



A DEVICE AND A METHOD FOR AUTOMATICALLY INSPECTING THE
SURFACE QUALITY OF A WAFER BY MEASURING BONDING SPEED

The present invention relates in general to the
processing of materials, more particularly substrates for
5 electronics, optics, or optoelectronics.

More precisely, the invention relates to a device
for characterizing the bonding speed between two wafers
of material.

The invention also relates to a method using said
10 device.

Devices of the above-mentioned type are already
known.

In particular, the bonding speed between two wafers
of material can be characterized in a known manner, when
15 at least one of the wafers is formed from a semi-
conductor material such as silicon.

Such wafers generally have a disk-shaped outline and
are typically of the order of few hundred microns thick.

Such wafers can be bonded one to another to
20 constitute multi-layer structures, the two bonded wafers
possibly being of different materials.

Further, specifications regarding the quality of
such wafers can be extremely exacting, in particular as
regards wafers for use in constituting substrates of the
25 above-mentioned type.

When bonding wafers together, said surface quality
specifications are even more stringent, in particular as
regards the surface roughness of the wafer and the
absence of impurities on that surface.

30 Clearly, then, it is particularly important that
high performance means should be available to
characterize said surface quality.

One known means for characterizing the surface
quality of two wafers (at least one wafer possibly being
35 formed from a semiconductor material such as silicon, and
the two wafers having the same disk-shaped outline) is
constituted by the following operations:



- bringing the respective surfaces of said wafers into contact to constitute a stack having the general shape of a disk and with the two wafers placed side by side;
- compressing the stack formed by the two wafers at any point on said stack;
- measuring the time required to establish a bond between the two wafers following said compression.

10 That time is termed the "bonding time".

"Bonding" actually corresponds to forming hydrogen bonds between the surfaces of the two wafers (more accurately, between OH bonds on the respective surfaces of the two wafers).

15 To determine the bonding speed, an operator records the time between the initial compression and the arrival of a bonding wave at the other extremity of the stack, said bonding wave being observed through the wafers by transmitting infrared radiation from a source placed
20 beneath the stack, the operator observing said stack from above (using means such as a screen reconstituting the image provided by an infrared camera located above the stack).

25 The bonding speed is representative of the surface quality of the wafers: a high bonding speed indicates good surface quality, while a slower bonding speed indicates the presence of defects and/or impurities on the wafer surface.

30 The surfaces of wafers leaving a fabrication facility exhibit several defects and residues which are both chemical in nature (principally OH bonds with superficial wafer particles) and mechanical in nature (typically, roughness defects, the presence of abrasive particles and superficial metallic contaminants).

35 To improve the surface quality, measurement of the bonding speed is generally preceded by cleaning the wafers, consisting in immersing them in succession in:

- at least one basic dip. This step is intended to develop the hydrophilicity of the wafer, by creating OH type bonds at the surface of said wafers;
- then an acid dip, to remove contaminating elements (in particular metals) from the wafer surface, which contaminants may have been introduced by preceding wafer processing steps (in particular the basic dip).

5

10 Thus, a method for characterizing surface quality of wafers is known.

However, that method has a disadvantage, namely that it is carried out manually by an observer who implements the different steps (placing the wafers on the measuring device, initial compression, followed by observing the bonding wave, timing to determine the bonding speed, etc...).

15

Further, that prior art necessitates carrying out measurements of the bonding speed on a dedicated manual device: thus, wafer bonding cannot be carried out automatically.

20

Devices exist which allow automatic bonding of wafers to be carried out with the aim of operational bonding rather than characterizing the surface quality.

25

Clearly, an operator could employ such automatic bonding devices to carry out a measurement of the bonding speed in conjunction with bonding, thus producing information regarding the surface quality of the wafer.

However, currently, it is not possible to envisage such a use of automatic bonding devices by an operator.

30

The micro-mechanisms present above and below the support for positioning, aligning and bonding the wafers do not allow an operator to view the bonding wave.

Thus, a bonding wave can currently only be characterized in a manual manner using a dedicated device.

35

Naturally, this substantially limits the rates that can be obtained.

One aim of the invention is to overcome that limitation.

5 To this end, in a first aspect the invention provides a device for inspecting the surface quality of a wafer employing measuring the bonding speed of two wafers at a bonding interface defined between the two wafers, characterized in that the device comprises automatic
10 means for detecting bonding initiation and automatic means for detecting the passage of a bonding wave.

The following are preferred but non limiting features of such a device:

- 15 • the automatic means for detecting the passage of a bonding wave comprise a source of electromagnetic radiation and a sensor that can detect at least a portion of the spectrum of electromagnetic radiation emitted by the source, the sensor being disposed in a manner
20 that collects the radiation from a predetermined measuring site of the bonding interface;
- the device comprises a processing unit to which the automatic means for detecting bonding
25 initiation and the automatic means for detecting the passage of a bonding wave are connected;
- the processing unit can calculate the instantaneous bonding speeds for each measuring
30 site of the bonding interface;
- the sensor can detect a change in a characteristic of the electromagnetic wave it receives from the source via at least one measuring site;
- 35 • the change in the characteristic of the electromagnetic wave is a change in contrast;

- the automatic means for detecting the passage of a bonding wave further comprises, in association with at least one measuring site, an opening passing through the support and allowing radiation from the source to pass through so that it then passes through the wafers at the measuring site, so that the portion of the radiation from the source which is transmitted through the wafers reaches the sensor;
- the detection means comprise at least one detection assembly constituted by an electromagnetic source, an opening and an electromagnetic sensor, wherein the source and the sensor are aligned either side of the opening;
- the automatic means for detecting the passage of a bonding wave also comprises, in association with at least one measuring site, a source of electromagnetic radiation directed towards the measuring site and reflected towards an associated sensor by the wafers;
- the source is a lamp;
- the sensor is optoelectronic;
- the electromagnetic spectrum emitted by the source encompasses the infrared site;
- the device comprises a plurality of assemblies for detecting the passage of a bonding wave between the two wafers, respectively associated with a plurality of measuring sites on the wafers to be inspected, so that each of said assemblies allows local determination of the instant of local bonding at the associated measuring site;
- the automatic means for detecting the instant of bonding comprise a plurality of openings respectively associated with the measuring

sites, each opening allowing local detection of the instant of local bonding at the associated measuring site.

5 In a second aspect, the invention also provides a method for inspecting the surface quality of a wafer employing measuring the bonding speed of two wafers at a bonding interface, characterized in that the method comprises the following operations:

- 10 • automatic acquisition of the instant of bonding initiation;
- automatic acquisition of the instant for passage of a bonding wave;
- automatic determination of a bonding speed from said two data acquisitions.

15 The following are preferred but non-limiting features of the method of the invention:

- 20 • the instants for passage of a bonding wave are acquired at a wafer measuring site from a change in a characteristic of an electromagnetic wave deriving from the measuring site;
- the change in the characteristic of the electromagnetic wave is a change in contrast;
- the electromagnetic wave spectrum encompasses the infrared site;
- 25 • a plurality of instants for local passage of a bonding wave are respectively detected at a plurality of wafer measuring sites;

30 Finally, in a third aspect, the invention also proposes the application of a device or method according to one of the aforementioned aspects, for inspecting the surface quality of a wafer with a mean thickness in the range from a few micrometers to a few millimeters.

35 The following are preferred but non-limiting features of such an application:

- the structure of the inspected wafer comprises silicon;

- the structure of the inspected wafer comprises an SOI type structure.

Other aspects, aims, and advantages of the invention become apparent from the following detailed description.

5 The invention will also be better understood by referring to the accompanying drawing in which:

- Figure 1 is a diagram of a device in accordance with the invention;
- 10 • Figure 2 shows an example of the progress of a bonding wave between two stacks placed side by side and that between them define a bonding interface with no defects;
- 15 • Figure 3 shows an example of the progress of a bonding wave between two stacks placed side by side and that between them define a bonding interface with a defect.

Referring firstly to Figure 1, a stack 10 is constituted by two wafers 11 and 12 placed side by side to define a bonding interface 13 between them.

20 It should be understood that the term "placed side by side" as used in the present text is distinct from the term "bonded":

- two wafers that are "placed side by side" are simply disposed in a manner such that they are
25 in contact with each other with no bond existing between the wafers;
- while two "bonded" wafers are integral with each other, with bonds (for example hydrogen type bonds) existing between the wafers.

30 The stack 10 is placed on a bonding support 20.

Advantageously, said wafers 11 and 12 have been immersed in basic and acidic dips as mentioned above, in order to clean them.

The device in Figure 1 is shown in a highly
35 diagrammatic manner: said device can actually also include all of the micro-mechanisms mentioned in the

introduction to the present specification concerning known automatic bonding devices.

The invention can be implemented by adapting such a known automatic bonding device.

5 For the purposes of simplification, such micro-mechanisms (which can be disposed above and/or beneath the wafers) are not shown in the figures.

10 The support surface 20 receiving the stack 10 must be particularly flat, in particular if wafers 11 and 12 of large surface area and of thickness in the order of a few microns are being studied.

Poor flatness of the support 20 can cause distortions in the wafer 12 compared with the wafer 11, and can thus disturb the stack 10 at the bonding
15 interface 13.

A source 30 of electromagnetic radiation and a sensor 40 that can detect at least a portion of the spectrum of said electromagnetic radiation emitted by the source 30 constitute, along with an opening 21 in the
20 support 20, an assembly 50 for detecting the passage of the front of a bonding wave.

Radiation from the source 30 is directed towards the sensor 40 through the opening 21.

Said radiation is intercepted by the stack 10 when
25 the latter is in position on the device. The properties of the materials constituting the stack 10 and of the radiation from the source 30 are selected so that a significant portion of said radiation passes through the stack and that this portion that has passed through the
30 stack reaches the sensor 40.

When two silicon wafers are used, for example, infrared radiation and an infrared sensor can be used.

It is not obligatory for the elements of the assembly 50 to be aligned as shown in Figure 1 (the
35 source 30 and the sensor 40 are aligned either side of the opening 21 in this figure).

It is possible to provide reflecting mirrors between the source 30, the opening 21 and the sensor 40. In that case, the mirrors route the radiation from the source 30:

- towards the opening 21, by directing the
5 radiation along the axis of said opening;
- then from the stack through which the radiation
passes on its way to the sensor 40.

The source is preferably a white lamp.

The emission from the source 30 preferably
10 encompasses the infrared wavelength spectrum.

The sensor 40 is preferably an optoelectronic apparatus.

The opening 21 formed in the support 20 acts as an electromagnetic window and thus allows electromagnetic
15 radiation emitted by the source 30 to pass through the support 20 and to be detected by the sensor 40.

The opening 21 passes through the support 20 at a site X of said support which faces the stack 10 when the stack is positioned on the device.

20 The opening 21 must be sufficiently wide to avoid disturbing the electromagnetic waves emitted by the source 30 too greatly.

Said disturbances can, for example, be a substantial loss of signal by reflection from the face of the support
25 20 closest to the source 30.

The disturbances can also be diffraction and/or absorption of the waves.

The opening 21 must also be sufficiently narrow to escape any equipment surrounding the wafers specific to
30 the automatic wafer bonding device.

Further, the fact that a small diameter opening 21 is used allows the quantity of radiation from the source 30 directed towards the sensor 40 and intercepted by stack 10 to be reduced: this also reduces the possibility
35 of local heating of the wafers constituting the stack.

The width of the opening 21 is typically of the order of a few millimeters.

It is also possible to provide a plurality of openings similar to opening 21 provided at various sites on the support (said sites always facing a predetermined portion of the stack 10 when the stack is in position).

5 In this case, the radiation from the source 30 can pass through each opening (by using suitable separating and reflecting mirrors), so that after passing through the stack at the corresponding site via the opening, they reach the sensor 40 (again by using suitable separation
10 and reflection mirrors).

It is also possible to provide a specific source and/or sensor in association with each opening (or with some of the openings) to recreate assemblies similar to assembly 50 for each (or some) opening(s).

15 The device of the invention functions as follows:

 A bonding piston brings the two wafers 11 and 12 into contact at the interface 13 by exerting an initial pressure 100 at a predetermined site X1 on the surface of the stack 10, which pressure is sufficient to initiate
20 bonding between the two wafers.

Said piston is controlled by an instruction sent by the central processing unit which is connected to the piston and which stores the instant at which bonding was initiated.

25 As an alternative, it is also possible for the instant of bonding initiation to be determined by a bonding initiation detector associated with the piston.

 This automatic bonding initiation detector can be a piezo-electric transducer, for example.

30 In all cases, bonding initiation is automatically triggered following an initial instruction and the associated instant of bonding initiation is stored.

 The initial instruction can be provided by an operator or by an automatic device that is regulated by
35 time sequences governed by a clock.

The source 30 is activated so that it constantly emits radiation directed through the stack 10 towards the sensor 40 associated with the source.

5 Bonding then propagates over the whole of the surface of the wafers at the interface 13 as a bonding propagation wave 200.

10 When the bonding wave 200 reaches the site "X" on the stack, i.e., in opening 21, the sensor 40 detects a change in the electromagnetic signal it receives from the source 30 through the stack 10, compared with a reference signal which it was receiving through the same stack before the passage of the bonding wave.

15 This change in the electromagnetic signal typically derives from an optical characteristic of the source radiation and can in particular correspond to a change in contrast, revealing the appearance of bonding forces between the two wafers 11 and 12 following the establishment of hydrogen bonds between the two wafers.

20 In the case of a change in contrast, the spectrum of the optical waves emitted by the source 30 is preferably located in the infrared.

25 As soon as the sensor 40 detects the passage of the bonding wave at site X on the wafers which is located in the opening 21, it transmits a signal, indicating detection of the passage of the bonding front, to the processing unit to which it is also connected.

30 Said processing unit then calculates the bonding time between the stored instant of bonding initiation and the time at which the bonding front passes, which physically corresponds to establishing bonding between the wafers.

35 To calculate this bonding time between the two points of the stack (bonding initiation point X1 and bonding front passage detection point X), the processing unit is also connected to a clock.

Since the distance between the points X1 and X is known and stored in the processing unit, said unit

automatically deduces a bonding speed which is characteristic of the surface quality of wafers 11 and 12 between the measuring sites X1 and X.

5 In a variation, a plurality of through openings 21 are distributed over the support 20 so that passage of the bonding wave can be detected at different sites of the wafers 11 and 12, thereby enabling the processing unit to calculate a bonding speed for each of said sites.

10 It should be pointed out in this regard that if a sensor 40 receives signals corresponding to radiation which has passed through different openings of the support and different sites of the stack, the sensor includes means for distinguishing between the different signals (said signals can, for example have specific
15 wavelengths as a function of the emission source, or more generally of the opening passed through).

In such a variation, the processing unit can calculate different "instantaneous" bonding speeds for the different openings.

20 It should be pointed out that the processing unit is connected to all of the sensors 40 and that it receives all of the bonding wave passage signals for the different sites associated with a support opening 20.

The processing unit can then calculate the bonding
25 speeds between any two of said sites by processing the time difference between the passage of the bonding wave at each of the two sites (the distances between the different sites associated with an opening in the support being known and stored in the processing unit).

30 It is possible to provide the openings at desired sites of the support corresponding to sites of the stack at which characterization of the instantaneous bonding speed is particularly desired.

The openings can be disposed so that they are
35 regularly distributed across the expected path of the bonding wave so that any change in the bonding speed can be tracked during propagation of the wave.

Optionally, in this variation, there are a plurality of sensors 40 and/or a plurality of sources 30.

In particular, a sensor 40 can be associated with each source 30, aligned with the source and the opening, the sensor and the source being on opposite sides of the opening 21.

In this case, a plurality of automatic detection assemblies 50 are obtained, each resembling the assembly 50 shown in Figure 1, said detection assemblies being disposed to allow different bonding speeds in different sites of the stack 10 to be determined, depending on the progress of the bonding wave 200 over the interface 13.

The invention is not limited to the detection means shown in Figure 1.

The invention can employ any automatic means for detecting bonding initiation and any automatic means for detecting the instant of passage of the bonding front.

In this respect, rather than detecting a change in signal transmitted through the wafers, it is possible to detect a change in signal reflected by the stack 10.

It is possible to produce detection assemblies equivalent to assembly 50, with a radiation source directed onto a pre-determined site of the stack, said site reflecting radiation from the source to an associated sensor.

In this case, changes in the reflected radiation occasioned by passage of the bonding wave are detected and used to calculate the bonding speeds.

The automatic means for detecting the instant for passage of the bonding front can also comprise one or more automatic detection assemblies such that each is suitable for detecting the instant of bonding at a local site of interface 13.

Referring now to Figure 2, the action of a local initial compression 100 at X1 on two wafers 11 and 12 in contact (initial compression produced by a piston) initiates a bonding wave which produces a front 200a

(Figure 2a) which then propagates (front 200b - Figure 2b) and finishes (front 200c) at a site opposite the initial pressure site 100 (Figure 2c).

In the example of the device shown in Figure 1,
5 detection assembly 50 is then preferably placed close to the wave front 200c at X2 and the bonding speed is determined on the basis of the time taken by the bonding wave to cover the distance separating the site X1 where the initial pressure was exerted at 100 and the site X2
10 where the point for detecting bonding completion is located.

Referring now to Figure 3, a pressure 100 similar to pressure 100 in Figure 2 is exerted at the same site X1 on wafers 11' and 12' that are similar to the wafers 11
15 and 12 in Figure 2.

Propagation follows several steps 200a' (Figure 3a), 200b' (Figure 3b) and 200c' (Figure 3c) respectively corresponding to steps 200a, 200b and 200c in Figure 2.

However, propagation is disturbed at 201 (Figure
20 3b). This disturbance is indicative of a surface defect (roughness and/or presence of particulate surface residues) between wafers 11' and 12', which did not exist for wafers 11 and 12, visible at 203 (Figure 3c) following bonding in the form of a "bubble" between the
25 two wafers, indicating that bonding has not been properly carried out in site 203 while the principal wave 200c' reaches the periphery of the wafer.

A detection assembly 50 placed at X2, i.e., at the same site as in the case of Figure 2, would detect a
30 delay in the arrival of the wave compared with the case of Figure 2, as the wave would have been slowed down by the surface defect 201.

Thus, it can be seen how measuring a bonding speed can allow the surface quality of the wafer to be deduced
35 automatically.

In a variation of a device in accordance with the invention comprising a plurality of openings 21 or, in a

more general case, in a variation of a device in accordance with the invention employing a plurality of assemblies for automatic detection of the instant of bonding, detection being carried out locally over the whole surface of the stack 10, wafer bonding dynamics can be determined, and better information on the surface quality of the wafer can be obtained, along with information regarding the nature and location of any surface defects.

10 In this implementation, if a sufficiently large number of local instants of bonding are detected over the whole surface of the stack 10, a map of the surface quality of the wafer is obtained.

Such a device or method in accordance with the invention is preferably applied to wafers intended for micro-electronics, namely wafers several centimeters in diameter with thicknesses of the order of one micron or several tens of microns.

20 This type of wafer contains at least one semiconductor material such as silicon.

In a preferred mode, said wafers comprise SOI (silicon on insulator) type structures.

One of the wafers (11 or 12) may not be intended for a micro-electronics application and can act as a particularly flat reference wafer, for example.

30 Finally, it should be noted that the measurements made by the device of the invention (instant of bonding initiation, passage of bonding wave at different measuring sites, etc...) can remain stored in the processing unit along with the parameters deduced therefrom (bonding speeds, etc...).

This means that the bonding speeds and therefore the quality of the wafers produced can be inspected. It is also possible in this case to make use of the stored data as a whole, e.g. to apply statistical methods to the procedure.

CLAIMS

1. A device for inspecting the surface quality of a wafer employing measuring the bonding speed of two wafers (11, 12) at a bonding interface (13) defined
5 between the two wafers, characterized in that the device comprises automatic means for detecting bonding initiation and automatic means for detecting the passage of a bonding wave.
- 10 2. A device according to the preceding claim, characterized in that the automatic means for detecting the passage of a bonding wave comprise a source (30) of electromagnetic radiation and a
15 sensor (40) that can detect at least a portion of the spectrum of electromagnetic radiation emitted by the source (30), the sensor (40) being disposed in a manner that collects the radiation from a predetermined measuring site (X) of the bonding
20 interface.
3. A device according to the preceding claim, characterized in that the device comprises a processing unit to which the automatic means for
25 detecting bonding initiation and the automatic means for detecting the passage of a bonding wave are connected.
4. A device according to the preceding claim, characterized in that the processing unit can
30 calculate the instantaneous bonding speeds for each measuring site of the bonding interface.
5. A device according to one of the three preceding
35 claims, characterized in that the sensor (40) can detect a change in a characteristic of the electromagnetic wave which it receives from the source (30) via at least one measuring site.

6. A device according to the preceding claim,
characterized in that the change in the
characteristic of the electromagnetic wave is a
change in contrast.
7. A device according to any one of the five preceding
claims, characterized in that the automatic means
for detecting the passage of a bonding wave further
comprises, in association with at least one
measuring site, an opening passing through the
support and allowing the radiation from the source
to pass through so that it then passes through the
wafers at the measuring site, so that the portion of
the radiation from the source which is transmitted
through the wafers reaches the sensor.
8. A device according to the preceding claim,
characterized in that the detection means comprise
at least one detection assembly (50) constituted by
an electromagnetic source (30), an opening (21) and
an electromagnetic sensor (40), wherein the source
(30) and the sensor (40) are aligned either side of
the opening (21).
9. A device according to any one of the seven preceding
claims, characterized in that the automatic means
for detecting the passage of a bonding wave also
comprises, in association with at least one
measuring site, a source of electromagnetic
radiation directed towards the measuring site and
reflected towards an associated sensor by the
wafers.
10. A device according to any one of the preceding
claims, characterized in that the source (30) is a
lamp.

11. A device according to any one of the preceding claims, characterized in that the sensor (40) is optoelectronic.

5

12. A device according to any one of the preceding claims, characterized in that the electromagnetic spectrum emitted by the source (30) comprises the infrared site.

10

13. A device according to any one of the eleven preceding claims, characterized in that the device comprises a plurality of assemblies (50) for detecting the passage of a bonding wave between the two wafers, respectively associated with a plurality of measuring sites on the wafers to be inspected, so that each of said assemblies allows local determination of the instant of local bonding at the associated measuring site.

20

14. A device according to the preceding claim in combination with claim 7 or claim 8, characterized in that the automatic means for detecting the instant of bonding comprise a plurality of openings (21) respectively associated with measuring sites, each opening (21) allowing local detection of the instant of local bonding at the associated measuring site.

25

30 15. A method of inspecting the surface quality of a wafer, employing measuring the bonding speed of two wafers (11, 12) at a bonding interface (13), characterized in that the method comprises the following operations:

35

- automatic acquisition of the instant of bonding initiation;

- automatic acquisition of the instant for passage of a bonding wave;
- automatic determination of a bonding speed from said two data acquisitions.

5

16. A method according to the preceding claim, characterized in that the instants for passage of a bonding wave are acquired at a wafer (11, 12) measuring site from a change in a characteristic of an electromagnetic wave deriving from the measuring site.

10

17. A method according to the preceding claim, characterized in that the change in the characteristic of the electromagnetic wave is a change in contrast.

15

18. A method according to any one of the two preceding claims, characterized in that the electromagnetic wave spectrum encompasses the infrared site.

20

19. A process according to any one of the three preceding claims, characterized in that a plurality of instants for passage of a local bonding wave are respectively detected at a plurality of wafer measuring sites.

25

20. The use of a device according to any one of claims 1 to 14 or a method according to any one of claims 15 to 19, for inspecting the surface quality of a wafer with a mean thickness in the range from one micrometer to a few millimeters.

30

21. A use according to the preceding claim, characterized in that the structure of the inspected wafer comprises silicon.

35

22. Application according to the preceding claim,
characterized in that the structure of the inspected
wafer comprises an SOI type structure.