this embodiment, the components 12, 14, 16, 18, 22, 24 are arranged as described with reference to figure 2, but the actuating electrodes 20 are instead arranged to deflect a separate relatively stiff cantilever beam 34 mounted on the substrate 10. The beam 34 is positioned so that upon deflection its end, which carries a suitable force-applying part 36, applies a force along line 26 directly to the end portion 18 of the flexible cantilever 14. This directly-applied force reliably splays the portion 18 into conforming contact with the switch contact 12. Once again, the RF signals can be kept well-separated from the switch-actuating circuitry.

[0054] Figures 6A and 6B show in side elevation and plan section another direct-acting embodiment which has a more compact footprint than that of figure 5. Here the actuating cantilever 34 is superimposed above the switching cantilever 14. Applying an appropriate voltage to the electrodes 20 pulls the actuating cantilever down onto the end portion 18 of the cantilever 14, which deflects downwards, the portion 18 pivoting about the hinge 24 into conforming contact with the switch contact surface 12.

[0055] The beams 14, 34 are shown as straight, and indeed the switch would work in accordance with the invention in such a configuration provided that the pad 36 applies force to the portion 18 over a sufficient area to flatten any local deformities and conform it to the switch contact 12.

[0056] The beam 14 and 34 are of sandwich construction in which dielectric (silicon nitride or silicon nitride/oxide/nitride as described hereafter) layers are disposed between metal layers 38, 40, (for beam 14) and 20, 41 (for beam 34). These metal layers provide a thermally-balanced structure which is relatively resistant to distortion with change in temperature. If the layers 38 and 41 were omitted there would be a tendency for the beams to curl with change in temperature due to stresses arising from the difference in thermal expansion coefficients between the dielectric layers and the metal layer 40, 20.

[0057] In the variant of figure 7, there are two parallel cantilever actuating beams 34 disposed one on each side of the switching beam 14, and co planar with it except for a raised portion 44 at the end which stands over the portion 18 of the beam 14. This arrangement reduces the separation between the electrodes 20 on the actuator beam and those on the substrate 10. Thereby the operating voltage can be reduced.

[0058] Figures 8A and 8B illustrate the origin of undesirable tilt or curvature in the cantilever beam 14 in prior art switches. The beam is of sandwich construction with a silicon nitride layer 46 between two metal layers 45, 47, parts of the lower of which constitute the actuator electrode 20 and the switch surface 19 of portion 18. When laid down by conventional CVD techniques, the silicon nitride layer 46 is of reduced thickness in the hinge portion 48 of the beam between the metal layer portions 19, 20, and residual stresses in it cause the end of the beam to be curved and/or tilted upwards.

[0059] One solution we have identified for this is to replace the single silicon nitride layer with a three-layer construction of a silicon oxide layer 50 between two silicon nitride layers 52, 54, as shown in figure 9. Then by appropriate control of the process parameters during deposition of the layers so as to utilise the difference in the coefficients of expansion of silicon oxide and silicon nitride, a stress can be established in the silicon oxide layer to counteract the stresses in the nitride layers, or indeed to provide an up or down tilt as required. Tilt or curvature can be provided by depositing the silicon nitride layers at different temperatures. Then differential contraction between those layers upon return to ambient temperature results in the required shape being imposed on the structure. A similar result can be achieved by depositing the two silicon nitride layers at different pressures. The lower-pressure layer will be less stiff per unit thickness then the higher pressure layer and thus the structure will curve away from that layer when returned to ambient temperature.

[0060] Figure 10 shows another solution. Here a silicon nitride structure is formed between the metal layers 45, 47 in two parts. First, a silicon nitride layer is deposited as in figure 8B. However, instead of then depositing the metal layer 45, the silicon nitride layer is etched back (planarised) to the upper surface of the metal layer 47, leaving only a portion 54 of the nitride layer in the region between the electrode 20 and the switching surface 19. A further silicon nitride layer 56 is then laid down on the resulting uninterrupted flat surface. Because this layer 56 is of even thickness it has relatively little residual stress, and a substantially straight beam can be achieved.

[0061] Figures 11A and 11B show a directly-actuated capacitive switch which has a flexible element in which the contact surfaces 19, 19' are, on a section 18, 28 of gull-winged shape. By 'gull-winged' we mean that the curvature of the section reverses or inflects, as at 58. This provides clearance over the edges of the switch contacts 12, 12', which here are shown as having a dielectric surface coating 60. The switch beam 14 is generally similar to that of figure 6 except for the gull-winged portion.

[0062] A further actuator beam 34 is provided above the flexible beam 14 and a force-applying pad 36 contacts the gull-winged section 18, 28 to conform the contact surfaces 19, 19' on to the switch contacts 12, 12'.

[0063] In a variation of this embodiment, shown in figure 11C, a stop block 62 is provided between the switch contacts 12, 12'. This is contacted by the central portion 28 of the gull-wing section after predetermined spreading of the contact surfaces 19, 19' on to the switch contacts. This prevents excessive deformation of the gull-wing section.

[0064] Figure 12A, B and C illustrate the manufacture of a gull-winged portion 18, 28 of a flexible switch beam such as in figure 11B or 11C. The fixed switch contacts 12, 12' are deposited on to the substrate 10 so as to leave a gap 64 between them. A sacrificial layer e.g. of polyimide is deposited on top of the contacts and the substrate and then selectively removed to leave an infill block 66 in the gap 64. The block 66 has shoulders 68 which are raised over the edges of the contacts 12, 12' which define the gap. A further layer 70 of polyimide or other suitable known sacrificial material is deposited which has the effect of providing more rounded shoulders 68 so that the shape of the upper surface of the resist layer 70 provides the required profile for the underside 76 of the gull-winged portion 18, 28. This is then deposited using e.g. the stress-controlling technique described with references to figures 8, 9 and 10. The extent to which the gull-winged portion is cranked upwards as at 58 to provide an intermediate inflected region between the contact position and the centre section is determined by the choice of thickness of the first polyimide layer. The thicker the layer, the more pronounced are the shoulders which remain over the edge of the contacts 12, 12'.

[0065] Figure 12D shows a less pronounced gull-wing shape which nevertheless still inflects at 58. With this component (obtained by reducing the thickness of the block 66), a tendency for the ends 18, 18' of the gull-winged section to tilt upwards can be reduced. Thereby consistent contact between the surfaces 19, 19' and the switch contacts 12, 12' is more likely to be repeatably achieved. A stop-block as at 62 in figure 11C may be also provided if desired in the embodiments of figure 12C and 12D.

[0066] Figure 13 shows another embodiment in which stresses are controlled to provide a desired shape of flexible cantilever switch beam. It is similar to the multi-layer beam 14 of figure 6A, (corresponding parts having the same reference numerals) and in principle can be used in both directly-actuated and indirectly-actuated configuration. The beam comprises a central silicon nitride layer 37 which in the shank portion 22 of the beam is disposed between outer upper and lower layers 38, 40 of aluminium/silicon/copper alloy. In the contact portion 18 of the beam the silicon nitride layer is disposed between the lower layer 40 of aluminium alloy and an upper layer 39 of either titanium or of aluminium alloy which has been deposited at lower pressure than the layer 40. When the layer 39 is of titanium, advantage is taken of the differing coefficients of thermal expansion of titanium and aluminium to impose the preferred shape on the contact portion 18 of the beam when it is at ambient temperature. Because aluminium has a higher coefficient of expansion than titanium, the aluminium layer contracts more on cooling from the elevated deposition temperature to ambient than does the titanium layer. This results in the contract portion 18 of the beam adopting a concave - downwards shape as at 71.

[0067] A similar control of the shape of the portion 18 can be achieved when both the layers 39 and 40 are of aluminium (and thus have similar co efficients of thermal expansion) by depositing the layers at different elevated temperatures. The layer deposited at the higher temperature will contract more on cooling to ambient than will the other layers. Thus, depositing layer 40 at a high temperature than layer 39 results in the beam portion 19 having a concave-down shape. Alternatively or in addition, other deposition parameters (e.g. pressure) can be varied so that the layers 39 and 40 have different characteristics (e.g. grain size) and thereby different residual internal stresses. This too can be used to achieve shaping of the portion 18. Indeed, if one of the layers 39. 40 is relatively thick, a gradation of internal stress can be provided across its thickness by varying e.g. its grain size. Then the layer can by itself impose a required curvature on the portion 18.

[0068] If the metal layer 40 of the shank portion is utilised as one of the actuator electrodes, application of the appropriate operating voltage between it and the electrode 20 can be used to overcome any residual upward curvature (e.g. as at 73). The applied voltage can straighten the shank portion by the so-called "zipper effect" and pull the contact portion 18 down into conforming contact with the other switch electrode (not shown), the beam flexing as necessary at the hinge 24.

[0069] The switch beam of figure 14 is similar to that of figure 13, and only the point of difference will be described. In this embodiment, the hinge 24 comprises a gap in the layer 40 which is overlaid on the opposite surface of the beam by an extended portion of the layer 39. The tendency of that layer to produce a concave-down shape as described above is assisted by the compliance of the line of weakness provided by the gap 75, resulting in the end portion 18 being tilted bodily downwards at 77.

[0070] The switches so far described are packaged on the substrate 60 as shown in figure 15. Just the contact beam 14 and the switch contact electrodes 12, 12' are shown in the figure as representative of a typical switch as a whole.

[0071] The switch is encased in a glass dome-shaped lid 80, at least the internal and external top surfaces of which are polished, so that the lid is optically transparent, and the condition of the switch and if necessary its operation can be inspected. The side walls of the lid are bonded and sealed by known techniques in a reduced pressure or inert gas environment to the silicon substrate 10 on which the switch is constructed. The volume within the lid thus is in a controlled atmosphere and care must be taken to ensure that the making of connections to the switch from outside do not break the hermetic seal between the lid and the substrate. Normally such connections are made to aluminium tracks as at 88 which extend through the lid/substrate bond, but here the invention offers an alternative solution. A portion 90 of the wall of the lid 80 is made thicker so that a via 92 can be formed through the substrate within the width of the wall without compromising the seal. A connection can then be made directly to a connection track 94 of the switch from a backplane track 96 of the substrate 10. In addition to preserving the integrity of the seal, this approach permits an all-surface-mounted configuration for the switch, and also avoids the difficulty of having to de-oxidise an exposed aluminium track before making a wire-bonded or soldered connection to it at 88. Further, by incorporating the connection within the perimeter of the package walls, not only is the footprint of the device is reduced, allowing for greater packing density both during manufacture and in the finished product, but the package wall provides additional structural strength during formation of the via and thereafter, improving long term reliability of the assembly.

[0072] Figure 16 shows an alternative form of the lid 80. Here the wall 98 is formed as a separate component, either of glass or of silicon. The wall 98 is first bonded to the substrate 10, and then the transparent glass lid is bonded onto it, e.g. by frit bonding. Figure 14 also illustrates that a via 100 may be provided through the wall

98 to provide access to a track on the substrate to permit a connection to be made thereto if a backplane connection is not available.

[0073] Figures 17 A-E illustrate the process of packaging MEMS switches (here shown as in figure 11C) in bulk on a wafer. In figure 17A, the top surface of the substrate 10 first is cut back around the switches on the wafer (only one shown) to leave a peripheral pad 102 around each switch to form a mounting for the lid 80. An array of lids 80 are then bonded to their respective pads 102 (Figure 17B). A wax layer or tape 104 is applied to the polished top surface of the lid to protect it during subsequent handling (fig 17C), and the underside of the wafer substrate 10 is ground at 105 in preparation for the deposition of gold backplane tracks 106 (fig 17D). The packaged switches are then sawn-through at 108 to separate them into individual units (figure 17E).

[0074] The invention also includes any novel feature or combination of features whether or not specifically claimed. In particular but without limitation a feature appearing in a first claim or series of claims may be introduced into another claim a series of claims not dependent from the first claim or series of claims.

Claims

1. A packaged RF or other MEMS device wherein a package in which the device is contained is at least partially optically transparent.

2. The device of claim 1 wherein the package comprises a transparent glass cover.

3. The device of claim 2 comprising a separate wall structure which spaces the glass cover from a circuit substrate.

4. The device of claim 3 wherein the wall structure is of glass or an oxide of silicon.

5. The device of claim 3 or 4 wherein the cover is frit-bonded to the wall structure.

6. The device of any of claims 3 to 5 comprising a via extending through the circuit substrate beneath the wall structure to form an electrical connection to the device.

7. The device of any preceding claim comprising a via through the wall structure to form an electrical connection to a conductor on the substrate.

8. The device of any preceding claim, being a MEMS switch.

9. The device of claim 8 being a switch for use at radio or microwave frequencies and comprising a pair of contact-making surfaces, at least one of which is moveable relative to the other to open or close the switch, a said surface being carried by a flexible element, and actuator means configured to effect said relative movement, the arrangement being such that when the switch is closed the flexible element is deformed to conform the contacting surface defined thereon to the other contacting surface.

10. The device of claim 9 wherein the actuator means is moveable relative to the flexible element and is adapted to apply the closing force along a line of action which passes through the contacting surfaces.

11. The device of claim 9 wherein a said contacting surface is on a first portion of the flexible element which is attached to a further portion of the flexible element, internal stresses in the flexible element having been chosen so as to control the shape of the first portion and/or its angular disposition relative to the further portion.

12. A method of packaging a MEMS device comprising mounting the device on a circuit substrate, preparing a perimeter area around the device to receive a wall structure of a cover, and securing a perimeter wall of a transparent cover to the perimeter area.

13. The method of claim 12 comprising securing a perimeter wall structure to the perimeter area, and then securing a transparent lid to the wall structure.

14. The method of claim 12 or 13 comprising providing a via through the circuit substrate beneath the wall structure.

15. The method of any of claims 12 to 13 comprising providing a via through the wall structure to form an electrical connection to a conductor on the substrate.

Fig.1.

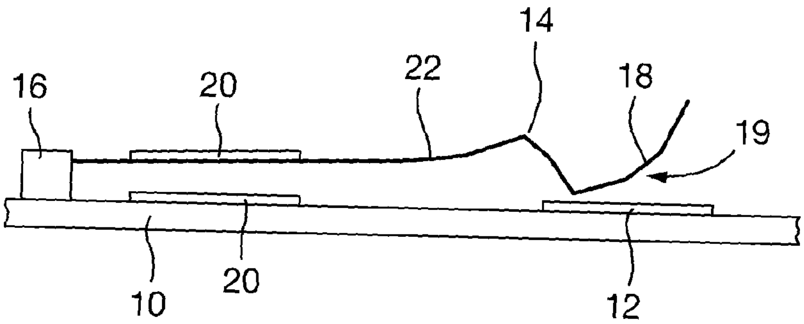


Fig.2.

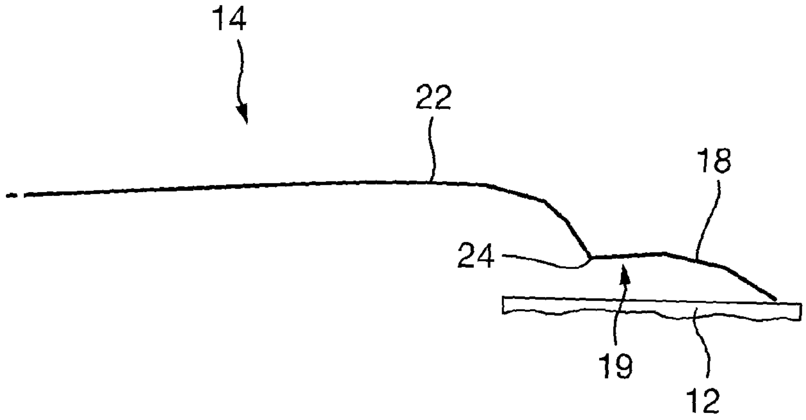


Fig.3.

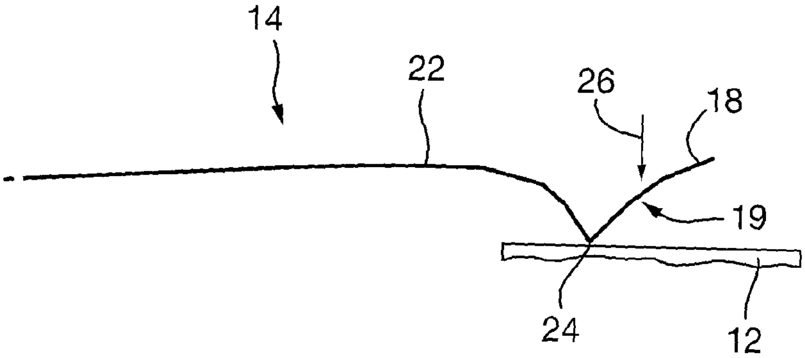


Fig.4.

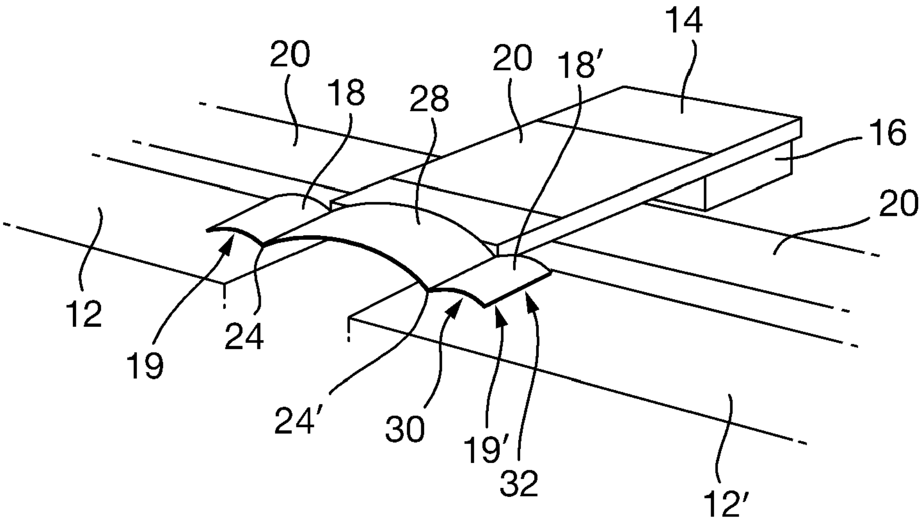

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Fig.5.

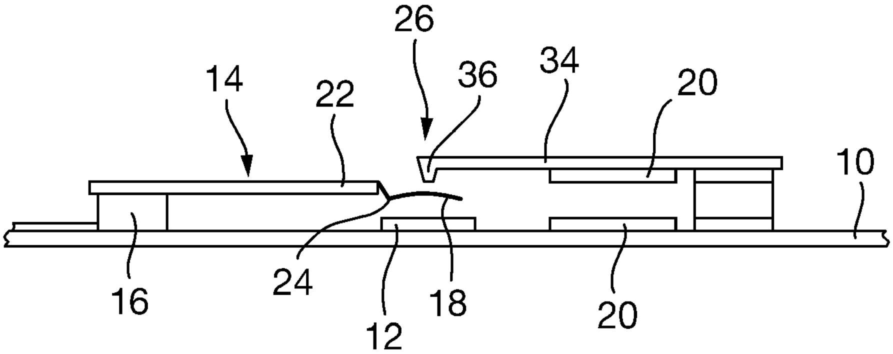
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Fig.6A.

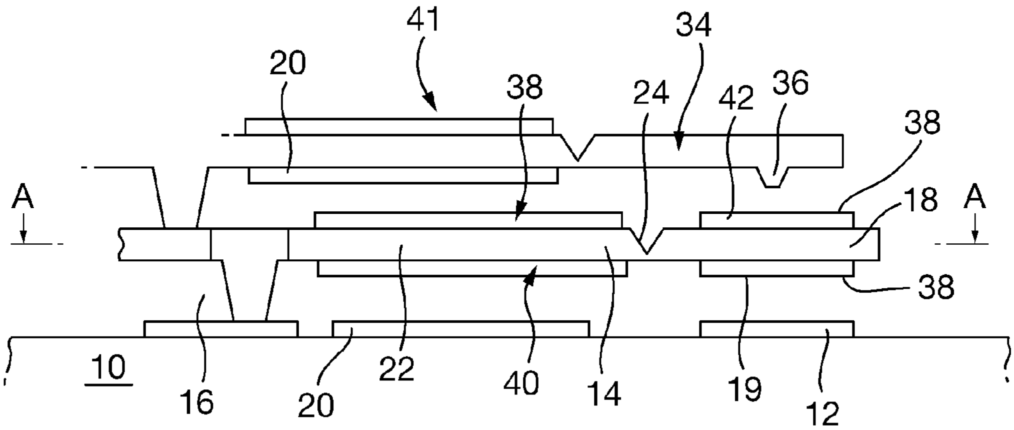
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Fig.6B.

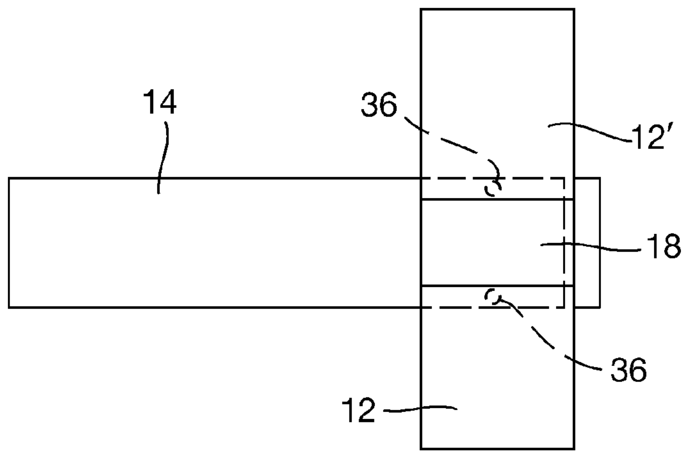

14
36
12′
18
36
12

Fig.7.

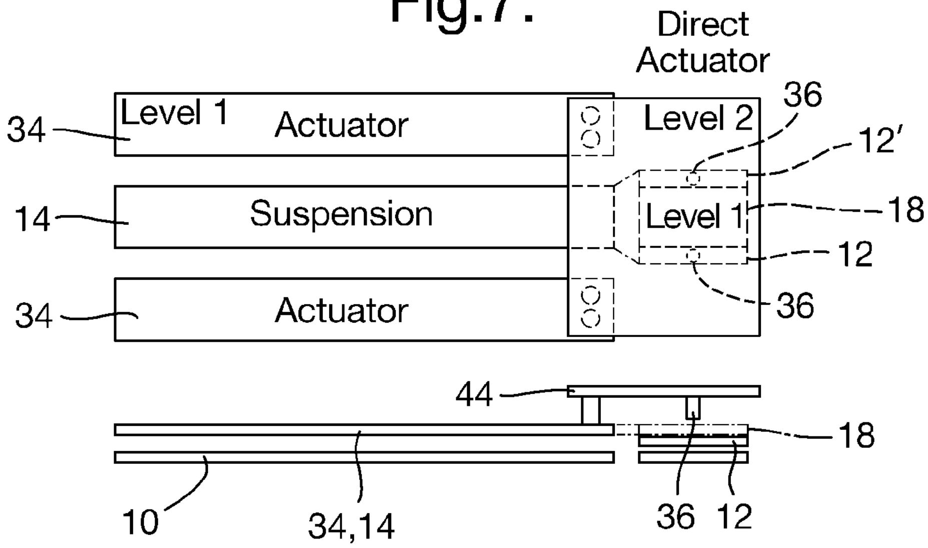


Fig.15.

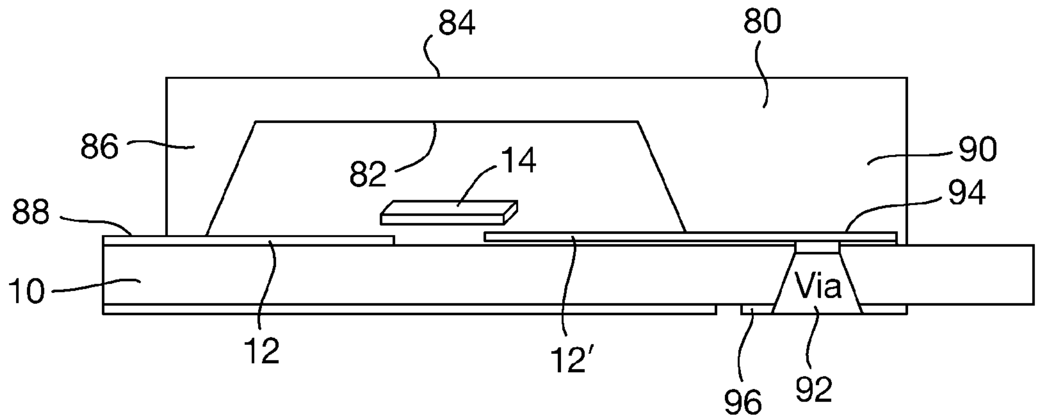


Fig.16.

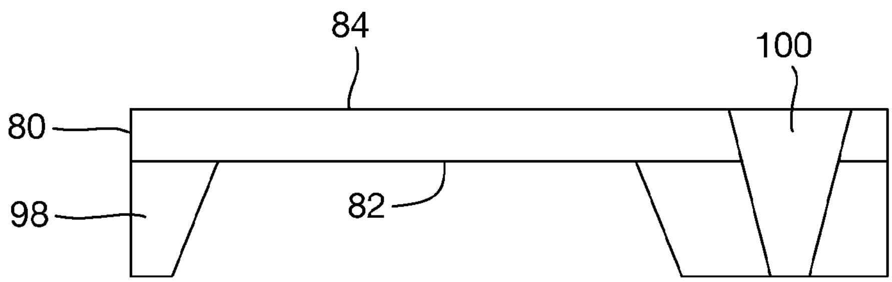


Fig.8A.

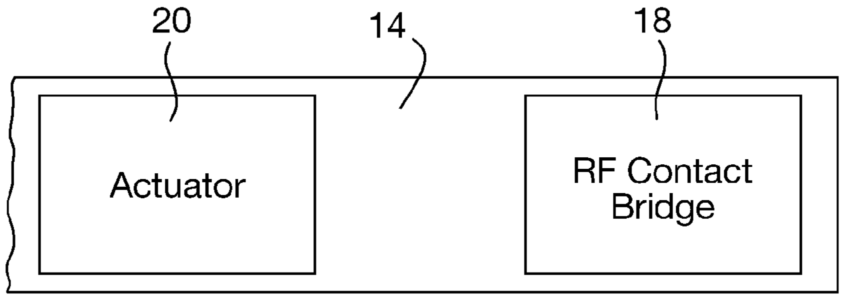


Fig.8B.

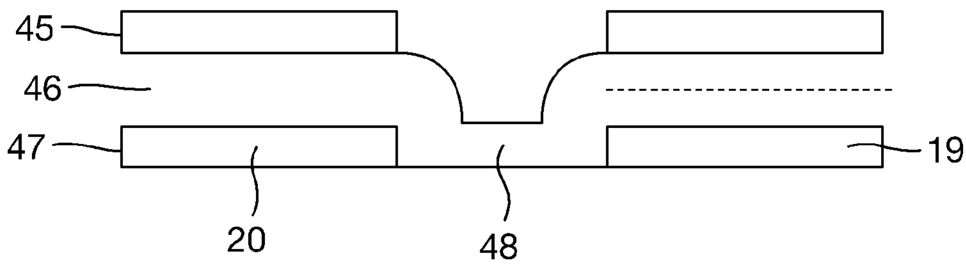


Fig.9.

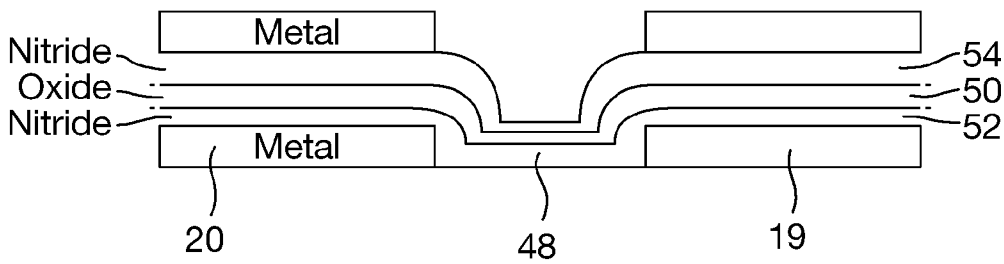
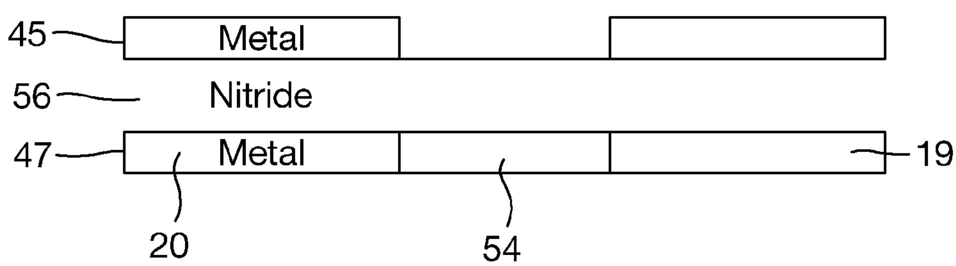


Fig.10.



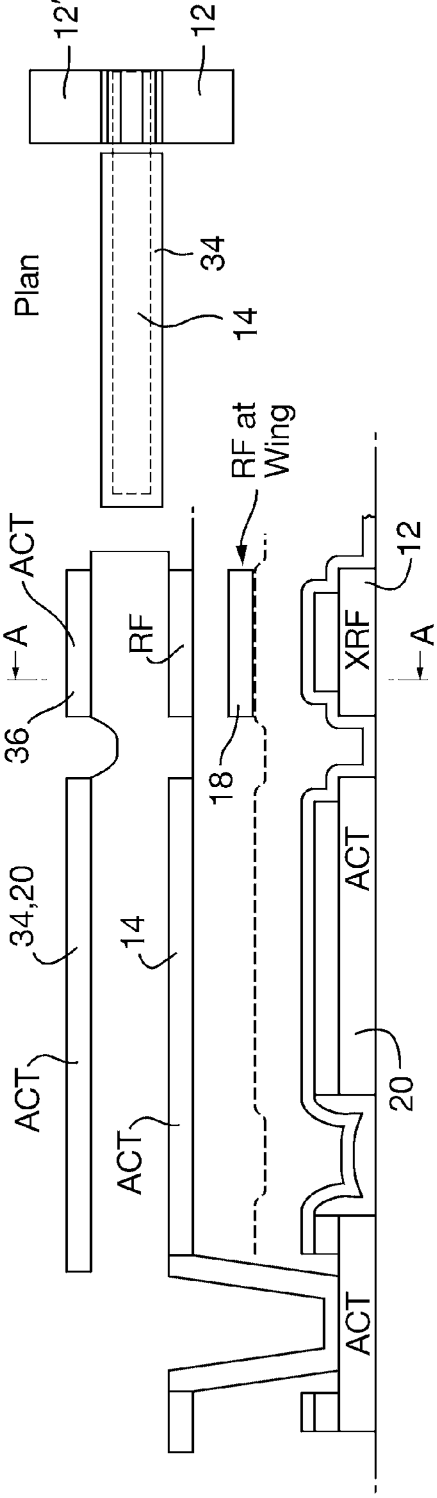


Fig.11A.

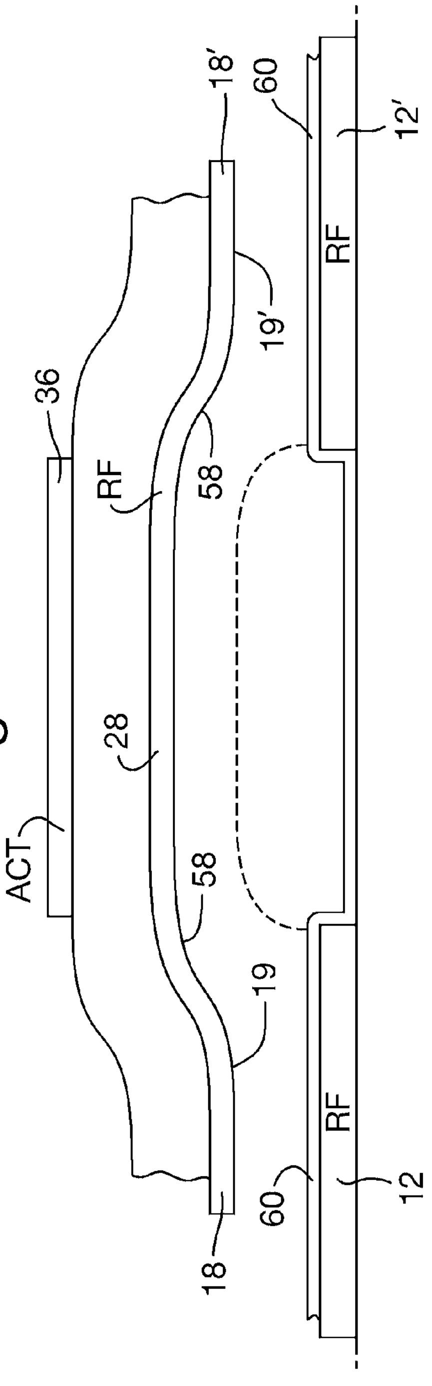


Fig.11B.

Fig.11C.

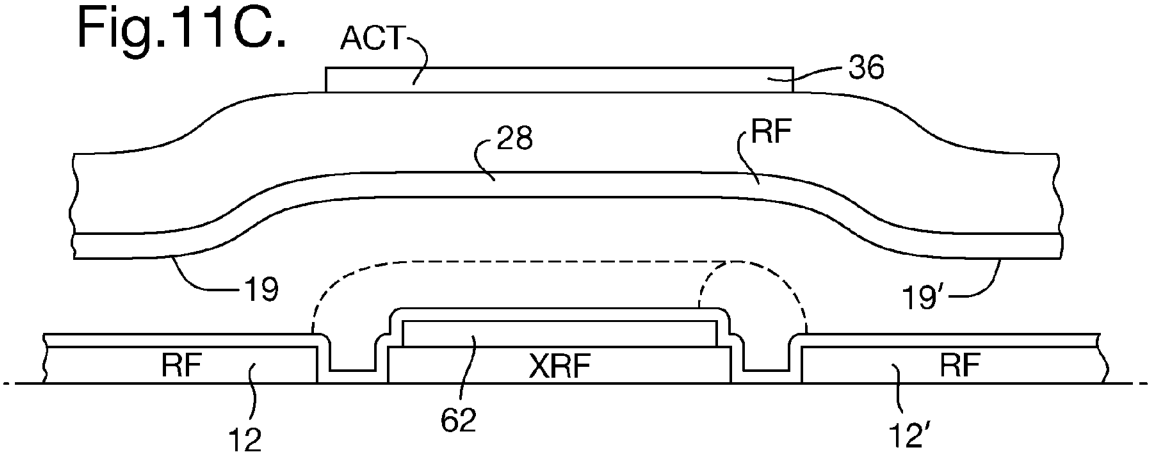


Fig.12A.

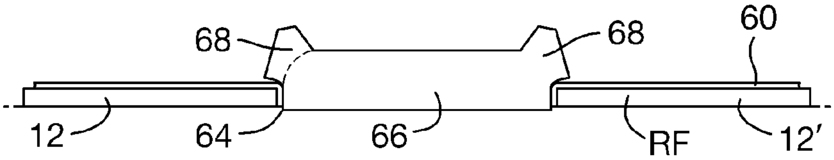


Fig.12B.

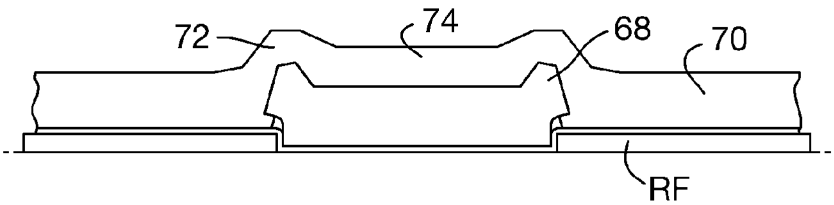


Fig.12C.

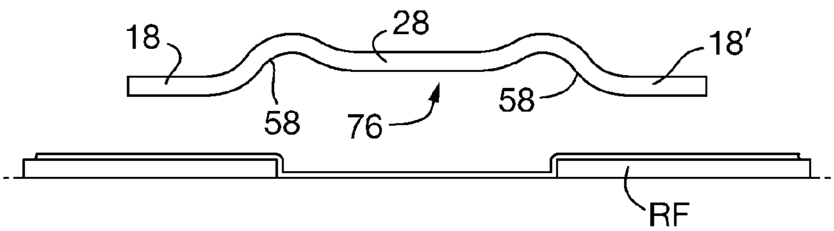


Fig.12D.

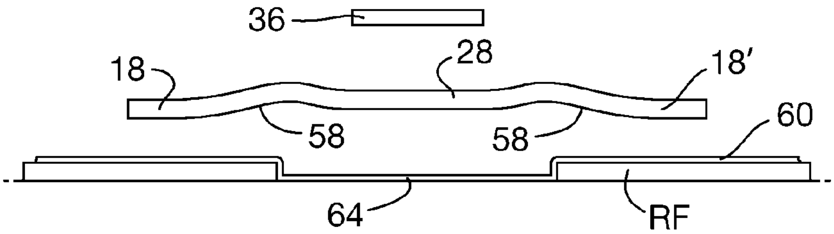


Fig.13.

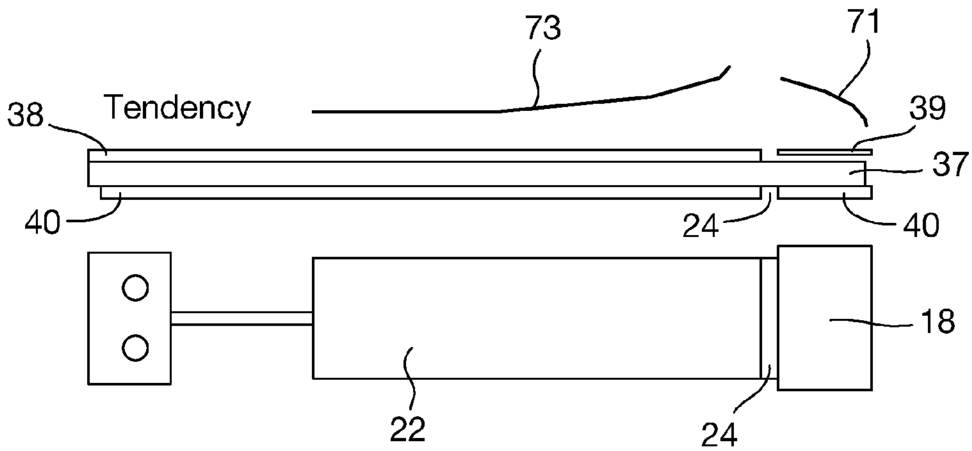
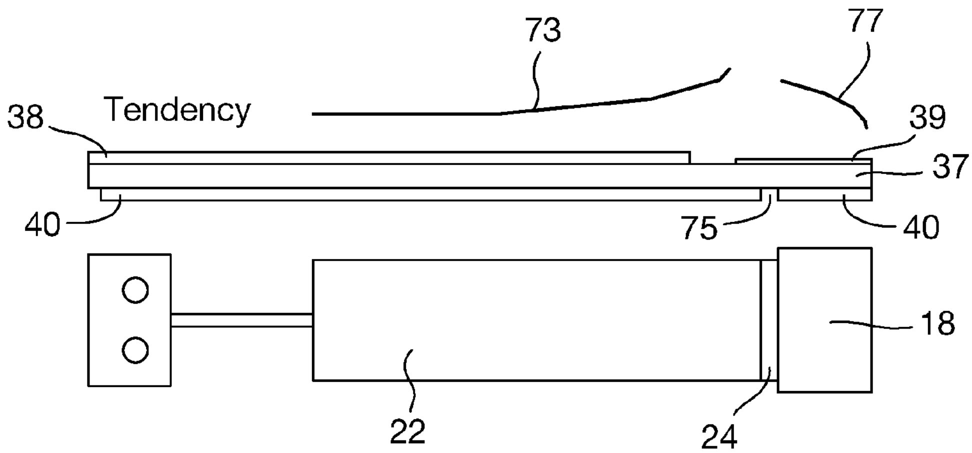

73
71
Tendency
38
39
37
40
24
40
18
22
24

Fig.14.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77
Tendency
38
39
37
40
75
40
18
22
24

Fig.17A.

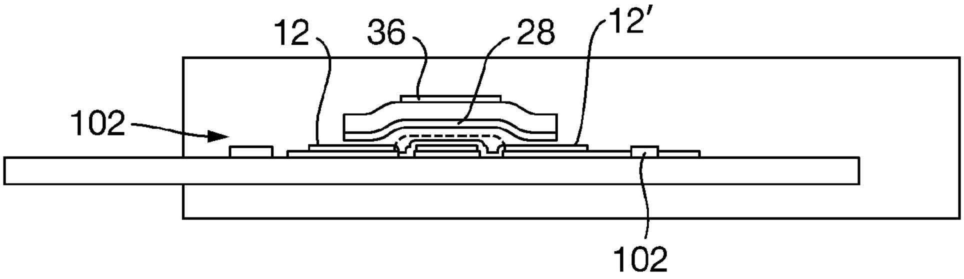


Fig.17B.

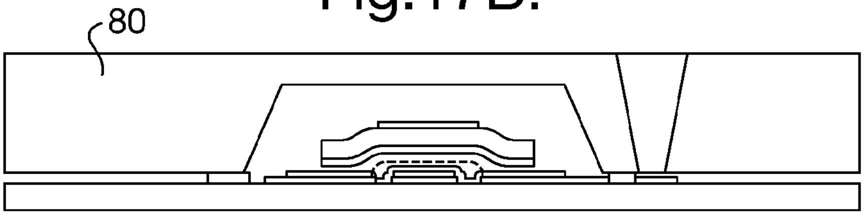


Fig.17C.

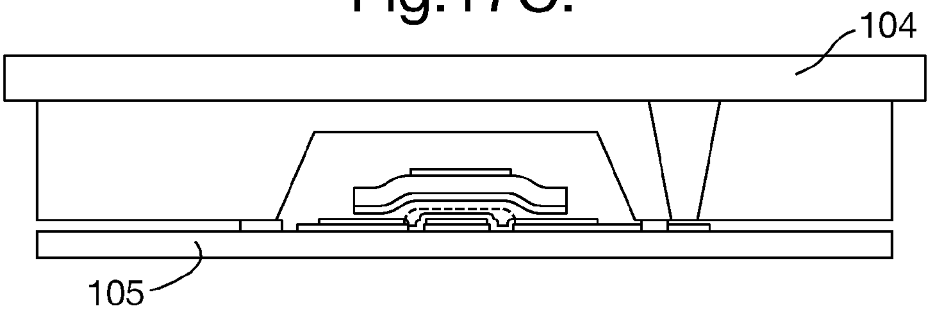


Fig.17D.

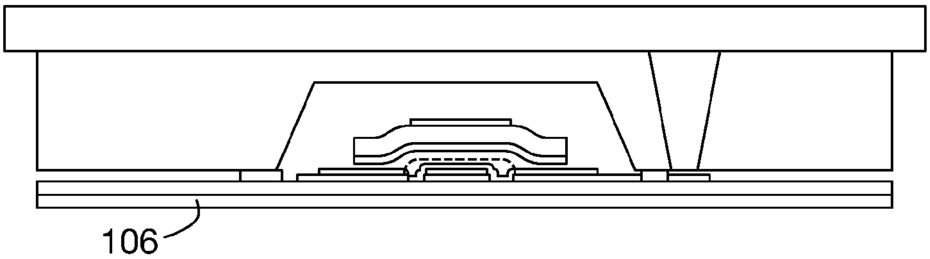
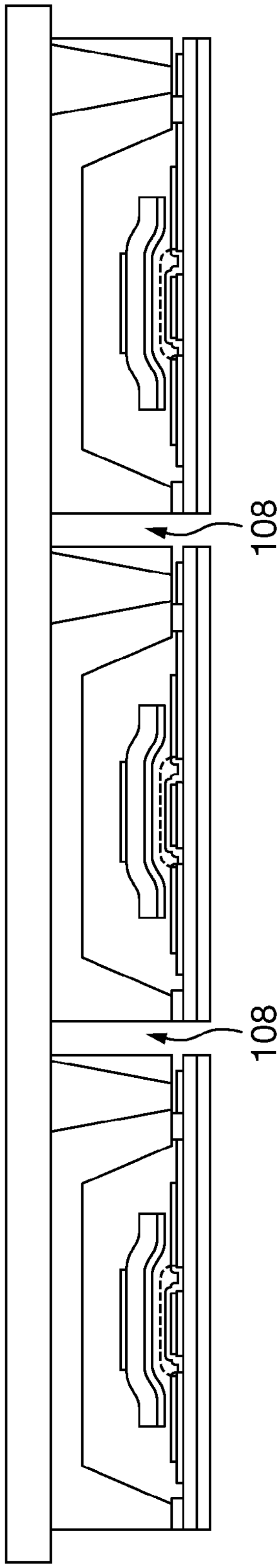


Fig.17E.



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EUROPEAN SEARCH REPORT

Application Number
EP 09 27 5108

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 6 494 095 B1 (WAN LAWRENCE A [US]) 17 December 2002 (2002-12-17) * column 2, lines 1-8; figure 4 * -----	1,8,12, 13 2-5	INV. H01H59/00
Y	US 4 794 370 A (SIMPSON GEORGE R [US] ET AL) 27 December 1988 (1988-12-27) * column 3, lines 29-37; figure 1 * -----	2-5	

TECHNICAL FIELDS SEARCHED (IPC)

H01H

~~The present search report has been drawn up for all claims~~

1

Place of search	Date of completion of the search	Examiner
Munich	17 March 2010	Simonini, Stefano

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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European Patent Office
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Application Number
EP 09 27 5108

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-5, 8, 12, 13

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 09 27 5108

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-5, 8, 12, 13

   Invention 1 relates to the problem of choosing a material for the transparent packaging.

   ---

2. claims: 6, 7, 14, 15

   Invention 2 relates to the problem of providing an electrical connection to the device.

   ---

3. claims: 9-11

   Invention 3 relates to the problem of providing an actuator to the device.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 27 5108

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-03-2010

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 6494095	B1	17-12-2002	NONE	
US 4794370	A	27-12-1988	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82