Pressure Transmission Apparatus for Bonding of Chips to a Substrate

Specification

This invention relates to a pressure transmission apparatus for bonding a plurality of chips to a substrate and a bonding device for bonding a plurality of chips to a substrate.

In the semiconductor industry there are several possibilities for connecting, especially bonding, different functional units to one another. One of these possibilities is the chip-to-wafer (C2W) method in which individual chips are bonded individually to a substrate. Another important method is the so-called "advanced chip-to-wafer" (AC2W) method in which the chips are first tentatively (temporarily) joined to the substrate and a permanent connection takes place in one bonding step, all chips being permanently bonded to the substrate at the same time. In the bonding step the chips and the substrate are heated while the chips are being pressed onto the substrate (bonding force).

The aforementioned pressure and heating processes engender technical problems especially for structures which are becoming smaller and smaller, for example due to thermal expansion during heating.

Embodiments of this invention disclose a pressure transmission apparatus and a bonding device with which the aforementioned method can be optimized and scrap is minimized during bonding.

According to a first aspect, there is provided a pressure transmission apparatus for bonding a plurality of chips to a substrate with:

- a pressure body for applying a bonding force which acts in the bonding direction to the chip, the pressure body having a first pressure side and an opposite second pressure side which run transversely to the bonding direction,
- fixing means which can be attached to the periphery of the pressure transmission apparatus for fixing of the pressure transmission apparatus on a retaining body in the bonding direction, and
- a sliding layer for sliding motion of the pressure body transversely to the bonding direction, characterized in that the fixing means

a) being made elastic transversely to the bonding direction and/or

b) are made as clamps for clamping of the pressure body in the direction of the retaining body, especially with a sliding layer located in between

According to a second aspect, there is provided a bonding device for bonding a plurality of chips to a substrate with:

- a pressure transmission apparatus as claimed in one of the preceding claims,
- the retaining body,
- a receiver for accommodating the substrate,
- heating means for heating of the chip and of the substrate,

- drive means for producing the bonding force, especially by movement of the retaining body in the bonding direction.

According to a third aspect, there is provided a method for bonding a plurality of chips on a substrate with the above transmission apparatus or the above transmission method.

All combinations of at least two of the features given in the specification, the claims and/or the figures also fall within the scope of the invention. At the given value ranges, values within the indicated limits will also be considered to be disclosed as boundary values and will be claimed in any combination.

Embodiments of this invention provide a pressure transmission apparatus for bonding of a plurality of chips to a substrate such that it is made to allow a sliding motion of the pressure body transversely to the bonding direction B. But it is advantageous if there are limiting means for limiting the sliding motion transversely to the bonding direction B, especially in the form of fixing means for fixing of the pressure transmission apparatus on a retaining body in the bonding direction B. The use of this invention is especially advantageous with an AC2W method in which the chips are temporarily joined to the substrate and then bonded using the pressure transmission apparatus in a bonding process. As per embodiments of the invention it is advantageous here if prior to the pressure transmission the process of heating to the bonding temperature is at least largely completed. In this way the pressure body can slide transversely to the bonding direction B more freely than with an adjacent bonding force in the bonding direction B.

The substrate is especially a semiconductor, preferably a wafer.

Embodiments of the invention largely solve the technical problem of thermal stresses which occur during bonding between the pressure transmission apparatus and the chip surfaces since only the stresses of the pressure body itself are relevant since it is at least largely decoupled from all components on the other side of the sliding layer transversely to the bonding direction B by the sliding layer as

per embodiments of the invention. The sliding layer thus allows almost completely frictionless relative motion of the components bordering it. As per embodiments of the invention the sliding layer is made especially as a preferably largely carbon-containing solid. Graphite whose basal planes is aligned at least largely perpendicular to the bonding direction B is chosen as the material.

According to one advantageous embodiment of the invention it is provided that the fixing means are made elastic transversely to the bonding direction B. Thus at the same time the fixing means can provide for holding the pressure transmission apparatus together in the bonding direction B while the sliding motion of the pressure body transversely to the bonding direction B is allowed. At the same time the fixing means can act in this way as the above described limiting means and thus can assume several functions as per embodiments of the invention.

Here it is especially advantageous if the fixing means are made as clamps for clamping a pressure body in the direction of the retaining body, especially with the sliding layer located in between. This configuration can be implemented especially easily in a space-saving manner and performs the aforementioned multiple functions.

In one embodiment of the invention it is provided that the pressure body, especially with respect to material and/or dimensions, is chosen such that its thermal expansion properties at least in the transverse direction to the bonding direction B correspond to the thermal expansion properties of the product substrate. The material is preferably the material of the substrate and/or of the chip. It is especially advantageous as per embodiments of the invention if the dimensions of the pressure body

essentially agree with the dimensions of the substrate, especially transversely to the bonding direction B. The thermal expansion properties comprise especially the coefficient of thermal

expansion of the pressure body and/or of the substrate and/or of the chip. In particular, but not exclusively, material classes such as metal, ceramics, plastics or composite materials can be used, in particular Si, CTE matched glass, therefore glass whose coefficient of thermal expansion has been aligned to that of the product substrate, low CTE metals, etc. CTE matched glass and low CTE metals are also known. Mainly materials whose thermal conductivity is very high are preferred. The coefficient of thermal expansion of silicon is for example $2.6 \cdot 10^{-6}$ K^{-1}. The absolute amount of the difference of the coefficients of thermal expansion of the product substrate and the embodiment of the invention is less than $100 \cdot 10^{-6}$ K^{-1}, preferably less than $10 \cdot 10^{-6}$ K^{-1}, more preferably less than $1 \cdot 10^{-6}$ K^{-1}, most preferably less than $0.1 \cdot 10^{-6}$ K^{-1} , most preferably of all less than $0.01 \cdot 10^{-6}$ K^{-1}, most ideally 0 K^{-1}.

By there being a layer which is elastic at least in the bonding direction B and especially which is at least partially interrupted on intermediate spaces of the chip for pressure compensation, the pressure transmission apparatus also compensates for expansions, stresses and height differences in the bonding direction B so that uniform pressure application is enabled. The elastic layer is thus used as a compensation layer. In particular the elastic layer has a modulus of elasticity between 1 MPa and 100 GPa, preferably between 1 MPa and 10 GPa, even more preferably between 1 MPa and 1 GPa. Preferred materials are polymers. Rubber with an effective isotropic modulus of elasticity of roughly 1 MPa is used as the comparison value of the modulus of elasticity. Fiber-reinforced polymers are preferred with an effective modulus of elasticity along the longitudinal axis of the fiber of roughly 100 GPa. They mark the upper limit of the elastic material.

In another advantageous embodiment of the invention it is provided that between the pressure body and the chip there is a hard layer which is at least partially interrupted

especially on intermediate spaces of the chip for direct pressure transmission to the chips. The hard layer has a greater modulus of elasticity (especially twice as great) than the elastic layer, the hard layer being used as a protective layer. In particular the hard layer is also used to form a planar surface, especially with an average surface roughness of less than 10 μm, preferably less than 1 μm, even more preferably less than 100 nm, most preferably less than 10 nm. The hard layer is preferably made as an ultrahard layer. Preferred materials are metals and ceramics, especially iron materials, nonferrous metals, hard metals, nitride layers, carbide layers, boride layers and oxide ceramics. The thickness of the hard layer in the bonding direction B is less than 10 mm, more preferably less than 5 mm, even more preferably less than 2 mm, most preferably less than 500 μm, most preferably of all less than 100 μm.

Advantageously according to another embodiment it is provided that the pressure body has fixing sites which are located on the periphery of the first pressure side, especially in the form of a preferably ring-shaped offset. In this way space-saving fixing of the pressure body on the retaining body is possible, due to possible heat transfer from the retaining body to the chips which are to be bonded during bonding a configuration of the pressure transmission apparatus as thin as possible in the bonding direction B being advantageous.

The described features of the pressure transmission apparatus apply analogously to the bonding device as per embodiments of the invention.

Other advantages, features and details of the invention will become apparent from the following description of preferred exemplary embodiments and using the drawings.

Figure 1 shows a schematic side view of the bonding device as claimed in the invention,

Figure 2a shows a schematic detail view of the bonding device as claimed in the invention in a first embodiment,

Figure 2b shows a schematic front view of another embodiment of the pressure transmission apparatus as claimed in the invention,

Figure 2c shows a schematic side view of the pressure transmission apparatus as claimed in the invention in another embodiment,

Figure 3a shows a schematic detail view of another embodiment of the bonding device as claimed in the invention,

Figure 3b shows a schematic side view of the pressure transmission apparatus as claimed in the invention in another embodiment, and

Figure 3c shows a schematic side view of the pressure transmission apparatus as claimed in the invention in another embodiment.

The same or equivalent components are identified with the same reference numbers in the figures.

Figure 1 shows a schematic and highly simplified representation of a bonding device with a housing 11 which surrounds a bonding chamber 16 and which can be loaded and unloaded via an opening which is not shown and which can be closed with a door which is not shown. In the bonding chamber 16 a defined atmosphere and temperature can be set, for which there can be corresponding feed lines and discharge lines or heating means. Especially the retaining body 9 and/or the receiver 10 are used as heating means.

On the floor of the bonding chamber 16 there is a receiver 10 for accommodating a product substrate 14, and fixing of the product substrate can take place especially by vacuum paths, mechanical clamping or by electrostatics.

The product substrate 14 consists of a substrate 12 which rests on the receiver 10 and is fixed on the latter, and chips 13 which are temporarily fixed on the substrate 12 and for whose permanent fixing the bonding device is intended.

Above the receiver 10 there is a retaining body 9, the retaining body 9 being able to move relative to the receiver 10, specifically in one X, one Y and one Z direction. The retaining body 9 can preferably also be turned around the X, Y and/or Z axis in order to compensate for wedge faults or to improve the orientation of the surfaces to one another. The relative motion takes place preferably by movement of the retaining body 9, while the receiver 10 is rigid or does not have any degrees of freedom.

After loading of the product substrate 14 into the bonding chamber 16 and attaching a pressure transmission apparatus 1 to one lower side 9u of the retaining body 9, the pressure transmission apparatus 1 is aligned relative to the product substrate 14 and lowered until the pressure transmission apparatus 1 adjoins its side 1u which is opposite the product substrate 14 and a defined bonding force is applied to the chip surface 13o of the chip 13 by a corresponding control of the movement in the bonding direction B. At the same time or subsequently the product substrate 14 is heated to a bonding temperature. The process is controlled by a control apparatus.

Figure 2a details the pressure transmission apparatus 1 and the product substrate 14, the relations of the illustrated parts being made highly schematic for purposes of representation and

especially the chips 13 not corresponding to true circumstances.

In the first illustrated embodiment according to Figure 2a the pressure transmission apparatus 1 in addition to a pressure body 2 which all embodiments have, additionally has a retaining body 4 which is clamped to the pressure body 2 via a fixing means 8 in the form of several clamps which have been clipped on the periphery of the pressure body 2 and of the retaining body 4.

Between the pressure body 2 and the retaining body 4 there is a sliding layer 3, especially over the entire surface, by which the sliding motion of the pressure body 2 transversely to the bonding direction B is enabled.

The pressure body 2 and the retaining body 4 are made especially mirror-imaged (reflected on the sliding layer 3).

The pressure transmission apparatus 1 is fixed on the retaining body 9 of the bonding device by the fixing means 8, especially arms 8a molded on the clamps. Alternatively or in addition the retaining body 4 can be fixed on the retaining body 9 by vacuum paths.

The fixing means 8 have a U-shaped section 8u between whose arms the clamping of the pressure body 2 to the retaining body 4 takes place. The U-shaped section 8u thus surrounds one part of the periphery of the pressure body 2 and of the retaining body 4. For engaging the U-shaped section 8u there are fixing sites 17 on the pressure body 2 on a first pressure side 2o, especially in the form of an especially preferably ring-shaped offset on the periphery of the pressure body 2. Transversely to the bonding direction B at the fixing site there is play 18 so that a sliding motion of the pressure body 2 transversely to the bonding direction B is enabled.

The opposite arm of the U-shaped section 8u engages a corresponding fixing site of the

retaining body 4, preferably there being fixing without play here.

On a first pressure side 2o of the pressure body 2 which is facing away from the sliding layer 3, pressure elements 5 are attached, specifically at the positions which correspond to the chips 13 on the substrate 12 along the X and Y direction, therefore along the first pressure side 2o. The pressure elements 5 consists of an elastic layer 6 which is interrupted corresponding to the intermediate spaces 15 between the chips 13, and of a hard layer 7 which has been applied to the elastic layer 6. The hard layer is likewise interrupted analogously to the elastic layer 6 in the region of the intermediate spaces 15 so that any side forces which run transversely to the bonding direction are minimized when pressure is applied to the chips 13.

When pressure is applied to the chips 13 with the pressure surface 1u, here on one surface 7o of the hard layer 7, the centers of gravity 5s of the pressure elements 5 are aligned centered to the centers of gravity 13s of the individual chips 13. The pressure elements 5 exactly follow the chips 13 due to the similar or identical coefficients of thermal expansion of the pressure body 2 and of the substrate 12 and due to the largely frictionless relative motion of the pressure body 2 transversely to the bonding direction B so that no transverse displacements and transverse forces are caused.

In Figure 2b there is a simplified fixing means 8' in which the pressure body 2 and the retaining body 4 are fixed by a modified fixing means 8' which fixes exclusively at fixing sites of the pressure body 2, but not on the retaining body 4 so that the fixing takes place in the bonding direction B between the pressure body 2 and the retaining body 9. The kinematics of the pressure body 2 and of the sliding layer 3 with the play 18 is that in Figure 2a. Thus an altered pressure transmission apparatus 1' in a simpler execution is formed since the fixing means 8' and the retaining

body 4' are made simpler.

In the embodiment according to Figure 2c the retaining body 4 is omitted and the sliding layer 3 is provided directly between the pressure body 2 and the retaining body 9. An altered pressure transmission apparatus 1" is formed which is made simpler than the above described pressure transmission apparatus 1, 1' since a retaining body 4, 4' can be omitted and the pressure transmission apparatus 1" can be made thinner and better transfers the heat, to the extent heat is produced by the retaining body 9.

Conversely, in the embodiment shown in Figure 3a the pressure elements 5 shown in Figures 2a to 2c are omitted so that the first pressure side 2o of the pressure body 2 assumes the function of the hard layer 7. There is an elastic layer 6' between the pressure body 2 and the retaining body 4. On the interface between the elastic layer 6' and the pressure body 2 there is the sliding layer 3 while the fixing means 8 corresponds to the fixing means 8 from Figure 2a. Thus an altered embodiment of the pressure transmission apparatus 1"' arises.

The first pressure side 2o in this embodiment acts as a pressure surface 1u' with which pressure is applied to the surface 13o of the chip 13.

In the embodiment shown in Figure 3b, according to the embodiment shown in 2b there are fixing means 8' which omit engagement with the retaining body 4'. Thus an altered embodiment of the pressure transmission apparatus 1"" arises.

In the execution of the pressure transmission apparatus 1""" shown in Figure 3c the retaining body 4,4' is omitted according to the execution described in Figure 2c. Accordingly fixing means analogously to the fixing means 8" are used.

Reference number list

1, 1', 1", 1"', 1""	pressure transmission apparatus
1u, 1u'	pressure surfaces
2	pressure body
2o	first pressure side
2f	second pressure side
3	sliding layer
4, 4'	retaining body
5	pressure element
6, 6'	elastic layer
7	hard layer
8, 8' 8"	fixing means
8a	arms
8u	u-shaped section
9	retaining body
9u	lower side
10	receiver
11	housing
12	substrate
13	chips

13o	chip surface
13s	center of gravity
14	product substrate
15	intermediate spaces
16	bonding chamber
17	fixing sites
18	play
Bonding direction	B

Claims

1. A pressure transmission apparatus for bonding a plurality of chips (13) to a substrate (12) with:

- a pressure body (2) for applying a bonding force which acts in the bonding direction (B) to the chip (13), the pressure body (2) having a first pressure side (2o) and an opposite second pressure side (2f) which run transversely to the bonding direction (B),
- fixing means (8, 8', 8") which can be attached to the periphery of the pressure transmission apparatus (1) for fixing of the pressure transmission apparatus (1) on a retaining body (9) in the bonding direction (B), and
- a sliding layer (3) for sliding motion of the pressure body (2) transversely to the bonding direction (B),

characterized in that the fixing means (8, 8', 8")

a) being made elastic transversely to the bonding direction (b) and/or

b) are made as clamps for clamping of the pressure body (2) in the direction of the retaining

body (9), especially with a sliding layer (3) located in between

2. The pressure transmission apparatus as claimed in Claim 1, wherein there is a layer (6) which is elastic at least in the bonding direction (B) and especially which is at least interrupted on intermediate spaces (15) of the chip (13) for pressure compensation.

3. The pressure transmission apparatus as claimed in one of the preceding claims, in which between the pressure body (2) and the chip (13) there is a hard layer (7) which is interrupted especially on intermediate spaces (15) of the chip (13) for direct pressure transmission to the chips (13).

4. The pressure transmission apparatus as claimed in one of the preceding claims, in which the pressure body (2) has fixing sites which are located on the periphery of the first pressure side (2o), especially in the form of a preferably ring-shaped offset.

5. A bonding device for bonding a plurality of chips (13) to a substrate (12) with:

- a pressure transmission apparatus (1) as claimed in one of the preceding claims,
- the retaining body (9),
- a receiver (10) for accommodating the substrate (12),
- heating means for heating of the chip (13) and of the substrate (12),
- drive means for producing the bonding force, especially by movement of the retaining body (9) in the bonding direction (B).

6. Method for bonding a plurality of chips (13) on a substrate (12) with a pressure transmission apparatus (1) according to claim 1 or a bonding device according to claim 5.

7. Method according to claim 6, wherein the pressure body (2), especially with respect to material and/or dimensions, is chosen such that its thermal expansion properties at least in the transverse direction to the bonding direction (B) correspond to the thermal expansion properties of the substrate (2).