

Method for transferring a functional unit, transmitter substrate and apparatus for performing such a method

5 The present invention relates to a method for transferring a functional unit, a transmitter substrate for such a method and an apparatus for performing such a method.

The semiconductor industry is increasingly reaching its limits with miniaturisation. Transistors now have node sizes that are so small that further miniaturisation is becoming increasingly difficult, expensive or even physically impossible. A few years ago, a new approach was therefore developed to not only reduce the size of functional units laterally,
10 but also to arrange them three-dimensionally.

Initially, the solution was to make several functional layers on top of each other and bond them via TSVs (through silicon vias).
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A further development consisted of making different functional units on different substrates. In particular, the production could also be performed by different companies. For example, one company could specialise in the production of microchips, while a second company could specialise in the production of memory chips. The substrates were then aligned with each other and bonded together. The bonding was preferably a fusion bond, in particular a hybrid bond. Since the individual functional units of the first substrate had to be located at least in the vicinity of the functional units of the second substrate, a grid along which the functional units were created had to be the same. If 10,000 functional units were created on the first substrate, there also had to be 10,000 functional units on
20 the second substrate. A serious disadvantage of this method was that a non-functioning functional unit was always bonded to an opposite functioning functional unit. The chip bonded with these two functional units and later separated from the substrate stack was of course no longer functional and had to be disposed of. It was therefore not possible to use only functioning units ('known-good-dies') and remove the non-functioning ones from the bonding process beforehand, as these were part of the substrate. Methods in which two
25 substrates, in particular wafers, are bonded together are also known as W2W methods (wafer-2-wafer or wafer-to-wafer).
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A further development consisted of using a first substrate on which individual functional units were made. Each individual functional unit on the substrate was tested for its functionality. The functional units of a second substrate, which had already been separated by
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a dicing process, were then individually bonded to the functional units of the first substrate using a chip-to-wafer bonder, but only if the functional unit on the second substrate and the previously tested, already separated functional unit were functional. This ensured that a bonding process only took place between functional units that were functioning. This
5 stacking process could be continued with further functional units, resulting in a single substrate on which there were several layers of functional units. The substrate created in this way was then either moulded or otherwise protected before separation into individual chips. Publications WO 2018 157 937 A1 and WO 2009 115 240 A1, for example, show such methods and devices. This method greatly reduced waste. A disadvantage was that
10 the already separated functional units had to be individually bonded to the functional units, which was time-consuming and cost-intensive. Another disadvantage was that the functional units were mostly chips, i.e. moulded dies. These chips were embedded in a moulding compound and had solder balls (bumps) on at least one side, but ideally at least contacts to establish an electrically conductive bond with the functional units of the substrate
15 or the other chips stacked on them. The moulding compound and the solder balls unnecessarily enlarge the stacked functional unit created in this way.

One problem in the prior art is therefore that the functional units are usually chips or chiplets, i.e. already moulded dies, which in particular still have solder balls or at least
20 electrical contacts with a certain height. It would be preferable to bond the dies directly, especially as ultra-thin functional units. The dies can be active on one or both sides, i.e. have a function and/or contacts on their front and/or back.

Another problem is that the individual functional units generally also differ in their lateral
25 dimensions, i.e. length and width. It is therefore desirable not only to stack the functional units in the third dimension, but also to arrange them optimally within a plane.

Another problem is the transfer of functional units. The thinner the functional units are, the more difficult it is to transfer them from a transmitter substrate to a receiver substrate.
30 Even if the transfer itself is successfully performed by a bonding process, the functional unit still has to be separated from the transmitter substrate. Since the functional units are ultra-thin substrates, the method steps must be performed in such a way that the functional units are not damaged.

A further problem in the prior art is that the functional units created on a receiver substrate, in particular stacked functional units, must also be separated from the receiver substrate again in order to finally be moulded into finished chips or chiplets in the last method steps.

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The present invention achieves the object with a method for transferring a functional unit according to claim 1, with a transmitter substrate according to claim 14 and with an apparatus according to claim 15. Advantageous further embodiments of the invention are given in the subclaims. All combinations of at least two features specified in the description, in
10 the claims and/or in the drawings also fall within the scope of the invention. In the case of stated value ranges, values lying within the stated limits are also to be regarded as limit values disclosed and can be claimed in any combination.

According to a first aspect of the present invention, a method for transferring a functional
15 unit from a transmitter substrate transmitting the functional unit to a receiver substrate receiving the functional unit is provided, in particular as a partial step for building up a product substrate, comprising:

- providing a transmitter substrate and a receiver substrate, the transmitter substrate having a functional unit, preferably several functional units, and a separation layer, preferably integrated in a system of layers,
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- aligning the transmitter substrate and the receiver substrate with respect to one another by means of an alignment unit,
- separating the separation layer in the region of the functional unit and
- removing the transmitter substrate without the functional unit,

25 wherein the functional unit is left on the receiver substrate or a product substrate structure on the receiver substrate to form a product substrate.

In contrast to the approaches commonly used in the prior art, it is provided according to the invention that the functional unit is provided by a transmitter substrate which itself
30 does not become part of the product substrate, but which has the task of leaving the functional unit on the receiver substrate. As a result, particularly thin functional units can be placed on the receiver substrate during the build up of the product substrate without having to add stabilising components to the functional units in order to place it on the receiver substrate. This avoids components that fill the installation space when assembling the
35 product substrate. A functional unit is understood by the skilled person to be, in particular, a structure that has a functional character, i.e. that can be regarded as an active part. Ex-

amples of this would be microchips, memory chips, LEDs, MEMS, etc. The present invention thus enables ultrathin functional units to be bonded directly to a product substrate structure or to another ultrathin functional unit. Furthermore, the functional units can also be assembled with a high packing density in the lateral plane. The ultra-thin functional
5 units can preferably be bonded with each other directly or via TSVs (through silicon vias).

The product substrate preferably comprises a large number of functional units in the manufactured state, which are in particular arranged offset in height relative to one another. It is also possible to arrange functional units laterally, in particular different functional units,
10 on a plane in bond with a vertically offset assembly. The product substrate is preferably built up by successive assembly of one or more functional units. In an intermediate step, a dielectric medium or a dielectric layer is deposited in order to realise a height offset between the individual height offset and possibly laterally offset functional units layer by layer. The method for transferring the functional units is preferably used to build up the
15 product substrate. The product substrate then forms, for example, a chip or a precursor for a chip.

In particular, a product substrate structure is to be understood as an arrangement of layers that have already been built up as part of the method for producing the product substrate, more preferably using the method described, before all the layers for the product
20 substrate have been assembled.

Furthermore, it is preferably provided that the transmitter substrate comprises a first transmitter substrate part and a second transmitter substrate part. The first transmitter substrate part serves in particular as a carrier and the second transmitter substrate part comprises one or more functional units. A separation layer is preferably formed in a sandwich-like manner between the first transmitter substrate part and the second transmitter substrate part, in particular along a stacking direction perpendicular to the main extension plane. The transmitter substrate can have an expansion along a direction parallel to the
25 main extension plane that is greater than the corresponding expansion of the later product substrate or comparable with regard to the expansion of the later product substrate. For this purpose, it is conceivable, for example, that the transmitter substrate has been separated from a larger transmitter substrate structure. The transmitter substrate is, for example, at least partially built monolithic, for example by means of epitaxy.
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35 The separation layer is characterised in particular by the fact that it can be separated or is separated in a targeted manner, in particular at a fixed point in time and preferably to a

fixed extent. For this purpose, a separation layer is preferably provided, which can arrange the separation or dissolution under the action of a trigger. Accordingly, the separation layer is adapted to or co-ordinated with the corresponding trigger, for example a chemical or optical agent.

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Another aspect of the present invention is a method of building a product substrate comprising:

- providing a transmitter substrate and a receiver substrate, wherein the transmitter substrate comprises a functional unit, preferably a plurality of functional units, and
- 10 a separation layer, preferably integrated in a system of layers,
- aligning the transmitter substrate and the receiver substrate with respect to each other by means of an alignment unit,
- separating the separation layer in the region of the functional unit and
- removing the transmitter substrate without the functional unit,

15 leaving the functional unit on the receiver substrate or a product substrate structure to form a product substrate. All the properties and advantages described for the method for transferring can be transferred analogously to the method for building up the product substrate.

20 Preferably, it is provided that the functional unit left behind is bonded and/or a dielectric layer is applied to the receiver substrate. Preferably, a permanent bonding is made from a pre-bond. This is preferably provided when the functional unit is placed on the product substrate. For example, bonding is carried out by increasing the temperature, which can be done before or after separating the separation layer. The application of the dielectric

25 layer preferably forms a layer that extends next to the functional unit in a plane parallel to the main extension plane. A further functional unit can then be left on the functional unit and/or the dielectric layer. In this way, a product substrate is successively formed. It is conceivable that the dielectric layer essentially has a thickness that corresponds to the thickness of the functional unit. This can be realised, for example, by removing part of the

30 applied layer of dielectric material, i.e. part of the dielectric layer, again.

Furthermore, it is preferably provided that a contact is made between the transmitter substrate on one side and the receiver substrate or the product substrate structure on the other side, wherein the contact, in particular the direct contact, between the transmitter

35 substrate and the receiver substrate or the product substrate structure is made via a contact side of the transmitter substrate, wherein a section of the functional unit forms part of the contact side. In other words, the functional unit faces the receiver substrate or the

product substrate when it is placed on the receiver substrate or the product substrate.

This allows, for example, the functional unit to be placed directly on the product substrate structure or the receiver substrate. In addition, direct access to the functional unit is possible before it is removed, which allows a functional test to be carried out. In particular, it is provided that a pre-bond is caused by the contact. This can be supported or caused, for example, by a suitable preparation of an outer side of the receiver substrate or the product substrate structure.

In particular, it is provided that the separation layer is separated optically and/or chemically. Optical separating proves to be particularly advantageous, as it allows, for example, localised separating. Chemical dissolution can prove advantageous in cases where the product substrate structure and/or receiver substrate are not transparent to light, which could otherwise be used for separating.

Preferably, it is provided that the separation layer is separated locally to a limited extent. This makes it advantageously possible to separate only a single functional unit or a limited number of functional units from the transmitter substrate. This allows the individual selection of functional units in a transmitter substrate with several functional units, which is particularly advantageous if a functional unit or a few functional units in the transmitter substrate are defective. These can then be left out and only functional units that are in good working order can be transferred or left behind.

Furthermore, it is more preferably provided that the separation layer and/or the system of layers comprises at least one layer of an inorganic material, in particular consisting of the inorganic material. This allows a separation layer to be provided which can be separated comparatively easily, for example by means of a laser, and which does not require any additional cleaning steps. In a preferred embodiment of the method, it is provided that the separation layer is made of a metal or nitride, preferably TiN. An inorganic separation layer made of metal or a nitride is particularly suitable, as these also enable stable bonding in particular. A tin-based separation layer is most preferably used.

The system of layers comprises at least one layer. The at least one layer is a release layer which can be influenced by the application of an external agent, preferably electromagnetic radiation, most preferably a laser, most preferably of all an infrared laser, in such a way that a release of at least one substrate from at least one side of the system of layers can take place. Further layers can fulfil the task of a bond layer, an absorption layer, an absorption-enhancing layer, a seed layer, an overgrowth layer, etc.

The layers of the system of layers preferably consist of at least one material of one of the following material classes

- Dielectric, in particular
- 5 - Nitride, in particular
- TiN, CrN, TaN, AlN, NiN, Si₃N₄
- Carbide, in particular carbon layers
- oxide
- less preferably polymer
- 10 - electric, preferably
- metal, in particular
- Cr, Al, Ta, Co, Ni, Mn, Fe, Au, Ga, Sn, Ge, W, Cu, In

It is preferable for the functional unit to be subjected to a functional test before contact is made between the transmitter substrate and the receiver substrate. This has the advantage of preventing defective functional units from being subjected to a bonding process. After all, such manufactured product substrates cannot be used due to their lack of functionality. This reduces the number of defective product substrates that have to be rejected.

Furthermore, it is preferably provided that a plurality of functional units are arranged on the receiver substrate offset in height, in particular also offset in relation to each other. This successively realises a product substrate structure and finally the product substrate with a three-dimensional assembly of functional units.

Furthermore, it is preferably provided that the functional unit is part of a plurality of functional units, which are left on the receiver substrate and/or the product substrate structure, in particular from the same transmitter substrate, preferably simultaneously or successively. In particular, a part of functional units, at least one functional unit, is transferred from the plurality of functional units.

In particular, it is provided that laser light, in particular pulsed laser light, is used for separating. In a preferred embodiment of the method, it is provided that the laser beams have a wavelength between 0.1 µm and 500 µm, preferably between 0.2 µm and 100 µm, more preferably between 0.3 µm and 50 µm, most preferably between 0.5 µm and 10 µm, ut-

most preferably between 1 μm and 2.5 μm . In this way, the separation layer can be irradiated in a particularly efficient and targeted manner. The carrier substrate is preferably permeable to the laser beams.

- 5 In a preferred embodiment of the method, it is provided that the pulse energy of the laser beams is between 0.01 μJ and 128 μJ , preferably between 0.125 μJ and 64 μJ , more preferably between 0.25 μJ and 32 μJ , most preferably between 0.5 μJ and 16 μJ , utmost preferably between 1 μJ and 8 μJ . It has been found that damage to the product substrate can be avoided with these pulse energies. In a preferred embodiment of the method, it is
- 10 provided that the pulse duration of the laser beams is between 10,000 ps and 1 ps, preferably between 1,000 ps and 1 ps, more preferably between 500 ps and 1 ps, most preferably between 100 ps and 1 ps, utmost preferably between 50 ps and 1 ps. This pulse duration allows targeted action for separation.
- 15 Furthermore, it is preferably provided that the functional unit is part of a plurality of functional units that are left on the receiver substrate by the same transmitter substrate, preferably simultaneously or successively.

Preferably, it is provided that the product substrate or the product substrate structure is

20 detached from the receiver substrate via a separation layer on the receiver substrate side. In this way, the manufactured product substrate is provided, in particular without having to destroy or lose the receiver substrate. It is also conceivable that the product substrate structure is passed on for further processing before the final product substrate structure is manufactured.

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It is also conceivable that the product substrate remains on the receiver substrate and thus forms a new product substrate. In other words, the receiver substrate becomes part of the product substrate. In particular, the receiver substrate can also have a functionality or functional units. More preferably, however, the product substrate is separated from the

30 receiver substrate, as the receiver substrate can then be reused.

In particular, it is provided that the functional unit has a thickness dimensioned perpendicular to a main extension plane which is less than 50 μm , more preferably less than 25 μm and most preferably less than 1 μm or even less than 100 nm, wherein the functional unit

35 is preferably encapsulated. The advantageous method proves to be particularly advantageous for such ultra-thin functional units because, due to their reduced thickness, they do

not have sufficient stability of their own to allow individual transport. In particular, the ultra-thin functional units can also be so-called 2D materials.

Preferably, the method comprises the following method steps

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In a first method step, a transmitter substrate is made, which is composed of a stabilising first transmitter substrate part, a system of layers and a second transmitter substrate part comprising the functional units. The system of layers has at least one separation layer which allows the functional units to be separated, in particular selectively, from the first transmitter substrate part.

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In a second method step, the transmitter substrate is aligned relative to a receiver substrate. In particular, the functional units of the transmitter substrate are aligned relative to alignment markers and/or to other functional units already present on the receiver substrate. The alignment is preferably carried out optically, in particular with an alignment unit (aligner). The alignment can be performed using a face-to-face, back-to-back, face-to-back or back-to-face method.

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In a third method step, the transmitter substrate is contacted with the receiver substrate.

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This contacting represents a pre-bonding. In particular, the transmitter substrate and/or the receiver substrate surface may be hydrophilised in order to create a more efficient pre-bond.

In a fourth method step, a chemical and/or physical effect is applied to the separation layer within the system of layers. Preferably, the separation layer is exposed to a laser in such a way that the functional unit is separated from the transmitter substrate. The separation layer is vaporised or sublimated, for example. The effect is preferably selective, i.e. only functional units are released from the transmitter substrate. Ideally, all functional units of the transmitter substrate are transferred.

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In a fifth method step, the transmitter substrate is removed from the receiver substrate. The transferred functional units are now located on the receiver substrate. It is possible to arrange different large functional units with different functions next to each other and bonding them to the receiver substrate. The corresponding functional units are preferably ultra-thin. Therefore, another transmitter substrate with other functional units can contact the already partially populated receiver substrate and bond the other functional units to the receiver substrate.

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In a sixth, preferably optional method step, a heat treatment is carried out which permanently bonds the functional units. It is also conceivable that this heat treatment step takes place after the third or fourth method step, depending on how strong the pre-bond is. The stronger the pre-bond, the later the heat treatment can be carried out, as there is less risk of displacement of the functional units.

In a seventh method step, the functional units are dielectrically embedded on the receiver substrate. All common methods can be used for this. Since it is technically difficult to deposit the dielectric material with exactly the same thickness as the functional units and because functional units of different thicknesses can also exist within a plane, the dielectric material is deposited in such a way that the resulting dielectric layer has a greater thickness than the thickest functional unit. Preferably, after the deposition process, the dielectric layer is back thinned and/or ground back to a desired thickness. Vias can then be created. The region above the functional units is explicitly described as a connection layer, particularly in the figure descriptions. It is conceivable that the connecting layer is made of a different material than the dielectric layer in which the functional units are embedded. Preferably, however, they are made of the same material and are deposited in just one method step.

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The second exemplary method is a D2W (die-to-wafer) process in which a D2W or C2W bonder is used to align and bond individual dies.

In a first method step, a transmitter substrate is made, which consists of a stabilising first transmitter substrate part, a system of layers and a second transmitter substrate part comprising the functional units. The system of layers has at least one separation layer which allows the functional units to be separated, in particular selectively, from the transmitter substrate. The transmitter substrate is then separated. There are then several transmitter substrate single pieces, each of which in turn is to be understood as a transmitter substrate in the sense of the invention.

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In a second method step, a C2W bonder is used. The bonding head of the C2W bonder picks up an transmitter substrate single piece and aligns it relative to a position on the receiver substrate. In particular, the functional unit of the transmitter substrate single piece is aligned relative to alignment markers and/or to another functional unit already present on the receiver substrate.

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In a third method step, the transmitter substrate single piece is contacted with the receiver substrate. This contacting represents a pre-bonding. In particular, the surface of the transmitter substrate single piece and/or the receiver substrate surface may have been hydrophilised in order to create a more efficient pre-bond.

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In a fourth method step, a chemical and/or physical effect is applied to the separation layer within the system of layers. Preferably, the separation layer is exposed to a laser in such a way that the functional unit is separated from the donor substrate. The separation layer is vaporised or sublimated, for example. The advantage over the first method is that only those transmitter substrate single pieces are used whose functional units do not have a malfunction.

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In a fifth method step, the transmitter substrate parts above the system of layers are removed from the functional units fixed to the receiver substrate. The transferred functional units are now located on the receiver substrate. It is possible to arrange different sized functional units with different functions next to each other and bonding them to the receiver substrate. The targeted positioning within the lateral plane is particularly easy when using a C2W bonding.

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In a sixth, preferably optional method step, a heat treatment is carried out which permanently bonds the functional units. It is also conceivable that this heat treatment step takes place after the third or fourth method step, depending on how strong the pre-bond is. The stronger the pre-bond, the later the heat treatment can be carried out, as there is less risk of displacement of the functional units.

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In a seventh method step, the functional units are dielectrically embedded on the receiver substrate. Dielectric embedding can be performed by various methods, for example and more preferably by CVD (chemical vapor deposition), PVD (physical vapor deposition), a sol-gel process and less preferably by ALD (atomic layer deposition), molecular beam epitaxy. However, embedding in a polymer is also conceivable.

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In the majority of cases, the deposited dielectric layer covers the functional units and must therefore be thinned back to the functional units. Back thinning is achieved by grinding and/or polishing processes. Re-etching would also be conceivable. These method steps are known to the skilled person. They are not mentioned in the remainder of the text, as they do not contribute to an understanding of the invention.

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In a further development, the functional units released from the transmitter substrate self-align by a self-assembly process after transfer to the receiver substrate. The self-alignment may be caused and/or assisted by several chemical and/or physical circumstances.

5 In a further preferred embodiment, the pre-bonding of the functional units takes place on elevations (mesa). In particular, these elevations can be provided with a thin film of water. If the functional unit is placed on one of these elevations, it is centered relative to the elevation by an energy minimization process. The thickness of the elevations is less than 1 mm, preferably less than 0.5 mm, more preferably less than 0.1 mm, most preferably less
10 than 0.05 mm, utmost preferably less than 0.01 mm. In particular, the elevation is intended to serve the purpose of fixing a water film on-site, as the water film is fixed in its position by the edge of the elevation.

In a further preferred embodiment, the receiver substrate surface is chemically and/or
15 physically masked. Masking is understood to mean the preparation of a surface in such a way that at least two types of areas with different chemical and/or physical properties are created. It is conceivable, for example, that the regions in which the functional units are to be fixed are hydrophilic. The surrounding regions are hydrophobic. Another possibility would be to create regions with a high adhesive strength, while the surrounding areas
20 have a very low adhesive strength. Such masking can easily be achieved by combined methods of photolithography, imprint lithography and coating technology.

The latter two embodiments can also be advantageously combined with each other. It is conceivable, for example, that the surface of the elevations is hydrophilized in order to fix
25 the water film even better and to planarize it, while the environment set off from the elevation is hydrophobic, i.e. water-repellent.

Another object of the present invention is a transmitter substrate for a method according to the invention, wherein the transmitter substrate comprises the functional unit and the
30 separation layer. All the advantages and properties described for the method can be transferred analogously to the transmitter substrate and vice versa.

A further object of the present invention is an apparatus for performing a method according to the invention, wherein the apparatus comprises at least one control device which
35 coordinates the method. All the advantages and features described for the method can be transferred analogously to the apparatus and vice versa.

Further advantages, features and details of the invention are apparent from the following description of preferred embodiments and from the drawings. These show in:

- 5
Figure 1 a schematic, partial and side view of a transmitter substrate,
Figure 2 a schematic, partial and side view of a receiver substrate,
Figure 3a a first method step of a first method according to the invention,
10 Figure 3b a second method step of a first method according to the invention,
Figure 3c a third method step of a first method according to the invention,
Figure 3d a fourth method step of a first method according to the invention,
15 Figure 3e a fifth method step of a first method according to the invention,
Figure 3f a sixth method step of a first method according to the invention,
20 Figure 3g a seventh method step of a first method according to the invention,
Figure 3h an eighth method step of a first method according to the invention,
Figure 4a a first method step of a second method according to the invention,
25 Figure 4b a second method step of a second method according to the invention,
Figure 4c a third method step of a second method according to the invention,
30 Figure 4d a fourth method step of a second method according to the invention,
Figure 4e a fifth method step of a second method according to the invention,

35 In the figures, identical components or components with the same function are indicated by the same reference signs.

Figure 1 shows a schematic partial and side view of a transmitter substrate 1, which is a system of layers 3 with a separation layer 6, a first transmitter substrate part 2 and a second transmitter substrate part 2' with functional units 4. The transmitter substrate 1 can be made in any desired manner. Preferably, the separation layer 6, the first transmitter substrate part 2 and the second transmitter substrate part are sandwiched, wherein the separation layer 6 is arranged between the first transmitter substrate part 2 and the second transmitter substrate part 2'.

A first exemplary method for making a transmitter substrate 1 uses oxide layers. On a second starting substrate, which later becomes the second transmitter substrate part 2' and on which functional units 4 are already located or in which functional units are already integrated, an oxide layer 7 is deposited, which later becomes part of the system of layers 3. At the same time, at least one separation layer 6 is deposited on a first starting substrate, which later becomes the first transmitter substrate part 2. It is also conceivable that an oxide 7 is also deposited over the separation layer 6. The first and second starting substrates are then bonded to form the transmitter substrate 1. This is followed by back thinning or removal of at least part of the second starting substrate, in particular on the side opposite the first starting substrate, up to the functional units 4. It would also be conceivable to use a SmartCut process. The functional units 4 can be made before and/or after bonding. However, the skilled person in the field is aware of countless methods for making the transmitter substrate 1 shown in Figure 1.

A second method for producing a transmitter substrate 1 produces at least the separation layer 6 as part of the system of layers 3 on the first transmitter substrate part 2 and produces the second transmitter substrate part 2' by means of epitaxy on the system of layers 3. In this case, no bonding process is necessary to create the transmitter substrate 1 with the functional units 4. The transmitter substrate 1 is thus constructed monolithically, for example.

The first transmitter substrate part 2 is mainly used for stabilization, i.e. as a carrier. The system of layers 3 generally comprises a plurality of, in particular dielectric, hard material layers. However, it is also conceivable that at least one of the layers is dielectric and organic. Preferably, all dielectric hard material layers comprise a nitride, oxide or carbide. The system of layers 3 has at least one separation layer 6, which performs a separation of the first transmitter substrate part 2 from the second transmitter substrate part 2' by chemical and/or physical means, preferably by laser light. When a laser is used, the transmitter substrate part 2 and all other layers of the system of layers 3 up to the separation layer 6

must be transparent to the laser beam used. The separation layer 6 itself should have the highest possible absorption for the laser light used.

5 The functional units 4 preferably have electrical contacts 5 with which an electrical bond can be made to other functional units 4.

The functional units 4 on the transmitter substrate 1 can all be tested before a bonding process in order to identify the functioning functional units 4 ("good-known-dies") or the defective functional units 4. In the further method, only the functioning functional units 4
10 are then transferred, i.e. a selective transfer process takes place.

The magnification of Figure 1 shows a schematic partial and side view of a system of layers 3 comprising a separation layer 6 and two oxide layers 7. In this specific case, the separation layer 6 was first deposited on the first transmitter substrate part 2 and an oxide
15 layer 7 was deposited on the separation layer 6 to increase the bond strength. A second oxide layer 7 was deposited on the second transmitter substrate part 2'. The transmitter substrate parts 2, 2' were then bonded together via their oxide layers 7. The system of layers 3 shown is only one of many possibilities. Another possibility could be to deposit only the separation layer 6 on the transmitter substrate part 2 and bonding it directly to the oxide
20 layer 7 of the transmitter substrate part 2'. Another possibility would be to build up the transmitter substrate 1 completely monolithically, to make a system of layers 3 with at least one separation layer 6 on the transmitter substrate part 2, and then to create the transmitter substrate part 2' by means of a growth process, in particular an epitaxial growth process. Epitaxial growth would make it possible to make functional units 4 in the
25 second transmitter substrate part 2'. In the case of a monolithic structure, no bonding step is required to create the transmitter substrate 1, and the oxide layers 7 are at least not used for bonding. It is conceivable to use oxide layers for an overgrowth process during the epitaxial production of the second transmitter substrate part 2'.

30 **Figure 2** shows a schematic partial and side view of a receiver substrate 8 consisting of a receiver substrate part 9 and a system of layers 3 created thereon, as well as a partial enlargement. In this simple case, the system of layers 3 consists of only a single separation layer 6 on the receiver substrate side. It is also conceivable in this case that the system of layers 3 is made up of several layers that fulfil different tasks. By using a system of layers
35 3, it will in turn be possible later to separate the functional unit stacks 16 created on the transmitter substrate 8 (see, for example, Figure 3h) from the receiver substrate part 9 in order to be able to encapsulate them in further method steps. It is also conceivable that

the receiver substrate 8 has no system of layers 3, in particular no separation layer 6 on the receiver substrate side. However, other methods would then have to be used to separate the functional unit stacks 16, in particular the receiver substrate 8, in particular the receiver substrate part 9, would have to be ground back. This would lead to destruction of the receiver substrate 8, which would be associated with immense costs. By using a system of layers 3 with a separation layer 6 on the receiver substrate side, the functional unit stacks 16 can later be separated from the receiver substrate 8 and the receiver substrate 8 can be reused. It is also conceivable that the receiver substrate 8 does not have to be removed. In particular, it can itself have further functional units 4 or simply become part of the later functional unit stack 16 by simply being separated vertically.

Figure 3a shows a first method step of a first method according to the invention, in which a transmitter substrate 1 is provided. The transmitter substrate 1 comprises at least one functional unit 4 and a system of layers 3. The system of layers 3 comprises at least one separation layer 6 (not shown, see Figure 1).

Figure 3b shows a second method step of the exemplary first method according to the present invention, in which the transmitter substrate 1 is aligned relative to a (not yet populated) receiver substrate 8. Alignment markers on the transmitter substrate 1 and/or the receiver substrate 8 are not shown. The alignment is carried out using optics 17, for example. The receiver substrate 8 shown could have already been processed in such a way that it already has functional units in its initial state. In order to keep the figures as simple as possible, an already processed receiver substrate 8 is not shown. The receiver substrate 8 is therefore shown as an unprocessed substrate.

Figure 3c shows a third method step of the exemplary first method according to the present invention, in which the transmitter substrate 1 is bonded to the receiver substrate 8. Since the transmitter substrate surface and the receiver substrate surface are dielectric, this is a direct bonding. The transmitter substrate surface and/or the receiver substrate surface may have been chemically and/or physically treated, in particular hydrophilization takes place.

Figure 3d shows a fourth method step of the exemplary first method according to the present invention, in which an effect is applied on the system of layers 3, in particular on the separation layer 6 contained in the system of layers 3. Preferably, this is a thermal effect, in particular by electromagnetic radiation, most preferably created by a laser 18. By using a laser 18, a local and thus in particular selective effect, i.e. limited to a well-defined area,

is possible. The figure shows the transmission of the laser beam 19 through the encoder substrate 1. It is conceivable that a laser beam 19 acts via the transmitter substrate 1 and/or the receiver substrate 8. In the further course of the method, however, several functional units 4 are stacked on the receiver substrate 8, so that transmission of the laser beam 19 through the receiver substrate 8 is no longer possible or only possible to a limited extent. Preferably, the laser beam 19 is therefore focused through the transmitter substrate 1 onto the system of layers 3, in particular the separation layer 6.

Figure 3e shows a fifth method step of the exemplary first method according to the present invention, in which the transmitter substrate 1 is again removed from the receiver substrate 8. By way of example, only one transferred functional unit 4 on the receiver substrate 8 is shown in order to emphasize the selectivity of the method. In a production environment, preferably all (functional) functional units 4 of the transmitter substrate 1 are transferred to the receiver substrate 8. If some of the functional units of the transmitter substrate 1 are damaged, the missing functional units on the receiver substrate are removed by further functional units of another transmitter substrate (not shown). It is also possible that further transmitter substrates 1", 1''' (not shown) with further functional units of a different size, nature, shape or functionality are transferred to the receiver substrate. For the sake of clarity, these further functional units are also not shown.

Figure 3f shows a sixth method step of the exemplary first method according to the present invention, in which a heat treatment is performed. This method step can also be performed after the third method step (see Figure 3c) or after the fourth method step (see Figure 3d). The heat treatment ensures that the pre-bond is converted into a permanent bonding.

Figure 3g shows a seventh method step of the exemplary first method according to the present invention, in which an embedding of the functional units 4 in a dielectric layer 11 takes place. This method step creates a new receiver substrate surface to which a new set of functional units 4 can be attached. In general, the dielectric layer 11 is deposited over the functional units and must be thinned back in a further method step, in particular until the functional unit is no longer covered by the applied dielectric layer. Back thinning is preferably carried out by means of CMP (chemical mechanical polishing). This method step is not explicitly shown. Figure 3g only shows the final result of the deposition of the dielectric layer 11. It is also conceivable that the functional units 4 must be provided with electrical contacts 5 after back thinning if these are not yet present on the exposed surface. All method steps for creating such contacts are also not shown. Figure 3g appears

to show that the dielectric layer 11 has been thinned back to the height of the functional units 4, which is impossible or very difficult to realize in a production process. Preferably, the deposited dielectric layer 11 is not thinned back to the functional units 4, but covers them minimally (see left magnification Fig. 3h). If the dielectric layer 11 is nevertheless
5 thinned back to the functional units 4, a further coating with an interconnect layer 21 (see right, alternative magnification Fig. 3h) is possible. In a further, most preferred embodiment, the dielectric layer 11 would be thinned back to the functional units 4 and the functional units 4 of the next plane would be contacted directly with the functional units 4 of the plane below. Should production processes improve in the future, this process flow would
10 allow for an even more compact and thinner end product, i.e. product substrate.

Figure 3h shows an eighth method step of the exemplary first method according to the present invention with the final result. Several functional units 4, 4', 4'', 4''', 4'''' have been arranged offset in height and partially within a lateral plane (4'', 4'''). The different functional units 4, 4', 4'', 4''', 4'''' are shown in different shades of gray for the sake of clarity.
15 Figure 3h also shows two possible enlargements of the functional units 4, 4', 4'', 4''', 4'''' in order to be able to represent the electrical contacts 5 via which the functional units 4, 4', 4'', 4''', 4'''' are bonded with each other. The first, left-hand magnification represents the most common case encountered in industry, in which the dielectric layer 11 has not been
20 completely thinned back to the height of the functional units 4, 4', 4'', 4''', 4'''. The through silicon vias (TSVs) 20 allow the functional units 4, 4', 4'', 4''', 4'''' of different planes to be contacted through the dielectric layer 11. The second, right-hand magnification represents an alternative (the character v represents a mathematical OR) in which the dielectric layer 11 has been thinned back to the functional units 4, 4', 4'', 4''', 4'''. An interconnect layer 21
25 was then deposited over the dielectric layer 11 and the functional units 4, 4', 4'', 4''', 4'''. The interconnect layer 21 may be formed from the same or a different material as the dielectric layer 11. It is also conceivable that both methods are combined, i.e. the dielectric layer 11 is thinned back to just above the functional units 4, 4', 4'', 4''', 4'''' and then an additional interconnect layer 21 is deposited (not shown). These vias 20 and additional con-
30 ductive tracks can be made using the dual damascene process in particular. These possibilities are known to the skilled person in the field and are not explained further here, as they do not contribute anything to the actual patent idea. It is also conceivable that the functional units 4, 4', 4'', 4''', 4'''' are directly bonded with each other in a stacked manner, i.e. that the production of dielectric layers 11 deposited over the functional units 4, 4', 4'',
35 4''', 4'''' and/or of interconnect layers 21 and vias 20 is completely or at least partially dispensed with. The set of these functional units 4, 4', 4'', 4''', 4'''' forms a functional unit stack 16, which can later be used as a chip. This is separated from the receiver substrate 8,

possibly molded and provided with contacts or solder balls. It is also conceivable that the new functional unit stack 16 is further processed again directly according to one of the described methods of the present invention. The receiver substrate 8 thus obtained can then be separated and further processed, for example into an end product such as a chip 15 (see Figure 5).

A representation was deliberately chosen in which the lowest functional unit 4 has a smaller lateral dimension than the functional unit 4' bonded to it in order to show the possibilities of this method. In the production process, it may be that the lowest functional unit 4 has the largest lateral dimensions and the functional units 4', 4'', 4''', 4'''' stacked above it have smaller and smaller lateral dimensions with increasing distance from the functional unit 4. Furthermore, it can be seen that two functional units 4''' and 4'''' are stacked on the right-hand side of the functional unit 4', while the left-hand side has only a single functional unit 4''.

Figure 4a shows a first method step of a second exemplary method according to the present invention, in which at least one transmitter substrate single piece 12 has been separated from a larger transmitter substrate 1 (not shown). This individual transmitter substrate piece itself represents a transmitter substrate 1.

Figure 4b shows a second method step of the second exemplary method according to the present invention, in which a bonding head 13 of a chip-to-wafer bonder (not shown) fixes an encoder substrate individual piece 12 on the back and positions it over the receiver substrate 8. The positioning can again be optical, in particular by means of alignment markers, and/or computer-controlled. The receiver substrate 8 shown could have already been processed in such a way that it already has functional units in its initial state. In order to keep the figures as simple as possible, an already processed receiver substrate 8 is not shown. The receiver substrate 8 is therefore shown as an unprocessed substrate.

Figure 4c shows a third method step of the second exemplary method according to the present invention, in which the transmitter substrate single piece 12 is bonded to the receiver substrate 8. Since the transmitter substrate single piece surface and the receiver substrate surface are dielectric, this is a direct bonding. The transmitter substrate single piece surface and/or the receiver substrate surface may have been chemically and/or physically treated, in particular hydrophilization takes place.

Figure 4d shows a fourth method step of the second method according to the invention, in which an effect is applied on the system of layers 3, in particular the separation layer 6 contained in the system of layers 3. Preferably, this is a thermal effect, in particular by electromagnetic radiation, most preferably created by a laser 18. The selectivity of the second method already consists in the fact that individual transmitter substrate pieces 12 are used, while in the first method the selectivity is defined by the use of the laser. The figure shows the transmission of the laser beam 19 through the individual encoder substrate piece 12. It is conceivable that a laser beam 19 acts via the transmitter substrate single piece 12 and/or the receiver substrate 8. In the further course of the method, however, several functional units 4 are stacked on the receiver substrate 8, so that transmission of the laser beam 19 through the receiver substrate 8 is no longer possible or only possible to a limited extent. Preferably, the laser beam 19 is therefore focused through the transmitter substrate single piece 12 onto the system of layers 3, in particular the separation layer 6.

Figure 4e shows a fifth method step of the second method according to the invention, in which the transmitter substrate single piece 12 is again removed from the receiver substrate 8. By way of example, only one transferred functional unit 4 on the receiver substrate 8 is shown in order to emphasize the selectivity of the method. Preferably, in a production environment, multiple (functioning) functional units 4 of multiple transmitter substrate single pieces 12 are transferred to the receiver substrate 8. If the functional unit of a transmitter substrate single piece 12 is damaged, it is not even removed from the set of all transmitter substrate single pieces 12. Furthermore, it is possible that further transmitter substrate single pieces 12', 12" (not shown) with further functional units of a different size, nature, shape or functionality are transferred to the receiver substrate 8. For the sake of clarity, these further functional units 4 are also not shown.

The further method steps of the second method are identical to the method steps of the first method according to the figure descriptions and Figures 3f, 3g and 3h and are not explicitly explained again here.

Figure 5 shows a schematic sketch of one of many possible end products, a chip 15 embedded in a casting compound 13 and provided with solder balls 14. The contact between the two central solder balls 14 and the functional unit 4 is not explicitly shown. Other end products are conceivable in which no solder balls 14 but flat contacts (pads) are used, end products that are not encapsulated in a Casting compound, etc.

List of reference signs

	1	transmitter substrate
	2	first transmitter substrate part
5	2'	second transmitter substrate part
	3	system of layers
	4, 4', 4'', 4''', 4''''	functional unit
	5	electrical contacts
	6	separation layer
10	7	oxide layer
	8	receiver substrate
	9	receiver substrate part
	10	solder balls
	11	dielectric layer
15	12	transmitter substrate single piece
	13	bond head
	14	casting compound
	15	chip
	16	functional unit stack
20	17	optics
	18	laser
	19	laser beam
	20	through silicon via (TSV)
	21	Interconnecting layer
25		

Claims

1. A method for transferring a functional unit (4, 4', 4'', 4''', 4''') from a transmitter substrate (1) transmitting the functional unit (4, 4', 4'', 4''', 4''') to a receiver substrate (8) receiving the functional unit (4, 4', 4'', 4''', 4'''), in particular as a partial step for building up a product substrate, comprising the following:
 - providing a transmitter substrate (1) and a receiver substrate (8), the transmitter substrate (1) having a functional unit (4, 4', 4'', 4''', 4'''), preferably a plurality of functional units (4, 4', 4'', 4''', 4'''), and a separation layer (6), preferably integrated in a system of layers (3),
 - aligning the transmitter substrate (1) and the receiver substrate (8) with respect to one another by means of an alignment unit,
 - separating the separation layer (6) in the region of the functional unit (4, 4', 4'', 4''', 4''') and
 - removing the transmitter substrate (1) without the functional unit (4, 4', 4'', 4''', 4'''),wherein the functional unit (4, 4', 4'', 4''', 4''') is left on the receiver substrate (8) or a product substrate structure on the receiver substrate (8) to build up a product substrate.
2. The method according to claim 1, wherein the functional unit (4, 4', 4'', 4''', 4''') left behind is bonded and/or a dielectric layer is applied to the receiver substrate (8).
3. The method according to any one of the preceding claims, wherein a contact is made between the transmitter substrate (1) on one side and the receiver substrate (8) or the product substrate structure on the other side, wherein the contact, in particular a direct contact, is made between the transmitter substrate (1) and the receiver substrate (8) or the product substrate structure via a contact side of the transmitter substrate (1), wherein a section of the functional unit (4, 4', 4'', 4''', 4''') forms part of the contact side.
4. The method according to any one of the preceding claims, wherein the separation layer (6) is optically and/or chemically separated.
5. The method according to any one of the preceding claims, wherein the separation layer (6) is separated locally to a limited extend.

6. The method according to any one of the preceding claims, wherein the separation layer (6) and/or the system of layers comprises at least one layer of an inorganic material, in particular consisting of an inorganic material.
- 5 7. The method according to any one of the preceding claims, wherein the functional unit (4, 4', 4'', 4''', 4'''') is subjected to a functional test at a time before the contact between the transmitter substrate (2) and the receiver substrate (8) is made.
- 10 8. The method according to any one of the preceding claims, wherein a plurality of functional units (4, 4', 4'', 4''', 4'''') are arranged on the receiver substrate (8) or the product substrate structure offset in height relative to each other.
- 15 9. The method according to any one of the preceding claims, wherein laser light, in particular a pulsed laser light, is used for separating.
- 20 10. The method according to any one of the preceding claims, wherein the functional unit (4, 4', 4'', 4''', 4'''') is part of a plurality of functional units (4, 4', 4'', 4''', 4'''') left on the receiver substrate (8) by the same transmitter substrate (1), preferably simultaneously or successively.
- 25 11. The method according to any one of the preceding claims, wherein in a preparatory step a transmitter substrate (1) is produced, on the contact side of which the functional unit (4, 4', 4'', 4''', 4''''), preferably a plurality of functional units (4, 4', 4'', 4''', 4''''), is formed.
- 30 12. The method according to any one of the preceding claims, wherein the product substrate or the product substrate structure is detached from the receiver substrate (8) via a separation layer (6) on the receiver substrate side.
- 35 13. The method according to any one of the preceding claims, wherein the functional unit (4, 4', 4'', 4''', 4'''') has a thickness dimensioned perpendicular to a main extension plane which is less than 50 μm , more preferably less than 25 μm and most preferably less than μm or even less than 100 nm, wherein the functional unit (4, 4', 4'', 4''', 4'''') is preferably encapsulated.
14. A transmitter substrate (1) for a method according to any one of the preceding claims, wherein the transmitter substrate (1) comprises the functional unit (4, 4', 4'',

4''', 4''''), preferably a plurality of functional units (4, 4', 4'', 4''', 4''''), and the separation layer (6).

- 5 15. An apparatus for performing a method according to any one of claims 1 to 13, comprising at least one control device for coordinating the method according to any one of claims 1 to 13.