[0004] In view of the foregoing, in a combined substrate in which a first substrate and a second substrate are bonded to each other, a device layer formed on a surface of the second substrate is appropriately transcribed to the first substrate.

MEANS FOR SOLVING THE PROBLEMS

[0005] In one exemplary embodiment, there is provided a substrate processing method of transcribing, in a combined substrate in which a first substrate and a second substrate are bonded to each other, a device layer formed on a surface of the second substrate to the first substrate. A laser beam is radiated in a pulse shape from a rear surface side of the second substrate to a laser absorption layer formed between the second substrate and the device layer.

EFFECTS OF THE INVENTION

[0006] According to the present disclosure, in the combined substrate in which the first substrate and the second substrate are bonded to each other, the device layer formed on the surface of the second substrate can be appropriately transcribed to the first substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is an explanatory diagram comparing a power of a laser beam when a pulse wave and a continuous wave are used.

FIG. 2 is a side view schematically illustrating a configuration of a combined wafer to be processed in a wafer processing system.

FIG. 3 is a plan view schematically illustrating a configuration of the wafer processing system.

[0019] Cassettes Ct, Cw1 and Cw2 configured to accommodate a plurality of combined wafers T, a plurality of first wafers W1 and a plurality of second wafers W2, respectively, are carried in/out between the carry-in/out block 10 and, for example, the outside. A cassette placing table 11 is provided in the carry-in/out block 10. In the illustrated example, a plurality of, for example, three cassettes Ct, Cw1 and Cw2 can be placed in a row in an X-axis direction on the cassette placing table 11. The number of cassettes Ct, Cw1 and Cw2 placed on the cassette placing table 11 is not limited to the present exemplary embodiment, but can be arbitrarily determined.

[0020] The transfer block 20 is provided with a wafer transfer device 22 which is movable along a transfer path 21 elongated in the X-axis direction. The wafer transfer device 22 has, for example, two transfer arms 23 and 23 which hold and transfer the combined wafer T, the first wafer W1 and the second wafer W2. Each transfer arm 23 is movable in a horizontal direction, in a vertical direction, around a horizontal axis and around a vertical axis. The configuration of the transfer arm 23 is not limited to the present exemplary embodiment, but can be arbitrarily determined. Also, the wafer transfer device 22 is configured to transfer the combined wafer T, the first wafer W1 and the second wafer W2 to the cassettes Ct, Cw1 and Cw2 on the cassette placing table 11, the laser radiation device 31 and the cleaning device 32.

[0021] The processing block 30 is equipped with the laser radiation device 31 and the cleaning device 32. The laser radiation device 31 radiates a laser beam to the laser absorption layer P of the second wafer W2. The configuration of the laser radiation device 31 will be described later.

[0022] The cleaning device 32 cleans a front surface of the laser absorption layer P formed on the front surface W1a of the first wafer W1 separated by the laser radiation device 31. For

carried out of the laser radiation device 31. The transfer pad 120 may also be configured to invert front and rear surfaces of a wafer by an inverting mechanism (not shown).

[0029] In the laser radiation device 31 shown in **FIG. 5**, the transfer arm 23 accesses the transfer pad 120 from the positive X-axis direction side. However, the transfer arm 23 may access the transfer pad 120 from the negative Y-axis direction side by rotating the laser radiation device 31 shown in **FIG. 5** 90 degrees counterclockwise.

[0030] When the combined wafer T is carried into the laser radiation device 31, the combined wafer T is delivered from the transfer arm 23 to the elevating pin to be placed on the chuck 100 by lowering the elevating pin. Further, when the separated second wafer W2 is carried out of the laser radiation device 31, the combined wafer T placed on the chuck 100 is raised by the elevating pin to be delivered from the elevating pin to the transfer arm 23.

[0031] Hereinafter, the wafer processing performed in the wafer processing system 1 configured as described above will be described. In the present exemplary embodiment, the first wafer W1 and the second wafer W2 are bonded to each other in an external bonding device (not shown) of the wafer processing system 1 to form the combined wafer T in advance.

[0032] First, the cassette Ct accommodating therein a plurality of combined wafers T is placed on the cassette placing table 11 of the carry-in/out block 10.

[0033] Then, a combined wafer T in the cassette Ct is taken out by the wafer transfer device 22 and transferred to the laser radiation device 31. In the laser radiation device 31, the combined wafer T is transferred from the transfer arm 23 to the elevating pin to be attracted and held by the chuck 100. Subsequently, the movement mechanism 104 moves the chuck 100 to a processing position. This processing position is a position where the laser beam can be radiated from the laser radiation unit 110 to the combined wafer T (laser absorption layer P).

[0034] Then, as shown in **FIG. 6** and **FIG. 7**, a laser beam L (CO_2 laser beam) is radiated in a pulse shape from the laser radiation unit 110 to the laser absorption layer P, more specifically, an interface between the laser absorption layer P and the second wafer W2. Herein, the laser beam L is transmitted through the second wafer W2 from the rear surface W2b of the second wafer W2 to be absorbed by the laser absorption layer P. Thereafter, the laser beam L causes separation at the interface between the laser absorption layer P and the second wafer W2. Almost all of the laser beam L is absorbed by the laser absorption layer P and does not reach the device layer D2. Therefore, it is possible to suppress damage to the device layer D2.

[0035] When the laser absorption layer P is irradiated with the laser beam L, the rotation mechanism 103 rotates the chuck 100 (combined wafer T) and the movement mechanism 104 moves the chuck 100 in the Y-axis direction. Then, the laser beam L is radiated to the laser absorption layer P from an outer side to an inner side thereof in a diametrical direction. As a result, the laser beam L is radiated in a spiral shape from the outer side to the inner side. Further, the black arrows shown in **FIG. 7** indicate a rotation direction of the chuck 100.

[0036] A radiation start position of the laser beam L is preferably between an outer edge Ea of the second wafer W2 and a bonding edge Eb between the first wafer W1 and the second wafer W2 in the combined wafer T. In this case, for example, even if a center of the first wafer W1 is misaligned and eccentric with a center of the second wafer W2 in the combined wafer T, an eccentric amount is absorbed and the laser beam L can be appropriately radiated to the laser absorption layer P.

[0037] As shown in **FIG. 8**, the laser beam L may be annularly radiated in a concentric circular shape to the laser absorption layer P. However, in this case, since the rotation of the chuck 100 and the movement of the chuck 100 in the Y-axis direction are alternately performed, it is preferable to radiate

radiating the laser beam L can be made uniform.

[0048] The second method is to control the frequency of the laser beam L. That is, when the radiation position of the laser beam L is on the outer side in the diametrical direction of the laser absorption layer P, the frequency is increased, and when the radiation position of the laser beam L is on the inner side, the frequency is decreased. The adjustment of the frequency is performed depending on the rotation speed of the chuck 100. Even in this case, the rotation speed of the chuck 100 can be made constant and the interval of radiating the laser beam L can be made uniform.

[0049] Also, in order to shorten the processing time (tact) of the laser radiation and improve the throughput, it is preferable to maintain the rotation speed of the chuck 100 by using the laser beam L having a high frequency in the first method.

[0050] Alternatively, the first method and the second method may be performed together. In this case, the frequency of the laser beam L is increased while decreasing the rotation speed of the chuck 100 on the outer side in the diametrical direction. Meanwhile, the frequency of the laser beam L is decreased while increasing the rotation speed of the chuck 100 on the inner side in the diametrical direction.

[0051] Here, when controlling the frequency of the laser beam L in the second method, for example, when controlling the frequency of the laser beam L in a laser oscillator of the laser head 111, it is necessary to adjust parameters in consideration of the output or the pulse waveform of the laser beam L. For example, if the energy of the laser beam L required for the separation on the outer side in the diametrical direction of the laser absorption layer P is identical to the energy of the laser beam L required for the separation on the inner side in the diametrical direction of the

X-axis direction, the chuck 210 is moved in the Y-axis direction and the laser beam L is radiated to the laser absorption layer P.

[0084] In the present exemplary embodiment as well, the same effects as obtained in the above-described exemplary embodiment can be achieved. That is, since the laser beam L is radiated in the pulse shape to the laser absorption layer P, the separation can occur at the interface between the laser absorption layer P and the second wafer W2. Moreover, since the radiation and the scanning of the laser beam L in a row in the X-axis direction are not stopped, the processing time of laser radiation can be shortened and the throughput can be further improved.

[0085] The radiation of the laser beam L in the spiral shape (or concentric circular shape) according to the above-described exemplary embodiment may be combined with the radiation and the scanning of the laser beam L according to the above-described exemplary embodiment.

[0086] If the chuck 210 (combined wafer T) is rotated, the rotation speed of the chuck 210 increases as the laser beam L moves from the outer side to the inner side in the diametrical direction to make the pulse interval uniform as described above. Therefore, in the above-described exemplary embodiment, at least the rotation speed of the chuck 210 or the frequency is controlled to adjust the interval of radiating the laser beam L.

[0087] In this regard, as shown in **FIG. 19**, on an outer peripheral portion of the laser absorption layer P, the laser beam L is radiated in a spiral shape by moving the radiation position of the laser beam L from the outer side to the inner side in the diametrical direction by moving the chuck 210 while rotating the chuck 210. When the rotation speed of the chuck 210 reaches an upper limit, rotation of the chuck 210 is stopped at the central portion of the laser absorption layer P and the scanning range A is scanned while radiating the laser beam L. Although the scanning range A is illustrated as having a square shape, the shape

The holding member 250 is arranged at each of a plurality of, for example, three locations on concentric circles of the chuck 100. The holding member 250 is configured to be movable forwards and backwards by a movement mechanism 251 so as to be in contact with or separated from the second wafer W2. Further, the holding member 250 is configured to be rotatable together with the chuck 100. Since the holding member 250 holds the second wafer W2, it is possible to suppress misalignment and slipping-down of the second wafer W2. In the guide unit 240, a notch 243 is formed at a position corresponding to the holding member 250. Further, the holding member 250 is moved through the notch 243 so as not to interfere with the guide unit 240.

[0093] Although both the guide unit 240 and the holding member 250 are provided in the present exemplary embodiment, only the guide unit 240 may be provided or only the holding member 250 may be provided. If only the guide unit 240 is provided, the vertical portion 241 can suppress the misalignment and the slipping-down of the second wafer W2. In particular, when a gap between the vertical portion 241 and the second wafer W2 is within an allowable range of the misalignment, the guide unit 240 becomes useful. However, when both the guide unit 240 and the holding member 250 are provided, it is more effective in centering the combined wafer T and suppressing the misalignment and the slipping-down of the second wafer W2.

[0094] In this case, when the combined wafer T is held by the chuck 100 at the delivery position, the three holding members 250 retreat to positions where they are not in contact with the second wafer W2. Then, after the chuck 100 holding the combined wafer T is moved to the processing position, the three holding members 250 are moved to positions where they are in contact with the side surface of the second wafer W2 to hold the second wafer W2.

[0095] When the guide unit 240 and the holding member 250 are not provided, if the laser beam L is radiated in the spiral shape from the outer side to the inner side in the diametrical

the laser absorption layer P2 and the Si film S as shown in **FIG. 26D**. Thereafter, the laser beam L causes the separation at the interface between the laser absorption layer P2 and the Si film S.

[00117] Subsequently, in a state where the transfer pad 120 attracts and holds the rear surface W2b of the second wafer W2, the transfer pad 120 is raised as shown in **FIG. 26E** to separate the laser absorption layer P2 from the Si film S. In the present exemplary embodiment as well, the separation position of the laser absorption layer P2 may be adjusted by adjusting the absorption position of the laser beam L, *i.e.*, the separation position of the laser absorption layer P2, as in the case shown in **FIG. 24A** and **FIG. 24B**, and the separation may occur at the interface between the second wafer W2 and the laser absorption layer P2.

[00118] A case of processing the combined wafer T shown in **FIG. 27A** to **FIG. 27E** will be described. As shown in **FIG. 27A** and **FIG. 27B**, a laser absorption layer P3 made of an oxide film (SiO_2 film), an SiGe film S1 made of SiGe and an Si film S2 made of Si are formed between the second wafer W2 and the device layer D2 to be stacked in this order from the second wafer W2.

[00119] Then, as shown in **FIG. 27B**, the device layer D2 and the front surface film F2 are formed on a front surface of the Si film S2 made of Si.

[00120] Thereafter, as shown in **FIG. 27C**, the first wafer W1 and the second wafer W2 are bonded to each other. The device layer D1 and the front surface film F1 are formed on the front surface W1a of the first wafer W1, and the front surface film F1 is bonded to the front surface film F2.

[00121] Then, in the laser radiation device 31 of the wafer processing system 1, the laser beam L is radiated in the pulse shape from the laser radiation unit 110 to the interface between the laser absorption layer P3 and the second wafer W2 as shown in **FIG. 27D**. Thereafter, the laser

beam L causes the separation at the interface between the laser absorption layer P3 and the second wafer W2.

[00122] Subsequently, in a state where the transfer pad 120 attracts and holds the rear surface W2b of the second wafer W2, the transfer pad 120 is raised as shown in **FIG. 27E** to separate the second wafer W2 from the laser absorption layer P3.

[00123] A case of processing the combined wafer T shown in **FIG. 28A** to **FIG. 28D** will be described. The combined wafer T has a structure in which a Ge-pMOS is stacked on an Si-nMOS. As shown in **FIG. 28A**, the device layer D1 and the front surface film F1 are formed on the front surface W1a of the first wafer W1. That is, the first wafer W1 is the Si-nMOS.

[00124] Then, as shown in **FIG. 28B**, the first wafer W1 and the second wafer W2, which is the Ge-pMOS, are bonded to each other. A laser absorption layer P4 made of an oxide film (SiO_2 film), the device layer D2 made of Ge and the front surface film F2 are stacked on the front surface W2a of the second wafer W2 in this order from the second wafer W2.

[00125] Thereafter, as shown in **FIG. 28B**, the first wafer W1 and the second wafer W2 are bonded to each other. Specifically, the front surface film F1 and the front surface film F2 are bonded to each other.

[00126] Then, in the laser radiation device 31 of the wafer processing system 1, the laser beam L is radiated in the pulse shape from the laser radiation unit 110 to the interface between the laser absorption layer P4 and the device layer D2 as shown in **FIG. 28C**. Thereafter, the laser beam L causes the separation at the interface between the laser absorption layer P4 and the device layer D2.

[00127] Subsequently, in a state where the transfer pad 120 attracts and holds the rear surface W2b of the second wafer W2, the transfer pad 120 is raised as shown in **FIG. 28D** to

separate the laser absorption layer P4 from the device layer D2. In the present exemplary embodiment as well, the separation position of the laser absorption layer P4 may be adjusted by adjusting the absorption position of the laser beam L, *i.e.*, the separation position of the laser absorption layer P4, as in the case shown in **FIG. 24A** and **FIG. 24B**, and the separation may occur at the interface between the second wafer W2 and the laser absorption layer P4.

[00128] Any of the processing targets shown in **FIG. 25A** to **FIG. 28D** can achieve the same effects as obtained in above-described exemplary embodiments.

[00129] In the combined wafer T processed in the above-described exemplary embodiment, a reflective film R may be provided between the laser absorption layer P and the device layer D2 as shown in **FIG. 29**. That is, the reflective film R is formed on a surface of the laser absorption layer P opposite to an incident surface of the laser beam L. As the reflective film R, a material, *e.g.*, a metal film, having a high reflectance to the laser beam L and a high melting point is used. The device layer D2 is a functional layer and is different from the reflective film R.

[00130] In this case, the laser beam L output from the laser radiation unit 110 is transmitted through the second wafer W2 and is almost completely absorbed by the laser absorption layer P. However, even if there is a laser beam L that cannot be completely absorbed, the laser beam L is reflected by the reflective film R. As a result, the laser beam L does not reach the device layer D2. Therefore, it is possible to reliably suppress damage to the device layer D2.

[00131] Further, the laser beam L reflected by the reflective film R is absorbed by the laser absorption layer P. Therefore, it is possible to improve the separation efficiency of the second wafer W2.

[00132] The exemplary embodiments disclosed herein are illustrative in all aspects and do not limit the present disclosure. The above-described exemplary embodiments may be omitted,

WE CLAIM

1. A substrate processing method of transcribing, in a combined substrate in which a first substrate and a second substrate are bonded to each other, a device layer formed on a surface of the second substrate to the first substrate,

wherein a laser beam is radiated in a pulse shape from a rear surface side of the second substrate to a laser absorption layer formed between the second substrate and the device layer.

2. The substrate processing method of Claim 1,

wherein while the combined substrate is rotated, the laser beam is radiated from an outer side to an inner side of the laser absorption layer in a diametrical direction.

3. The substrate processing method of Claim 2,

wherein a rotation speed of the combined substrate is higher when the laser beam is radiated to the inner side of the laser absorption layer in the diametrical direction than when the laser beam is radiated to the outer side.

4. The substrate processing method of Claim 2 or 3,

wherein a frequency of the laser beam is higher when the laser beam is radiated to the outer side of the laser absorption layer in the diametrical direction than when the laser beam is radiated to the inner side.

5. The substrate processing method of any one of Claims 2 to 4,

wherein radiation of the laser beam starts between an outer edge of the second substrate and a bonding edge between the first substrate and the second substrate in the combined substrate.

6. The substrate processing method of Claim 1, further comprising:

scanning the laser absorption layer with the laser beam radiated to the laser absorption layer; and

moving the combined substrate,

wherein the scanning of the laser absorption layer with the laser beam and the moving of the combined substrate are repeatedly performed.

7. The substrate processing method of Claim 1,

wherein while the combined substrate is moved, the laser absorption layer is scanned with the laser beam radiated to the laser absorption layer.

8. The substrate processing method of Claim 1,

wherein the laser beam is radiated to an outer peripheral portion of the laser absorption layer while the combined substrate is rotated, and

a central portion on an inner side of the outer peripheral portion in a diametrical direction is scanned with the laser beam in a state where rotation of the combined substrate is stopped.

9. The substrate processing method of any one of Claims 1 to 8,

wherein an absorption position of the laser beam in the laser absorption layer is adjusted by controlling an energy density of the laser beam.

10. The substrate processing method of any one of Claims 1 to 9,

wherein when the laser beam is radiated to the laser absorption layer, the laser beam is oscillated in the pulse shape from a laser oscillator toward an optical element, and the optical element adjusts a frequency of the laser beam.

11. The substrate processing method of Claim 10,

wherein a pulse waveform of the laser beam from the laser oscillator is identical to a pulse waveform of the laser beam radiated to the laser absorption layer.

12. The substrate processing method of Claim 10 or 11,

wherein a frequency of the laser beam from the laser oscillator is a highest frequency that is allowed to be controlled by the optical element.

13. The substrate processing method of any one of Claims 10 to 12,

wherein when the laser beam is radiated to the laser absorption layer, an attenuator attenuates the laser beam from the laser oscillator.

14. The substrate processing method of any one of Claims 1 to 13,

wherein a reflective film is formed on a surface of the laser absorption layer opposite to an incident surface of the laser beam,

in the laser beam radiated to the laser absorption layer, the laser beam not absorbed by the laser absorption layer is reflected by the reflective film, and

the laser beam reflected by the reflective film is absorbed by the laser absorption layer.

15. A substrate processing apparatus configured to transcribe, in a combined substrate in which a first substrate and a second substrate are bonded to each other, a device layer formed on a surface of the second substrate to the first substrate, the apparatus comprising:

a holder configured to hold a rear surface of the first substrate; and

a laser radiation unit configured to radiate a laser beam in a pulse shape from a rear surface side of the second substrate to a laser absorption layer formed between the second substrate and the device layer in a state where the holder holds the first substrate.

16. The substrate processing apparatus of Claim 15, further comprising:

a rotation mechanism configured to rotate the holder; and

a controller configured to control the rotation mechanism and the laser radiation unit,

wherein the controller controls the rotation mechanism and the laser radiation unit to radiate the laser beam from an outer side to an inner side of the laser absorption layer in a diametrical direction while the holder holding the combined substrate is rotated.

17. The substrate processing apparatus of Claim 16,

wherein the controller controls the rotation mechanism and the laser radiation unit to radiate the laser beam in a spiral shape to the laser absorption layer.

18. The substrate processing apparatus of Claim 16 or 17,

wherein the controller controls the rotation mechanism and the laser radiation unit to make a rotation speed of the combined substrate higher when the laser beam is radiated to the inner side of the laser absorption layer in the diametrical direction than when the laser beam is radiated to the outer side.

19. The substrate processing apparatus of any one of Claims 16 to 18,

wherein the controller controls the rotation mechanism and the laser radiation unit to make a frequency of the laser beam higher when the laser beam is radiated to the outer side of the laser absorption layer in the diametrical direction than when the laser beam is radiated to the inner side.

20. The substrate processing apparatus of any one of Claims 16 to 19,

wherein the controller controls the laser radiation unit to start radiation of the laser beam between an outer edge of the second substrate and a bonding edge between the first substrate and the second substrate in the combined substrate.

21. The substrate processing apparatus of Claim 15, further comprising:

a movement mechanism configured to move the holder; and

a controller configured to control the movement mechanism and the laser radiation unit,

wherein the laser radiation unit radiates the laser beam to the laser absorption layer while scanning the laser absorption layer with the laser beam, and

the controller controls the movement mechanism and the laser radiation unit to sequentially and repeatedly perform scanning the laser absorption layer with the laser beam radiated to the laser absorption layer and moving the holder.

22. The substrate processing apparatus of Claim 15, further comprising:

a movement mechanism configured to move the holder; and

a controller configured to control the movement mechanism and the laser radiation unit,

wherein the laser radiation unit radiates the laser beam to the laser absorption layer while scanning the laser absorption layer with the laser beam, and

the controller controls the movement mechanism and the laser radiation unit to scan the laser absorption layer with the laser beam radiated to the laser absorption layer while moving the holder.

23. The substrate processing apparatus of Claim 15, further comprising:

a rotation mechanism configured to rotate the holder;

a movement mechanism configured to move the holder; and

a controller configured to control the rotation mechanism, the movement mechanism and the laser radiation unit,

wherein the laser radiation unit radiates the laser beam to the laser absorption layer while scanning the laser absorption layer with the laser beam, and

the controller controls the rotation mechanism, the movement mechanism and the laser radiation unit to radiate the laser beam to an outer peripheral portion of the laser absorption layer while the combined substrate is rotated and to scan a central portion on an inner side of the outer peripheral portion in a diametrical direction with the laser beam in a state where rotation of the combined substrate is stopped.

24. The substrate processing apparatus of any one of Claims 15 to 23, further comprising:

a controller configured to control the laser radiation unit,

wherein the controller adjusts an absorption position of the laser beam in the laser absorption layer by controlling an energy density of the laser beam.

25. The substrate processing apparatus of any one of Claims 15 to 24, further comprising:

a controller configured to control the laser radiation unit,

wherein the laser radiation unit includes:

a laser oscillator configured to oscillate the laser beam in the pulse shape; and

an optical element configured to divert the laser beam from the laser oscillator in a different direction, and

wherein the controller controls the optical element to adjust a frequency of the laser beam radiated to the laser absorption layer.

26. The substrate processing apparatus of Claim 25,

wherein a pulse waveform of the laser beam from the laser oscillator is identical to a pulse waveform of the laser beam radiated to the laser absorption layer.

27. The substrate processing apparatus of Claim 25 or 26,

wherein a frequency of the laser beam from the laser oscillator is a highest frequency that is allowed to be controlled by the optical element.

28. The substrate processing apparatus of any one of Claims 25 to 27,

wherein the laser radiation unit includes an attenuator configured to attenuate the laser beam from the laser oscillator.

29. The substrate processing apparatus of any one of Claims 25 to 28,

wherein the optical element is an acousto-optic modulator.