

DESCRIPTION

TITLE OF THE INVENTION: SUBSTRATE PROCESSING METHOD,  
BONDING SYSTEM, AND SEMICONDUCTOR DEVICE

5 TECHNICAL FIELD

[0001]

The present disclosure relates to a substrate processing method, a bonding system, and a semiconductor device.

10 BACKGROUND ART

[0002]

Patent Document 1 describes a technique for bonding singulated chips to a substrate. The chips are also called dies.

15 RELATED ART DOCUMENTS

PATENT DOCUMENT

[0003]

Patent Document 1: Japanese Unexamined Patent Application  
Publication No. 2021-197430

20

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0004]

25 An aspect of the present disclosure provides a technique for  
increasing die integration density.

MEANS FOR SOLVING THE PROBLEMS

[0005]

30 A substrate processing method according to an aspect of the  
present disclosure includes stacking a first die and a second die on a target  
substrate in this order. The target substrate includes an insulating film and a  
plurality of electrodes on a surface of the target substrate facing the first die. The  
first die includes an insulating film and one or more electrodes on a surface of the

first die facing the target substrate, and further includes an insulating film and one or more electrodes on a surface of the first die facing the second die. The second die includes an insulating film and one or more electrodes on a surface of the second die facing the first die. The method further includes bonding the insulating  
5 film of the target substrate to the insulating film of the first die; bonding the plurality of electrodes of the target substrate to the one or more electrodes of the first die; bonding the insulating film of the first die to the insulating film of the second die; and bonding the one or more electrodes of the first die to the one or more electrodes of the second die.

## EFFECTS OF THE INVENTION

[0006]

According to one aspect of the present disclosure, die integration intensity is increased.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

[FIG. 1] FIG. 1 is a cross-sectional view illustrating a semiconductor device according to an embodiment.

[FIG. 2] FIG. 2 is a plan view illustrating a bonding system according to an embodiment.

[FIG. 3] (A) of FIG. 3 is a cross-sectional view illustrating an example of a target substrate; (B) of FIG. 3 is a cross-sectional view illustrating an example of a plurality of first dies mounted on a first carrier; and (C) of FIG. 3  
25 is a cross-sectional view illustrating an example of a plurality of second dies mounted on a second carrier.

[FIG. 4] FIG. 4 is a cross-sectional view illustrating an example of a first bonding device.

[FIG. 5] FIG. 5 is a cross-sectional view illustrating an example of  
30 a second bonding device.

[FIG. 6] FIG. 6 is a flowchart illustrating a substrate processing method according to an embodiment.

[FIG. 7] FIG. 7 is a cross-sectional view illustrating an example of

step S4.

[FIG. 8] FIG. 8 is a cross-sectional view illustrating an example of step S5.

5 [FIG. 9] FIG. 9 is a cross-sectional view illustrating an example of step S6.

[FIG. 10] FIG. 10 is a plan view illustrating a bonding system according to a modified example.

[FIG. 11] FIG. 11 is a flowchart illustrating a substrate processing method according to a modified example.

10 [FIG. 12] FIG. 12 is a flowchart illustrating an example of a sub-process of step S2.

[FIG. 13] (A) of FIG. 13 is a cross-sectional view illustrating an example of step S21; (B) of FIG. 13 is a cross-sectional view illustrating an example of step S22; and (C) of FIG. 13 is a cross-sectional view illustrating an example of step S23.

[FIG. 14] (A) of FIG. 14 is a cross-sectional view illustrating an example of step S24; (B) of FIG. 14 is a cross-sectional view illustrating an example of step S24 subsequent to (A) of FIG. 14; and (C) of FIG. 14 is a cross-sectional view illustrating an example of step S24 subsequent to (B) of FIG. 14.

20 [FIG. 15] FIG. 15 is a flowchart illustrating an example of a sub-process of step S21.

[FIG. 16] (A) of FIG. 16 is a cross-sectional view illustrating an example of step S211; (B) of FIG. 16 is a cross-sectional view illustrating an example of step S214; and (C) of FIG. 16 is a cross-sectional view illustrating an example of step S215.

[FIG. 17] (A) of FIG. 17 is a cross-sectional view illustrating an example of step S216; and (B) of FIG. 17 is a cross-sectional view illustrating an example of step S217.

30 [FIG. 18] FIG. 18 is a flowchart illustrating an example of a sub-process of step S211.

[FIG. 19] (A) of FIG. 19 is a cross-sectional view illustrating an example of step S2111; (B) of FIG. 19 is a cross-sectional view illustrating an example of step S2112; and (C) of FIG. 19 is a cross-sectional view illustrating an

example of step S2113.

[FIG. 20] (A) of FIG. 20 is a cross-sectional view illustrating an example of step S2114; (B) of FIG. 20 is a cross-sectional view illustrating an example of step S2115; and (C) of FIG. 20 is a cross-sectional view illustrating an example of step S2116.

## DESCRIPTION OF EMBODIMENTS

[0008]

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. In each of the drawings, identical or corresponding components are denoted by the same reference numerals, and description thereof may be omitted. In this specification, the X-axis direction, the Y-axis direction, and the Z-axis direction are mutually perpendicular. The X-axis direction and the Y-axis direction are horizontal directions, and the Z-axis direction is a vertical direction. The X-axis direction includes an X-axis positive direction and an X-axis negative direction opposite to the X-axis positive direction. The Y-axis direction includes a Y-axis positive direction and a Y-axis negative direction opposite to the Y-axis positive direction. The Z-axis direction includes a Z-axis positive direction and a Z-axis negative direction opposite to the Z-axis positive direction.

[0009]

A semiconductor device 2 according to an embodiment will be described with reference to FIG. 1. The semiconductor device 2 includes, for example, a plurality of first dies 20 and a plurality of second dies 60 stacked in this order on a target substrate 10. The semiconductor device 2 includes the target substrate 10, the plurality of first dies 20, and the plurality of second dies 60. The second dies 60 are provided on a side opposite to the target substrate 10 with respect to the first dies 20. Alternatively, the semiconductor device 2 may include one first die 20 and one second die 60.

[0010]

Although not illustrated, the semiconductor device 2 may further include a plurality of third dies, or may be formed by stacking the first dies 20, the second dies 60, and the third dies in this order on the target substrate 10. The

semiconductor device 2 may not include the second dies 60, and may be formed by stacking the first dies 20 on the target substrate 10.

[0011]

The target substrate 10 includes an insulating film 12 and a  
5 plurality of electrodes 13 on a surface 10a facing the first dies 20. The insulating film 12 is, for example, a silicon oxide film. Silicon oxide films can be bonded to each other by hydrogen bonding between OH groups. After bonding, the bonding strength can be increased by a dehydration condensation reaction. The surface of the silicon oxide film may be activated by plasma before bonding, and then OH  
10 groups may be imparted to the surface by supplying water molecules. The silicon oxide film may be formed using TEOS (tetraethoxysilane), for example. The insulating film 12 is formed on a semiconductor substrate 11. The semiconductor substrate 11 is a silicon wafer in the embodiment, but may be a compound semiconductor wafer. A conductive film (not illustrated) or the like may be  
15 provided between the semiconductor substrate 11 and the insulating film 12. The plurality of electrodes 13 are provided in openings of the insulating film 12.

[0012]

The first die 20 includes an insulating film (e.g., a first insulating film 32 described later) and one or more electrodes (e.g., a first electrode 33  
20 described later) on a surface 20a facing the target substrate 10. The first die 20 includes an insulating film (e.g., a sixth insulating film 54 described later) and one or more electrodes (e.g., a sixth electrode 55 described later) on a surface 20b facing the second die 60. The surfaces 20a and 20b are opposite each other. The insulating film is, for example, a silicon oxide film and is formed using, for  
25 example, TEOS.

[0013]

The first die 20 is formed by, for example, stacking a first stacking substrate 30, a second stacking substrate 40, and a third stacking substrate 50 in this order. In other words, the first die 20 includes a stack of the first stacking  
30 substrate 30, the second stacking substrate 40, and the third stacking substrate 50 in this order. Although not illustrated, the first die 20 may further include a fourth stacking substrate, in other words, may include a stack of the first stacking substrate 30, the second stacking substrate 40, the third stacking substrate 50, and

the fourth stacking substrate in this order. The first die 20 may be a stack of the second stacking substrate 40 on the first stacking substrate 30, without including the third stacking substrate 50.

[0014]

5                   The first stacking substrate 30 includes a first semiconductor substrate 31. The first semiconductor substrate 31 is a silicon wafer in the present embodiment, but may be a compound semiconductor wafer. The first stacking substrate 30 includes a first insulating film 32 formed on one surface of the first semiconductor substrate 31, and first electrodes 33 provided in openings of the  
10                   first insulating film 32. The first stacking substrate 30 also includes a second insulating film 34 formed on the other surface of the first semiconductor substrate 31, and second electrodes 35 provided in openings of the second insulating film 34. The first electrodes 33 are electrically connected to the second electrodes 35.  
[0015]

15                   The second stacking substrate 40 includes a second semiconductor substrate 41. The second semiconductor substrate 41 is a silicon wafer in the present embodiment, but may be a compound semiconductor wafer. The second stacking substrate 40 includes a third insulating film 42 formed on one surface of the second semiconductor substrate 41, and third electrodes 43 provided in  
20                   openings of the third insulating film 42. The second stacking substrate 40 also includes a fourth insulating film 44 formed on the other surface of the second semiconductor substrate 41, and fourth electrodes 45 provided in openings of the fourth insulating film 44. The third electrodes 43 are electrically connected to the fourth electrodes 45.

25                   [0016]

                    The third stacking substrate 50 includes a third semiconductor substrate 51. The third semiconductor substrate 51 is a silicon wafer in the present embodiment, but may be a compound semiconductor wafer. The third stacking substrate 50 includes a fifth insulating film 52 formed on one surface of the third  
30                   semiconductor substrate 51, and fifth electrodes 53 provided in openings of the fifth insulating film 52. The third stacking substrate 50 also includes a sixth insulating film 54 formed on the other surface of the third semiconductor substrate 51, and sixth electrodes 55 provided in openings of the sixth insulating film 54.

The fifth electrodes 53 are electrically connected to the sixth electrodes 55.

[0017]

The insulating film 12 of the target substrate 10 is brought into contact with and bonded to the first insulating film 32 of the first stacking substrate 30. The electrodes 13 of the target substrate 10 are in contact with and bonded to the first electrodes 33 of the first stacking substrate 30. The electrodes 13 are electrically connected to the first electrodes 33. The number of the electrodes 13 and the number of the first electrodes 33 are not particularly limited.

[0018]

The second insulating film 34 of the first stacking substrate 30 is brought into contact with and bonded to the third insulating film 42 of the second stacking substrate 40. The second electrodes 35 of the first stacking substrate 30 are in contact with and bonded to the third electrodes 43 of the second stacking substrate 40. The second electrodes 35 are electrically connected to the third electrodes 43. The number of the second electrodes 35 and the number of the third electrodes 43 are not particularly limited.

[0019]

The fourth insulating film 44 of the second stacking substrate 40 is brought into contact with and bonded to the fifth insulating film 52 of the third stacking substrate 50. The fourth electrodes 45 of the second stacking substrate 40 are in contact with and bonded to the fifth electrodes 53 of the third stacking substrate 50. The fourth electrodes 45 are electrically connected to the fifth electrodes 53. The number of the fourth electrodes 45 and the number of the fifth electrodes 53 are not particularly limited.

[0020]

The second die 60 includes an insulating film 62 and one or more electrodes 63 on a surface 60a facing the first die 20. The insulating film 62 is, for example, a silicon oxide film and is formed using, for example, TEOS. The electrodes 63 are provided in openings of the insulating film 62.

[0021]

Like the first die 20, the second die 60 may be formed by stacking a plurality of stacking substrates. Since the structure of the second die 60 is similar to that of the first die 20, detailed description of the second die 60 is

omitted. The second die 60 may have the same function as that of the first die 20 or may have a different function.

[0022]

5 The insulating film (for example, the sixth insulating film 54) of the first die 20 is brought into contact with and bonded to the insulating film 62 of the second die 60. The electrodes (for example, the sixth electrodes 55) of the first die 20 are in contact with and bonded to the electrodes 63 of the second die 60. The sixth electrodes 55 are electrically connected to the electrodes 63. The number of the sixth electrodes 55 and the number of the electrodes 63 are not  
10 particularly limited.

[0023]

In the case where the semiconductor device 2 includes third dies (not illustrated), the second die 60 includes an insulating film 64 and one or more electrodes 65 on a surface 60b facing the third die. The surfaces 60a and 60b are  
15 opposite to each other. The electrodes 65 are provided in openings of the insulating film 64. The third die includes an insulating film and one or more electrodes on a surface facing the second die 60.

[0024]

The insulating film 64 of the second die 60 is brought into contact  
20 with and bonded to the insulating film of the third die. The electrodes 65 of the second die 60 are in contact with and bonded to the electrodes of the third die. The electrodes 65 of the second die 60 are electrically connected to the electrodes of the third die. The number of the electrodes (for example, the electrodes 65) is not particularly limited.

25 [0025]

According to the present embodiment, the target substrate 10, the first dies 20, and the second dies 60 are stacked without intervening bumps. Therefore, the die integration intensity can be increased. The first stacking substrate 30, the second stacking substrate 40, and the third stacking substrate 50  
30 which constitute the first die 20 are stacked without intervening bumps. Therefore, the integration intensity of the semiconductor circuit can be increased.

[0026]

Next, a bonding system 101 according to an embodiment will be

described with reference mainly to FIGS. 2 through 5. The bonding system 101 stacks the first dies 20 and the second dies 60 on the target substrate 10 in this order. In other words, the bonding system 101 manufactures the semiconductor device 2. As described above, the semiconductor device 2 does not need to include the second dies 60, and may include only a stack of the first dies 20 disposed on the target substrate 10.

[0027]

As illustrated in FIG. 2, the bonding system 101 includes a loading and unloading station 110, a processing station 120, and a control circuit 190. The loading and unloading station 110 and the processing station 120 are arranged in this order from the X-axis negative direction side to the X-axis positive direction side.

[0028]

The loading and unloading station 110 includes a mounting table 102. Cassettes C101 through C106 are placed on the mounting table 102. The cassette C101 accommodates the target substrate 10 illustrated in (A) of FIG. 3. The cassette C102 accommodates the first carrier 70 on which a plurality of first dies 20 are mounted as illustrated in (B) of FIG. 3. The cassette C103 accommodates the first carrier 70 after the plurality of first dies 20 have been peeled from the first carrier 70.

[0029]

The first carrier 70 includes, for example, a frame 71 and a tape 72 that covers an opening of the frame 71. A plurality of first dies 20 are disposed on the tape 72. Although not illustrated, the first carrier 70 may alternatively be an electrostatic carrier that electrostatically attracts the first dies 20. The electrostatic carrier may have a size corresponding to that of the target substrate 10. The electrostatic carrier includes a carrier substrate and a resin film. The first dies 20 are mounted on a surface of the resin film opposite to the carrier substrate.

[0030]

The resin film may have tackiness. The resin film may retain the first dies 20 by pressing the first dies 20 against the resin film. By pressing the first dies 20 against the resin film, the resin film is deformed so that gas between the first dies 20 and the resin film is expelled, thereby allowing the first dies 20 to

be vacuum-adhered to the resin film. Accordingly, the first carrier 70 need not be an electrostatic carrier.

[0031]

As illustrated in (C) of FIG. 3, the cassette C104 accommodates  
5 the second carrier 80 on which a plurality of second dies 60 are mounted. The cassette C105 accommodates the second carrier 80 after the plurality of second dies 60 have been peeled from the second carrier 80. The second carrier 80 includes, for example, a frame 81 and a tape 82 covering the opening of the frame 81. The second dies 60 are disposed on the tape 82. The second carrier 80 may  
10 include a carrier substrate and a resin film, similar to the first carrier 70.

[0032]

The cassette C106 accommodates the semiconductor device 2.

[0033]

The loading and unloading station 110 includes a transfer region  
15 111 and a transfer device 112. The transfer region 111 is adjacent to the mounting table 102. The transfer region 111 extends in the Y-axis direction. The transfer device 112 includes a substrate transfer arm 112a and a carrier transfer arm 112b. The substrate transfer arm 112a holds and transfers the target substrate 10 in the transfer region 111. The target substrate 10 to be transferred may be a substrate  
20 before the first dies 20 or the like are bonded or a substrate after the first dies 20 or the like are bonded. The carrier transfer arm 112b holds and transfers the first carrier 70 or the second carrier 80 in the transfer region 111. The first carrier 70 or the second carrier 80 to be transferred may be a carrier on which the first dies 20 or the second dies 60 are mounted or a carrier after the first dies 20 or the second  
25 dies 60 have been peeled from the carrier.

[0034]

The transfer device 112 includes a driver (not illustrated) for moving or rotating the substrate transfer arm 112a and the carrier transfer arm 112b. The substrate transfer arm 112a and the carrier transfer arm 112b can be  
30 moved in a horizontal direction (both directions of the X-axis direction and the Y-axis direction) and a vertical direction (the Z-axis direction), and rotated about a vertical axis.

[0035]

The substrate transfer arm 112a and the carrier transfer arm 112b may be mounted on the same Y-axis slider and moved in the Y-axis direction simultaneously as illustrated in FIG. 2, or they may be mounted on different Y-axis sliders and moved in the Y-axis direction independently. The substrate transfer arm 112a and the carrier transfer arm 112b are arranged at different heights.

[0036]

The processing station 120 includes a first bonding device 130, a second bonding device 140, and a heating device 150. The first bonding device 130, the second bonding device 140, and the heating device 150 are adjacent to the transfer region 111. The first bonding device 130 bonds the first dies 20 to the target substrate 10. The second bonding device 140 bonds the first dies 20 to the second dies 60. The heating device 150 heats the target substrate 10, the first dies 20, and the second dies 60.

[0037]

The control circuit 190 is, for example, a computer, and includes an arithmetic unit 191, such as a CPU (central processing unit), and a storage 192, such as a memory. The storage 192 stores a program for controlling various processes executed in the bonding system 101. The control circuit 190 controls the operation of the bonding system 101 by causing the arithmetic unit 191 to execute a program stored in the storage 192. A device controller for controlling the operation of each device constituting the bonding system 101 may be provided, and a system controller for controlling a plurality of device controllers may be provided. The device controller and the system controller may constitute the control circuit 190.

[0038]

The control circuit 190 includes an electronic circuit such as a CPU, an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit), and executes various control operations described herein by executing instruction codes stored in a memory or by being designed for a special application.

[0039]

Next, an example of the first bonding device 130 will be described

with reference to FIG. 4. The first bonding device 130 includes, for example, a carrier holder 131, a substrate holder 132, a transferer 133, and a mounter 134. The carrier holder 131 holds the first carrier 70. The substrate holder 132 holds the target substrate 10. The transferer 133 receives and transfers the first die 20 from the first carrier 70 held by the carrier holder 131. Although there is one transferer 133 in the present embodiment, there may be a plurality of transferers. The mounter 134 receives the first die 20 from the transferer 133 and bonds the received first die 20 to the target substrate 10 held by the substrate holder 132.

[0040]

The carrier holder 131 holds the first carrier 70 horizontally. The substrate holder 132 holds the target substrate 10 horizontally. The transferer 133 peels the first die 20 from the first carrier 70 and transfers the peeled first die 20. The transferer 133 may rotate the first die 20 by 180° during transfer of the first die 20. The mounter 134 receives the first die 20 from the transferer 133 and bonds the received first die 20 to the target substrate 10 held by the substrate holder 132.

[0041]

The transferer 133 includes, for example, an attraction head 133a and a moving mechanism 133b. The attraction head 133a attracts the first die 20. The attraction head 133a may attract the first die 20 in a non-contact manner. The moving mechanism 133b moves the attraction head 133a. The moving mechanism 133b rotates the attraction head 133a by 180° to flip the first die 20.

[0042]

The first bonding device 130 may include a presser 135. The presser 135 presses only one first die 20 by locally pressing the first carrier 70, for example. The presser 135 presses this one first die 20 in the direction in which the first die 20 is peeled from the first carrier 70. In the case where the transferer 133 can peel the first die 20 from the first carrier 70 only by raising the first die 20 together with the attraction head 133a, the presser 135 may be omitted.

[0043]

The mounter 134 includes, for example, an attraction head 134a and a moving mechanism 134b. The attraction head 134a attracts the first die 20 from the side opposite to the attraction head 133a. The attraction head 134a may

attract the first die 20 in a non-contact manner. The moving mechanism 134b moves the attraction head 134a to bond the first die 20 to the target substrate 10. [0044]

5 The first bonding device 130 may include an imaging unit (not illustrated) to improve the accuracy of the bonding positions of the first die 20 to the target substrate 10. The imaging unit captures an image of an alignment mark on the bonding surface of the target substrate 10 or the first die 20. The alignment mark may be a dedicated mark or a part of an electric circuit. The imaging unit does not need to capture an image every time the first die 20 and the target  
10 substrate 10 are bonded, but may capture an image periodically. [0045]

Next, an example of the second bonding device 140 will be described with reference to FIG. 5. The second bonding device 140 includes, for example, a carrier holder 141, a substrate holder 142, a transferer 143, and a  
15 mounter 144. The carrier holder 141 holds the second carrier 80. The substrate holder 142 holds the target substrate 10. The transferer 143 receives and transfers the second die 60 from the second carrier 80 held by the carrier holder 141. Although there is one transferer 143 in the present embodiment, there may be a plurality of transferers. The mounter 144 receives the second die 60 from the  
20 transferer 143 and bonds the received second die 60 to the first die 20 held by the substrate holder 142. [0046]

The carrier holder 141 holds the second carrier 80 horizontally. The substrate holder 142 holds the target substrate 10 horizontally. The  
25 transferer 143 peels the second die 60 from the second carrier 80 and transfers the peeled second die 60. The transferer 143 may rotate the second die 60 by 180° during transfer of the second die 60. The mounter 144 receives the second die 60 from the transferer 143 and bonds the received second die 60 to the first die 20. [0047]

30 The transferer 143 includes, for example, an attraction head 143a and a moving mechanism 143b. The attraction head 143a attracts the second die 60. The attraction head 143a may attract the second die 60 in a non-contact manner. The moving mechanism 143b moves the attraction head 143a. The

moving mechanism 143b may rotate the attraction head 143a by 180° so as to flip the second die 60.

[0048]

5 The second bonding device 140 may include a presser 145. The presser 145 presses only one second die 60 by locally pressing the second carrier 80, for example. The presser 145 presses this one second die 60 in the direction in which the second die 60 is peeled from the second carrier 80. In the case where the transferer 133 can peel the second die 60 from the second carrier 80 only by raising the second die 60 together with the attraction head 143a, the presser 145  
10 may be omitted.

[0049]

The mounter 144 includes, for example, an attraction head 144a and a moving mechanism 144b. The attraction head 144a attracts the second die 60 from the side opposite to the attraction head 143a. The attraction head 144a  
15 may attract the second die 60 in a non-contact manner. The moving mechanism 144b moves the attraction head 144a to bond the second die 60 to the first die 20.

[0050]

The second bonding device 140 may include an imaging unit (not illustrated) to improve the accuracy of the bonding positions of the second die 60  
20 to the first die 20. The imaging unit images an alignment mark on the bonding surface of the first die 20 or the second die 60. The alignment mark may be a dedicated mark or a part of an electric circuit. The imaging unit does not need to capture an image every time the second die 60 and the first die 20 are bonded, but may capture an image periodically.

25 [0051]

Next, a substrate processing method according to an embodiment will be described with reference to FIGS. 6 through 9. The substrate processing method includes, for example, steps S1 through S6. Preparation of the target substrate 10 (step S1) includes, for example, placing the cassette C101 on the  
30 mounting table 102. Preparation of the first dies 20 (step S2) includes, for example, placing the cassette C102 on the mounting table 102. Preparation of the second dies 60 (step S3) includes placing the cassette C104 on the mounting table 102.

[0052]

The substrate transfer arm 112a takes out the target substrate 10 from the cassette C101 and transfers the target substrate 10 to the first bonding device 130. The carrier transfer arm 112b takes out the first carrier 70 on which  
5 the first dies 20 are mounted from the cassette C102 and transfers the first carrier 70 to the first bonding device 130. Next, the first bonding device 130 peels the first dies 20 from the first carrier 70 and bonds the first dies 20 to the target substrate 10 (step S4).

[0053]

10 As illustrated in FIG. 7, step S4 includes bonding the insulating film of the target substrate 10 to the insulating films of the first dies 20 (for example, the insulating film 12 and the first insulating films 32) to each other. The electrodes 13 and the first electrodes 33 may be recessed with respect to the interface between the insulating film 12 and the first insulating films 32, and may  
15 not be in contact with each other. The electrodes are softer than the insulating films. Therefore, by polishing both the electrodes and the insulating films at the same time, steps can be formed between the electrodes and the insulating films.

[0054]

After step S4, the substrate transfer arm 112a takes out the target  
20 substrate 10 bonded to the first dies 20 from the first bonding device 130 and transfers the target substrate 10 to the second bonding device 140. The carrier transfer arm 112b takes out the second carrier 80 on which the second dies 60 are mounted from the cassette C104 and transfers the second carrier 80 to the second bonding device 140. Next, the second bonding device 140 peels the second dies  
25 60 from the second carrier 80 and bonds the second dies 60 to the first dies 20 (step S5).

[0055]

Step S5 includes bonding the insulating films of the first dies 20 and the insulating films of the second dies 60 (for example, the sixth insulating  
30 films 54 and the insulating films 62) to each other, as illustrated in FIG. 8. The sixth electrodes 55 and the electrodes 63 may be recessed with respect to the interface between the sixth insulating films 54 and the insulating films 62, and may not be in contact with each other. The electrodes are softer than the insulating

films. Therefore, by polishing both the electrodes and the insulating films at the same time, steps can be formed between the electrodes and the insulating films. [0056]

After step S5, the substrate transfer arm 112a takes out the target substrate 10 bonded to the first dies 20 and the second dies 60 from the second bonding device 140 and transfers the target substrate 10 to the heating device 150. Next, the heating device 150 heats the target substrate 10, the first dies 20, and the second dies 60 (step S6). [0057]

Step S6 includes bonding the target substrate 10 to the electrodes of the first dies 20 (for example, the electrodes 13 and the first electrodes 33) and bonding the electrodes of the first dies 20 to the electrodes of the second dies 60 (for example, the sixth electrodes 55 and the electrodes 63) in one processing step, as illustrated in FIG. 9. The number of steps can be thereby reduced. The electrodes have a thermal expansion coefficient larger than that of the insulating films. Therefore, heating can bring the electrodes separated from each other into contact with each other, thereby bonding the electrodes. The electrodes are diffusion-bonded. [0058]

After step S6, the substrate transfer arm 112a takes out the target substrate 10 bonded to the first dies 20 and the second dies 60 from the heating device 150 and transfers the target substrate 10 to the cassette C106. The carrier transfer arm 112b takes out the first carrier 70 from which the first dies 20 have been peeled from the first bonding device 130 and transfers the first carrier 70 to the cassette C103. The carrier transfer arm 112b takes out the second carrier 80 from which the second dies 60 have been peeled from the second bonding device 140 and transfers the second carrier 80 to the cassette C105. [0059]

Next, a bonding system 101 according to a modified example will be described with reference to FIG. 10. Hereinafter, differences from the foregoing embodiments will be mainly described. The processing station 120 includes the first bonding device 130, the second bonding device 140, a first heating device 150A, and a second heating device 150B. The first heating device

150A heats the target substrate 10 and the first dies 20 after the target substrate 10 is bonded to the first dies 20 but before the first dies 20 are bonded to the second dies 60. The second heating device 150B heats the first dies 20 and the second dies 60 after the first dies 20 are bonded to the second dies 60. The second heating device 150B may also heat the target substrate 10.  
[0060]

Next, a substrate processing method according to a modified example will be described with reference to FIG. 11. Hereinafter, differences from the foregoing embodiments will be mainly described. The substrate processing method includes steps S6A and S6B instead of step S6. Step S6A includes bonding the electrodes (e.g., the electrodes 13 and the electrodes 33) of the target substrate 10 to the electrodes of the first dies 20 by heating the target substrate 10 and the first dies 20 after step S4 but before step S5. Step S6B includes, after step S5, bonding the electrodes of the first dies 20 to the electrodes of the second dies 60 (for example, the sixth electrodes 55 and the electrodes 63) by heating the first dies 20 and the second dies 60.  
[0061]

Next, an example of a sub-process of step S2 illustrated in FIGS. 6 and 11 will be described with reference to FIGS. 12 through 14. As illustrated in FIG. 12, step S2 includes, for example, steps S21 through S24. In step S21, as illustrated in (A) of FIG. 13, a first substrate 21 supported by a first support substrate 36 is prepared. The first substrate 21 before being singulated into a plurality of first dies 20 includes, for example, the first stacking substrate 30, the second stacking substrate 40, and the third stacking substrate 50.  
[0062]

In step S22, as illustrated in (B) of FIG. 13, the first substrate 21 is singulated into a plurality of first dies 20. The singulation method is not particularly limited, and may be plasma dicing or laser dicing, for example. Plasma dicing and laser dicing enable singulation with a high aspect ratio and narrow streets as compared with blade dicing.  
[0063]

As illustrated in (C) of FIG. 13, step S23 includes mounting the plurality of first dies 20 on the first carrier 70. The first carrier 70 includes, for

example, the frame 71 and the tape 72 covering an opening of the frame 71. The plurality of first dies 20 are disposed on the tape 72. Step S22 is performed before step S23 in order to suppress degradation of the tape 72 by plasma or laser.

[0064]

5                   As illustrated in (A) to (C) of FIG. 14, step S24 includes peeling the plurality of first dies 20 from the first support substrate 36. For example, first, as illustrated in (A) of FIG. 14, a laser-modified layer 22 is created by irradiating the interface between the first support substrate 36 and the first dies 20 with a laser beam LB from the side opposite to the first dies 20. A plurality of laser-  
10   modified layers 22 are thereby created at intervals. The laser-modified layers 22 may be created inside the first support substrate 36. The laser-modified layers 22 do not need to be created.

[0065]

                  Next, as illustrated in (B) of FIG. 14, a blade 23 is inserted into the  
15   interface between the first support substrate 36 and the first dies 20 to create a peeling starting point. Next, as illustrated in (C) of FIG. 14, the first dies 20 are peeled from the first support substrate 36. Thereafter, although not illustrated, the peeled surfaces of the first dies 20 may be polished. By polishing, steps can be formed between the electrodes and the insulating films.

20   [0066]

                  In steps S21 through S24, the plurality of first dies 20 (see (B) of FIG. 3) mounted on the first carrier 70 are obtained. Since the plurality of second dies 60 mounted on the second carrier 80 (see (C) of FIG. 3) can be obtained in the same manner as the plurality of first dies 20 mounted on the first carrier 70,  
25   detailed description thereof is omitted.

[0067]

                  Next, an example of a sub-process of step S21 illustrated in FIG. 12 will be described with reference to FIGS. 15 through 17. As illustrated in FIG. 15, step S21 includes, for example, steps S211 through S217. As illustrated in (A)  
30   of FIG. 16, step S211 includes preparing the first stacking substrate 30 supported by the first support substrate 36. Although not illustrated, step S212 includes preparing the second stacking substrate 40 supported by a second support substrate 46. Although not illustrated, step S213 includes preparing the third

stacking substrate 50 supported by a third support substrate 56.

[0068]

As illustrated in (B) of FIG. 16, step S214 includes bonding the first stacking substrate 30 supported by the first support substrate 36 to the second stacking substrate 40 supported by the second support substrate 46. The bonding of the first stacking substrate 30 to the second stacking substrate 40 may be performed in the same manner as the bonding of the first dies 20 to the second dies 60. For example, insulating films (for example, the second insulating film 34 and the third insulating film 42) are bonded to each other, and then electrodes (for example, the second electrodes 35 and the third electrodes 43) are bonded to each other.

[0069]

As illustrated in (C) of FIG. 16, step S215 includes peeling the second stacking substrate 40 from the second support substrate 46. Peeling of the second stacking substrate 40 from the second support substrate 46 may be performed in the same manner as peeling of the plurality of first dies 20 from the first support substrate 36 (step S24 illustrated in FIG. 12). Thereafter, although not illustrated, the separated surface of the second stacking substrate 40 may be polished. Steps can be formed between the electrodes and the insulating film by polishing.

[0070]

As illustrated in (A) of FIG. 17, step S216 includes bonding the second stacking substrate 40 to the third stacking substrate 50 supported by the third support substrate 56. Bonding of the second stacking substrate 40 to the third stacking substrate 50 may be performed in the same manner as bonding of the first dies 20 to the second dies 60. For example, insulating films (for example, the fourth insulating film 44 and the fifth insulating film 52) are bonded to each other, and then electrodes (for example, the fourth electrodes 45 and the fifth electrodes 53) are bonded to each other.

[0071]

As illustrated in (B) of FIG. 17, step S217 includes peeling the third stacking substrate 50 from the third support substrate 56. Peeling of the third stacking substrate 50 from the third support substrate 56 may be performed in the

same manner as peeling of the plurality of first dies 20 from the first support substrate 36 (step S24 illustrated in FIG. 12). Thereafter, although not illustrated, the separated surface of the third stacking substrate 50 may be polished. Steps can be formed between the electrodes and the insulating film by polishing.

5 [0072]

The first substrate 21 supported by the first support substrate 36 (see (A) of FIG. 13) is obtained by steps S211 through S217. The first substrate 21 includes the first stacking substrate 30, the second stacking substrate 40, and the third stacking substrate 50. The bonding between the electrodes of the first  
10 stacking substrate 30 and the electrodes of the second stacking substrate 40, and the bonding between the electrodes of the second stacking substrate 40 and the electrodes of the third stacking substrate 50 may be performed in one processing step. The number of steps can be thereby reduced.

[0073]

15 Next, an example of a sub-process of step S211 illustrated in FIG. 15 will be described with reference to FIGS. 18 through 20. As illustrated in FIG. 18, step S211 includes, for example, steps S2111 through S2116. Step S2111 includes, as illustrated in (A) of FIG. 19, forming the first insulating film 32 on one surface of the first semiconductor substrate 31 and forming the first electrodes  
20 33 in openings of the first insulating film 32.

[0074]

Step S2112 includes, as illustrated in (B) of FIG. 19, bonding the first support substrate 36 to the first semiconductor substrate 31. The first support substrate 36 includes a semiconductor substrate 38 and an insulating film 37  
25 formed on the semiconductor substrate 38. The insulating film 37 of the first support substrate 36 is bonded to the first insulating film 32. These insulating films are, for example, silicon oxide films and are formed using, for example, TEOS.

[0075]

30 As illustrated in (C) of FIG. 19, step S2113 includes thinning the first semiconductor substrate 31. The thinning process includes, for example, grinding. The first semiconductor substrate 31 can be thinned by grinding the first semiconductor substrate 31 from the side opposite to the first support substrate 36.

The thinning process may include laser processing. In addition to thinning the first semiconductor substrate 31, step S2113 may include trimming the periphery of the first semiconductor substrate 31. The bevel of the first semiconductor substrate 31 can be thereby removed. The trimming process includes, for example, laser processing. The trimming process is performed before thinning.  
[0076]

As illustrated in (A) of FIG. 20, step S2114 includes selectively etching the first semiconductor substrate 31 in comparison with the first insulating film 32. The etching process includes, for example, plasma etching. The first electrodes 33 are protected by the first insulating film 32 and are therefore not etched. The first insulating film 32 and the first electrodes 33 project from the opposite surface of the first semiconductor substrate 31.  
[0077]

As illustrated in (B) of FIG. 20, step S2115 includes forming the second insulating film 34 on the opposite surface of the first semiconductor substrate 31 (the surface opposite to the first support substrate 36). The second insulating film 34 is formed, for example, by a CVD (chemical vapor deposition) method. The second insulating film 34 is, for example, a silicon oxide film and is formed, for example, using TEOS.  
[0078]

As illustrated in (C) of FIG. 20, step S2116 includes planarizing the second insulating film 34. The planarization of the second insulating film 34 includes, for example, CMP (chemical mechanical polishing). By planarizing the second insulating film 34 with the polishing plate 39, the second electrodes 35 are provided in openings of the second insulating film 34.  
[0079]

The first stacking substrate 30 supported by the first support substrate 36 (see (A) of FIG. 16) is obtained by steps S2111 through S2116. The second stacking substrate 40 supported by the second support substrate 46 and the third stacking substrate 50 supported by the third support substrate 56 are obtained in the same manner as the first stacking substrate 30 supported by the first support substrate 36, and therefore, detailed description thereof is omitted.  
[0080]

The embodiments of the substrate processing method, the bonding system, and the semiconductor device according to the present disclosure have been described above, but the present disclosure is not limited to the above embodiments. Various changes, alterations, substitutions, additions, deletions, and combinations are possible within the scope of the claims. These also naturally fall within the technical scope of the present disclosure.

[0081]

This application claims priority to Japanese Patent Application No. 2023-190259, filed in the Japanese Patent Office on November 7, 2023, and the entire contents of Japanese Patent Application No. 2023-190259 are incorporated herein by reference.

#### REFERENCE SIGNS LIST

[0082]

|    |     |                       |
|----|-----|-----------------------|
| 15 | 10  | Target substrate      |
|    | 10a | Surface               |
|    | 12  | Insulating film       |
|    | 13  | Electrode             |
|    | 20  | First die             |
| 20 | 20a | Surface               |
|    | 20b | Surface               |
|    | 32  | First insulating film |
|    | 33  | First electrode       |
|    | 54  | Insulating film       |
| 25 | 55  | Sixth electrode       |
|    | 60  | Second die            |
|    | 60a | Surface               |
|    | 62  | Insulating film       |
|    | 63  | Electrode             |
| 30 |     |                       |

## CLAIMS

### [Claim 1]

- 5                   A substrate processing method comprising:  
                  stacking a first die and a second die on a target substrate in this  
                  order, wherein
- the target substrate includes an insulating film and a  
                  plurality of electrodes on a surface of the target substrate facing the first die,
- 10                   the first die includes an insulating film and one or more  
                  electrodes on a surface of the first die facing the target substrate, and further  
                  includes an insulating film and one or more electrodes on a surface of the first die  
                  facing the second die, and
- the second die includes an insulating film and one or more
- 15                   electrodes on a surface of the second die facing the first die;  
                  bonding the insulating film of the target substrate to the insulating  
                  film of the first die;  
                  bonding the plurality of electrodes of the target substrate to the one  
                  or more electrodes of the first die;
- 20                   bonding the insulating film of the first die to the insulating film of  
                  the second die; and  
                  bonding the one or more electrodes of the first die to the one or  
                  more electrodes of the second die.

### 25   [Claim 2]

- The substrate processing method according to claim 1, wherein
- bonding the insulating film of the target substrate to the insulating  
                  film of the first die and bonding the insulating film of the first die to the insulating  
                  film of the second die are performed in this order, and subsequently, by heating
- 30                   the target substrate, the first die, and the second die, bonding the plurality of  
                  electrodes of the target substrate to the one or more electrodes of the first die and  
                  bonding the one or more electrodes of the first die to the one or more electrodes of  
                  the second die are performed in one processing step.

[Claim 3]

The substrate processing method according to claim 1, wherein the processing steps are performed in the following order:

- 5 (1) bonding the insulating film of the target substrate to the insulating film of the first die,
- (2) bonding the plurality of electrodes of the target substrate to the one or more electrodes of the first die by heating the target substrate and the first die,
- 10 (3) bonding the insulating film of the first die to the insulating film of the second die, and
- (4) bonding the one or more electrodes of the first die to the one or more electrodes of the second die by heating the first die and the second die.

15 [Claim 4]

The substrate processing method according to any one of claims 1 to 3, wherein

the insulating film formed on the surface of the first die facing the target substrate is formed using TEOS (tetraethoxysilane).

20

[Claim 5]

The substrate processing method according to any one of claims 1 to 3, wherein

25 the insulating film formed on the surface of the first die facing the second die is formed using TEOS (tetraethoxysilane).

[Claim 6]

The substrate processing method according to any one of claims 1 to 3, the method further comprising:

30 stacking the first die, the second die, and a third die on the target substrate in this order, wherein

the second die includes an insulating film and one or more electrodes on a surface of the second die facing the third die, and

the third die includes an insulating film and one or more electrodes on a surface of the third die facing the second die,

bonding the insulating film of the second die to the insulating film of the third die; and

5                      bonding the one or more electrodes of the second die to the one or more electrodes of the third die.

[Claim 7]

10                      The substrate processing method according to any one of claims 1 to 3, wherein

the first die includes a first stacking substrate and a second stacking substrate,

the first stacking substrate includes

a first semiconductor substrate,

15                      a first insulating film formed on one surface of the first semiconductor substrate,

a first electrode provided in an opening of the first insulating film,

20                      a second insulating film formed on the other surface of the first semiconductor substrate, and

a second electrode provided in an opening of the second insulating film, wherein

the first electrode and the second electrode are electrically connected to each other,

25                      the second stacking substrate includes

a second semiconductor substrate,

a third insulating film formed on one surface of the second semiconductor substrate,

30                      a third electrode provided in an opening of the third insulating film,

a fourth insulating film formed on the other surface of the second semiconductor substrate, and

a fourth electrode provided in an opening of the fourth

insulating film, wherein

the third electrode and the fourth electrode are electrically connected to each other, and

the second insulating film of the first stacking substrate is brought  
5 into contact with and bonded to the third insulating film of the second stacking substrate, and the second electrode of the first stacking substrate is brought into contact with and bonded to the third electrode of the second stacking substrate.

[Claim 8]

10 A substrate processing method comprising:

stacking a first die on a target substrate, wherein

the target substrate includes an insulating film and a plurality of electrodes on a surface of the target substrate facing the first die,

the first die includes an insulating film and one or more  
15 electrodes on a surface of the first die facing the target substrate;

bonding the insulating film of the target substrate to the insulating film of the first die; and

bonding the plurality of electrodes of the target substrate to the one or more electrodes of the first die, wherein

20 the first die includes a first stacking substrate and a second stacking substrate,

the first stacking substrate includes

a first semiconductor substrate,

a first insulating film formed on one surface of the first  
25 semiconductor substrate,

a first electrode provided in an opening of the first insulating film,

a second insulating film formed on the other surface of the first semiconductor substrate, and

30 a second electrode provided in an opening of the second insulating film, wherein

the first electrode and the second electrode are electrically connected to each other,

the second stacking substrate includes  
a second semiconductor substrate,  
a third insulating film formed on one surface of the second  
semiconductor substrate,  
5 a third electrode provided in an opening of the third  
insulating film,  
a fourth insulating film formed on the other surface of the  
second semiconductor substrate, and  
a fourth electrode provided in an opening of the fourth  
10 insulating film, wherein  
the third electrode and the fourth electrode are electrically  
connected,  
the second insulating film of the first stacking substrate is brought  
into contact with and bonded to the third insulating film of the second stacking  
15 substrate, and  
the second electrode of the first stacking substrate is brought into  
contact with and bonded to the third electrode of the second stacking substrate.

[Claim 9]

20 The substrate processing method according to claim 8, further  
comprising:  
singulating a first substrate including the first stacking substrate  
and the second stacking substrate into a plurality of first dies, each being the first  
die;  
25 performing the following before singulating the first substrate into  
the plurality of first dies:  
(1) preparing the first stacking substrate supported by a first  
support substrate;  
(2) preparing the second stacking substrate supported by a  
30 second support substrate;  
(3) bonding the first stacking substrate to the second  
stacking substrate; and  
(4) peeling the second stacking substrate from the second

support substrate after (3) bonding the first stacking substrate to the second stacking substrate.

[Claim 10]

- 5                   The substrate processing method according to claim 8, wherein  
the first die further includes a third stacking substrate,  
the third stacking substrate includes  
a third semiconductor substrate,  
a fifth insulating film formed on one surface of the third  
10 semiconductor substrate,  
a fifth electrode provided in an opening of the fifth  
insulating film,  
a sixth insulating film formed on the other surface of the  
third semiconductor substrate, and  
15 a sixth electrode provided in an opening of the sixth  
insulating film, wherein  
the fifth electrode and the sixth electrode are electrically  
connected to each other, and  
the fourth insulating film of the second stacking substrate is  
20 brought into contact with and bonded to the fifth insulating film of the third  
stacking substrate, and the fourth electrode of the second stacking substrate is  
brought into contact with and bonded to the fifth electrode of the third stacking  
substrate.
- 25 [Claim 11]
- The method according to claim 10, further comprising:  
singulating a first substrate including the first stacking substrate,  
the second stacking substrate, and the third stacking substrate into a plurality of  
first dies, each being the first die; and  
30 performing the following after singulating the first substrate into  
the plurality of first dies:  
(1) preparing the first stacking substrate supported by a first  
support substrate;

(2) preparing the second stacking substrate supported by a second support substrate;

(3) preparing the third stacking substrate supported by a third support substrate;

5 (4) bonding the first stacking substrate to the second stacking substrate;

(5) peeling the second stacking substrate from the second support substrate after (4) bonding the first stacking to the second stacking substrate;

10 (6) bonding the second stacking substrate to the third stacking substrate after (5) peeling the second stacking substrate from the second support substrate; and

(7) peeling the third stacking substrate from the third support substrate after (6) bonding the second stacking substrate to the third  
15 stacking substrate.

[Claim 12]

A bonding system configured to stack a first die and a second die in this order on a target substrate, wherein

20 the target substrate includes an insulating film and a plurality of electrodes on a surface of the target substrate facing the first die,  
the first die includes an insulating film and one or more electrodes on a surface of the first die facing the target substrate, and further includes an insulating film and one or more electrodes on a surface of the first die  
25 facing the second die,

the second die includes an insulating film and one or more electrodes on a surface of the second die facing the first die, and

the bonding system includes a first bonding device configured to bond the insulating film of the target substrate to the insulating film of the first  
30 die, and a second bonding device configured to bond the insulating film of the first die to the insulating film of the second die.

[Claim 13]

The bonding system according to claim 12, comprising:

a heating device configured to heat the target substrate, the first die, and the second die to bond the plurality of electrodes of the target substrate to the one or more electrodes of the first die and bond the one or more electrodes of  
5 the first die to the one or more electrodes of the second die in one processing step.

[Claim 14]

The bonding system according to claim 12, further comprising:

a first heating device configured to heat the target substrate and the  
10 first die to bond the plurality of electrodes of the target substrate to the one or more electrodes of the first die; and

a second heating device configured to heat the first die and the second die to bond the one or more electrodes of the first die to the one or more electrodes of the second die.

15

[Claim 15]

A semiconductor device comprising a target substrate and a first die, wherein

the target substrate includes an insulating film and an electrode  
20 provided in an opening of the insulating film on one surface of the target substrate,

the first die includes a first stacking substrate and a second stacking substrate,

the first stacking substrate includes

25 a first semiconductor substrate,

a first insulating film formed on one surface of the first semiconductor substrate,

a first electrode provided in an opening of the first insulating film,

30 a second insulating film formed on the other surface of the first semiconductor substrate, and

a second electrode provided in an opening of the second insulating film, wherein

the first electrode and the second electrode are electrically connected to each other,

the second stacking substrate includes

a second semiconductor substrate,

5 a third insulating film formed on one surface of the second semiconductor substrate,

a third electrode provided in an opening of the third insulating film,

10 a fourth insulating film formed on the other surface of the second semiconductor substrate, an

a fourth electrode provided in an opening of the fourth insulating film, wherein

the third electrode and the fourth electrode are electrically connected to each other,

15 the insulating film of the target substrate is brought into contact with and bonded to the first insulating film of the first stacking substrate, and the electrode of the target substrate is brought into contact with and bonded to the first electrode of the first stacking substrate, and

20 the second insulating film of the first stacking substrate is brought into contact with and bonded to the third insulating film of the second stacking substrate, and the second electrode of the first stacking substrate is brought into contact with and bonded to the third electrode of the second stacking substrate.