(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 March 2012 (01.03.2012)

PCT

(10) International Publication Number
WO 2012/025532 A1

(51) International Patent Classification: *G01N 19/04* (2006.01)

(21) International Application Number: PCT/EP2011/064481

(22) International Filing Date: 23 August 2011 (23.08.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data: 1056719 24 August 2010 (24.08.2010) FR

(71) Applicant (*for all designated States except US*): **SOITEC** [FR/FR]; Chemin des Franques, F-38190 Bernin (FR).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **LANDRU, Didier** [FR/FR]; Rue des Armariniers, F-38190 Champ Pres Froges (FR).

(74) Agent: **COLLIN, Jérôme**; Cabinet Regimbeau, 20, rue de Chazelles, F-75847 Paris Cedex 17 (FR).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17**:

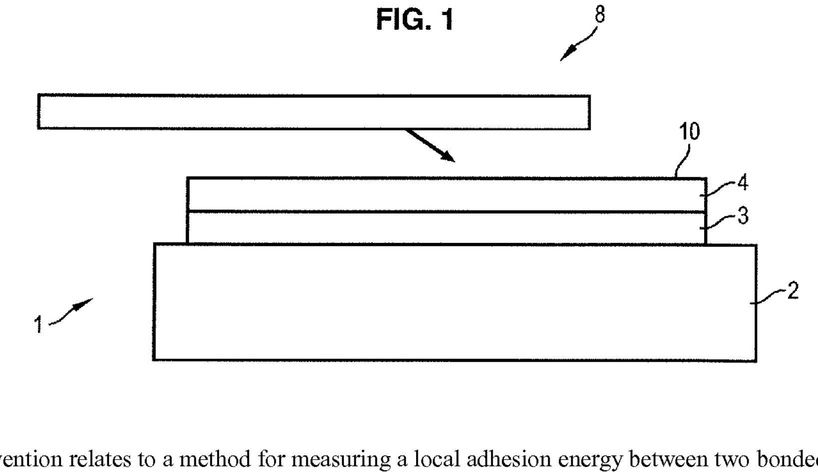
— *of inventorship (Rule 4.17(iv))*

**Published**:

— *with international search report (Art. 21(3))*

**(54) Title**: METHOD FOR MEASURING ADHESION ENERGY AND ASSOCIATED SUBSTRATES

**FIG. 1**




**(57) Abstract**: The invention relates to a method for measuring a local adhesion energy between two bonded substrates, in a transverse direction, characterized in that it comprises the steps consisting of: - providing that at least one (1) of the two substrates (1, 8) comprise a plurality of elementary test cells (6), each being capable of exerting locally, in the transverse direction, a predetermined mechanical stress (σ) that is a function of the temperature (T), on a bonding interface (10) between the substrates (1, 8), in a direction tending to separate them, - subjecting (21) the substrates to a test temperature, and - identifying (22) zones of the bonding interface (10) showing debonding to deduce from it the local adhesion energy at the test temperature at said zones, the local adhesion energy at a zone of the bonding interface (10) being deduced from the stress exerted by the test cells (6) having caused debonding at said zone.

WO 2012/025532 A1

# Method for measuring adhesion energy and associated substrates

GENERAL TECHNICAL FIELD

The invention relates to a method for measuring an adhesion energy between substrates to be bonded together. The invention also relates to a substrate for measuring such an adhesion energy, and a structure including such a substrate.

STATE OF THE ART

In the field of electronics and microelectronics, it is customary to carry out a step of adhesive bonding two substrates together. This type of bonding is used for example for manufacturing substrates of the SOI (Silicon on Insulator) type or for 3D integration of substrates comprising electronic circuits to be interconnected.

However, it is generally necessary to evaluate the quality of the bonding, which is characterized in particular by the adhesion energy, also called bonding energy, between the two substrates.

Various metrological methods have been proposed in the prior art for characterizing this adhesion energy.

A tensile test method is known from the prior art, which is a direct and macroscopic method of determining the adhesion energy. This process, however, is very difficult to implement.

A bonding measurement method is also known, proposed by Maszara in the document entitled "Bonding of silicon wafers for silicon-on-insulators," *J. Appl. Phys.* 1988, 64, 4943.

In this method, a blade is inserted at the bonding interface between the two substrates. The application of a mechanical force through the blade, in a direction parallel to the plane of the bonding interface, causes local debonding of the two substrates and propagation of the debonded zone over a certain distance. The propagation length of the debonded zone gives an indication of the adhesion energy existing between the two substrates.

This method, however, has several drawbacks.

This method is an indirect measurement of the adhesion energy, because it is extrapolated from the propagation of the debonding of the interface. The quantity measured is therefore the resistance to tearing of an interface and not the adhesion energy itself.

In addition, this method is sensitive to the conditions of insertion of the blade and to the operator, which makes it a low accuracy method.

Further, the method is macroscopic, that is it only allows the determination of a mean adhesion energy over a considerable area, and not a local adhesion energy.

Finally, this method is implemented at ambient temperature, and therefore characterizes the adhesion energy only at ambient temperature.

It therefore appears that the prior art methods for measuring adhesion energy have numerous drawbacks.

PRESENTATION OF THE INVENTION

The invention proposes to mitigate the aforementioned disadvantages.

To this end, the invention proposes a process for measuring adhesion energy between two bonded substrates, along a transverse direction, characterized in that it comprises the steps consisting of:

- arranging that at least one of the two substrates include a plurality of elementary test cells, each capable of locally exerting, in the transverse direction, a predetermined mechanical stress that is a function of temperature, on a bonding interface between the two substrates, in a direction tending to separate them,
- subjecting the substrates to a test temperature, and
- identifying zones of the bonding interface showing debonding to deduce from them the local adhesion energy at the test temperature at said zones, the local adhesion energy at a zone of the interface being deduced from the stress exerted by the test cells that caused debonding at said zone.

The invention is advantageously completed by the following features, taken alone or in any combination of them that is technically possible:

- the sequence including the steps consisting of subjecting the substrates to a test temperature, and identifying the zones of the bonding interface showing debonding, is repeated over a range including several test temperatures, in order to deduce the local adhesion energy for said range of test temperatures;

- each elementary test cell exerts a predetermined stress at a predetermined temperature during the step of subjecting it to a test temperature, the set consisting of said predetermined stress and of said test temperature being different from one cell to another;
- the substrate includes a plurality of test structures distributed so as to exert forces on a plurality of zones of the bonding interface, each test structure comprising a plurality of different elementary test cells;
- each cell is labeled materially by a set of indications including a predetermined stress exerted by said cell and a predetermined temperature at which said stress is exerted, and/or a local adhesion energy and a temperature at which said energy is attained, the step of deducing the local adhesion energy being accomplished based on the reading of said set of indications;
- the identification of the zones of the bonding interface showing debonding is performed by acoustic microscopy.

The invention also proposes a substrate including a plurality of elementary test cells, each able to exert locally, in a transverse direction, a predetermined mechanical stress that is a function of temperature on a bonding interface located at a free surface of the substrate.

The substrate can also include at least one of the following features:

- each elementary test cell is able to exert a predetermined stress at a predetermined temperature, the set consisting of said predetermined stress and of said predetermined temperature being different from one cell to another;
- the elementary test cells are distributed within a test layer arranged under the bonding layer, a free surface of the bonding layer constituting the bonding interface;
- the elementary test cells are placed at the free surface of the substrate;
- the substrate comprises a plurality of test structures being able to exert stresses on a plurality of zones of the bonding interface, each test structure comprising a plurality of different elementary test cells;
- each cell is labeled materially by a set of indications comprising a predetermined stress exerted by said cell and a predetermined temperature at which said stress is exerted, and/or a local adhesion energy and a temperature at which said energy is attained;
- the substrate includes a transparent base layer below the test layer.

The invention also proposes a structure comprising the substrate described previously and a second substrate bonded to said substrate at the bonding interface. In one embodiment, at least one of the substrate and the second substrate includes electronic circuits.

The invention has numerous advantages.

One advantage of the invention is to offer a simple and direct measurement of the adhesion energy at a bonding interface.

Another advantage of the invention is to offer an accurate measurement of said adhesion energy.

Yet another advantage of the invention is to offer a local measurement of said adhesion energy.

Finally, another advantage of the invention is to offer a measurement of the adhesion energy at different temperatures.

PRESENTATION OF FIGURES

Other features, aims and advantages of the invention will appear from the description that follows, which is purely illustrative and without limitation, and which must be read with reference to the appended drawings in which:

- Figure 1 shows an embodiment of a substrate according to a first aspect of the invention;
- Figure 2 shows an embodiment of a plurality of elementary test cells used in the substrate of Figure 1;
- Figure 3 shows an embodiment of an elementary test cell;
- Figure 4 shows an embodiment of a combination of elementary test cells usable in a substrate of Figure 1;

- Figure 5 shows an embodiment of a plurality of elementary test cells labeled with the predetermined stress and temperature associated with each of said cells;
- Figure 6 shows an embodiment of test structures each comprising a plurality of elementary test cells;
- Figure 7 shows an embodiment of a method for measuring the adhesion energy according to a second aspect of the invention;
- Figure 8 shows schematically a principle of test cell observation following a heat treatment step.

DETAILED DESCRIPTION

An embodiment of a substrate 1 according to a first aspect of the invention is shown in Figure 1. The substrate 1 comprises a bonding layer 4, on one of its faces, designed to be bonded to a second substrate 8. The bonding layer is for example an oxide layer. The bonding is intended to be carried out in a transverse direction collinear with the vector normal to the plane of the substrates 1, 8 positioned for bonding.

The substrates to be bonded can be of any type, as for example substrates of the SOI (Silicon on Insulator) type.

The substrate 1 also comprises at least one test layer 3, placed below the bonding layer 4.

The substrate 1 generally comprises a base substrate set below the test layer 3. The base substrate 2 is made of silicon for example. It is clear that the substrate 1 can comprise additional layers or elements depending on needs and applications. In particular, the first substrate 1 and/or the second substrate 8 can include electronic circuits within the conventional scope of 3D integration.

As shown in Figures 2 and 3, the test layer 3 is particularly characterized by the fact that it comprises a plurality of elementary test cells 6, each cell 6 being able to exert locally, in the transverse direction, a predetermined mechanical stress $\sigma$ on a bonding interface 10 located between the substrate 1 and the substrate 8.

This stress is a function of the temperature T to which the substrate 1 is subjected and is oriented transversely in a direction tending to separate the substrates 1 and 8. In other words, the cells 6 are dimensioned to exert a tension stress $\sigma$ on the bonding interface 10, as shown schematically in Figure 3.

The bonding interface 10 is the interface at which the bonding between the substrate 1 and the substrate 8 is accomplished. In particular, the bonding interface 10 is located at a free surface of the bonding layer 4.

The bonded substrates 1 and 8 constitute a structure wherein the second substrate 8 is bonded to the first substrate 1 at the bonding interface 10. This structure constitutes a third aspect of the invention.

Generally, each elementary test cell 6 is dimensioned to exert a predetermined stress at a predetermined temperature on the bonding interface 10. An elementary test cell can for example exert a stress $\sigma$ of 100MPa at 300°C.

If the stress $\sigma$ exerted locally by the cells 6 is greater than the local adhesion energy at a given temperature T, the bonding interface 10 will show debonding at the zone of the bonding interface 10 located above the test cell 6, which allows determination of the local adhesion energy at the temperature T. This is generally the zone of the bonding interface 10 located in line with the test cell 6 in the transverse direction.

A notable advantage of the invention is that the cells 6 can be buried, that is that they are not present at the bonding interface 10 or in the bonding layer 4 but, for example, in a test layer located below the bonding layer, a free surface of the bonding layer constituting the bonding interface. This makes it possible to obtain a homogeneous bonding layer 4 and avoid disturbing the treatment operations of the bonding layer 4, in particular of the free surface of the bonding layer 4. The local adhesion energy can therefore be measured without disturbing or damaging the bonding interface, particularly the free surface of the bonding layer. Many drawbacks and limitations of prior art methods and devices are thereby avoided.

For example, each cell 6 comprises two pads 13, 14 of a thermally expansive material such as copper. By pad is meant a structure having the general shape of a cube or parallelepiped. Generally, the material of each cell is chosen with a thermal expansion coefficient different from the thermal expansion coefficient of the test layer 3, which is for example an oxide layer. However, the number of pads can vary and, more generally, the cell can have any competent structure allowing attainment of the desired result.

The stress $\sigma$ exerted by each cell depends on the temperature and the size of the cell. In the case of the pads 13, 14 embodied in Figure 3, the stress exerted by the cell 6 is a function of the spacing between the pads, of the width L of the pads, of the transverse height h of the pads, and of the distance e with respect to the bonding interface 10. For example, the cells are of micrometer size.

Advantageously, the test layer 3 comprises a plurality of test cells 6, dimensioned so that each exerts a different stress, as shown in Figure 4.

Advantageously, each elementary test cell 6 is able to exert a predetermined stress at a predetermined temperature, and the set consisting of the predetermined stress and of the predetermined temperature differs from one cell to another, as shown schematically in Figure 5. As particularly described later, increasing the number of test cells 6 makes it possible to increase the adhesion energy resolution for each test temperature to which the structure comprising the first 1 and the second 8 substrates is subjected.

For example, a cell can be characterized by the fact that it exerts a stress of 100MPa at a temperature of 200°C. These values are predetermined and known to the operator, by the selection and the dimensioning of the test cells.

Advantageously, the test layer 3 comprises a plurality of test structures 15 being able to exert stresses on a plurality of different zones of the bonding interface 10, each test structure 15 comprising a plurality of different elementary test cells 6.

Advantageously, each elementary test cell of a test structure is able to exert a predetermined stress at a predetermined temperature, the set consisting of the stress and the temperature being different from one cell to another in a given test structure.

This comes down to duplicating the plurality of test cells 6, as for example the test cells 6 shown in Figure 5, over several zones of the test layer 3. Thanks to this configuration, it is possible to measure the local adhesion energy in several zones of the bonding interface 10. Generally, a test structure has a surface area on the order of 0.5 $cm^2$. Therefore, for each zone covered by a test structure 15, a local adhesion energy value at different temperatures is obtained. It is clear that, the greater the number of test structures 15, the more bonding interface 10 zones are available for which the adhesion energy is known.

An embodiment of a method of measuring adhesion energy according to a second aspect of the invention is now described, implementing the substrate 1 described previously.

In a first step 20, the bonding layer 4 of said substrate 1 is bonded in a transverse direction with a second substrate 8. This type of bonding is widely known to the person skilled in the art and is not detailed.

The structure comprising the substrate 1 and the substrate 8 bonded together is then subjected (Step 21) to a heat treatment.

This is a treatment wherein said structure is subjected to a rise in temperature up to a test temperature. This rise in temperature is accomplished in known fashion in an oven.

During the rise in temperature, and as described previously, the test cells 6 of the test layer 3 then exert a transverse tensile stress on the bonding interface 10 located between the substrate 1 and the substrate 8. Depending on the test temperature applied to the structure comprising the substrate 1 and the substrate 8, only certain test cells will exert a stress, said stress being predetermined and proper to each cell, as illustrated in Figure 5.

Indeed, the test structures 15 of the test layer are dimensioned so that each elementary test cell 6 of the test structure exerts a predetermined stress at a predetermined temperature during the step 22 of subjecting to a test temperature, the set consisting of said predetermined stress and of said predetermined temperature being different from one cell 6 to another.

It will be noted that the heat treatment previously described is commonly used for hardening the bond between the two substrates. In fact, bonding of the two substrates at ambient temperature does not generally provide sufficient mechanical strength for the needs of the electronic or microelectronic industry. The invention therefore makes use of this step of hardening the bond as a testing step, which makes it possible to avoid adding additional steps that are costly and harmful to the structure under test, as in the prior art methods.

In certain cases, at least one of the substrates 1 and/or 8 is equipped with electronic circuits. The so-called 3D integration fabrication process is known, for example, consisting of bonding layers of substrate including electronic circuits, and connecting said circuits to form an electronic component. The bonding most often includes a heat treatment step.

Advantageously, the zones of the interface 10 equipped with test cells can be arranged at the post-bonding cutout lines of the substrates.

The test structures are then integrated into the electronic circuits which conventionally contain on their perimeter, generally in the cutout lines, a certain number of test and measurement structures for the monitoring process.

The adhesion energy test structures conforming to the invention are very easy to integrate, particularly by modification of a set of masks.

One advantage of this solution is that it constitutes a means for directly checking the adhesion energy during the fabrication process called 3d integration and therefore makes it possible to detect possible defects or problems in manufacture. In particular, this solution makes use of the heat treatment step necessary for bonding layers including electronic circuits for characterizing the adhesion energy.

In the later step 22, the bonding interface 10 is observed. The zones of the bonding interface 10 showing debonding and/or defects are identified and indicate that the local adhesion energy has been reached and possibly exceeded.

The local adhesion energy at each zone of the bonding interface 10 is deduced from the stress exerted by the test cell 6 or the test cells 6 having caused debonding of said zone, as illustrated in Figure 8. The test cells 6 of Figure 8 constitute a test structure 15.

The zones of the bonding interface 10 showing a defect and/or debonding are identified which allows the test cells 6 which caused debonding (shown schematically in black in Figure 8) to be identified. In the case of pads, the debonding occurs in the zone of the bonding interface located between the pads.

For example, in Figure 8, the structure comprising the first substrate 1 and the second substrate 2 has been subjected to a test temperature of 300°C. It is then observed that the bonding interface 10 has debonded only at the cells of the structure 15 dimensioned to exert stresses at 300°C which are greater than the local bonding energy.

It is deduced from this that the stress having caused debonding in the corresponding zone of the bonding interface 10 is comprised between 29MPa and 30MPa at 300°C.

This makes it possible to deduce, particularly from nomograms giving the relation between stress, temperature and energy, the local adhesion energy at a given temperature at the bonding interface zone located in line with the test structure 15 in the transverse direction. These nomograms are prepared from models that take into account the different implementation parameters of the method: stress, temperature, type of material...

In the case of Figure 8 described previously, and based on the stress determined as detailed previously, the local adhesion energy at 300°C of the debonded zone can be deduced.

The local adhesion energy at a zone of the bonding interface 10 is therefore advantageously deduced from the stress exerted by the test cells 6 having caused debonding at said zone.

It is understood that the more test cells are available for a given test structure, the more measurement points are available. In particular, the fact of having available a large number of different predetermined stress/predetermined temperature pairs increases the measurement resolution. The local adhesion energy resolution is then increased for each temperature.

Likewise, the fact of having available a plurality of test structures, themselves consisting of a plurality of elementary test cells 6, allows the determination of the local adhesion energy in a large number of zones of the bonding interface 10.

Advantageously, the steps 21 and 22 can be repeated iteratively, in the case of a rising temperature.

In particular, the sequence consisting of subjecting the first and the second substrates to a test temperature, and of identifying the zones of the bonding interface showing debonding, is repeated over a range comprising several test temperatures. A series of discrete measurements is then obtained, which allows a curve of the variation of adhesion as a function of the temperature to be plotted for each bonding interface 10 zone considered. However, this principle only works in the case where a progressive rise in temperature is applied over the course of successive tests.

In practice, the first 1 and the second 8 substrates bonded together are subjected to a new test temperature, then the bonding interface 10 is observed. This sequence is repeated as often as necessary.

The invention offers a measurement of the local adhesion energy in different zones of the bonding interface 10.

The observation of the defects in the bonding interface 10 can be carried out according to any technique known to the person skilled in the art.

Advantageously, the observation of the zones of the bonding interface 10 can be done after annealing, by acoustic microscope of the SAM (Scanning Acoustic Microscope). However, it is also possible to contemplate observation of the defects of the interface in real time, that is at the same time as the bonded substrates are subjected to the test temperature.

In one advantageous embodiment, each cell is materially labeled with a set of indications comprising the predetermined stress exerted by the cell and the predetermined temperature at which said stress is exerted, as illustrated in Figure 8, and/or a set of indications comprising the local adhesion energy and the temperature at which said energy is attained. These data are engraved or written near each cell.

Thus, the deduction of the local adhesion energy is carried out based on a direct reading of said set.

Advantageously, the base layer 2 is transparent, which makes it possible to read directly the stress or the adhesion energy using a microscope. This can for example be a layer of glass or of quartz.

The invention can advantageously be applied to the test case or to the case of monitoring the bonding within the scope of a 3D integration of substrates.

The test cells can in both cases be directly located at the free surface of one or the other of the substrates, that is at the bonding interface 10. In particular, the test cells can be flush with the free surface of one or the other of the substrates (that is, with the distance e being zero or almost zero), or even include a portion emerging from the free surface. It is then possible to eliminate the bonding layer, that to say that the test cells are no longer buried.

The test cells are identical to those described in the foregoing embodiments, and can be arranged in the form of test structures distributed at the free surface of the substrate.

In the case of 3D integration, it is additionally possible to provide that the substrate including the test cells also include electronic circuits. This is equally applicable in the case where the substrates are bonded through a bonding layer (also known to the person skilled in the art as a "blanket") or not, that is to say that the substrates are directly assembled at their upper layer which includes electronic circuits.

Generally, the measurements obtained by the process according to the invention are accurate and improve on the results of the prior art, as for example the results obtained by the method proposed by Maszara.

Further, the invention offers direct and simple measurement of the adhesion energy of the bonding interface.

In addition, the invention offers a measurement of the adhesion energy at different temperatures.

Finally, the method according to the invention is advantageous because it is less invasive. An operator seeking to measure the adhesion energy between two substrates to be bonded will easily be able to use the substrate according to the invention, which comprises all the layers necessary for a given application (bonding layer and base substrate) and differs only by the presence of test cells, buried or not. In addition, the method needs only a few additional steps in addition to the conventional steps for bonding and heat hardening the bonded substrates.

The invention is therefore very advantageous, in terms of flexibility as well as cost. The invention finds numerous applications, and particularly in the fields of electronics, of microelectronics or of optics.

# CLAIMS

1. A method for measuring an adhesion energy between two bonded substrates, in a transverse direction, characterized in that it comprises the steps consisting of:

- providing that one (1) at least of the two substrates (1, 8) include a plurality of elementary test cells (6), each being able to exert locally, in the transverse direction, a predetermined mechanical stress (σ) that is a function of the temperature (T), on a bonding interface (10) between the substrates (1,8) in a direction tending to separate them,
- subjecting (21) the substrates to a test temperature, and
- identifying (22) zones of the bonding interface (10) showing debonding, to deduce from them the local adhesion energy at the test temperature at said zones,

the local adhesion energy at a zone of the interface (10) being deduced from the stress exerted by the test cells (6) that caused debonding at said zone.

2. A method according to claim 1, wherein the sequence comprising the steps consisting of:

- subjecting (21) the substrates (1, 8) to a test temperature, and
- identifying (22) the zones of the bonding interface (10) showing debonding,

is repeated over a range comprising several test temperatures, in order to deduce the local adhesion energy for said test temperature range.

3. A method according to one of claims 1 or 2, wherein each elementary test cell (6) exerts a predetermined stress at a predetermined temperature during the step of subjecting (21) to a test temperature, the set consisting of said predetermined stress and of said predetermined temperature being different from one cell (6) to another.

4. A method according to one of claims 1 through 3, wherein the substrate comprises a plurality of test structures (15) distributed so as to exert stresses over a plurality of zones of the bonding interface (10), each test structure (15) comprising a plurality (6) of different elementary test cells.

5. A method according to one of claims 1 through 4, wherein each cell (6) is materially labeled by a set of indications comprising

a predetermined stress exerted by said cell and a predetermined temperature at which said stress is exerted, and/or

a local adhesion energy and a temperature at which said energy is attained,

the step of deducing the local adhesion energy being performed based on the reading of said set of indications.

6. A method according to one of claims 1 through 5, wherein the identification of the zones of the bonding

interface (10) showing debonding is performed using an acoustic microscope.

7. A substrate (1) comprising a plurality of elementary test cells (6), each able to exert locally, in a transverse directions, a predetermined mechanical stress (σ) that is a function of the temperature (T), on a bonding interface (10) located at a free surface of the substrate (1), the elementary test cells (6) being arranged, at least partly, below the free surface of the substrate (1).

8. A substrate according to claim 7, wherein each elementary test cell (6) is able to exert a predetermined stress at predetermined temperature, the set consisting of said predetermined stress and of said predetermined temperature being different from one cell (6) to another.

9. A substrate according to one of claims 7 or 8, wherein the elementary test cells (6) are distributed within a test layer (3) arranged below a bonding layer (4), a free surface of the bonding layer (4) constituting the bonding interface (10).

10. A substrate according to one of claims 7 or 8, wherein the elementary test cells (6) are arranged at the free surface of the substrate (1).

11. A substrate according to one of claims 7 to 10, comprising a plurality of test structures (15) being

able to exert stresses on a plurality of zones of the bonding interface (10), each test structure (15) comprising a plurality of different elementary test cells (6).

12. A substrate according to one of claims 7 to 11, wherein each cell (6) is materially labeled by a set of indications comprising

a predetermined stress exerted by said cell and a predetermined temperature at which said stress is exerted,

and/or a local adhesion energy and a temperature at which said energy is attained.

13. A substrate according to one of claims 9, 11 or 12, further comprising a transparent base layer (2) below the test layer (3).

14. A structure comprising the substrate (1) according to one of claims 7 to 13 and a second substrate bonded to said first substrate (1) at the bonding interface (10).

15. A structure according to claim 14, characterized in that at least one of the substrate and the second substrate (1, 8) includes electronic circuits.

FIG. 1

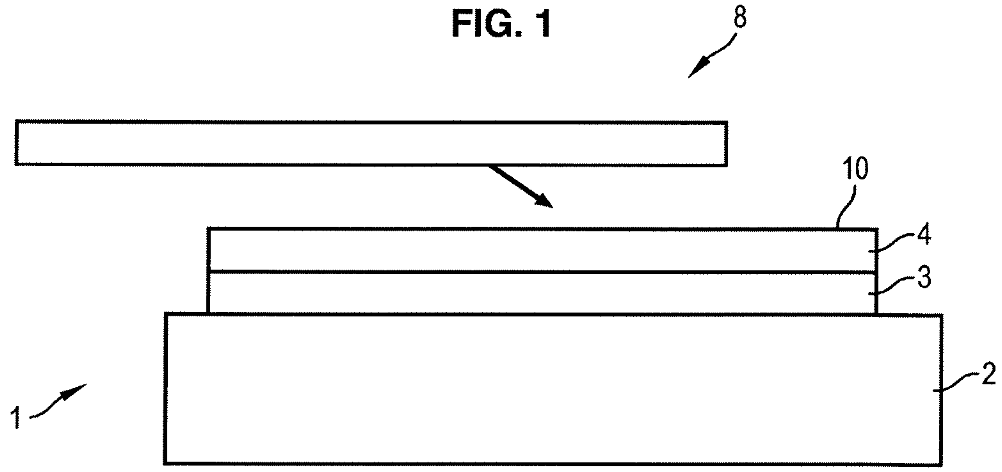



FIG. 2

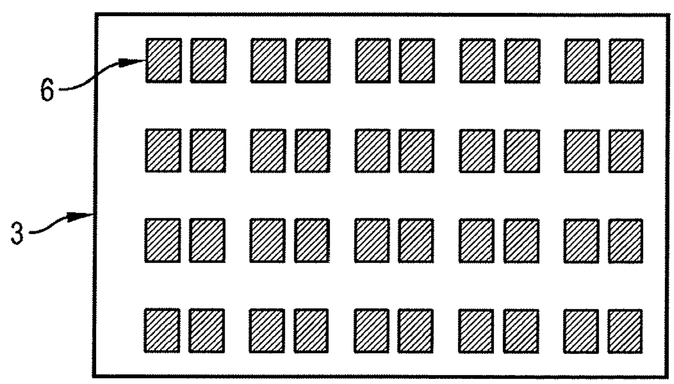


FIG. 3

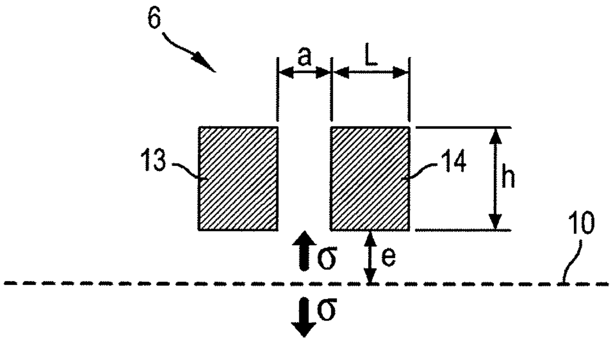
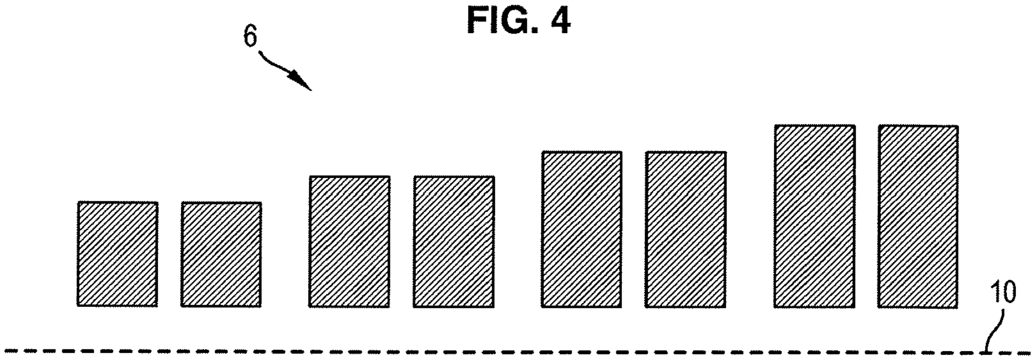



FIG. 4



3/4

FIG. 5

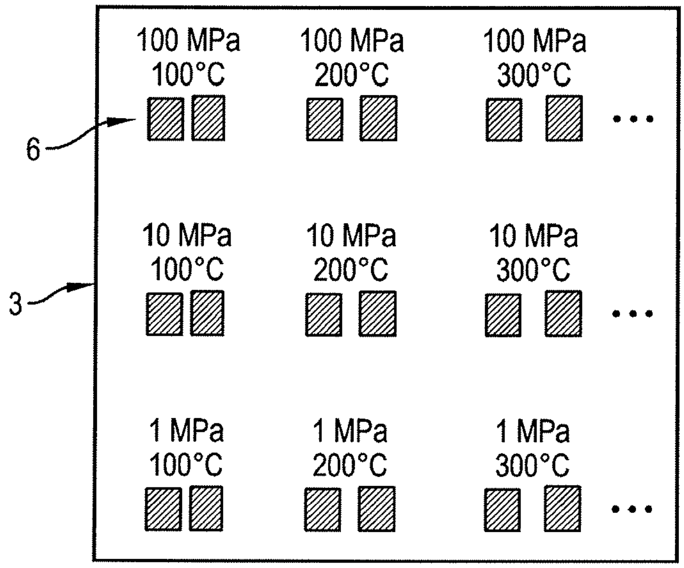

100 MPa
100°C
100 MPa
200°C
100 MPa
300°C
6
10 MPa
100°C
10 MPa
200°C
10 MPa
300°C
3
1 MPa
100°C
1 MPa
200°C
1 MPa
300°C

FIG. 6

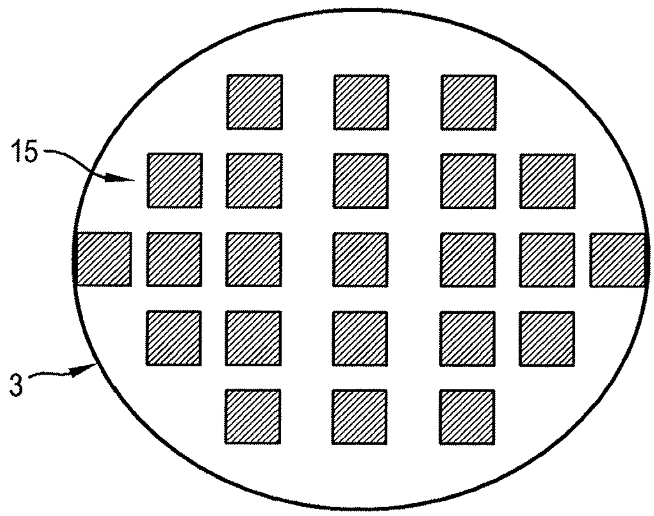

15
3

FIG. 7

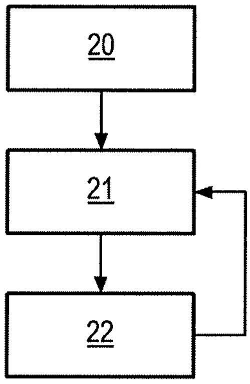
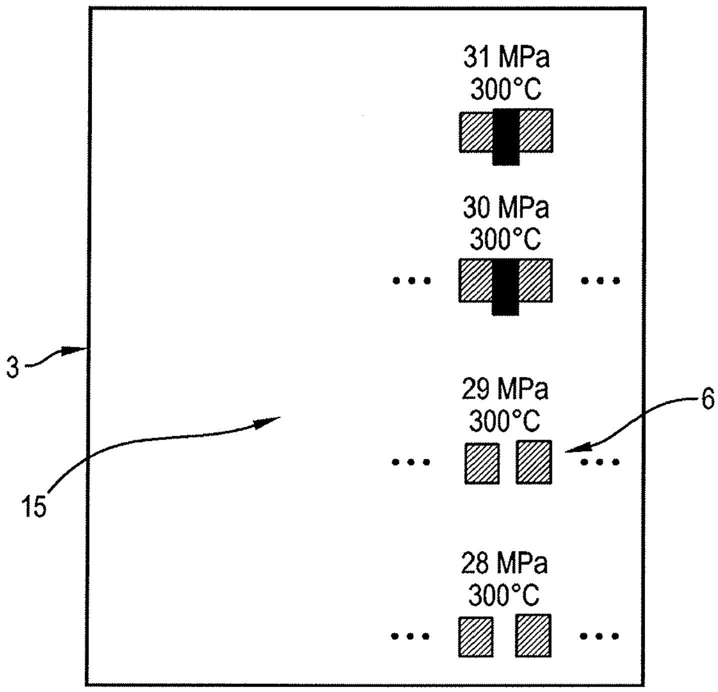



FIG. 8



# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/064481

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G01N19/04
ADD.

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)
G01N

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 practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 03/008938 A2 (SIEMENS AG [DE]; LAMPENSCHERF STEFAN [DE]) 30 January 2003 (2003-01-30) the whole document ----- | 1-15 |
| X | US 2007/039395 A1 (GUPTA VIJAY [US] ET AL) 22 February 2007 (2007-02-22) paragraph [0088]; figure 13 ----- | 7-15 |
| X | WO 03/019157 A1 (SYMYX TECHNOLOGIES INC [US]) 6 March 2003 (2003-03-06) figures 4-16 ----- | 1,7 |
| X | US 6 523 419 B1 (NONAKA NOBUYOSHI [JP] ET AL) 25 February 2003 (2003-02-25) figure 3 ----- -/-- | 7-15 |

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 16 September 2011 | 04/10/2011 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 | Cantalapiedra, Igor |

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 2007/237448 A1 (SATO KEIICHI [JP] ET AL) 11 October 2007 (2007-10-11) paragraphs [0051] - [0067]; figures 3-8 | 1-15 |
| A | US 6 117 695 A (MURPHY ADRIAN S [US] ET AL) 12 September 2000 (2000-09-12) figures 3-7 | 1-15 |
| A | US 6 616 332 B1 (RENKEN WAYNE [US] ET AL) 9 September 2003 (2003-09-09) figures 6-8 | 1-15 |
| A | US 5 696 327 A (HUANG HE [US] ET AL) 9 December 1997 (1997-12-09) claim 1 | 1 |
| A | US 5 537 884 A (NISHIMURA ASAO [JP] ET AL) 23 July 1996 (1996-07-23) the whole document | 1,15 |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/064481

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| WO 03008938 | A2 | 30-01-2003 | NONE | | | |
| US 2007039395 | A1 | 22-02-2007 | NONE | | | |
| WO 03019157 | A1 | 06-03-2003 | AU | 2002331701 | A1 | 10-03-2003 |
| US 6523419 | B1 | 25-02-2003 | JP | 3321455 | B2 | 03-09-2002 |
| | | | JP | 2000349118 | A | 15-12-2000 |
| US 2007237448 | A1 | 11-10-2007 | JP | 4721435 | B2 | 13-07-2011 |
| | | | JP | 2007278848 | A | 25-10-2007 |
| US 6117695 | A | 12-09-2000 | NONE | | | |
| US 6616332 | B1 | 09-09-2003 | JP | 2003515118 | A | 22-04-2003 |
| | | | TW | 455677 | B | 21-09-2001 |
| | | | WO | 0136916 | A2 | 25-05-2001 |
| US 5696327 | A | 09-12-1997 | NONE | | | |
| US 5537884 | A | 23-07-1996 | NONE | | | |