

Description

5 Title

Production method for a micromechanical device having inclined optical windows,
and corresponding micromechanical device

10 The present invention relates to a production method for a micromechanical device having inclined optical windows, and to a corresponding micromechanical device.

Prior art

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Although also applicable to any desired optical devices and systems, the present invention and the problem addressed thereby are explained on the basis of optical micromechanical micromirror scanner devices.

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Micromechanical MEMS components have to be protected for protection against harmful external environmental influences (e.g. moist, aggressive media, etc.). Protection against mechanical contact/destruction and in order to allow singulation from a wafer assemblage into chips by sawing is likewise necessary. In many cases, the setting of a specific atmosphere (e.g. gas type and/or gas pressure) also has to be made possible by means of a hermetic encapsulation.

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The encapsulation of MEMS components with a cap wafer having cavities and through holes in the wafer assemblage has become widely established. For this purpose, a cap wafer is aligned with the wafer having the MEMS structures and is joined together with said wafer. The joining together can be carried out for example by anodic bonding or direct bonding (connection between glass and silicon in a manner free of joining agents), by means of eutectic joining layers or by means of glass solders or adhesives. The MEMS component(s) lie(s) below the cavities of the cap wafer, wherein electrical bond pads for connecting the MEMS component using thin wires are accessible via the through holes in the cap wafer.

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Optical micromechanical MEMS components (MOEMS), such as e.g. micromirrors, require the protection described above and additionally a transparent window having high optical quality and possibly also having specific optical coatings. Occasionally, through holes for electrical connection are also realized in the caps.

When optical rays pass through the transparent window, reflections arise at the interfaces. If the stationary reflections of a micromechanical micromirror scanner device lie in the scanning region of the micromirror, their intensity exceeds that of the projected image and therefore has a disturbing effect. An antireflection coating of the optical window can only reduce the intensity of these disturbing reflections. Since the micromirror usually oscillates or is deflected symmetrically about its rest position, the reflection is always in the scanning region if the optical window is parallel to the rest position of the mirror surface and if the distance between the mirror plane and the optical window is small (this is always the case for MEMS components).

The only possibility for avoiding a disturbance as a result of the reflections is to direct them from the scanning region by the optical window and the mirror surface not being parallel to one another in the undeflected state. There are two possibilities for this, namely firstly an inclination of the optical window or secondly an inclination of the rest position of the mirror. Both possibilities are known in the prior art.

Inclined windows for singulated chips are disclosed in EP 1 688 776 A1, for example. Inclined windows or else other forms of windows with which the reflections are avoidable are described for wafer level packaging in EP 1 748 029 A2.

In accordance with EP 1 748 029 A2, the three-dimensional surface structures (for example inclined windows) are produced from a transparent material (glass or plastic) in a wafer assemblage. The methods by which the three-dimensional structures are produced either are very expensive or do not yield the required optical quality. Moreover, wafers having corresponding three-dimensional

structures are problematic during processing, for example during wafer bonding, since the structures can easily be damaged.

Further methods for producing protective caps having inclined optical windows are known from DE 10 2008 040 528 A1, DE 10 2010 062 118 A1 and DE 10 2012 206 858 A1, for example.

Disclosure of the invention

The invention provides a production method for a micromechanical device having inclined optical windows according to Claim 1, and a corresponding micromechanical device according to Claim 10.

The respective dependent claims relate to preferred developments.

Advantages of the invention

The concept underlying the present invention resides in forming a plurality of spaced-apart through holes in the first substrate, which through holes are arranged along a plurality of spaced-apart rows in the first substrate. A respective continuous oblique groove is formed along each of the rows, which define a seat for the inclined optical windows.

The present invention thus enables a cost-effective production method for a micromechanical device having an inclined optical window, which device can be used for example as a protective wafer for a micromechanical micromirror scanner device. The inclined optical transparent windows are producible with high optical quality. The production method according to the invention is robust and suitable for series production and also more cost-effective than known methods. The further processing process with MEMS substrates that is known per se has to be only slightly modified.

The inclined optical windows can be produced by processes that are customary in MEMS and semiconductor technology. Scratches, particles and damage on the inclined optical window during processing can easily be avoided.

Rectangular optical windows possibly without a step-cut profile can be used with the concept according to the invention. Thus, the benefit per wafer of the optical glass can be doubled and the singulation process can be simplified, which is a further cost advantage.

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In accordance with one preferred development, adjacent grooves are bevelled in opposite directions. This enables a stable substrate structure and a close arrangement of the chips, such that only one common opening need be provided for electrical bond pads of adjacent chips.

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In accordance with a further preferred development, the optical windows are joined, e.g. adhesively bonded, in a hermetically sealed manner along their entire circumference. This makes it possible to form hermetically sealed windows.

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In accordance with a further preferred development, the grooves are formed in a mechanical grinding process. This is an efficient way of forming the grooves.

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In accordance with a further preferred development, after forming the grooves, a second substrate is bonded onto the front side, wherein insertion openings for inserting the optical windows are formed in the second substrate. This enables additional protection and an orientation aid for the windows and also further processing of the substrates and automatic handling, e.g. by edge suction.

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In accordance with a further preferred development, the grooves and the second substrate are fashioned in such a way that the optical windows are completely sunk in the second substrate. Such protection is particularly effective and prevents damage to the windows by avoiding a mechanical contact.

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In accordance with a further preferred development, the insertion openings are configured as lateral guides for the optical windows. This enables the windows to be oriented securely.

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In accordance with a further preferred development, the optical windows are provided with a glass solder circumferentially at the edge for inserting purposes, are subsequently inserted into the grooves by a pick-and-place process and then in the inserted state are hermetically joined, e.g. adhesively bonded, in a

hermetically sealed thermally with the glass solder being softened. This enables a robust method suitable for series production.

In accordance with a further preferred development, the first and/or second substrate are/is wafer substrates, in particular glass wafer substrates, silicon wafer substrates, ceramic wafer substrates, metal wafer substrates or plastic wafer substrates. Such substrates are stable and can be processed well.

Brief description of the drawings

Further features and advantages of the present invention are explained below on the basis of embodiments with reference to the figures.

In the figures:

Figs 1a)-e) show schematic cross-sectional illustrations for elucidating a production method for a micromechanical device having inclined optical windows and a corresponding micromechanical device in accordance with a first embodiment of the present invention;

Fig. 2 shows a schematic plan view of the micromechanical device in accordance with the first embodiment of the present invention;

Figs 3a)-d) show schematic cross-sectional illustrations for elucidating a production method for a micromechanical device having inclined optical windows and a corresponding micromechanical device in accordance with a second embodiment of the present invention; and

Fig. 4 shows a schematic plan view of the micromechanical device in accordance with the second embodiment of the present invention.

Embodiments of the invention

In the figures, identical reference signs designate identical or functionally identical elements.

Figs 1a)-e) are schematic cross-sectional illustrations for elucidating a production method for a micromechanical device having inclined optical windows and a corresponding micromechanical device in accordance with a first embodiment of the present invention, and Fig. 2 is a schematic plan view of the micromechanical device in accordance with the first embodiment of the present invention.

The micromechanical device having inclined optical windows in accordance with the first embodiment is usable for example as a protective wafer device for a micromechanical micromirror scanner device.

The production of the micromechanical device is described at the wafer level, although it is not restricted thereto and could also be implemented at a different substrate level. In order to simplify the illustration, only the production of two inclined optical windows is shown here, although a large multiplicity of inclined optical windows can of course be produced at the wafer level.

In Fig. 1a), reference sign S1 denotes a first wafer substrate, for example a silicon wafer substrate or glass wafer substrate or plastic substrate or metal wafer substrate or ceramic wafer substrate, etc. Fig. 1a) corresponds to the section A-A' in Fig. 2.

A first production step involves processing the first wafer substrate S1 having a front side VS and a rear side RS.

Through holes F1 and F2 are introduced into the first wafer substrate S1 for example by means of KOH etching or sandblasting or by means of any other material-removing method (including mechanical drilling, grinding, eroding or laser machining). The through holes F1, F2 and further through holes (not illustrated) are formed in parallel rows R1, R2 in matrix form on the first wafer substrate S1.

Fig. 1b) corresponds to the section B-B' in Fig. 2. As shown in Fig. 1b), in a subsequent process step, after forming the through holes F1, F2 etc. on the front side VS, continuous oblique grooves N1, N2 are formed along the rows R1, R2, which define a seat or a sealing surface for the optical windows to be inserted later. Said grooves N1, N2 can be worked from the substrate for example by

grinding with a corresponding profile. In the present example, the bevel relative to the normal to the first wafer substrate S1 is 60°, but arbitrary bevels can be chosen in principle depending on the application. In this case, each groove N1, N2 extends through a respective row of through holes F1, F2. Adjacent grooves N1, N2 are preferably bevelled in opposite directions, as illustrated in Fig. 1b).

Fig. 1c) corresponds to the section A-A' in Fig. 2 and illustrates the grooves N1, N2 together with the through holes F1, F2. Fig. 1d) corresponds to the section A-A' in Fig. 2.

As illustrated in Fig. 1d), the optical windows G1, G2, which were provided with glass solder circumferentially along their entire circumference beforehand, are inserted and joined in a hermetically sealed manner by means of a pick-and-place fitting method (chip-to-wafer fitting). After the insertion of the optical windows G1, G2, the first wafer substrate completely fitted with the optical windows F1, F2 is heated on a heating plate (not illustrated), and when the softening point of the glass solder is reached, the optical windows G1, G2 are pressed into their respective seat by way of a pressure difference between front side VS and rear side RS. The glass solder situated between the optical window G1, G2 and the first wafer substrate S1 softens and deliquesces as a result. Subsequent cooling is followed by producing a hermetic connection between the optical windows G1, G2 and the first wafer substrate.

Fig. 1e) corresponds to the section B-B' in Fig. 2.

The latter process step concludes the production of the protective wafer. For the formation of a hermetic composite assembly with an actuator or sensor wafer, glass solder, for example, is likewise applied (not illustrated) on the rear side RS of the first wafer substrate S1.

The production of such a wafer composite assembly with a MEMS wafer is carried out using customary wafer composite assembly processes and wafer composite assembly installations. In this case, a reduced pressure or excess pressure relative to the surroundings can be set in the cavities between the first wafer substrate and the actuator or sensor wafer (not illustrated), as known in the

prior art. The final singulation of the chips is also carried out using a standard process, such as e.g. sawing.

Figs 3a)-d) are schematic cross-sectional illustrations for elucidating a production method for a micromechanical device having inclined optical windows and a corresponding micromechanical device in accordance with a second embodiment of the present invention, and Fig. 4 is a schematic plan view of the micromechanical device in accordance with the second embodiment of the present invention.

Figs 3a), 3b), 3c) correspond to the section C-C' in Fig. 4. Fig. 3c) corresponds to the section D-D' in Fig. 4.

The process state in accordance with Fig. 3a) follows the process state in accordance with Fig. 1c). A second wafer substrate S2 is bonded onto the front side VS of the first wafer substrate S1. At this point in time the second wafer substrate S2 may already have been thinned to its final target thickness and also have insertion openings D1, D2 for the optical windows G1, G2. The thinning and the introduction of the insertion openings D1, D2 for the glass windows G1, G2 can be carried out depending on the process implementation e.g. by means of KOH etching, sandblasting, mechanical grinding, trench etching, etc., or by means of combinations of the structuring methods mentioned.

In the present exemplary embodiment, however, the second wafer substrate S2 is firstly bonded onto the first wafer substrate S1 and then thinned to its final target thickness, and after that the insertion openings D1, D2 for inserting the optical windows G1, G2 are formed.

The depth of the grooves N1, N2 and also the thickness of the second wafer substrate S2 are preferably chosen in such a way that the optical windows G1, G2 are completely sunk with respect to the exposed surface of the second wafer substrate S2. This makes it possible to ensure that the optical windows G1, G2 are not damaged after insertion, i.e. for example scratches as a result of mechanical influences are avoided. Preferably, the insertion openings D1, D2 are configured as lateral guides for the optical windows G1, G2. As a result of such a

lateral guidance, the optical windows G1, G2 cannot slip within the insertion openings D1, D2, as shown in Fig. 3d).

As already described above in association with Fig. 1d), the optical windows G1, G2, which were provided with glass solder circumferentially beforehand, are inserted by means of a pick-and-place fitting method, after which the glass softening temperature step is carried out.

The use of the second wafer substrate S2 enables a structure-free edge of the first wafer substrate S1 and also a circumferential joining surface of the chips. The grooves N1, N2 can thus extend over the entire wafer diameter as far as the edge, which is highly advantageous in terms of production engineering since for example grinding wheels having a large diameter are usable. That is highly advantageous for the rate of removal and also for the accuracy of the profile of the grooves N1, N2. As described above, adjacent grooves N1, N2 are preferably bevelled in opposite directions.

The further processing of the protective wafer produced in this way can be carried out in the manner as already described in association with the first embodiment.

Although the present invention has been described on the basis of preferred exemplary embodiments, it is not restricted thereto. In particular, the materials and topologies mentioned are merely by way of example and not restricted to the examples explained.

In particular, other inclination directions, angles, geometries, etc. can be chosen.

If only one substrate S1 is used, the optical windows can also be introduced continuously as strips into the groove and be joined.

Claims

- 5 1. Production method for a micromechanical device having inclined optical windows, which production method comprises the following steps:
- providing a first substrate (S1) having a front side (VS) and a rear side (RS);
- 10 forming a plurality of spaced-apart through holes (F1, F2) in the first substrate (S1), which through holes are arranged along a plurality of spaced-apart rows (R1, R2) in the first substrate (S1);
- forming a respective continuous oblique groove (N1, N2) along each of the rows
- 15 (R1, R2), which define a seat for the inclined optical windows (G1, G2); and
- inserting the optical windows (G1, G2) above the through holes (F1, F2) into the grooves (N1, N2).
- 20 2. Production method according to Claim 1, wherein adjacent grooves (N1, N2) are bevelled in opposite directions.
3. Production method according to Claim 1 or 2, wherein the optical windows (G1, G2) are joined in a hermetically sealed manner along their entire
- 25 circumference.
4. Production method according to any of the preceding claims, wherein the grooves (N1, N2) are formed in a mechanical grinding process.
- 30 5. Production method according to any of the preceding claims, wherein after forming the grooves (N1, N2), a second substrate (S2) is bonded onto the front side (VS), and wherein insertion openings (D1, D2) for inserting the optical windows (G1, G2) are formed in the second substrate (S2).

6. Production method according to Claim 5, wherein the grooves (N1, N2) and the second substrate (S2) are fashioned in such a way that the optical windows (G1, G2) are completely sunk in the second substrate (S2).

5 7. Production method according to Claim 5 or 6, wherein the insertion openings (D1, D2) are configured as lateral guides for the optical windows (G1, G2).

10 8. Production method according to any of the preceding claims, wherein the optical windows (G1, G2) are provided with a glass solder circumferentially at the edge for inserting purposes, are subsequently inserted into the grooves (N1, N2) by a pick-and-place process and then in the inserted state are joined in a hermetically sealed manner thermally with the glass solder being softened.

15 9. Production method according to any of the preceding claims, wherein the first and/or second substrate (S1, S2) are/is wafer substrates, in particular glass wafer substrates, silicon wafer substrates, ceramic wafer substrates, metal wafer substrates or plastic wafer substrates.

20 10. Micromechanical device having inclined optical windows, comprising:

a first substrate (S1) having a front side (VS) and a rear side (RS);

25 a plurality of spaced-apart through holes (F1, F2) in the first substrate (S1), which through holes are arranged along a plurality of spaced-apart rows (R1, R2) in the first substrate (S1);

a respective continuous oblique groove (N1, N2) along each of the rows (R1, R2), which define a seat for the inclined optical windows (G1, G2);

30 a plurality of optical windows (G1, G2), which are joined in a hermetically sealed manner above the through holes (F1, F2) into the grooves (N1, N2).

35 11. Micromechanical device having inclined optical windows according to Claim 10, wherein adjacent grooves (N1, N2) are bevelled in opposite directions.

12. Micromechanical device having inclined optical windows according to Claim 10 or 11, wherein the optical windows (G1, G2) are joined in a hermetically sealed manner along their entire circumference.

5 13. Micromechanical device having inclined optical windows according to any of Claims 10 to 12, wherein a second substrate (S2) is bonded onto the front side (VS), and wherein insertion openings (D1, D2) for inserting the optical windows (G1, G2) are formed in the second substrate (S2).

10 14. Micromechanical device having inclined optical windows according to any of Claims 10 to 13, wherein the grooves (N1, N2) and the second substrate (S2) are fashioned in such a way that the optical windows (G1, G2) are completely sunk in the second substrate (S2).

15 15. Micromechanical device having inclined optical windows according to any of Claims 10 to 14, wherein the insertion openings (D1, D2) are configured as lateral guides for the optical windows (G1, G2).