

DESCRIPTION

TITLE: METHOD FOR TRANSFERRING A SEALING LAYER

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FIELD OF THE INVENTION

The present invention relates to the field of electromechanical microsystems and/or substrates, notably to the field of membrane-based devices.

In particular, the present invention relates to a method for transferring a layer intended to collectively seal a plurality of cavities formed on a carrier substrate.

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More specifically, the transfer method according to the present invention is intended to limit the appearance of zones, referred to as non-transferred zones, liable to appear in a contour of the carrier substrate.

TECHNOLOGICAL BACKGROUND OF THE INVENTION

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Layer transfer methods are nowadays widely used when forming suspended membranes and/or sealing cavities.

In this regard, such methods may comprise executing the following steps:

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Ai) a step of providing a donor substrate 1 (Figure 1) and a carrier substrate 2 (Figure 2) provided with a plurality of cavities 3 opening in a main face 4 of said carrier substrate 2,

Bi) a step of assembling the donor substrate 1 and the receiver substrate 2 to seal the cavities 3 (Figure 3),

Ci) a step of thinning the donor substrate 1 so as to conserve only a part of said substrate 1, referred to as the sealing layer 5.

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The thinning step Ci) may be executed according to a first aspect using mechanical grinding and/or chemical etching, permanently thinning the donor substrate (Figure 4).

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Furthermore, the uniformity of the sealing layer on completion of step Ci) is highly dependent on the technique used during step Ci), and is difficult to control.

To overcome the issues related to uniformity and obtaining thin membranes, the “Smart-Cut™” approach described in document EP533551 may be used. This approach enables a sealing layer to be transferred by detaching said sealing layer from the donor substrate along a

fracture zone. The fracture zone formed by implantation and/or amorphization enables a relatively thin sealing layer to be delimited.

However, implementing this method with no other considerations results in the formation of defects, and more specifically the appearance of non-transferred zones or voids through the sealing layer. Figure 5 shows an example of this. Notably, Figure 5 is a photograph of a void appearing in a zone near to the edge of the sealing layer and diametrically opposite the notch in the carrier substrate. These voids adversely affect the overall performance of the method in question and are also a source of contamination.

One objective of the present invention is to propose a method for sealing a plurality of cavities with a sealing layer that limits the appearance of defects in said sealing layer.

BRIEF DESCRIPTION OF THE INVENTION

The objective of the invention is achieved by a method for transferring a layer onto a main face of a carrier substrate, the method comprising:

a) a step of forming cavities in a carrier substrate, said cavities opening in a main face of said carrier substrate,

b) a step of transferring a layer, referred to as the sealing layer, from a donor substrate, to cover the main face and to seal all of the cavities formed during step a),

step a) being executed such that all of the cavities are distributed regularly over a zone, referred to as the main zone, of the main face, and such that said main face comprises a peripheral ring with no cavities and inside which the main zone is circumscribed, the peripheral ring extending from the edge of the carrier substrate over a length L less than a predetermined length L_p , said predetermined length L_p being a length below which the sealing layer is free of non-transferred zones in the peripheral ring.

According to one embodiment, step a) of forming cavities comprises the following sub-steps:

a1) a sub-step of forming a peripheral mask to cover the peripheral ring and to protect said peripheral ring from physical grinding or chemical etching,

a2) a sub-step of forming a main mask to cover the main zone and at least partially cover the peripheral mask, the main mask comprising openings defining the position and size of the cavities to be formed,

a3) an etching sub-step resulting in the formation of the cavities in the main zone,

5 a4) a sub-step of removing the main mask and the peripheral mask to expose the whole of the main face to the external environment.

According to one embodiment, the peripheral mask is made using a photolithography process using a negative photosensitive resin.

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According to one embodiment, the main mask is made using another photolithography process using a photosensitive resin.

15 According to one embodiment, the layer transfer step results in the formation of an edge ring on the main face that extends over a distance D from the edge of the carrier substrate, said edge ring being a zone from which the sealing layer is absent, the length L being greater than the distance D and less than the sum of the distance D and a distance H , H being less than 500 μm , advantageously less than 200 μm , and even more advantageously less than 100 μm .

20 According to one embodiment, the length L is between 500 μm and 2500 μm , advantageously between 500 μm and 1500 μm , also advantageously between 500 μm and 1000 μm , even more advantageously between 500 μm and 800 μm , still even more advantageously between 500 μm and 700 μm .

25 According to one embodiment, the cavities are rectangular and each side thereof has a length of between 2 μm and 500 μm , advantageously between 2 μm and 500 μm , and even more advantageously between 2 μm and 40 μm .

30 According to one embodiment, step b) is executed such that the sealing layer has a thickness of between 100 nm and 2000 nm.

According to one embodiment, step b) comprises the following sequence of sub-steps:

b1) a step of forming a fragilization plane in the volume of the donor substrate, the fragilization plane delimiting the sealing layer with a face, referred to as the assembly face, of the donor substrate,

5 b2) a step of assembling the donor substrate and the carrier substrate by bringing the assembly face and the main face into contact,

b3) a fracture step intended to initiate a fracture wave along the fragilization plane to enable the sealing layer to be detached from the donor substrate.

10 According to one embodiment, sub-step b1) of forming a fragilization plane comprises an implantation of species.

According to one embodiment, sub-step b2) comprises a molecular bonding of the assembly face with the main face.

15 According to one embodiment, sub-step b3) comprises a heat treatment intended to initiate propagation of the fracture wave.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Other characteristics and advantages of the invention will emerge from the detailed description which will follow, with reference to the appended figures, in which:

[Fig. 1] Figure 1 is a schematic representation of one of the faces of a donor substrate that can be used when executing a layer transfer method known in the prior art, the layer transfer method being notably implemented to seal cavities formed on a receiver substrate (shown in Figure 2),

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[Fig. 2] Figure 2 is a schematic representation of a receiver substrate that can be used when executing a layer transfer method known in the prior art, the receiver substrate being notably represented by a face in which the cavities open,

30 [Fig. 3] Figure 3 is a schematic representation of assembly step Bi) of a layer transfer method known in the prior art, showing the donor substrate and the carrier substrate in cross section in a plane perpendicular to the main faces of these two substrates,

[Fig. 4] Figure 4 is a schematic representation of thinning step Ci) of a layer transfer method known in the prior art, showing the sealing layer and the receiver substrate in cross section in a plane perpendicular to the main faces of the receiver substrate,

5 [Fig. 5] Figure 5 is a photograph of a void observed in a sealing layer transferred according to a transfer method known in the prior art,

[Fig. 6] Figure 6 is a schematic representation of the sequence of steps executed during implementation of the method according to one advantageous embodiment of the present
10 invention,

[Fig. 7] Figure 7 is a schematic representation of the sequence of steps executed during implementation of one advantageous embodiment of the method according to one advantageous
15 embodiment of the present invention,

[Fig. 8] Figure 8 is a schematic representation of a carrier substrate on a main face of which a photosensitive negative resin layer is formed, the carrier substrate being notably shown in cross section in a plane perpendicular to its main face,

20 [Fig. 9] Figure 9 is a schematic representation of the insolation of the resin layer formed on the main face of the carrier substrate, the carrier substrate being notably shown in cross section in a plane perpendicular to its main face,

[Fig. 10] Figure 10 is a schematic representation of the development of the negative resin layer
25 following insolation, in order to crosslink said negative resin on a peripheral zone, said peripheral zone extending along a length L from the edge of the carrier substrate, the carrier substrate being shown in cross section in a plane perpendicular to its main face,

[Fig. 11] Figure 11 is a schematic representation of a carrier substrate on a main face of which
30 a photosensitive resin layer is formed, covering the main zone and the peripheral zone, the carrier substrate being shown in cross section in a plane perpendicular to its main face,

[Fig. 12] Figure 12 is a schematic representation of the formation of the main mask on the main
35 face of the carrier substrate, said main mask being formed to impose patterns on the cavities to be formed by etching, the carrier substrate being shown in cross section in a plane perpendicular to its main face,

[Fig. 13] Figure 13 is a schematic representation of a carrier substrate on a face of which cavities are formed following a step of etching through the main mask and removing said main mask and the peripheral zone, the carrier substrate being shown in cross section in a plane perpendicular to its main face,

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[Fig. 14] Figure 14 is a schematic representation of the carrier substrate to which a sealing layer is transferred, the sealing layer notably being transferred thereto to cover the main face and seal the cavities, the carrier substrate being shown in cross section in a plane perpendicular to its main face,

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[Fig. 15] Figure 15 is a schematic representation of step b1) of the method according to the present invention, the arrows representing the implantation of species via a free face of the donor substrate, the donor substrate being shown in cross section in a plane perpendicular to its free face,

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[Fig. 16] Figure 16 is a schematic representation of step b2) of the method according to the present invention, notably showing assembly of the donor substrate with the carrier substrate, which are both shown in cross section in a plane perpendicular to the main face,

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[Fig. 17] Figure 17 is a schematic representation of step b3) of the method according to the present invention, notably showing the fracture sub-step that results in transfer of the sealing layer onto the main face of the carrier substrate, the carrier substrate being shown in cross section in a plane perpendicular to the main face.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a process for transferring a sealing layer onto a main face of a carrier substrate. Notably, the sealing layer is transferred to cover (and seal) cavities formed in the carrier substrate that open in the main face of said carrier substrate.

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Thus, the invention relates to a method for transferring a layer onto a main face of a carrier substrate, the method comprising:

a) a step of forming cavities in a carrier substrate, said cavities opening in a main face of said carrier substrate,

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b) a step of transferring a layer, referred to as the sealing layer, from a donor substrate, to cover the main face and to seal all of the cavities formed during step a),

step a) being executed such that all of the cavities are distributed regularly over a zone, referred to as the main zone, of the main face, and such that said main face comprises a peripheral ring with no cavities and inside which the main zone is circumscribed, the peripheral ring extending from the edge of the carrier substrate over a length L less than a predetermined length L_p , said predetermined length L_p being a length below which the sealing layer is free of non-transferred zones in the peripheral ring.

“Free of non-transferred zones” means a zone of the sealing layer that has no voids, and notably no through-voids.

Figure 6 shows schematically the steps executed during implementation of the method. Notably, the method according to the present invention comprises a step a) of forming cavities in a carrier substrate, said cavities opening in a main face of said carrier substrate.

Advantageously and as illustrated in Figure 7, step A) may comprise execution of a set of sub-steps. Notably, step a) may comprise the following sub-steps:

a1) a sub-step of forming a peripheral mask to cover the peripheral ring and to protect said peripheral ring from physical grinding or chemical etching,

a2) a sub-step of forming a main mask to cover the main zone and at least partially cover the peripheral mask, the main mask comprising openings defining the position and size of the cavities to be formed,

a3) an etching sub-step resulting in the formation of the cavities in the main zone,

a4) a sub-step of removing the main mask and the peripheral mask to expose the whole of the main face to the external environment.

Still advantageously and as shown in Figure 7, step b) may comprise the execution of a set of sub-steps. Notably, step b) may comprise the following sub-steps:

b1) a step of forming a fragilization plane in the volume of the donor substrate, the fragilization plane delimiting the sealing layer with a face, referred to as the assembly face, of the donor substrate,

b2) a step of assembling the donor substrate and the carrier substrate by bringing the assembly face and the main face into contact,

b3) a fracture step intended to initiate a fracture wave along the fragilization plane to enable the sealing layer to be detached from the donor substrate.

The present invention makes reference to a donor substrate and a carrier substrate. It is understood that a substrate, according to the principles set out in the present disclosure, comprises two faces that are essentially parallel with one another and connected by a contour or an edge. Furthermore, said contour or edge describes a circle.

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Furthermore, a substrate may comprise a notch that notably enables its crystalline orientation to be determined and/or defined.

10 The remainder of the disclosure of the present invention is dedicated to the description of the embodiment illustrated in Figure 7.

Sub-step a1) is illustrated in Figure 8, Figure 9 and Figure 10.

15 Figure 8 thus represents a carrier substrate 10 on one face, referred to as the main face 11, of which a resin layer 12 is formed. It is understood that the resin layer covers the main face 11 entirely. Furthermore, the resin used is advantageously M78Y negative resin (sold by JSR Corporation).

20 The formation of the resin layer 12 is followed by an insolation step, as illustrated in Figure 9. Notably, this insolation step defines, in the resin layer 12, a peripheral zone 13 and a central zone 14 circumscribed by the peripheral zone 13. Notably, the peripheral zone 13 extends over a length L from the edge of the carrier substrate 10. In other words, the peripheral zone 13 forms a ring delimited externally by an outer edge and internally by an inner edge, said inner edge being at a distance L from the edge of the carrier substrate 10.

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The insolation step is notably executed such that only the peripheral zone 13 is exposed to light radiation, thereby crosslinking said peripheral zone. In this regard, a mask (not shown) may be used to mask a central zone 14 of the resin layer 12.

30 Following insolation, the resin layer is subjected to a development step in which the central zone 14 of the resin layer 12 is removed to expose a main zone 15 of the main face 11 to the external environment (Figure 10). It is understood that the development step enables the peripheral zone 13, which covers a peripheral ring 16 of the main face 11 and inside which the

main zone 15 is circumscribed, to be conserved. Furthermore, the resin forming the resin layer 12 is designed to protect the peripheral zone 16 from physical grinding and/or chemical etching.

Sub-step a2) is illustrated in Figure 11 and Figure 12.

5 Sub-step a2) thus firstly comprises the formation of a resin layer 17 covering the main zone 15 and the peripheral zone 13 (Figure 11).

As illustrated in Figure 12, the resin layer 17 is exposed (or insolated) to light radiation, and notably ultraviolet light radiation, to be subsequently developed to form a main mask 17a. The exposure (or insolation) of the resin layer is implemented using photolithography
10 equipment (for example a photorepeater) that insulates the resin layer 17 through a photolithographic mask intended to print predefined patterns. Thus, following development, the main mask 17a comprises openings 18 defining the print of cavities to be formed by an etching step.

15 Sub-steps a3) and a4) are illustrated in Figure 13.

In this regard, Figure 13 represents the carrier substrate 10 following completion of a step of etching executed through the main mask 17a and removing, after etching, said main mask and the peripheral zone 13. Notably, the carrier substrate 10 comprises cavities 19 opening
20 in the main face 11 of the carrier substrate 10. It is understood that, where the peripheral zone 13 masks the peripheral ring 16, the cavities are only formed in the main zone. This is because the peripheral zone 13 protects the peripheral ring 16 from etching, thereby providing a zone free of cavities 19.

25 By way of example, the cavities 19 may be rectangular and each side thereof has a length of between 2 μm and 500 μm , advantageously between 2 μm and 500 μm , and even more advantageously between 2 μm and 40 μm .

30 The peripheral ring 16 according to the present invention extends from the edge of the carrier substrate over a length L.

The method according to the present invention also comprises a step b) of transferring a layer, referred to as the sealing layer 21, from a donor substrate 20, to cover the main face 11 and to seal all of the cavities 19 formed during step a).

Figure 14 shows an example of this.

Furthermore, step b) may be executed such that the sealing layer has a thickness of
5 between 100 nm and 2000 nm.

According to one advantageous embodiment, transfer step b) may be implemented according to the principles set out in Figure 7.

10 Notably, step b1), illustrated in Figure 15, comprises a step of forming a fragilization plane 23 in the volume of the donor substrate 20. The fragilization plane 23 in particular delimits the sealing layer 21 with a face, referred to as the assembly face 24, of the donor substrate 20.

15 Sub-step b1) of forming a fragilization plane may comprise an implantation of species. Said species may comprise at least one of the following elements: hydrogen and helium.

Step b) also comprises an assembly sub-step b2). In particular and as illustrated in Figure 16, sub-step b2) comprises bringing the assembly face 24 and the main face 11 into contact.
20 Sub-step b2) may also comprise an initiation of a bonding wave. Notably, this initiation of the bonding wave may be obtained by exerting a pressure tending to bring the assembly face and the main face closer together. This pressure is usually exerted using a pin or a finger on a face of the donor substrate opposite the assembly face, and near to the notch in said substrate.

25 “Near to the notch” means at a distance of less than 1 cm from said notch.

This pressure generates a local contact between the assembly face and the main face that is close enough to create local weak links (for example hydrogen links) between the two surfaces in question. This close contact spreads gradually over the entire interface in the form
30 of a bonding wave.

Thus, advantageously, sub-step b2) comprises a molecular bonding of the assembly face with the main face.

Step b) also comprises a fracture sub-step b3) intended to initiate a fracture wave along the fragilization plane to enable the sealing layer to be detached from the donor substrate (Figure 17). Advantageously, sub-step b3) may comprise a heat treatment intended to initiate propagation of the fracture wave.

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Implementation of the invention and notably the provision of a peripheral ring 16 free of cavities limits or obviates the appearance of voids in the sealing layer following transfer thereof to the main face.

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In particular, the inventors have observed that exclusion of the peripheral ring according to the terms of the present invention inevitably led to the appearance of voids in the sealing layer. Notably, the inventors have also observed that these voids were essentially present in a region diametrically opposite the initiation zone of the bonding wave.

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Thus, according to the present invention, the length L is less than a predetermined length L_p , said predetermined length L_p being a length below which the sealing layer is free of non-transferred zones in the peripheral ring.

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Furthermore, it is known that the layer transfer step results in the formation of an edge ring on the main face that extends over a distance D from the edge of the carrier substrate, said edge ring being a zone from which the sealing layer is absent. This distance D may be determined experimentally.

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Thus, according to the present invention, the length L is advantageously greater than the distance D and less than the sum of the distance D and a distance H , H being less than $500\text{ }\mu\text{m}$, advantageously less than $200\text{ }\mu\text{m}$, and even more advantageously less than $100\text{ }\mu\text{m}$.

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Alternatively, the length L is between $500\text{ }\mu\text{m}$ and $2500\text{ }\mu\text{m}$, advantageously between $500\text{ }\mu\text{m}$ and $1500\text{ }\mu\text{m}$, also advantageously between $500\text{ }\mu\text{m}$ and $1000\text{ }\mu\text{m}$, even more advantageously between $500\text{ }\mu\text{m}$ and $800\text{ }\mu\text{m}$, still even more advantageously between $500\text{ }\mu\text{m}$ and $700\text{ }\mu\text{m}$.

The lengths L set out above slow the bonding wave during execution of sub-step b2) in the peripheral ring, thereby limiting the trapping of gas bubbles when the bonding wave reaches, and closes, a zone diametrically opposite the initiation point.

- 5 Naturally, the invention is not limited to the embodiments described, and variations may be made thereto without thereby departing from the scope of the invention as defined in the claims.

CLAIMS

1. Method for transferring a layer onto a main face of a carrier substrate, the method comprising:
 - a) a step of forming cavities in a carrier substrate, said cavities opening in a main face of said carrier substrate,
 - b) a step of transferring a layer, referred to as the sealing layer, from a donor substrate, to cover the main face and to seal all of the cavities formed during step a),
 step a) being executed such that all of the cavities are distributed regularly over a zone, referred to as the main zone, of the main face, and such that said main face comprises a peripheral ring with no cavities and inside which the main zone is circumscribed, the peripheral ring extending from the edge of the carrier substrate over a length L less than a predetermined length L_p , said predetermined length L_p being a length below which the sealing layer is free of non-transferred zones in the peripheral ring.
2. Transfer method according to Claim 1, in which step a) of forming cavities comprises the following sequence of sub-steps:
 - a1) a sub-step of forming a peripheral mask to cover the peripheral ring and to protect said peripheral ring from physical grinding or chemical etching,
 - a2) a sub-step of forming a main mask to cover the main zone and at least partially cover the peripheral mask, the main mask comprising openings defining the position and size of the cavities to be formed,
 - a3) an etching sub-step resulting in the formation of the cavities in the main zone,
 - a4) a sub-step of removing the main mask and the peripheral mask to expose the whole of the main face to the external environment.
3. Transfer method according to Claim 2, in which the peripheral mask is made using a photolithography process using a negative photosensitive resin.
4. Transfer method according to Claim 2 or 3, in which the main mask is made using another photolithography process using a photosensitive resin.
5. Transfer method according to one of Claims 1 to 4, in which the layer transfer step results in the formation of an edge ring on the main face that extends over a distance D from the edge of the carrier substrate, said edge ring being a zone from which the sealing

layer is absent, the length L being greater than the distance D and less than the sum of the distance D and a distance H, H being less than 500 μm , advantageously less than 200 μm , and even more advantageously less than 100 μm .

- 5 6. Transfer method according to one of Claims 1 to 4, in which the length L is between 500 μm and 2500 μm , advantageously between 500 μm and 1500 μm , also advantageously between 500 μm and 1000 μm , even more advantageously between 500 μm and 800 μm , still even more advantageously between 500 μm and 700 μm .
- 10 7. Transfer method according to one of Claims 1 to 6, in which the cavities are rectangular and each side thereof has a length of between 2 μm and 500 μm , advantageously between 2 μm and 500 μm , and even more advantageously between 2 μm and 40 μm .
- 15 8. Transfer method according to one of Claims 1 to 7, in which step b) is executed such that the sealing layer has a thickness of between 100 nm and 2000 nm.
- 20 9. Transfer method according to Claim 1, in which step b) comprises the following sequence of sub-steps:
 - b1) a step of forming a fragilization plane in the volume of the donor substrate, the fragilization plane delimiting the sealing layer with a face, referred to as the assembly face, of the donor substrate,
 - b2) a step of assembling the donor substrate and the carrier substrate by bringing the assembly face and the main face into contact,
 - b3) a fracture step intended to initiate a fracture wave along the fragilization plane to enable the sealing layer to be detached from the donor substrate.
- 25 10. Transfer method according to Claim 9, in which sub-step b1) of forming a fragilization plane comprises an implantation of species.
- 30 11. Transfer method according to Claim 9 or 10, in which sub-step b2) comprises a molecular bonding of the assembly face with the main face.
12. Transfer method according to one of Claims 9 to 11, in which sub-step b3) comprises a heat treatment intended to initiate propagation of the fracture wave.