

DESCRIPTION

Title of Invention

SEMICONDUCTOR DIE PICK-UP APPARATUS AND SEMICONDUCTOR DIE PICK-UP METHOD

Technical Field

[0001]

The present invention relates to a structure of a semiconductor die pick-up apparatus used in a bonding apparatus, as well as to a semiconductor die pick-up method.

Background Art

[0002]

A semiconductor die is manufactured by dicing a 6-inch or 8-inch wafer into dies of a predetermined size. In order to prevent the diced semiconductor dies from falling apart during dicing, a dicing sheet is applied to a back surface of the wafer, and the wafer is cut from a front surface using a dicing saw or the like. At this time, the dicing sheet applied to the back surface holds the semiconductor dies in a state in which the sheet is slightly cut in but not cut off. Then, the diced semiconductor dies are picked up one by one from the dicing sheet, and transferred to a subsequent step such as die bonding.

[0003]

There is proposed a method of picking up a semiconductor die from a dicing sheet in which a dicing sheet is suctioned to a surface of a disc-shaped suction piece, a semiconductor die is plunged up by a plunge-up block provided at a central portion of the suction piece while the semiconductor die is suctioned to a collet, and the collet is moved upward to pick up the semiconductor die from the dicing sheet (cf., Fig. 9 through Fig. 23 of PTL 1). In order to separate the semiconductor die from the dicing sheet, it is effective to first separate a periphery portion of the semiconductor die, and then separate a central portion of the semiconductor die. Therefore, the conventional technique described in PTL 1 provides three plunge-up blocks: one for plunging up a portion around the semiconductor die, another for plunging up a central portion of the semiconductor die, and the last one for plunging up a middle portion between the earlier two portions, and employs a method in which the three blocks are first moved up to a predetermined height, then the blocks for the middle portion and for the central portion are moved up higher than the block for the portion around the semiconductor die, and finally the block for the central portion is moved higher than block for the middle portion.

[0004]

There is also proposed a method of separating a dicing sheet from a semiconductor die in which the dicing sheet is

suctioned to a surface of a disc-shaped ejector cap, a collet and a peripheral, a middle, and a central plunge-up blocks are moved up to a predetermined height higher than surface of the ejector cap while the semiconductor die is suctioned to the collet, then the height of the collet is maintained as it is, and the peripheral and the middle plunge-up blocks are moved down in order to a position lower than the surface of the ejector cap to separate the dicing sheet from the semiconductor die (cf., PTL 2).

[0005]

When a dicing sheet is separated from a semiconductor die by the method described in PTL 1 or 2, as illustrated in Figs. 40, 42, and 44 of PTL 1, and in Fig. 4A to Fig. 4d, and Fig. 5A to Fig. 5d of PTL 2, there is a case in which the semiconductor die is deformed and flexed along with the dicing sheet while the semiconductor die remains sticking to the dicing sheet before the semiconductor die is separated. If the separation of the dicing sheet is continued in the state in which the semiconductor die is deformed and flexed, the semiconductor die may likely be destroyed. Therefore, there is proposed a method, as illustrated in Fig. 31 of PTL 1, in which flexion of the semiconductor die is detected based on a change of a flow rate of suctioned air from the collet, and that as illustrated in Fig. 43 of PTL 1, it is determined that the semiconductor die is deformed when a suctioned air flow is detected, and the

plunge-up block is moved downward once and then moved upward again.

Citation List

Patent Literature

[0006]

PTL 1: Japanese Patent No. 4945339

PTL 2: US Patent No. 8092645

Summary of Invention

Technical Problem

[0007]

Incidentally, recent semiconductor dies have become increasingly thin, and some of such semiconductor dies are on the order of 20 μm , for example. In contrast, a thickness of a dicing sheet is on the order of 100 μm , which is four to five times greater than that of a semiconductor die. When such a thin semiconductor die is separated from a dicing sheet, the semiconductor die become more markedly susceptible to deformation following deformation of the dicing sheet. Therefore, the conventional technique described in PTLs 1 or 2 has a problem that a semiconductor die is more likely damaged when the semiconductor die is picked up from a dicing sheet.

[0008]

Thus, an object of the present invention is to allow picking up of a semiconductor die effectively while reducing occurrence of damages to the semiconductor die.

Solution to Problem

[0009]

A semiconductor die pick-up apparatus according to the present invention includes: a stage having a suction surface for suctioning a back surface of a dicing sheet with a front surface to which a semiconductor die to be picked up is applied; a stepped-surface forming mechanism configured to form a stepped surface for the suction surface, the stepped-surface forming mechanism having a plurality of moving elements disposed in an opening provided in the suction surface of the stage, the moving elements being movable between a first position and a second position, the first position being a position at which tip end surfaces of the moving elements are higher than the suction surface, the second position being a position at which the tip end surfaces of the moving elements are lower than the first position; and an opening pressure switch mechanism configured to switch an opening pressure of the opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure, wherein when the semiconductor die is picked up, at least one of the moving elements is moved from the first position to the second

position every time the opening pressure is switched from the first pressure to the second pressure.

[0010]

It is preferable that the semiconductor die pick-up apparatus according to the present invention includes: a suction pressure switch mechanism configured to switch a suction pressure of the suction surface between a third pressure that is near vacuum and a fourth pressure that is near the atmospheric pressure, wherein when the semiconductor die is picked up, the opening pressure is switched in a state in which the suction pressure is switched from the fourth pressure to the third pressure.

[0011]

It is preferable that the semiconductor die pick-up apparatus according to the present invention is configured such that when the semiconductor die is picked up, the opening pressure is switched while the suction pressure is maintained at the third pressure.

[0012]

It is preferable that the semiconductor die pick-up apparatus according to the present invention is configured such that when the semiconductor die is picked up, at least one of the moving elements is moved from the first position to the second position every time the suction pressure is switched from the third pressure to the fourth pressure and the opening

pressure is switched from the first pressure to the second pressure after the opening pressure is switched from the second pressure to the first pressure in a state in which the suction pressure is switched from the fourth pressure to the third pressure.

[0013]

It is preferable that the semiconductor die pick-up apparatus according to the present invention includes: a separation detection means configured to detect whether or not a portion of the semiconductor die facing against any of the tip end surfaces of the moving elements that has moved from the first position to the second position is separated from the front surface of the dicing sheet, wherein when the separation detection means has detected that the portion of the semiconductor die is unseparated from the dicing sheet, the opening pressure is switched from the first pressure to the second pressure without moving the moving elements from the first position to the second position, and then again the opening pressure is switched from the second pressure to the first pressure.

[0014]

It is preferable that the semiconductor die pick-up apparatus according to the present invention includes: a collet configured to suction a semiconductor die; a suctioning mechanism connected to the collet, and configured to suction

air from a surface of the collet; and a flow rate sensor configured to detect an amount of air flow suctioned by the suctioning mechanism, wherein the separation detection means determines that separation is successful when a number of times that a derivative signal changes over a predetermined threshold range is an even number, and determines that the separation is unsuccessful when the number of times is an odd number, the derivative signal being obtained by derivation of a signal of the amount of suctioned air flow detected by the flow rate sensor.

[0015]

It is preferable that the semiconductor die pick-up apparatus according to the present invention includes: a sheet displacement detection sensor configured to detect displacement of the dicing sheet between an inner surface of the opening of the stage and an outer circumference surface of the stepped-surface forming mechanism, the displacement being in an approaching and departing direction with respect to the suction surface, wherein if the sheet displacement detected by the sheet displacement detection sensor is a predetermined threshold value or smaller when the opening pressure is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure, the dicing sheet between the inner surface of the opening of the

stage and the outer circumference surface of the stepped-surface forming mechanism is separated from the semiconductor chip by switching the suction pressure from the third pressure to the fourth pressure and the opening pressure from the first pressure to the second pressure, and thereafter switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is again switched from the fourth pressure to the third pressure. It is also preferable that the semiconductor die pick-up apparatus according to the present invention is configured such that the sheet displacement detection sensor uses, as a light source, light of a wavelength whose light transmission rate through the dicing sheet is in a range from 0% to 30%, or that the sheet displacement detection sensor employs a reflection-type optical fiber using an LED of a short wavelength from 0 nm to 300 nm as a light source.

[0016]

It is preferable that the semiconductor die pick-up apparatus according to the present invention is configured such that the stepped-surface forming mechanism includes: a columnar moving element that is disposed in a center; a plurality of annular moving elements arranged around the columnar moving element in a telescopical manner; and a slider movable in a direction along the suction surface within the opening of the stage, each of the annular moving elements includes an inclined

surface that is in contact with the slider, and with which corresponding one of the annular moving elements moves between the first position and the second position based on movement of the slider, and the inclined surface of one of the annular moving elements on an outer circumference side and a different inclined surface of a different one of the annular moving elements on an inner circumference side are arranged in a displaced manner in a moving direction of the slider so that when the slider moves, a tip end surface of the annular moving element on the outer circumference side moves from the first position to the second position before a tip end surface of the different annular moving element on the inner circumference sided moves.

[0017]

It is preferable that the semiconductor die pick-up apparatus according to the present invention is configured such that the columnar moving element includes an inclined surface that is in contact with the slider, and with which the columnar moving element moves between the first position and the second position, and the inclined surface is disposed in a displaced manner in the moving direction of the slider so that when the slider moves, the tip end surface of the annular moving element on the inner circumference side moves from the first position to the second position before a tip end surface of the columnar moving element moves.

[0018]

It is preferable that the semiconductor die pick-up apparatus according to the present invention is configured such that the stepped-surface forming mechanism includes: a slider movable in a direction along the suction surface within the opening of the stage, a plurality of plated moving elements arranged side by side in a moving direction of the slider, each of the plated moving elements includes an inclined surface that is in contact with the slider, and with which corresponding one of the plated moving elements moves between the first position and the second position based on movement of the slider, and the inclined surfaces of the plated moving elements are arranged in a displaced manner in the moving direction of the slider so that the corresponding plated moving elements sequentially move from the first position to the second position along the moving direction of the slider.

[0019]

A semiconductor die pick-up method according to the present invention includes: a step of preparing a semiconductor die pick-up apparatus including: a stage having a suction surface for suctioning a back surface of a dicing sheet with a front surface to which a semiconductor die to be picked up is applied; a stepped-surface forming mechanism configured to form a stepped surface for the suction surface, the stepped-surface forming mechanism having a plurality of moving

elements disposed in an opening provided in the suction surface of the stage, the moving elements being movable between a first position and a second position, the first position being a position at which tip end surfaces of the moving elements are higher than the suction surface, the second position being a position at which the tip end surfaces of the moving elements are lower than the first position; an opening pressure switch mechanism configured to switch an opening pressure of the opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure; and a suction pressure switch mechanism configured to switch a suction pressure of the suction surface between a third pressure that is near vacuum and a fourth pressure that is near the atmospheric pressure; a positioning step of, assuming that a tip end surface of each of the moving elements of the stepped-surface forming mechanism is at the first position, moving the stage in a direction along the suction surface so that the semiconductor die to be picked up comes immediately above the stepped surface of the stepped-surface forming mechanism; a first-separation step of separating the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism from the semiconductor chip by switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to

the third pressure; and a second-separation step of separating a portion of the semiconductor die from the surface of the dicing sheet by moving at least one of the moving elements from the first position to the second position every time the opening pressure is switched from the first pressure to the second pressure in a state in which the suction pressure is maintained at the third pressure, the portion of the semiconductor die facing against the tip end surface of the at least one moving element. Further, it is preferable that the opening pressure switch mechanism switches the opening pressure for a plurality of times between the first pressure and the second pressure, before any of the moving elements is first moved from the first position to the second position.

[0020]

A semiconductor die pick-up method according to the present invention includes: a step of preparing a semiconductor die pick-up apparatus including: a stage having a suction surface for suctioning a back surface of a dicing sheet with a front surface to which a semiconductor die to be picked up is applied; a stepped-surface forming mechanism configured to form a stepped surface for the suction surface, the stepped-surface forming mechanism having a plurality of moving elements disposed in an opening provided in the suction surface of the stage, the moving elements being movable between a first position and a second position, the first position being a

position at which tip end surfaces of the moving elements are higher than the suction surface, the second position being a position at which the tip end surfaces of the moving elements are lower than the first position; an opening pressure switch mechanism configured to switch an opening pressure of the opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure; and a suction pressure switch mechanism configured to switch a suction pressure of the suction surface between a third pressure that is near vacuum and a fourth pressure that is near the atmospheric pressure; a positioning step of, assuming that a tip end surface of each of the moving elements of the stepped-surface forming mechanism is at the first position, moving the stage in a direction along the suction surface so that the semiconductor die to be picked up comes immediately above the stepped surface of the stepped-surface forming mechanism; a first-separation step of separating the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism from the semiconductor chip by switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure; and a third-separation step of separating a portion of the semiconductor die from the surface of the dicing sheet by moving at least one of the moving elements from the

first position to the second position every time the suction pressure is switched from the third pressure to the fourth pressure and the opening pressure is switched from the first pressure to the second pressure after the opening pressure is switched from the second pressure to the first pressure in a state in which the suction pressure is switched from the fourth pressure to the third pressure, the portion of the semiconductor die facing against the tip end surface of the at least one moving element. Further, it is preferable that the opening pressure switch mechanism switches the opening pressure for a plurality of times between the first pressure and the second pressure, before any of the moving elements is first moved from the first position to the second position.

[0021]

It is preferable that the semiconductor die pick-up method according to the present invention is configured such that the semiconductor die pick-up apparatus includes a sheet displacement detection sensor configured to detect displacement of the dicing sheet between an inner surface of the opening of the stage and an outer circumference surface of the stepped-surface forming mechanism, the displacement being in an approaching and departing direction with respect to the suction surface, and the first separation step includes: a first separation determination step of determining when the opening pressure is switched from the second pressure to the first

pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure, that the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is separated from the semiconductor chip if the sheet displacement detected by the sheet displacement detection sensor exceeds a predetermined threshold value, and that the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is unseparated from the semiconductor chip if the sheet displacement detected by the sheet displacement detection sensor is the predetermined threshold value or smaller; and a first retry step of separating the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism from the semiconductor chip, when the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is determined to be unseparated from the semiconductor chip in the first determination step, by switching the suction pressure from the third pressure to the fourth pressure and the opening pressure from the first pressure to the second pressure, and thereafter switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the

suction pressure is again switched from the fourth pressure to the third pressure. Further, it is also preferable that the sheet displacement detection sensor uses, as a light source, light of a wavelength whose light transmission rate through the dicing sheet is in a range from 0% to 30%, or that the sheet displacement detection sensor employs a reflection-type optical fiber using an LED of a short wavelength from 0 nm to 300 nm as a light source.

[0022]

It is preferable that the semiconductor die pick-up method according to the present invention is configured such that the semiconductor die pick-up apparatus includes: a collet configured to suction a semiconductor die; a suctioning mechanism connected to the collet, and configured to suction air from a surface of the collet; and a flow rate sensor configured to detect an amount of air flow suctioned by the suctioning mechanism, and

the second-separation step includes: a second separation determination step of determining that the portion of the semiconductor die facing against the tip end surface of the moving element that has moved from the first position to the second position is separated from the front surface of the dicing sheet when a number of times that a derivative signal changes over a predetermined threshold range is an even number, and determining that the portion of the semiconductor die is

unseparated from the front surface of the dicing sheet when the number of times is an odd number, the derivative signal being obtained by derivation of a signal of the amount of suctioned air flow detected by the flow rate sensor; and a second retry step of separating the portion of the semiconductor die from the front surface of the dicing sheet, when the portion of the semiconductor die is determined to be unseparated from the front surface of the dicing sheet in the second separation determination step, by switching the opening pressure from the first pressure to the second pressure without moving the moving element from the first position to the second position, and again switching the opening pressure from the second pressure to the first pressure.

[0023]

It is preferable that the semiconductor die pick-up method according to the present invention is configured such that the semiconductor die pick-up apparatus includes: a collet configured to suction a semiconductor die; a suctioning mechanism connected to the collet, and configured to suction air from a surface of the collet; and a flow rate sensor configured to detect an amount of air flow suctioned by the suctioning mechanism, and the third-separation step includes: a third separation determination step of determining that the portion of the semiconductor die facing against the tip end surface of the moving element that has moved from the first

position to the second position is separated from the front surface of the dicing sheet when a number of times that a derivative signal changes over a predetermined threshold range is an even number, and determining that the portion of the semiconductor die is unseparated from the front surface of the dicing sheet when the number of times is an odd number, the derivative signal being obtained by derivation of a signal of the amount of suctioned air flow detected by the flow rate sensor; and a third retry step of separating the portion of the semiconductor die from the front surface of the dicing sheet, when the portion of the semiconductor die is determined to be unseparated from the front surface of the dicing sheet in the third separation determination step, by switching the suction pressure from the third pressure to the fourth pressure and the opening pressure from the first pressure to the second pressure without moving the moving element from the first position to the second position, and again switching the suction pressure from the fourth pressure to the third pressure and the opening pressure from the second pressure to the first pressure.

Advantageous Effects of Invention

[0024]

The present invention provides an effect of picking up of a semiconductor die effectively while reducing occurrence of damages to the semiconductor die.

Brief Description of Drawings

[0025]

Fig. 1 is a diagram illustrating a system configuration of a semiconductor die pick-up apparatus according to an embodiment of the present invention.

Fig. 2 is a perspective view illustrating a stage of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 3A is a perspective view illustrating moving elements of a stepped-surface forming mechanism of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 3B is a perspective view illustrating a moving element of the stepped-surface forming mechanism of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 4A is a side view illustrating a stepped-surface forming mechanism of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 4B is a diagram illustrating a slider and linear cam surfaces of the moving elements of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 5 is a diagram illustrating a wafer applied to a dicing sheet.

Fig. 6 is a diagram illustrating a semiconductor die applied to the dicing sheet.

Fig. 7A is a plan view illustrating a configuration of a wafer holder.

Fig. 7B is an elevational view illustrating the configuration of the wafer holder.

Fig. 8 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 9 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 10 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 11 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 12 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 13 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 14 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 15 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 16 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 17 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 18 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 19 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 20A is a chart showing a temporal change in a height of a collet during the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 20B is a chart showing a temporal change in a position of a middle annular moving element during the operation of the

semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 20C is a chart showing a temporal change in a position of a peripheral annular moving element during the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 20D is a chart showing a temporal change in a suction pressure of the stage during the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 20E is a chart showing a temporal change in an opening pressure during the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 20F is a chart showing a temporal change in an amount of leaked air of the collet during the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 21A is a chart showing a temporal change in the amount of leaked air of the collet when separation is successful during an operation in a separation determination step of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 21B is a chart showing a temporal change in a derivative value of the amount of leaked air of the collet when separation is successful during the operation in the separation

determination step of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 21C is a chart showing a temporal change in the amount of leaked air of the collet when separation is unsuccessful during the operation in the separation determination step of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 21D is a chart showing a temporal change in the derivative value of the amount of leaked air of the collet when separation is unsuccessful during the operation in the separation determination step of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22A is a chart showing a temporal change in a height of a collet during a different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22B is a chart showing a temporal change in a position of a middle annular moving element during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22C is a chart showing a temporal change in a position of a peripheral annular moving element during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22D is a chart showing a temporal change in a suction pressure of the stage during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22E is a chart showing a temporal change in an opening pressure during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22F is a chart showing a temporal change in an amount of leaked air of the collet during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 23A is a chart showing a temporal change in a height of a collet during a different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 23B is a chart showing a temporal change in a position of a middle annular moving element during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 23C is a chart showing a temporal change in a position of a peripheral annular moving element during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 23D is a chart showing a temporal change in a suction pressure of the stage during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 23E is a chart showing a temporal change in an opening pressure during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 23F is a chart showing a temporal change in an amount of leaked air of the collet during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 24 is a perspective view illustrating the stage and different moving elements of a stepped-surface forming mechanism of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 25 is a perspective view illustrating a stage and moving elements of a stepped-surface forming mechanism of a semiconductor die pick-up apparatus according to a different embodiment of the present invention.

Fig. 26 is a diagram for illustration of an operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 27 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 28 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 29 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 30 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 31 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 32 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 33 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 34 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 35 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 36 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 37 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38A is a chart showing a temporal change in a height of a collet during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38B is a chart showing a temporal change in a position of a first plated moving element during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38C is a chart showing a temporal change in a position of a second plated moving element during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38D is a chart showing a temporal change in a position of a third plated moving element during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38E is a chart showing a temporal change in a suction pressure of the stage during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38F is a chart showing a temporal change in an opening pressure during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Fig. 38G is a chart showing a temporal change in an amount of leaked air of the collet during the operation of the semiconductor die pick-up apparatus according to the different embodiment of the present invention.

Description of Embodiments

[0026]

Hereinafter, a semiconductor die pick-up apparatus according to an embodiment of the present invention will be described with reference to the drawings. Referring to Fig. 1, a semiconductor die pick-up apparatus 500 according to this embodiment includes: a wafer holder 10 moving in a horizontal direction, and holding a dicing sheet 12 having a front surface 12a to which semiconductor dies 15 are applied; a stage 20 disposed under the wafer holder 10 and having a suction surface 22 for suctioning a back surface 12b of the dicing sheet 12; a plurality of moving elements 30 disposed in an opening 23

provided in the suction surface 22 of the stage 20; a stepped-surface forming mechanism 300 for forming a stepped surface for the suction surface 22; a collet 18 for picking up one of the semiconductor dies 15; an opening pressure switch mechanism 80 for switching a pressure of the opening 23 of the stage 20; a suction pressure switch mechanism 90 for switching a suction pressure of the suction surface 22 of the stage 20; a suctioning mechanism 100 for suctioning air from a surface 18a of the collet 18; a vacuum apparatus 140; a horizontal wafer-holder drive unit 110 for driving the wafer holder 10 in the horizontal direction; a vertical stage drive unit 120 for driving the stage 20 in a vertical direction; a collet drive unit 130 for driving the collet 18 in a vertical and horizontal direction; and a controller 150 for controlling driving of the semiconductor die pick-up apparatus 500.

[0027]

The stepped-surface forming mechanism 300 is contained within a base unit 24 as an upper portion of the stage 20, and driven by a motor 77 disposed within a drive unit 25 as a lower portion. The stepped-surface forming mechanism 300 includes: an ellipsoidal cam 75 connected to a shaft 76 of the motor 77; a drive rod 73 connected to a cam follower 74 in contact with the cam 75 and driven in the vertical direction; an L-shaped vertical direction drive member 70 connected to the drive rod 73; a plate member 57 connected to the vertical direction drive

member 70 via a spring 58; a piston 56 attached on an upper side of the plate member 57; a flange 55 attached on an upper surface of the piston 56; a guide rail 54 attached on the flange 55; a slider 51 guided by the guide rail 54 and configured to move within an upper interior 28 of the stage 20 in the horizontal direction so as to move the plurality of moving elements 30 in the vertical direction; and an L-shaped link member 60. The link member 60 is rotatably attached, at a center of a flexed portion thereof, to a pin 59 provided for the plate member 57. A pin 63 attached to a lower edge of the link member 60 is engaged with a groove 72 provided for an arm 71 of the vertical direction drive member 70. Further, a U-shaped groove 62 provided for an upper side of the link member 60 is engaged with a pin 53 of the slider 51. Moreover, the flange 55 is engageable with a stepped portion 29a within a lower interior 29 of the stage 20.

[0028]

In the stepped-surface forming mechanism 300, as the motor 77 of the drive unit 25 rotates in a counterclockwise direction as indicated by an arrow a in Fig. 1, the cam 75 also rotates in the counterclockwise direction as indicated by the arrow a, and the drive rod 73 to which the cam follower 74 in contact with the cam 75 is attached moves upward. With this, the vertical direction drive member 70 moves upward to press the flange 55 against the stepped portion 29a, and the arm 71

of the vertical direction drive member 70 pushes up the pin 63 under the link member 60. The flange 55 to which the guide rail 54 is attached is pressed against the stepped portion 29a within the stage 20 and does not move in the vertical direction. Therefore, as indicated by an arrow c in Fig. 1, the link member 60 rotates in a clockwise direction about the pin 59 of the plate member 57, and the groove 62 at the tip end causes the pin 53 of the slider 51 to slide rightward along the suction surface 22 as indicated by an arrow A in Fig. 1. As the slider 51 moves in the direction indicated by the arrow A, tip end surfaces of the plurality of moving elements 30 move downward as indicated by an arrow e in Fig. 1. The moving elements 30 will be described later in detail.

[0029]

The opening pressure switch mechanism 80 for switching a pressure of the opening 23 of the stage 20 includes a three-way valve 81, and a drive unit 82 for driving to open or close the three-way valve 81. The three-way valve 81 has three ports. A first port is connected to the base unit 24 communicated with the opening 23 of the stage 20 via a piping 83, a second port is connected to the vacuum apparatus 140 via a piping 84, and a third port is connected to a piping 85 open to air. The drive unit 82 either sets a pressure of the opening 23 to a first pressure P_1 that is near vacuum by making the first port be communicated with the second port and blocking the third port,

or sets the pressure of the opening 23 to a second pressure P_2 that is near atmospheric pressure by making the first port be communicated with the third port and blocking the second port. In this manner, the drive unit 82 switches the pressure of the opening 23 between the first pressure P_1 and the second pressure P_2 .

[0030]

Similarly to the opening pressure switch mechanism 80, the suction pressure switch mechanism 90 that switches a suction pressure of the suction surface 22 of the stage 20 includes a three-way valve 91 having three ports, and a drive unit 92 for driving to open or close the three-way valve 91. A first port of the three-way valve 91 is connected to a suction hole 27 communicated with grooves 26 of the stage 20 via a piping 93, a second port of the three-way valve 91 is connected to the vacuum apparatus 140 via a piping 94, and a third port is connected to a piping 95 open to air. The drive unit 92 either sets a pressure of the grooves 26 or the suction surface 22 to the third pressure P_3 that is near vacuum by making the first port be communicated with the second port and blocking the third port, or sets the pressure of the groove 26 or the suction surface 22 to a fourth pressure P_4 that is near atmospheric pressure by making the first port be communicated with the third port and blocking the second port. In this manner, the drive unit

92 switches the pressure of the grooves 26 or the suction surface 22 between the third pressure P_3 and the fourth pressure P_4 .
[0031]

Similarly to the opening pressure switch mechanism 80, the suctioning mechanism 100 suctioning air from the surface 18a of the collet 18 includes a three-way valve 101 having three ports, and a drive unit 102 for driving to open or close the three-way valve 101, and suctions air from the surface 18a through a suction hole 19 of the collet 18 to vacuumize the surface 18a of the collet 18. To a piping 103 that connects the suction hole 19 of the collet 18 and the three-way valve 101, a flow rate sensor 106 that detects an amount of an air flow suctioned to the vacuum apparatus 140 from the surface 18a of the collet 18 is attached.

[0032]

The horizontal wafer-holder drive unit 110, the vertical stage drive unit 120, and the collet drive unit 130 are units respectively for driving the wafer holder 10, the stage 20, and the collet 18, each in the horizontal direction or in the vertical direction by a motor and gear provided inside. Further, as illustrated in Fig. 1 and Fig. 4A, in a gap d between an inner surface 23a of the opening 23 of the stage 20 and an outer circumference surface 33 of the moving elements 30, a sheet displacement detection sensor 107 for detecting displacement of the dicing sheet 12 in an approaching and departing direction

with respect to the suction surface 22 is attached. Preferably, irradiation light from a light source of the sheet displacement detection sensor 107 is light having a high reflection rate that can not influence qualities of a dicing sheet, a die attach film between the dicing sheet and a die, and an adhesive layer of the die attach film, for example, short-wavelength light from 0 nm to 300 nm whose light transmission rate through the dicing sheet is from 0% to 30%. More preferably, the irradiation light is light from 100 nm to 300 nm, and most preferably, light using a reflection-type optical fiber having a LED of light from 200 nm to 300 nm or a blue LED as a light source. Further, while an example in which a reflection-type optical fiber is used is described in this embodiment, other types of sensors can be used as long as light having a high reflection rate through the dicing sheet can be emitted.

[0033]

The controller 150 is a computer having a CPU 151 that performs arithmetic processing, a memory unit 152, and a device/sensor interface 153. The CPU 151, the memory unit 152, and the device/sensor interface 153 are connected via a data bus 154. In the memory unit 152, a control program 155, a control data 156, a positioning program 157, a first separation program 158, a second separation program 159, and a third separation program 160 are stored.

[0034]

The drive unit 82 of the three-way valve 81 of the opening pressure switch mechanism 80, the drive unit 92 of the three-way valve 91 of the suction pressure switch mechanism 90, the drive unit 102 of the three-way valve 101 of the suctioning mechanism 100, the motor 77 of the stepped-surface forming mechanism 300, the horizontal wafer-holder drive unit 110, the vertical stage drive unit 120, the collet drive unit 130, and the vacuum apparatus 140 are connected to the device/sensor interface 153, and driven by commands from the controller 150, respectively. Further, the flow rate sensor 106 and the sheet displacement detection sensor 107 are connected to the device/sensor interface 153, and their detection signals are input to and processed by the controller 150. [0035]

Next, the suction surface 22 of the stage 20 and the moving elements 30 will be described in detail with reference to Fig. 2 through 4. As illustrated in Fig. 2, the stage 20 is cylindrical, and the planar suction surface 22 is provided on an upper surface of the stage 20. In the center of the suction surface 22, the square opening 23 is provided, and the moving elements 30 are attached to the opening 23 as illustrated in Fig. 3 and Fig. 4. As illustrated in Fig. 4A, the gap d is provided between the opening 23 and the outer circumference surface 33 of the moving elements 30. Around the opening 23, grooves 26 are doubly provided so as to enclose the opening 23.

Each of the grooves 26 includes the suction holes 27 that are connected to the suction pressure switch mechanism 90.

[0036]

As illustrated in Fig. 3A, the moving elements 30 is configured by a columnar annular moving element 45 that is disposed in a center, and a plurality of annular moving elements 31 and 40-43 that are arranged around the columnar annular moving element 45. As illustrated in Fig. 3A, the plurality of annular moving elements 31 and 40-43 are arranged around the columnar annular moving element 45 disposed in the center in a telescopic manner. Next, a configuration of the peripheral annular moving element 31 arranged at an outermost circumference will be described with reference to Fig. 3B. The peripheral annular moving element 31 includes a square annular member 33a having a width W_1 , a depth (longitudinal length) D_1 , and a height T_1 , and support plates 333a that project respectively under two facing sides of the annular member 33a. Both sides of each of the support plates 333a in the longitudinal direction respectively constitute guide surfaces 32a and 34a that are vertical to a tip end surface 38a of the annular member 33a, and extend in the vertical direction. As illustrated in Fig. 4A, each of the guide surfaces 32a and 34a is in contact with a vertical inner surface 28a of the upper interior 28 of the stage 20, and guides the peripheral annular moving element 31 in the vertical direction. On a lower surface of the support

plate 333a, there are provided a linear cam surface 35a as an inclined surface, and horizontal support surfaces 36a and 39a connected to the linear cam surface 35a and extend horizontally in the longitudinal direction. As illustrated in Fig. 4B, the horizontal support surface 36a is higher than the horizontal support surface 39a by a height H_2 . The linear cam surface 35a and the horizontal support surface 36a and 39a are surfaces that move while in contact with an apex 52a of a semi-columnar member 52 attached to an upper end of the slider 51, as illustrated in Fig. 4A and Fig. 4B. Further, on a side of the guide surface 34a of the support plate 333a (an end of the slider 51 in a moving direction indicated by arrows A in Fig. 4A and Fig. 4B), there is provided a hook portion 37a with which the semi-columnar member 52 of the slider 51 is engaged to fix the peripheral annular moving element 31.

[0037]

The middle annular moving elements 40-43 arranged between the columnar annular moving element 45 and the peripheral annular moving element 31 are configured in the same manner as the peripheral annular moving element 31, and a width W and a depth (longitudinal length) D of each of the annular members 33b-33e respectively of the middle annular moving elements 40-43 are smaller than dimensions of an annular member on an outer circumference side by a thickness of the annular member on the outer circumference side. As illustrated in Fig. 4A,

the annular members 33a-33e are arranged in a telescopic manner. Further, as illustrated in Fig. 3A, the support plates 333a-333e are arranged in a stacked manner in a width direction. Accordingly, as illustrated in Fig. 3A, the guide surfaces 34a-34e are continuously arranged from the outer circumference side to a central portion in an order of 34a, 34b, 34c, 34d, and 34e to form a single surface. This also applies to the guide surfaces 32a-32e on the other side while not illustrated.

[0038]

As illustrated in Fig. 4A, the linear cam surfaces 35a-35e respectively provided for the peripheral annular moving element 31 and the middle annular moving elements 40-43 are configured such that the more centrally provided the middle annular moving element is, the more corresponding one of the linear cam surfaces 35a-35e is displaced in the moving direction of the slider 51 as indicated by the arrows A in Fig. 4A and Fig. 4B. In other words, as illustrated in Fig. 4B, distances of points i_1 - i_5 at which heights of the linear cam surfaces 35a-35e that are inclined surfaces from the horizontal support surfaces 39a-39e become H_1 from a reference position are L_1 - L_5 ($L_1 > L_2 > L_3 > L_4 > L_5$), respectively. Further, the points j_2 - j_6 on the horizontal support surfaces 36a-36e whose heights of the horizontal support surfaces 39a-39e become H_2 are points at distances L_2 - L_6 ($L_2 > L_3 > L_4 > L_5 > L_6$) from the reference position. As the linear cam surfaces 35a-35e are thus configured, when the

slider 51 moves in the direction indicated by the arrow A in Fig. 4B, the tip end surface 38a of the peripheral annular moving element 31 on the outer circumference side moves from a first position to a second position before tip end surfaces 38b-38e of the middle annular moving elements 40-43 move. Moreover, for the tip end surfaces 38b-38e of the middle annular moving elements 40-43, a tip end surface of a middle annular moving element on the outer circumference side moves from the first position to the second position before a tip end surface of another annular moving element on an inner circumference side moves.

[0039]

As illustrated in Fig. 3A, the columnar annular moving element 45 includes a square columnar member 46 having a width w_2 and a depth (longitudinal length) D_2 , and two support plates 333f respectively connected to lower sides of the columnar member 46. Both sides of each of the support plates 333f in the longitudinal direction respectively constitute guide surfaces 32f and 34f that are in contact with the inner surface 28a, similarly to the annular moving elements 31 and 40-43. Further, as illustrated in Fig. 4A and Fig. 4B, on a lower surface of each of the support plates 333f of the columnar annular moving element 45, a linear cam surface as an inclined surface is not provided, and the horizontal support surface 39f extend in the longitudinal direction (the moving direction of the slider 51).

[0040]

As illustrated in Fig. 4A, when the slider 51 is at an initial position, the columnar annular moving element 45, the peripheral annular moving element 31, and the middle annular moving elements 40-43 are supported by the apex 52a (crest line) of the semi-columnar member 52 attached at an upper portion of the slider 51 being brought into contact with corresponding one of the horizontal support surfaces 39a-39f. The tip end surfaces 47 and 38a-38e respectively of the moving elements 45, 31, and 40-43 are at the first position projecting from the suction surface 22 of the stage 20 by a height H_0 , and constitute a single surface (a surface stepped from the suction surface 22).

[0041]

An operation of the semiconductor die pick-up apparatus 500 thus configured will be described with reference to Fig. 5 through Fig. 20A to Fig. 20F. In the following description, the moving elements 30 are described as three moving elements including a peripheral annular moving element 31, a middle annular moving element 40, and a columnar annular moving element 45. Here, before describing a pick-up operation of a semiconductor die 15, a step of setting the dicing sheet 12 to which the semiconductor dies 15 are applied to the wafer holder 10 will be described.

[0042]

Referring to Fig. 5, on a back surface of a wafer 11, the viscous dicing sheet 12 is applied, and the dicing sheet 12 is attached to a metallic ring 13. In this manner, the wafer 11 is handled while being attached to the metallic ring 13 with the dicing sheet 12 interposed therebetween. Then, as illustrated in Fig. 6, the wafer 11 is diced into the semiconductor dies 15 by being cut in a dicing step from its surface by a dicing saw or the like. Between the semiconductor dies 15, there are cut-in gaps 14 provided during dicing. A depth of the cut-in gaps 14 is as deep as to reach a portion of the dicing sheet 12 through the semiconductor dies 15, but the dicing sheet 12 is not cut off, and the semiconductor dies 15 are held by the dicing sheet 12.

[0043]

In this manner, the semiconductor dies 15 to which the dicing sheet 12 and the ring 13 are attached are attached to the wafer holder 10 as illustrated in Fig. 7A and Fig. 7B. The wafer holder 10 includes an annular expanded ring 16 having a flange, and a ring retainer 17 that fixes the ring 13 on the flange of the expanded ring 16. The ring retainer 17 is driven in the forward-backward direction toward the flange of the expanded ring 16 by a ring retainer drive unit that is not illustrated. An inner diameter of the expanded ring 16 is greater than a diameter of the wafer for the semiconductor dies 15. The expanded ring 16 has a predetermined thickness, and

its flange is disposed outside the expanded ring 16 so as to protrude outwardly on an end surface side away from the dicing sheet 12. Further, an outer circumference of the expanded ring 16 on a side of the dicing sheet 12 is configured to have a curved surface so that the dicing sheet 12 can be smoothly expanded when the dicing sheet 12 is attached to the expanded ring 16. As illustrated in Fig. 7B, the dicing sheet 12 to which the semiconductor dies 15 are applied is substantially flat before the dicing sheet 12 is set to the expanded ring 16.

[0044]

As illustrated in Fig. 1, when set to the expanded ring 16, the dicing sheet 12 is expanded along a curved surface on an upper portion of the expanded ring by an amount of a step between an upper surface and a flange surface of the expanded ring 16. Therefore, outward tension from a center of the dicing sheet 12 is applied to the dicing sheet 12 fixed over the expanded ring 16. Further, as the dicing sheet 12 is expanded by the tension, the gaps 14 between the semiconductor dies 15 applied to the dicing sheet 12 are also expanded.

[0045]

Next, the pick-up operation of the semiconductor die 15 will be described. The controller 150 first executes the positioning program 157 illustrated in Fig. 1. The controller 150 causes the horizontal wafer-holder drive unit 110 to move the wafer holder 10 in the horizontal direction to a standby

position on the stage 20. Then, when the wafer holder 10 is moved to a predetermined position at the standby position on the stage 20, the controller 150 stops movement of the wafer holder 10 in the horizontal direction. As described above, in an initial state, the tip end surfaces 47, 38a, and 38b respectively of the moving elements 45, 31, and 40 are at a first position projecting from the suction surface 22 of the stage 20 by the height H_0 . Therefore, the controller 150 causes the vertical stage drive unit 120 to move the stage 20 upward until the tip end surfaces 47, 38a, and 38b respectively of the moving elements 45, 31, and 40 are brought into close contact with the back surface 12b of the dicing sheet 12, and until a region slightly distant from the opening 23 of the suction surface 22 is brought into close contact with the back surface 12b of the dicing sheet 12. Then, when the tip end surfaces 47, 38a, and 38b of the moving elements 45, 31, and 40 and the region slightly distant from the opening 23 of the suction surface 22 are brought into close contact with the back surface 12b of the dicing sheet 12, the controller 150 stops the upward movement of the stage 20. Thereafter, the controller 150 again causes the horizontal wafer-holder drive unit 110 to adjust a horizontal position so that the semiconductor die 15 to be picked up comes immediately above the tip end surfaces (stepped surface) of the moving elements 30 that slightly projects from the suction surface 22 of the stage 20.

[0046]

As illustrated in Fig. 8, the semiconductor die 15 is smaller than the opening 23 of the stage 20 and larger than the moving elements 30 in width or depth. Therefore, upon completion of the position adjustment of the stage 20, an outer circumferential edge of the semiconductor die 15 is positioned between the inner surface 23a of the opening 23 of the stage 20 and the outer circumference surface 33 of the moving elements 30, that is, immediately above the gap d between the inner surface 23a of the opening 23 and the outer circumference surface 33 of the moving elements 30. In the initial state, the pressure of the grooves 26 or the suction surface 22 of the stage 20 is at the atmospheric pressure, and the pressure of the opening 23 is also at the atmospheric pressure. In the initial state, the tip end surfaces 47, 38a, and 38b respectively of the moving elements 45, 31, and 40 are at the first position projecting from the suction surface 22 of the stage 20 by the height H_0 , and therefore the height of the back surface 12b of the dicing sheet 12 in contact with the tip end surfaces 47, 38a, and 38b is also at the first position projecting from the suction surface 22 by the height H_0 . Further, the back surface 12b of the dicing sheet 12 is slightly lifted from the suction surface 22, at a circumferential edge of the opening 23, and brought into close contact with the suction surface 22 in a region distant from the opening 23. Upon

completion of position adjustment in the horizontal direction, the controller 150 causes the collet drive unit 130 illustrated in Fig. 1 to move the collet 18 down above the semiconductor die 15 and to bring the surface 18a of the collet 18 in contact with the semiconductor die 15. Upon contact of the collet 18 with the semiconductor die 15, the controller 150 causes the drive unit 102 of the suctioning mechanism 100 to switch the three-way valve 101 so that the suction hole 19 of the collet 18 is communicated with the vacuum apparatus 140. With this, the suction hole 19 becomes vacuumized, and the collet 18 suctions and fixes the semiconductor die 15 to the surface 18a (end of the positioning program). At this time, a height of the surface 18a of the collet 18 is a height H_c that is a total value of a height of the tip end surfaces 47, 38a, and 38b respectively of the moving elements 45, 31, and 40 (the height H_0 from the suction surface 22), a thickness of the dicing sheet 12, and a thickness of the semiconductor die 15, as illustrated in Fig. 8.

[0047]

Next, the controller 150 executes the first separation program 158 illustrated in Fig. 1. At time t_1 shown in Fig. 20D, the controller 150 outputs a command for switching the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that is near vacuum. By this command, the drive unit 92 of the suction pressure switch

mechanism 90 switches the three-way valve 91 so that the suction holes 27 are communicated with the vacuum apparatus 140. Then, as indicated by an arrow 201 in Fig. 9, air in the grooves 26 is suctioned by the vacuum apparatus 140 through the suction holes 27, and as illustrated in Fig. 20D, the suction pressure reaches the third pressure P_3 that is near vacuum at time t_2 . Thereafter, the back surface 12b of the dicing sheet 12 along the circumferential edge of the opening 23 is vacuum-suctioned to a front surface of the suction surface 22 as indicated by an arrow 202 in Fig. 9. As the tip end surfaces 47, 38a, and 38b respectively of the moving elements 45, 31, and 40 are at the first position projecting from the suction surface 22 of the stage 20 by the height H_0 , the dicing sheet 12 is applied with an obliquely downward tension F_1 . The tension F_1 can be resolved into a tension F_2 for pulling the dicing sheet 12 in a lateral direction, and a tension F_3 for pulling the dicing sheet 12 in a downward direction. The tension F_2 in the lateral direction produces a shear stress τ between the semiconductor die 15 and the front surface 12a of the dicing sheet 12. With the shear stress τ , displacement occurs between an outer circumferential portion or a periphery portion of the semiconductor die 15 and the front surface 12a of the dicing sheet 12. The displacement serves as a trigger for separation between the dicing sheet 12 and the outer circumferential portion or the periphery portion of the semiconductor die 15.

[0048]

After the suction pressure becomes the third pressure P_3 that is near vacuum at time t_2 as illustrated in Fig. 20D, the controller 150 maintains this pressure for a predetermined time period. Then, as illustrated in Fig. 20E, at time t_3 , the controller 150 outputs a command for switching the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum. By this command, the drive unit 82 of the opening pressure switch mechanism 80 switches the three-way valve 81 so that the opening 23 is communicated with the vacuum apparatus 140. Then, as indicated by an arrow 206 in Fig. 10, air in the opening 23 is suctioned by the vacuum apparatus 140, and as illustrated in Fig. 20E, the opening pressure reaches the first pressure P_1 that is near vacuum at time t_4 . With this, as indicated by an arrow 203 in Fig. 10, the dicing sheet 12 immediately above the gap d between the inner surface 23a of the opening 23 and the outer circumference surface 33 of the moving elements 30 is pulled downward. Further, the periphery portion of the semiconductor die 15 positioned immediately above the gap d is pulled by the dicing sheet 12, and deformed and flexed downward as indicated by an arrow 204. With this, the periphery portion of the semiconductor die 15 moves away from the surface 18a of the collet 18. At time t_2 , when the suction pressure becomes the third pressure P_3 that is near vacuum, as the periphery

portion of the semiconductor die 15 is provided with the trigger for separation from the front surface 12a of the dicing sheet 12 due to displacement occurring between the outer circumferential portion of the semiconductor die 15 and the front surface 12a of the dicing sheet 12, the periphery portion of the semiconductor die 15 starts to separate from the front surface 12a of the dicing sheet 12 as indicated by an arrow 204 in Fig. 10, although being deformed and flexed. Here, as indicated by a dotted line in Fig. 20E, during a period from time t_3 to t_6 , the drive unit 82 of the opening pressure switch mechanism 80 can output a command for switching the opening pressure more than one time between the second pressure P_2 that is near the atmospheric pressure and the first pressure P_1 that is near vacuum. With this, it is possible to further ensure separation of the front surface 12a of the dicing sheet 12 from the semiconductor die 15. [0049]

As illustrated in Fig. 10, as the periphery portion of the semiconductor die 15 moves away from the surface 18a of the collet 18, air enters the suction hole 19 of the collet 18 that is vacuum as indicated by an arrow 205 in Fig. 10. An amount of an entering air flow that has entered (amount of leaked air) is detected by the flow rate sensor 106. As illustrated in Fig. 20E, as the opening pressure decreases from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum from time t_3 to time t_4 , the semiconductor

die 15 is deformed and flexed by being pulled with the dicing sheet 12 in the downward direction. Therefore, as illustrated in Fig. 20F, the amount of leaked air entering the suction hole 19 of the collet 18 increases from time t_3 to time t_4 .

[0050]

As illustrated in Fig. 20E and Fig. 20D, the controller 150 maintains the opening 23 and the grooves 26 or the suction surface 22 of the stage 20 respectively at the first pressure P_1 and the third pressure P_3 that are near vacuum from time t_4 to time t_5 . During this time period, as indicated by an arrow 207 in Fig. 11, the periphery portion of the semiconductor die 15 moves back to the surface 18a of the collet 18 due to vacuum of the suction hole 19 of the collet 18 and elasticity of the semiconductor die 15. As the periphery portion of the semiconductor die 15 moves to the surface 18a of the collet 18, as shown by time t_4 to time t_5 in Fig. 20F, the amount of leaked air entering the suction hole 19 of the collet 18 decreases. As illustrated in Fig. 11, when the semiconductor die 15 is vacuum-suctioned to the surface 18a of the collet 18 at time t_5 , the amount of leaked air becomes zero. At this time, the periphery portion of the semiconductor die 15 is separated from the front surface 12a of the dicing sheet 12 positioned immediately above the gap d (initial separation step). When the initial separation of the periphery portion of the semiconductor die 15 from the front surface 12a of the dicing

sheet 12 occurs, the dicing sheet 12 positioned immediately above the gap d of the opening 23 is displaced in the downward direction. The controller 150 detects the displacement of the dicing sheet 12 in the downward direction (displacement in the approaching and departing direction with respect to the suction surface 22) using the sheet displacement detection sensor 107, and if the detected displacement is over a predetermined threshold value, determines that initial separation of the periphery portion of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 positioned immediately above the gap d has occurred. Further, if the detected displacement is smaller than the predetermined threshold value, the controller 150 determines that initial separation of the periphery portion of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 positioned immediately above the gap d has not occurred (first separation determination step). If it is determined that the initial separation of the periphery portion of the semiconductor die 15 has occurred, the controller 150 moves the process to a separation step that comes next. Alternatively, if it is determined that the initial separation of the periphery portion of the semiconductor die 15 has not occurred, the controller 150 performs a first retry step.

[0051]

In the first retry step, the controller 150 switches the three-way valves 81 and 91 of the opening pressure switch

mechanism 80 and the suction pressure switch mechanism 90 so that air is communicated with the opening 23, and the grooves 26, and sets the opening pressure and the suction pressure to be the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. Thereafter, the controller 150 again switches the three-way valves 81 and 91 of the opening pressure switch mechanism 80 and the suction pressure switch mechanism 90 so that the vacuum apparatus 140 is communicated with the opening 23, and the grooves 26, switches the opening pressure and the suction pressure respectively to the first pressure P_1 and the third pressure P_3 that are near vacuum from the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure, and determines whether or not the displacement detected by the sheet displacement detection sensor 107 is over the predetermined threshold value. Then, if the detected displacement is over predetermined displacement, the controller 150 terminates the first retry step, and moves the process to the next separation step (end of the first separation program).

[0052]

Next, the controller 150 executes the third separation program 160 illustrated in Fig. 1. It should be noted that the second separation program will be described later. As illustrated in Fig. 20E and Fig. 20D, the controller 150 maintains the opening pressure and the suction pressure

respectively at the first pressure P_1 and the third pressure P_3 that are near vacuum for a predetermined time period. Then, at time t_5 , the controller 150 outputs a command for switching the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. By this command, the drive unit 82 of the opening pressure switch mechanism 80 and the drive unit 92 of the suction pressure switch mechanism 90 respectively switch the three-way valves 81 and 91 so that the pipings 85 and 95 open to air are communicated with the opening 23 and the grooves 26. With this, as indicated by arrows 210 and 211 in Fig. 12, air enters the opening 23 and the grooves 26. Therefore, as illustrated in Fig. 20D and Fig. 20F, from time t_5 to time t_6 , the opening pressure and the suction pressure increase respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure.

[0053]

Upon the opening pressure and the suction pressure respectively reaching the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure, the dicing sheet 12 positioned immediately above the gap d and pulled in the downward direction by vacuum moves back upward by the tension applied when being fixed to the wafer holder 10, as

indicated by an arrow 212 in Fig. 12. Further, the dicing sheet 12 around the circumferential edge of the opening 23 is slightly lifted from the suction surface 22 due to the tension described above.

[0054]

When the opening pressure and the suction pressure respectively become the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure at time t_6 as illustrated in Fig. 20E and Fig. 20D, the controller 150 outputs a command for changing the height of the tip end surface 38a of the peripheral annular moving element 31 to a second position that is lower than the first position (the initial position at which the height from the suction surface 22 is H_0) by the height H_1 , as illustrated in Fig. 20C, . By this command, the motor 77 of the drive unit 25 illustrated in Fig. 1 rotates in the counterclockwise direction as indicated by the arrow A in Fig. 1. With this, the link member 60 rotates in the clockwise direction as indicated by the arrow c in Fig. 1, and the slider 51 moves rightward as indicated by the arrow A in Fig. 1.

[0055]

As illustrated in Fig. 4B, in the initial state, the apex 52a of the semi-columnar member 52 attached to the upper portion of the slider 51 is in contact with the horizontal support surfaces 39a, 39b, and 39f of the peripheral annular moving

element 31, the middle annular moving element 40, and the columnar annular moving element 45, and the tip end surfaces 38a and 38b of the annular members 33a and 33b of the moving elements 31 and 40, and the tip end surface 47 of the columnar member 46 of the columnar annular moving element 45 are at the first position (initial position) that is higher than the suction surface 22 by the height H_0 . Here, when the slider 51 moves rightward from the reference position as indicated by the arrow A in Fig. 4B, the apex 52a of the semi-columnar member 52 moves to the linear cam surface 35a of the peripheral annular moving element 31. Then, as the slider 51 moves further rightward, the peripheral annular moving element 31 as a whole moves in the downward direction by an amount that the linear cam surface 35a is inclined upward from the horizontal support surface 39a. As illustrated in Fig. 4B, when the slider 51 moves rightward from the reference position by the distance L_1 , the apex 52a of the slider 51 supports the point i_1 of the linear cam surface 35a of the peripheral annular moving element 31. As the point i_1 is higher than the horizontal support surface 39a by the height H_1 in Fig. 4B, the peripheral annular moving element 31 as a whole moves downward by the height H_1 from the initial first position. Further, as indicated by an arrow 214 in Fig. 13, the tip end surface 38a of the peripheral annular moving element 31 moves to the second position (position lower than the suction surface 22 by height $(H_1 - H_0)$) which is lower

than the first position (initial position) by the height H_1 and slightly lower than the suction surface 22. At this time, as the horizontal support surface 39b supports the middle annular moving element 41, the height of the tip end surface 38b thereof remains at the first position (initial position), as illustrated in Fig. 13. Similarly, as the columnar annular moving element 45 is supported by the horizontal support surface 39f, the height of the tip end surface 47 also remains at the first position (initial position). The tip end surface 38a and the tip end surfaces 38b and 47 are stepped surfaces having different levels from each other. Further, each of the tip end surfaces 38a, 38b, and 47 is a stepped surface for the suction surface 22. When the slider 51 moves rightward from the reference position by the distance L_1 , the controller 150 stops rotation of the motor 77.

[0056]

Next, at time t_6 , the controller 150 outputs a command for switching the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that is near vacuum. By this command, the drive unit 92 of the suction pressure switch mechanism 90 switches the three-way valve 91 so that the grooves 26 is communicated with the vacuum apparatus 140. With this, as indicated by an arrow 213 in Fig. 13, air in the grooves 26 is suctioned to the vacuum apparatus 140, the pressure of the grooves 26 and the suction pressure

of the suction surface 22 become the third pressure P_3 that is near vacuum, and the dicing sheet 12 is vacuum-suctioned to the suction surface 22. At this time, as illustrated in Fig. 20E, the pressure of the opening 23 is at the second pressure P_2 that is near the atmospheric pressure, and a gap is provided between the back surface 12b of the dicing sheet 12 and the tip end surface 38a of the peripheral annular moving element 31 positioned immediately above the gap d.

[0057]

As illustrated in Fig. 20E, at time t_7 , the controller 150 outputs a command for switching the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum. By this command, the drive unit 82 of the opening pressure switch mechanism 80 switches the three-way valve 81 so that the opening 23 is communicated with the vacuum apparatus 140. With this, as indicated by an arrow 215 in Fig. 14, air in the opening 23 is suctioned to the vacuum apparatus 140, and at time t_8 , as illustrated in Fig. 20E, the opening pressure becomes the first pressure P_1 that is near vacuum. When the opening pressure decreases from the second pressure that is near the atmospheric pressure to the first pressure P_1 that is near vacuum, the dicing sheet 12 positioned immediately above (facing toward) the tip end surface 38a of the peripheral annular moving element 31 is pulled downward as indicated by an arrow 216 in Fig. 14 so that

the back surface 12b is brought into contact with the tip end surface 38a. With this, as indicated by an arrow 217 in Fig. 14, a portion of the semiconductor die 15 positioned immediately above the tip end surface 38a of the semiconductor die 15 is deformed and flexed in the downward direction and moves away from the surface 18a of the collet 18, and air enters the suction hole 19 of the collet 18. An amount of leaked air entering the suction hole 19 is detected by the flow rate sensor 106 illustrated in Fig. 1. As illustrated in Fig. 20F, the amount of leaked air increases from time t_7 to time t_8 during which the opening pressure decreases.

[0058]

As illustrated in Fig. 20E and Fig. 20D, at time t_8 , the controller 150 outputs a command for increasing the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. By this command, the drive unit 82 of the opening pressure switch mechanism 80 switches the three-way valve 81 so that the opening 23 is communicated with the piping 85 open to air. Further, the drive unit 92 of the suction pressure switch mechanism 90 switches the three-way valve 91 so that the grooves 26 is communicated with the piping 95 open to air. With this, as indicated by arrows 220 and 221 in Fig. 15, air enters the opening 23 and the grooves 26, and

as illustrated in Fig. 20E and Fig. 20D, the pressure of the opening 23 and the pressure of the grooves 26 or the pressure of the suction surface 22 respectively increase up to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. With this, as indicated by an arrow 223 in Fig. 15, the dicing sheet 12 immediately above the gap d is displaced upward, moving away from the tip end surface 38a of the peripheral annular moving element 31. Further, along with the upward displacement of the dicing sheet 12, a region of the semiconductor die 15 facing toward the tip end surface 38a moves back to the surface 18a of the collet 18 as indicated by an arrow 224 in Fig. 15. When the semiconductor die 15 moves closer to the surface 18a of the collet 18, the amount of leaked air entering the suction hole 19 of the collet 18 starts decreasing as shown from time t_8 to time t_9 in Fig. 20F, and becomes zero at time t_9 in Fig. 20F. At this time, the semiconductor die 15 is vacuum-suctioned to the surface 18a of the collet 18, and the region of the semiconductor die 15 facing toward the tip end surface 38a is separated from the front surface 12a of the dicing sheet 12 (first third-separation step).

[0059]

At time t_9 , the controller 150 outputs a command for moving the tip end surface 38b of the middle annular moving element 40 to the second position that is lower than the first position (the position at which the height from the suction surface 22

is H_0) by the height H_1 . By this command, similarly to the previous case in which the tip end surface 38a of the peripheral annular moving element 31 is moved from the first position to the second position, by this command, the motor 77 of the drive unit 25 illustrated in Fig. 1 rotates in the counterclockwise direction as indicated by the arrow a in Fig. 1. Then, as illustrated in Fig. 4B, the slider 51 moves rightward to a position at the distance L_2 from the reference position (moves rightward by a distance (L_2-L_1)). Then, as illustrated in Fig. 4B, the apex (crest line) 52a of the semi-columnar member 52 attached to the slider 51 is brought into contact with a linear cam surface 35b of the middle annular moving element 40 at the point i_2 shown in Fig. 4B, and with the linear cam surface 35a of the peripheral annular moving element 31 at the point j_2 . Therefore, as indicated by an arrow 227 in Fig. 16, the tip end surface 38b of the middle annular moving element 40 moves to the second position that is lower than the first position (the position higher than the suction surface by the height H_0) by the height H_1 (the position lower than the suction surface 22 by H_1-H_0). Further, as indicated by an arrow 226 in Fig. 16, the tip end surface 38a of the peripheral annular moving element 31 at the second position moves to a third position that is lower than the first position (initial position) by height H_2 (the position lower than the suction surface 22 by H_2-H_0). The tip end surfaces 38a, 38b, and 47 are stepped surfaces having

different levels from each other, as well as stepped surfaces for the suction surface 22.

[0060]

Further, the controller 150 outputs a command for switching the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that is near vacuum at time t_9 as illustrated in Fig. 20D, and a command for switching the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum at time t_{10} , when a predetermined time elapses after time t_9 , as illustrated in Fig. 20E. By this command, the drive unit 92 of the suction pressure switch mechanism 90 and the drive unit 82 of the opening pressure switch mechanism 80 respectively switch the three-way valves 81 and 91 so that the grooves 26 and the opening 23 are communicated with the vacuum apparatus 140. With this, as indicated by arrows 225 and 228 in Fig. 17, air in the grooves 26 and air in the opening 23 are suctioned by the vacuum apparatus 140, and the opening pressure and the suction pressure respectively reach the first pressure P_1 and the third pressure P_3 that are near vacuum at time t_{11} . Then, as indicated by arrows 229 and 230 in Fig. 17, the dicing sheet 12 is pulled toward the tip end surface 38a of the peripheral annular moving element 31 that has moved downward to the third position and the tip end surface 38b of the middle annular moving element 40 that has moved

downward to the second position, and displaced in the downward direction. With this, the region of the semiconductor die 15 facing toward the tip end surfaces 38a and 38b also moves away from the surface 18a of the collet 18 and is deformed and flexed downward as indicated by an arrow 231 in Fig. 17. Then, as indicated by an arrow 232 in Fig. 17, air enters the suction hole 19 through the surface 18a of the collet 18 and the semiconductor die 15. With this, as illustrated in Fig. 20F, during a period from time t_{10} to time t_{11} , an amount of leaked air from the collet 18 flowing to the suction hole 19 increases. [0061]

As illustrated in Fig. 20E and Fig. 20D, at time t_{11} , the controller 150 outputs a command for switching the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. By this command, the drive unit 92 of the suction pressure switch mechanism 90 and the drive unit 82 of the opening pressure switch mechanism 80 respectively switch the three-way valves 81 and 91 so that the grooves 26 and the opening 23 are communicated with the pipings 85 and 95. Then, as indicated by arrows 241 and 242 in Fig. 18, air enters the opening 23 and the grooves 26, and the opening pressure and the suction pressure increase. Therefore, the dicing sheet 12 is displaced upward, as indicated by an arrow 243 in Fig. 18.

Due to upward displacement of the dicing sheet 12, and vacuum of the suction hole 19 of the collet 18, the semiconductor die 15 moves closer to the surface 18a of the collet 18. Therefore, as illustrated in Fig. 20F, during a period from time t_{11} to time t_{12} , the amount of leaked air entering the suction hole 19 decreases, finally down to zero at time t_{12} when the semiconductor die 15 is vacuum-suctioned to the surface 18a of the collet 18. Further, as illustrated in Fig. 20E and Fig. 20D, at time t_{12} , the opening pressure and the suction pressure respectively become the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. In this state, as illustrated in Fig. 18, while a region of the semiconductor die 15 corresponding to the tip end surface 47 of the columnar annular moving element 45 is attached to the dicing sheet 12, a major portion of the semiconductor die 15 is separated from the dicing sheet 12 (second third-separation step). Thus, the controller 150 ends the third separation program 160.

[0062]

As described above, the controller 150 switches the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure as in a period from time t_5 to t_6 , moves the tip end surface 38a of the peripheral annular

moving element 31 from the first position to the second position, switches the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure as in a period from time t_8 to t_9 , and moves the tip end surface 38b of the middle annular moving element 40 from the first position to the second position. Thus, the controller 150 separates the dicing sheet 12 step-by-step from a circumference to the center of the semiconductor die 15 by repeating the third-separation step such that the tip end surfaces are moved from the first position to the second position sequentially from the tip end surface of the annular moving element on the outer side to the tip end surface of the annular moving element on the inner side, every time the opening pressure and the suction pressure are respectively switched from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. [0063]

After the third separation program is completed, at time t_{12} , the controller 150 moves the slider 51 to a rightmost position illustrated in Fig. 4A so that the semi-columnar member 52 attached to the slider 51 is fitted in the hook portions 37a, 37b, and 37f of the moving element. By the movement of the slider 51, the horizontal support surface 36b of the middle

annular moving element 40 is supported by the apex 52a of the semi-columnar member 52, and therefore the tip end surface 38b of the middle annular moving element 40 moves downward from the second position to the third position, as indicated by an arrow 246 in Fig. 19. It should be noted, as illustrated in Fig. 19, the columnar annular moving element 45 does not include a linear cam surface, and the horizontal support surface 36f included in the moving direction of the slider 51 is flush with the horizontal support surface 39f to which the slider 51 at the initial position is in contact. Therefore, the tip end surface 47 does not change its position by the movement of the slider 51, and remains at the first position as the initial position. When the semi-columnar member 52 of the slider 51 is fitted with the hook portions 37a, 37b, and 37f, the moving elements 31, 40, and 45 are fixed in the vertical direction. Further, at time t_{12} , the controller 150 outputs a command for switching the suction pressure to the third pressure P_3 that is near vacuum. By this command, the drive unit 92 of the suction pressure switch mechanism 90 switches the three-way valve 91 so that the grooves 26 is communicated with the vacuum apparatus 140. With this, as indicated by an arrow 245 in Fig. 19, air in the grooves 26 is suctioned to the vacuum apparatus 140 to vacuumize the grooves 26, and the dicing sheet 12 is vacuum-suctioned to the suction surface 22. In the state illustrated in Fig. 19, while the region of the semiconductor die 15 corresponding to the tip

end surface 47 of the columnar annular moving element 45 is attached to the dicing sheet 12, the major portion of the semiconductor die 15 is separated from the dicing sheet 12.

[0064]

At time t_{13} in Fig. 20A, the controller 150 outputs a command for moving the collet 18 upward. By this command, the collet drive unit 130 illustrated in Fig. 1 drives the motor to move the collet 18 upward as indicated by an arrow 247 in Fig. 19. The moving elements 31, 40, and 45 are fixed in the vertical direction, and the dicing sheet 12 is vacuum-suctioned to the suction surface 22. Therefore, when the collet 18 moves upward, the region of the semiconductor die 15 corresponding to the tip end surface 47 of the columnar annular moving element 45 separates from the dicing sheet 12, and the semiconductor die 15 is picked up while being suctioned by the collet 18.

[0065]

Upon picking up of the semiconductor die 15, at time t_{14} , the controller 150 moves the slider 51 back to the initial position, and the tip end surfaces 38a, 38b, and 47 of the moving elements 31, 40, and 45 return to the first position. Then, the controller 150 resumes the suction pressure and the opening pressure to the atmospheric pressure, and completes the pick-up operation.

[0066]

According to the semiconductor die pick-up apparatus 500 of the embodiment described above, when the semiconductor die 15 is picked up, the dicing sheet 12 is separated step-by-step from a circumference to the center of the semiconductor die 15 by repeating the third-separation step such that the tip end surfaces are moved from the first position to the second position sequentially from the tip end surface of the annular moving element on the outer side to the tip end surface of the annular moving element on the inner side, every time the opening pressure and the suction pressure are respectively switched from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. Therefore, it is possible to provide an effect of suppressing damages to a semiconductor die when being picked up.

[0067]

It should be noted that while in the above embodiment, it is described that the tip end surface of one annular moving element is moved from the first position to the second position every time the opening pressure and the suction pressure are switched from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. However, the tip end surfaces of the plurality of annular moving elements can be moved from the first position to the second position by

setting a sliding distance of the slider 51 when the pressure is switched longer. Further, in this embodiment, it is described that the columnar annular moving element 45 does not include a linear cam surface, and the tip end surface 47 does not change its position from the first position. However, the columnar annular moving element 45 can include a linear cam surface, and the tip end surface 47 can be configured to move from the first position to the second position after a tip end surface of an annular moving member on the inner circumference side moves from the first position to the second position. Moreover, while it is described that the second position is a position lower than the suction surface 22 by $(H_1 - H_0)$ in this embodiment, the second position can be flush with the suction surface 22 or can be a position higher than the suction surface, as long as the second position is lower than the first position.

[0068]

Further, in the description of the operation according to this embodiment, the moving elements 30 are configured as the three moving elements of the peripheral annular moving element 31, the middle annular moving element 40, and the columnar annular moving element 45, and the third-separation step is performed two times. However, when the stepped-surface forming mechanism moving elements 30 are configured by the peripheral annular moving element 31, the four middle annular moving elements 40-43, and the columnar annular moving element

45 as illustrated in Fig. 3 and Fig. 4, the third-separation step is performed five times as the five tip end surfaces 38a-38e of the peripheral annular moving element 31 and the four middle annular moving elements 40-43 move from the first position to the second position. It should be understood that the number of the middle annular moving elements is not limited to the above examples, and can be two or three, or more than five. The more the number of the middle annular moving elements is, the more gradually the dicing sheet 12 is separated in multiple steps from the circumference of the semiconductor die 15, and it is possible to suppress damages to a semiconductor die when being picked up.

[0069]

Moreover, in this embodiment, it is described that the moving elements 30 are configured by the peripheral annular moving element 31, and the four middle annular moving elements 40-43, and the columnar annular moving element 45 as illustrated in Fig. 3 and Fig. 4, and the tip end surfaces 38a-38e, and 47 are flat surfaces. However, the tip end surfaces can not be flat surfaces, and can include a plurality of grooves, for example.

[0070]

For example, as illustrated in Fig. 24, the moving elements 30 can be configured by the peripheral annular moving element 31, the two middle annular moving elements 40 and 41,

and the columnar annular moving element 45, a surface of the tip end surface 38a of the peripheral annular moving element 31 can include a plurality of grooves 31a, and a plurality of grooves 45a can be arranged in a grid pattern on the tip end surface 47 of the columnar annular moving element 45. By such a configuration, as illustrated in Fig. 10 and Fig. 11, there are provided effects that when the opening 23 is made to a pressure near vacuum in a state in which the tip end surfaces 38a, 38b, and 47 of the moving elements 30 are in contact with the back surface 12b of the dicing sheet 12, it is possible to promote separation of the dicing sheet 12 around the semiconductor die 15, to encourage separation of the dicing sheet 12 near the center of the semiconductor die 15, and to reduce time for picking up the semiconductor die 15 from the dicing sheet 12.

[0071]

In the third-separation step previously described, the controller 150 performs the third separation determination step for determining whether or not the region of the semiconductor die 15 facing toward the tip end surface 38 is separated from the front surface 12a of the dicing sheet 12, and performs the third retry step if it is determined in the third separation determination step that the region of the semiconductor die 15 facing toward the tip end surface 38 is not separated from the front surface 12a of the dicing sheet 12. Hereinafter, the

third separation determination step and the third retry step will be described.

[0072]

As described above with reference to Fig. 14, when the opening pressure decreases down from a second pressure P_2 that is near the atmospheric pressure to a first pressure P_1 that is near vacuum at time t_7 as illustrated in Fig. 20F, the semiconductor die 15 is flexed, deformed, and separated from the surface 18a of the collet 18, and air enters the suction hole 19. Therefore, an amount of leaked air detected by the flow rate sensor 106 illustrated in Fig. 1 increases. Then, as illustrated in Fig. 20E and Fig. 20D, when the opening pressure and the suction surface pressure start increasing respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure at time t_8 , the amount of leaked air detected by the flow rate sensor 106 illustrated in Fig. 1 starts decreasing. As illustrated in Fig. 15, when the semiconductor die 15 is suctioned to the surface 18a of the collet 18 at time t_9 , the amount of leaked air becomes zero, and the region of the semiconductor die 15 facing toward the tip end surface 38a of the peripheral annular moving element 31 is separated from the front surface 12a of the dicing sheet 12. In contrast, if the semiconductor die 15 is not separated well from the front surface 12a of the dicing sheet 12, even

when the opening pressure and the suction surface pressure respectively increase up from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure, the amount of leaked air does not become zero at time t_9 , as the semiconductor die 15 remains being applied to the dicing sheet 12 and is not vacuum-suctioned to the surface of the collet 18.

[0073]

In this manner, when the semiconductor die 15 is separated from the dicing sheet 12, as illustrated in Fig. 21A, the amount of leaked air increases from zero and then decreases down to zero. Further, when the semiconductor die 15 is not separated well from the dicing sheet 12, as illustrated in Fig. 21C, the amount of leaked air maintains a certain amount and can not decrease down to zero after increasing from zero. As the amount of leaked air is an analog value, in the third separation determination step, a signal of the amount of leaked air shown in Fig. 21A and Fig. 21C is differentiated to calculate a derivative value for the amount of leaked air shown in Fig. 21B, Fig. 21D, in order to correctly detect separation.

[0074]

As illustrated in Fig. 21B, if the semiconductor die 15 is separated well, the amount of leaked air once increases up from zero, and then decreases down to zero. Therefore, the

derivative value for the amount of leaked air once takes a positive value, and then takes a negative value. In contrast, as illustrated in Fig. 21D, if the semiconductor die 15 is not separated well, the amount of leaked air increases up from zero, but then remains at the increased value. Therefore, the derivative value for the amount of leaked air once takes a positive value, and remains at a value near zero. Thus, by setting a range of a threshold value of the derivative value for the amount of leaked air between +S and -S as illustrated in Fig. 21B and Fig. 21D, the derivative value for the amount of leaked air changes over the range of the threshold value twice (total two times: once in a positive direction and once in a negative direction) when the semiconductor die 15 is separated well, as illustrated in Fig. 21B. In contrast, if the semiconductor die 15 is not separated well, the derivative value for the amount of leaked air changes over the range of the threshold value only once in the positive direction, as illustrated in Fig. 21D. Therefore, in the third separation determination step, when a number of times that the derivative value for the amount of leaked air changes over the range of the predetermined threshold value is 2 (even number) during a time period from time t_7 to time t_9 in Fig. 20F, it is determined that the semiconductor die 15 has been separated, and the process moves to the next separation step. When the number of times that the derivative value for the amount of leaked air

changes over the range of the predetermined threshold value is 1 (odd number), it is determined that the semiconductor die 15 has not been separated, and the number of times is set to 0 before the process moves to the third retry step described next (the counter is cleared).

[0075]

Further, in a region in Fig. 21B in which the derivative value for the amount of leaked air takes a negative value, when the derivative value for the amount of leaked air reaches $-S$ (at time t_1 in Fig. 21A and Fig. 21B), an actual amount of leaked collet air starts decreasing as illustrated in Fig. 21A, after reaching a maximum leaked amount. Accordingly, after time t_1 in Fig. 21A and Fig. 21B, it is predicted that the semiconductor die 15 is upright (the semiconductor die 15 faces the surface 18a of the collet 18), and therefore the threshold value $-S$ can be said to a turning point at which the separation starts converging. Accordingly, it is possible to move the operation to the next separation at the point at which the derivative value for the amount of leaked air reaches the threshold value $-S$, and thus to reduce separation time and damage to the semiconductor die 15.

[0076]

As illustrated in Fig. 22E and Fig. 22D, the controller 150 lowers the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that

is near vacuum at time t_9 without moving the peripheral annular moving element 31, and lowers the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum at time t_{21} . Then, at time t_{22} , as illustrated in Fig. 22D and Fig. 22E, the suction pressure and the opening pressure are respectively increased from the third pressure P_3 and the first pressure P_1 that are near vacuum up to the fourth pressure P_4 and the second pressure P_2 that are near the atmospheric pressure (third retry step). In the third retry step, if the amount of leaked air decreases down to zero during a time period from time t_{22} to time t_{23} in Fig. 22F, the derivative value for the amount of leaked air during this period changes over the range of the predetermined threshold value once (changes over a threshold value in the range on a negative side). With this, the derivative value for the amount of leaked air during a time period from time t_7 to time t_{23} shown in Fig. 22F changes over the range of the predetermined threshold value twice (even number). Therefore, the controller 150 determines that the semiconductor die 15 in the region facing toward the tip end surface 38a of the peripheral annular moving element 31 has been separated from the front surface 12a of the dicing sheet 12, terminates the third retry step, and resets the number of times to 0 before the next third-separation step (clears a counter).

[0077]

Here, when the third-separation step is performed more than once, the controller 150 can count the number of times that the derivative value for the amount of leaked air changes over the range of the predetermined threshold value, and can move the operation to the next third-separation step when the count is an even number, and to the third retry step when the count is an odd number. For example, if a predetermined portion of the semiconductor die 15 is separated in the first third-separation step, a count number of the derivative value is 2 (odd number), and therefore the operation moves to the second third-separation step. If the predetermined portion of the semiconductor die 15 is not separated in the second third-separation step, and the derivative value for the amount of leaked air changes over the range of the predetermined threshold value once, a total count number is 3 (odd number), and therefore the operation does not move to the third third-separation step, but to the third retry step. If the predetermined portion of the semiconductor die 15 is separated in the third retry step, the number of times that the derivative value for the amount of leaked air changes over the range of the predetermined threshold value is counted once, and the total count number is 4 (even number). Therefore, the operation moves to the third third-separation step. As described above, by determining whether or not the process moves to the next third-separation step based on if the total count number is even

or odd, it is possible to determine only by the number of count how the number of times by which the third-separation step is performed and whether or not the separation of the semiconductor die is performed.

[0078]

As described above, the semiconductor die pick-up apparatus 500 according to this embodiment confirms whether or not the semiconductor die 15 is separated from the dicing sheet 12, and then moves the process to the next separation step. Thus, it is possible to reduce damages to the semiconductor die 15 during the separation operation.

[0079]

Next, a second-separation step (the second separation program 159), a second separation-confirmation step, and a second retry step will be described with reference to Fig. 23. Like operations as in the third-separation step (the third separation program 160), the third separation-confirmation step, and the third retry step described previously with reference to Fig. 1 through Fig. 22A to Fig. 22F are denoted by like reference numerals, and descriptions for these operations shall be omitted.

[0080]

As illustrated in Fig. 23A to Fig. 23F, in the second-separation step (the second separation program 159), the second separation-confirmation step, and the second retry step,

similarly to the third-separation step (the third separation program 160), the third separation-confirmation step, and the third retry step, the opening pressure, the position of the peripheral annular moving element 31, the position of the middle annular moving element 40, and the position of the collet 18 are changed, in a state in which the suction pressure is maintained at the third pressure P_3 after the suction pressure is set to the third pressure P_3 that is near vacuum during a time period from time t_2 to t_3 . The second-separation step, the second separation-confirmation step, and the second retry step are the same as the third-separation step, the third separation-confirmation step, and the third retry step other than that the suction pressure is maintained at the third pressure P_3 . The second-separation step (the second separation program 159), the second separation-confirmation step, and the second retry step provide the same effects as those of the third-separation step (the third separation program 160), the third separation-confirmation step, and the third retry step.

[0081]

Next, an embodiment in which a moving element 630 is constituted from five plated moving elements 631-635 will be described with reference to Fig. 25 through Fig. 38. Like components as in the embodiment described previously with reference to Fig. 1 through Fig. 20A to Fig. 20F are denoted

by like reference numerals, and descriptions for these operations shall be omitted.

[0082]

As illustrated in Fig. 25, the moving element 630 is configured by five plated moving elements including the first to the fifth plated moving element 631-635 arranged side by side in the moving direction of the slider 51 illustrated in Fig. 4 such that the tip end surfaces 631a-635a project from the suction surface 22 of the stage 20 by the height H_0 . Similarly to the embodiment previously described, the plated moving elements 631-635 each include an inclined surface that is in contact with the slider 51, and with which corresponding one of the plated moving elements 631-635 moves between the first position and the second position based on the movement of the slider 51. The inclined surfaces are arranged in a displaced manner in the moving direction of the slider 51, so that the corresponding plated moving elements 631-635 sequentially move from the first position to the second position along the moving direction of the slider 51. When the stepped-surface forming mechanism 300 causes the slider 51 to move, the height of the tip end surfaces 631a-635a respectively of the moving elements 631-635 from the suction surface change in an order of $H_0 \rightarrow H_1 \rightarrow H_2$.

[0083]

Similarly to the embodiment previously described, the controller 150 first executes the positioning program 157

illustrated in Fig. 1. In the initial state, the tip end surfaces 631a-635a respectively of the plated moving elements 631-635 are at the first position projecting from the suction surface 22 of the stage 20 by the height H_0 . Therefore, the controller 150 moves the stage 20 upward to bring the tip end surfaces 631a-635a respectively of the moving elements 631-635 into contact with the back surface 12b of the dicing sheet 12. Thereafter, the controller 150 again causes the horizontal wafer-holder drive unit 110 to adjust a horizontal position so that the semiconductor die 15 to be picked up comes immediately above the tip end surfaces 631a-635a (stepped surface) of the moving element 630 that slightly projects from the suction surface 22 of the stage 20.

[0084]

As illustrated in Fig. 26, the semiconductor die 15 is smaller than the opening 23 of the stage 20 and larger than the moving element 630 in width or depth. Therefore, upon completion of the position adjustment of the stage 20, an outer circumferential edge of the semiconductor die 15 is positioned between the inner surface 23a of the opening 23 of the stage 20 and an outer surface 631b of the first plated moving element 631, or between the inner surface 23a and an the outer surface 635b of the fifth plated moving element 635, that is, immediately above the gap d between the inner surface 23a of the opening 23 and the outer surfaces 631b and 635b of the first

and the fifth plated moving element 631 and 635. In the initial state, the pressure of the grooves 26 or the suction surface 22 of the stage 20 is at the atmospheric pressure, and the pressure of the opening 23 is also at the atmospheric pressure. In the initial state, the tip end surfaces 631a-635a respectively of the plated moving elements 631-635 are at the first position projecting from the suction surface 22 of the stage 20 by the height H_0 , and therefore the height of the back surface 12b of the dicing sheet 12 in contact with the tip end surfaces 631a-635a is also at the first position projecting from the suction surface 22 by the height H_0 . Further, the back surface 12b of the dicing sheet 12 is slightly lifted from the suction surface 22, at a circumferential edge of the opening 23, and brought into close contact with the suction surface 22 in a region distant from the opening 23. Upon completion of position adjustment in the horizontal direction, the controller 150 causes the collet drive unit 130 illustrated in Fig. 1 to move the collet 18 down above the semiconductor die 15 and to bring the surface 18a of the collet 18 in contact with the semiconductor die 15. Upon contact of the collet 18 with the semiconductor die 15, the controller 150 causes the drive unit 102 of the suctioning mechanism 100 to switch the three-way valve 101 so that the suction hole 19 of the collet 18 is communicated with the vacuum apparatus 140. With this, the suction hole 19 becomes vacuumized, and the collet 18 suctions

and fixes the semiconductor die 15 to the surface 18a (end of the positioning program). At this time, a height of the surface 18a of the collet 18 is an height H_c that is a total value of a height of the tip end surfaces 631a-635a respectively of the plated moving elements 631-635 (the height H_0 from the suction surface 22), a thickness of the dicing sheet 12, and a thickness of the semiconductor die 15, as illustrated in Fig. 26.

[0085]

Next, the controller 150 executes the first separation program 158 illustrated in Fig. 1. At time t_1 shown in Fig. 38E, the controller 150 outputs a command for switching the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that is near vacuum. By this command, as illustrated in Fig. 38E, the suction pressure reaches the third pressure P_3 that is near vacuum at time t_2 . Thereafter, the back surface 12b of the dicing sheet 12 along the circumferential edge of the opening 23 is vacuum-suctioned to a front surface of the suction surface 22 as illustrated in as indicated by an arrow 202 in Fig. 27. As the tip end surfaces 631a-635a respectively of the plated moving elements 631-635 are at the first position projecting from the suction surface 22 of the stage 20 by the height H_0 , the dicing sheet 12 is applied with the obliquely downward tension F_1 . With the tension F_1 , displacement occurs between an outer circumferential portion or a periphery portion of the

semiconductor die 15 and the front surface 12a of the dicing sheet 12. The displacement serves as a trigger for separation between the dicing sheet 12 and the outer circumferential portion or the periphery portion of the semiconductor die 15. [0086]

After the suction pressure becomes the third pressure P_3 that is near vacuum at time t_2 as illustrated in Fig. 38E, the controller 150 maintains this pressure for a predetermined time period. Then, as illustrated in Fig. 38F, at time t_3 , the controller 150 outputs a command for switching the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum. By this command, as indicated by an arrow 206 in Fig. 28, air in the opening 23 is suctioned by the vacuum apparatus 140, and as illustrated in Fig. 38F, the opening pressure reaches the first pressure P_1 that is near vacuum at time t_4 . With this, as indicated by an arrow 203 in Fig. 28, the dicing sheet 12 immediately above the gap d between the inner surface 23a of the opening 23 and the outer surface 631b of the first plated moving element 631, and the gap d between the inner surface 23a of the opening 23 and the outer surface 635b of the fifth plated moving element 635 is pulled downward. Further, the periphery portion of the semiconductor die 15 positioned immediately above the gaps d is pulled by the dicing sheet 12, and deformed and flexed downward as indicated by an arrow 204. With this,

the periphery portion of the semiconductor die 15 moves away from the surface 18a of the collet 18. At time t_2 , when the suction pressure becomes the third pressure P_3 that is near vacuum, as the periphery portion of the semiconductor die 15 is provided with the trigger for separation from the front surface 12a of the dicing sheet 12 due to displacement occurring between the outer circumferential portion of the semiconductor die 15 and the front surface 12a of the dicing sheet 12, the periphery portion of the semiconductor die 15 starts to separate from the front surface 12a of the dicing sheet 12 as indicated by an arrow 204 in Fig. 28, although being deformed and flexed. [0087]

As illustrated in Fig. 28, as the periphery portion of the semiconductor die 15 moves away from the surface 18a of the collet 18, air enters the suction hole 19 of the collet 18 that is vacuum as indicated by an arrow 205 in Fig. 28. An amount of an entering air flow that has entered (amount of leaked air) is detected by the flow rate sensor 106. As illustrated in Fig. 38F, as the opening pressure decreases from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum from time t_3 to time t_4 , the semiconductor die 15 is deformed and flexed by being pulled with the dicing sheet 12 in the downward direction. Therefore, as illustrated in Fig. 38G, the amount of leaked air entering the suction hole 19 of the collet 18 increases from time t_3 to time t_4 .

[0088]

As illustrated in Fig. 38F and Fig. 38E, the controller 150 maintains the opening 23 and the grooves 26 or the suction surface 22 of the stage 20 respectively at the first pressure P_1 and the third pressure P_3 that are near vacuum from time t_4 to time t_5 . During this time period, as indicated by an arrow 207 in Fig. 29, the periphery portion of the semiconductor die 15 moves back to the surface 18a of the collet 18 due to vacuum of the suction hole 19 of the collet 18 and elasticity of the semiconductor die 15. As the periphery portion of the semiconductor die 15 moves to the surface 18a of the collet 18, as shown by time t_4 to time t_5 in Fig. 38G, the amount of leaked air entering the suction hole 19 of the collet 18 decreases. As illustrated in Fig. 29, when the semiconductor die 15 is vacuum-suctioned to the surface 18a of the collet 18 at time t_5 , the amount of leaked air becomes zero. At this time, the periphery portion of the semiconductor die 15 is separated from the front surface 12a of the dicing sheet 12 positioned immediately above the gaps d (initial separation step). When the initial separation of the periphery portion of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 occurs, the dicing sheet 12 positioned immediately above the gaps d of the opening 23 is displaced in the downward direction. The controller 150 detects the displacement of the dicing sheet 12 in the downward direction (displacement in the

approaching and departing direction with respect to the suction surface 22) using the sheet displacement detection sensor 107, and if the detected displacement is over a predetermined threshold value, determines that initial separation of the periphery portion of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 positioned immediately above the gaps d has occurred. Further, if the detected displacement is smaller than the predetermined threshold value, the controller 150 determines that initial separation of the periphery portion of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 positioned immediately above the gaps d has not occurred (first separation determination step). If it is determined that the initial separation of the periphery portion of the semiconductor die 15 has occurred, the controller 150 moves the process to a separation step that comes next. Further, similarly to the embodiment described above, if it is determined that the initial separation of the periphery portion of the semiconductor die 15 has not occurred, the controller 150 performs a first retry step, and if the detected displacement is over predetermined displacement, the controller 150 terminates the first retry step, and moves the process to the next separation step (end of the first separation program).

[0089]

Next, the controller 150 executes the third separation program 160 illustrated in Fig. 1. As illustrated in Fig. 38F and Fig. 38E, the controller 150 maintains the opening pressure and the suction pressure respectively at the first pressure P_1 and the third pressure P_3 that are near vacuum for a predetermined time period. Then, at time t_5 , the controller 150 outputs a command for switching the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. By this command, as indicated by arrows 210 and 211 in Fig. 30, air enters the opening 23 and the grooves 26. Therefore, as illustrated in Fig. 38E and Fig. 38G, from time t_5 to time t_6 , the opening pressure and the suction pressure increase respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. [0090]

Upon the opening pressure and the suction pressure respectively reaching the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure, the dicing sheet 12 positioned immediately above the gap d and pulled in the downward direction by vacuum moves back upward by the tension applied when being fixed to the wafer holder 10, as indicated by an arrow 212 in Fig. 30. Further, the dicing sheet

12 around the circumferential edge of the opening 23 is slightly lifted from the suction surface 22 due to the tension described above.

[0091]

When the opening pressure and the suction pressure respectively become the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure at time t_6 as illustrated in Fig. 38F and Fig. 38E, the controller 150 outputs a command for changing the height of the tip end surface 631a of the first plated moving element 631 to a second position that is lower than the first position (the initial position at which the height from the suction surface 22 is H_0) by the height H_1 , as illustrated in Fig. 38D. By this command, the motor 77 of the drive unit 25 illustrated in Fig. 1 rotates in the counterclockwise direction as indicated by the arrow a in Fig. 1. With this, the link member 60 rotates in the clockwise direction as indicated by the arrow c in Fig. 1, and the slider 51 moves rightward as indicated by the arrow A in Fig. 1.

[0092]

Similarly to the embodiment previously described, as illustrated in Fig. 4B, when the slider 51 moves rightward from the reference position by the distance L_1 , the first plated moving element 631 moves downward by the height H_1 from the initial first position. Further, as indicated by an arrow 214 in Fig. 31, the tip end surface 631a of the first plated moving

element 631 moves to the second position (position lower than the suction surface 22 by height (H_1-H_0)) which is lower than the first position (initial position) by the height H_1 and slightly lower than the suction surface 22. As illustrated in Fig. 31, the heights of the tip end surfaces 632a-635a of the second to the fifth plated moving element 632-635 remain at the first position (initial position). The tip end surface 631a of the first plated moving element 631 and the tip end surfaces 632a-635a are stepped surfaces having different levels from each other. Further, each of the tip end surfaces 632a-635a of the second to the fifth plated moving element 632-635 is a stepped surface for the suction surface 22. When the slider 51 moves rightward from the reference position by the distance L_1 , the controller 150 stops rotation of the motor 77.

[0093]

Next, at time t_6 , the controller 150 outputs a command for switching the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that is near vacuum. By this command, the drive unit 92 of the suction pressure switch mechanism 90 switches the three-way valve 91 so that the grooves 26 is communicated with the vacuum apparatus 140. With this, as indicated by an arrow 213 in Fig. 31, air in the grooves 26 is suctioned to the vacuum apparatus 140, the pressure of the grooves 26 and the suction pressure of the suction surface 22 become the third pressure P_3 that is

near vacuum, and the dicing sheet 12 is vacuum-suctioned to the suction surface 22. At this time, as illustrated in Fig. 38F, the pressure of the opening 23 is at the second pressure P_2 that is near the atmospheric pressure, and therefore a gap is provided between the back surface 12b of the dicing sheet 12 and the tip end surface 631a of the first plated moving element 631 positioned immediately above the gaps d.

[0094]

As illustrated in Fig. 38F, at time t_7 , the controller 150 outputs a command for switching the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum. By this command, as indicated by an arrow 215 in Fig. 32, air in the opening 23 is suctioned to the vacuum apparatus 140, and at time t_8 , as illustrated in Fig. 38F, the opening pressure becomes the first pressure P_1 that is near vacuum. When the opening pressure decreases from the second pressure that is near the atmospheric pressure to the first pressure P_1 that is near vacuum, the dicing sheet 12 positioned immediately above (facing toward) the tip end surface 631a of the first plated moving element 631 is pulled downward as indicated by an arrow 216 in Fig. 32 so that the back surface 12b is brought into contact with the tip end surface 631a. With this, as indicated by an arrow 217 in Fig. 32, a portion of the semiconductor die 15 positioned immediately above the tip end surface 631a of the semiconductor die 15 is

deformed and flexed in the downward direction and moves away from the surface 18a of the collet 18, and air enters the suction hole 19 of the collet 18. Further, similarly to the example described with reference to Fig. 28, when the opening pressure decreases from the second pressure that is near the atmospheric pressure to the first pressure P_1 that is near vacuum, the dicing sheet 12 positioned immediately above the gap d between the inner surface 23a of the opening 23 and the outer surface 635b of the fifth plated moving element 635 is pulled downward, and deformed and flexed as indicated by an arrow 204. With this, a periphery portion of the semiconductor die 15 on the side of the fifth plated moving element moves away from the surface 18a of the collet 18. Then, as indicated by an arrow 205 in Fig. 32, air enters the suction hole 19 of the collet 18 that is vacuum. An amount of leaked air entering the suction hole 19 is detected by the flow rate sensor 106 illustrated in Fig. 1. As illustrated in Fig. 38, the amount of leaked air increases from time t_7 to time t_8 during which the opening pressure decreases. [0095]

As illustrated in Fig. 38F and Fig. 38E, at time t_8 , the controller 150 causes the opening pressure and the suction pressure to increase respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. With this, as indicated by arrows 220

and 221 in Fig. 33, air enters the opening 23 and the grooves 26, and as illustrated in Fig. 38F and Fig. 38E, the pressure of the opening 23 and the pressure of the grooves 26 or the pressure of the suction surface 22 respectively increase up to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. With this, as indicated by an arrow 223 in Fig. 33, the dicing sheet 12 immediately above the gap d between the outer surface 631b of the first plated moving element 631 and the inner surface 23a of the opening 23 is displaced upward, moving away from the tip end surface 631a of the first plated moving element 631. Along with the upward displacement of the dicing sheet 12, a region of the semiconductor die 15 facing toward the tip end surface 631a moves back to the surface 18a of the collet 18 as indicated by an arrow 224 in Fig. 33. Further, as illustrated in Fig. 33, the dicing sheet 12 immediately above the gap d between the outer surface 635b of the fifth plated moving element 635 and the inner surface 23a of the opening 23 is displaced upward as indicated by an arrow 223, and therefore the periphery portion of the semiconductor die 15 on the side of the fifth plated moving element also moves back to the surface 18a of the collet 18 as indicated by an arrow 224 in Fig. 33. When the semiconductor die 15 moves closer to the surface 18a of the collet 18, the amount of leaked air entering the suction hole 19 of the collet 18 starts decreasing as shown from time t_8 to time t_9 in Fig.

38G, and becomes zero at time t_9 in Fig. 38G. At this time, the semiconductor die 15 is vacuum-suctioned to the surface 18a of the collet 18, and the region of the semiconductor die 15 facing toward the tip end surface 631a is separated from the front surface 12a of the dicing sheet 12 (first third-separation step).

[0096]

At time t_9 , the controller 150 outputs a command for moving the tip end surface 632a of the second plated moving element 632 to the second position that is lower than the first position (the position at which the height from the suction surface 22 is H_0) by the height H_1 . By this command, the slider 51 moves rightward to a position at the distance L_2 from the reference position (moves rightward by a distance (L_2-L_1)). Then, as indicated by an arrow 227 in Fig. 34, the tip end surface 632a of the second plated moving element 632 moves to the second position that is lower than the first position (the position higher than the suction surface by the height H_0) by the height H_1 (the position lower than the suction surface 22 by H_1-H_0). Further, as indicated by an arrow 226 in Fig. 34, the tip end surface 631a of the first plated moving element 631 at the second position moves to a third position that is lower than the first position (initial position) by height H_2 (the position lower than the suction surface 22 by H_2-H_0). The tip end surface 631a of the first plated moving element 631, the tip end surface 632a

of the second plated moving element 632, and the tip end surfaces 633a-635a of the third to the fifth plated moving element 633-635 are stepped surfaces having different levels from each other, as well as stepped surfaces for the suction surface 22.

[0097]

Further, the controller 150 outputs a command for switching the suction pressure from the fourth pressure P_4 that is near the atmospheric pressure to the third pressure P_3 that is near vacuum at time t_9 , as illustrated in Fig. 38E, and a command for switching the opening pressure from the second pressure P_2 that is near the atmospheric pressure to the first pressure P_1 that is near vacuum at time t_{10} , when a predetermined time elapses after time t_9 , as illustrated in Fig. 38F. With this, as indicated by arrows 225 and 228 in Fig. 35, air in the grooves 26 and air in the opening 23 are suctioned by the vacuum apparatus 140, and the opening pressure and the suction pressure respectively reach the first pressure P_1 and the third pressure P_3 that are near vacuum at time t_{11} . Then, as indicated by arrows 229 and 230 in Fig. 35, the dicing sheet 12 is pulled toward the tip end surface 631a of the first plated moving element 631 that has moved downward to the third position and the tip end surface 632a of the second plated moving element 632 that has moved downward to the second position, and displaced in the downward direction. With this, the region of the semiconductor die 15 facing toward the tip end surfaces 631a and 632a also

moves away from the surface 18a of the collet 18 and is deformed and flexed downward as indicated by an arrow 231 in Fig. 35. Then, as indicated by an arrow 232 in Fig. 35, air enters the suction hole 19 through the surface 18a of the collet 18 and the semiconductor die 15. Further, similarly to the example described with reference to Fig. 32, when the opening pressure decreases from the second pressure that is near the atmospheric pressure to the first pressure P_1 that is near vacuum, the dicing sheet 12 positioned immediately above the gap d between the inner surface 23a of the opening 23 and the outer surface 635b of the fifth plated moving element 635 is pulled downward, and deformed and flexed as indicated by an arrow 204. With this, a periphery portion of the semiconductor die 15 on the side of the fifth plated moving element moves away from the surface 18a of the collet 18. Then, as indicated by an arrow 205 in Fig. 35, air enters the suction hole 19 of the collet 18 that is vacuum. With this, as illustrated in Fig. 38G, during a period from time t_{10} to time t_{11} , an amount of leaked air from the collet 18 flowing to the suction hole 19 increases.

[0098]

As illustrated in Fig. 38F and Fig. 38E, at time t_{11} , the controller 150 outputs a command for switching the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near

the atmospheric pressure. By this command, as indicated by arrows 241 and 242 in Fig. 36, air enters the opening 23 and the grooves 26, and the opening pressure and the suction pressure increase. Therefore, the dicing sheet 12 is displaced upward, as indicated by an arrow 243 in Fig. 36. Due to the upward displacement of the dicing sheet 12, and vacuum of the suction hole 19 of the collet 18, the semiconductor die 15 moves closer to the surface 18a of the collet 18 as indicated by an arrow 244. Further, as illustrated in Fig. 36, the dicing sheet 12 positioned immediately above the gap d between the outer surface 635b of the fifth plated moving element 635 and the inner surface 23a of the opening 23 is displaced upward as indicated by an arrow 243, and the periphery portion of the semiconductor die 15 on the side of the fifth plated moving element moves closer to the surface 18a of the collet 18 as indicated by an arrow 244 in Fig. 36. With this, as illustrated in Fig. 38G, from time t_{11} to time t_{12} , the amount of leaked air entering the suction hole 19 decreases, and finally becomes zero at time t_{12} when the semiconductor die 15 is vacuum-suctioned to the surface 18a of the collet 18. Further, as illustrated in Fig. 38F and Fig. 38E, at time t_{12} , the opening pressure and the suction pressure respectively become the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure. In this state, as illustrated in Fig. 36, while a region of the semiconductor die 15 corresponding to the tip end surfaces

633a-635a of the third to the fifth plated moving element 633-635 is attached to the dicing sheet 12, a region of the semiconductor die 15 corresponding to the tip end surface 631a, 632a of the first and the second plated moving element 631 and 632, and a region of the semiconductor die 15 corresponding to the gap d, and a region of the periphery portion of the semiconductor die 15 on the side of the fifth plated moving element are separated from the dicing sheet 12 (second third-separation step). Thus, the controller 150 ends the third separation program 160.

[0099]

After the third separation program is completed, at time t_{12} , the controller 150 outputs a command for moving the tip end surface 633a of the third plated moving element 633 to the second position that is lower than the first position (the position at which the height from the suction surface 22 is H_0) by the height H_1 . By this command, the slider 51 moves rightward to a position at the distance L_3 from the reference position (moves rightward by a distance (L_3-L_2)). Then, as indicated by an arrow 247 in Fig. 37, the tip end surface 633a of the third plated moving element 633 moves to the second position that is lower than the first position (the position higher than the suction surface by the height H_0) by the height H_1 (the position lower than the suction surface 22 by H_1-H_0). Further, as indicated by an arrow 246 in Fig. 37, the tip end surface 632a

of the second plated moving element 632 at the second position moves to a third position that is lower than the first position (initial position) by height H_2 (the position lower than the suction surface 22 by $H_2 - H_0$). Moreover, the tip end surface 631a of the first plated moving element 631 remains at the third position. With this, the tip end surface 631a of the first plated moving element 631, the tip end surface 632a of the second plated moving element 632, the tip end surface 633a of the third plated moving element 633, and the tip end surfaces 634a and 635a of the fourth and the fifth plated moving element 634 and 635 become stepped surfaces having different levels from each other, as well as stepped surfaces for the suction surface 22. [0100]

Further, at time t_{12} , the controller 150 outputs a command for switching the suction pressure to the third pressure P_3 that is near vacuum. By this command, as indicated by an arrow 245 in Fig. 37, air in the grooves 26 is suctioned to the vacuum apparatus 140 to vacuumize the grooves 26, and the dicing sheet 12 is vacuum-suctioned to the suction surface 22. Through the steps in and before the second third-separation step described previously, the major portion of the semiconductor die 15 is separated from the dicing sheet 12, and therefore an adhesive force between the semiconductor die 15 and the dicing sheet 12 is significantly reduced. Accordingly, as the tip end surface 633a of the third plated moving element 633 moves to the second

position, the dicing sheet 12 of the region corresponding to the tip end surface 633a moves away from the semiconductor die 15 as indicated by an arrow 278 in Fig. 37 due to a tension F_6 in the obliquely downward direction produced by vacuumization of the grooves 26, in the state in which the semiconductor die 15 is suctioned to the collet 18. Therefore, in the state illustrated in Fig. 37, while the region of the semiconductor die 15 corresponding to the tip end surfaces 634a and 635a of the fourth and the fifth plated moving element 634 and 635 is attached to the dicing sheet 12, the major portion of the semiconductor die 15 is separated from the dicing sheet 12.

[0101]

At time t_{13} in Fig. 38A, the controller 150 outputs a command for causing the collet 18 to move upward. By this command, the collet drive unit 130 illustrated in Fig. 1 drives the motor to move the collet 18 as indicated by an arrow 279 in Fig. 37. As the dicing sheet 12 is vacuum-suctioned to the suction surface 22 by vacuumization of the grooves 26, when the collet 18 moves upward, the region of the semiconductor die 15 corresponding to the tip end surfaces 634a and 635a of the fourth and the fifth plated moving element 634 and 635 is separated from the dicing sheet 12, and the semiconductor die 15 is picked up in the state in which the semiconductor die 15 is suctioned to the collet 18.

[0102]

After picking up the semiconductor die 15, the controller 150 moves the slider 51 back to an initial position at time t_{14} in Fig. 38, and the tip end surfaces 631a-635a respectively of the plated moving elements 631-635 move back the first position. Further, the controller 150 resumes the suction pressure and the opening pressure to the atmospheric pressure, and terminates the pick-up operation.

[0103]

As described above, the controller 150 switches the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure as in a period from time t_5 to t_6 , moves the tip end surface 631a of the first plated moving element 631 from the first position to the second position, switches the opening pressure and the suction pressure respectively from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure as in a period from time t_8 to t_9 , and moves the tip end surface 632a of the second plated moving element 632 from the first position to the second position. Thus, the controller 150 separates the dicing sheet 12 step-by-step from the semiconductor die 15 from the one side to the other side along the moving direction of the slider 51 by repeating the third-separation step such that the

tip end surfaces are moved along the moving direction of the slider 51 from the first position to the second position sequentially from the first plated moving element 631 to the fifth plated moving element 635, every time the opening pressure and the suction pressure are respectively switched from the first pressure P_1 and the third pressure P_3 that are near vacuum to the second pressure P_2 and the fourth pressure P_4 that are near the atmospheric pressure.

[0104]

Similarly to the embodiment previously described, according to the semiconductor die pick-up apparatus of the embodiment described above, it is possible to provide an effect of suppressing damages to a semiconductor die when being picked up.

[0105]

The present invention is not limited to the embodiment described above, and includes any alterations and modifications without departing from the technical scope and the spirit of the present invention defined in the appended claims.

Reference Signs List

[0106]

10: wafer holder

11: wafer

12: dicing sheet

12a: front surface
12b: back surface
13: ring
14: gap
15: semiconductor die
16: expanded ring
18: collet
18a: surface
19: suction hole
20: stage
22: suction surface
23: opening
23a, 28a: inner surface
24: base unit
25: drive unit
26, 31a, 45a, 62, 72: groove
27: suction hole
28: upper interior
29: lower interior
29a: stepped portion
30, 630: moving element
31: peripheral annular moving element
32a, 34a: guide surface
33: outer circumference surface
333a-333f: support plate

33a-33e: annular member
35a-35e: linear cam surface
36a-36f, 39a-39f: horizontal support surface
37a-37f: hook portion
38a-38e, 47, 631a-635a: tip end surface
40-43: middle annular moving element
45: columnar moving element
46: columnar member
51: slider
52: semi-columnar member
52a: apex (crest line)
53, 59, 63: pin
54: guide rail
55: flange
56: piston
57: plate member
58: spring
60: link member
70: vertical direction drive member
71: arm
73: drive rod
74: cam follower
75: cam
76: shaft
77: motor

80: opening pressure switch mechanism
81, 91, 101: three-way valve
82, 92, 102: drive unit
83-85, 93-95, 103-105: piping
90: suction pressure switch mechanism
100: suctioning mechanism
106: flow rate sensor
107: sheet displacement detection sensor
110: horizontal wafer-holder drive unit
120: vertical stage drive unit
130: collet drive unit
140: vacuum apparatus
150: controller
151: CPU
152: memory unit
153: device/sensor interface
154: data bus
155: control program
156: control data
157: positioning program
158: first separation program
159: second separation program
160: third separation program
300: stepped-surface forming mechanism
500: semiconductor die pick-up apparatus

631-635: plated moving element

631b, 635b: outer surface

CLAIMS

1. A semiconductor die pick-up apparatus comprising:
 - a stage having a suction surface for suctioning a back surface of a dicing sheet with a front surface to which a semiconductor die to be picked up is applied;
 - a stepped-surface forming mechanism configured to form a stepped surface for the suction surface, the stepped-surface forming mechanism having a plurality of moving elements disposed in an opening provided in the suction surface of the stage, the moving elements being movable between a first position and a second position, the first position being a position at which tip end surfaces of the moving elements are higher than the suction surface, the second position being a position at which the tip end surfaces of the moving elements are lower than the first position; and
 - an opening pressure switch mechanism configured to switch an opening pressure of the opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure, wherein
 - when the semiconductor die is picked up, at least one of the moving elements is moved from the first position to the second position every time the opening pressure is switched from the first pressure to the second pressure.

2. The semiconductor die pick-up apparatus according to claim 1, comprising:

a suction pressure switch mechanism configured to switch a suction pressure of the suction surface between a third pressure that is near vacuum and a fourth pressure that is near the atmospheric pressure, wherein

when the semiconductor die is picked up, the opening pressure is switched in a state in which the suction pressure is switched from the fourth pressure to the third pressure.

3. The semiconductor die pick-up apparatus according to claim 2, wherein

when the semiconductor die is picked up, the opening pressure is switched while the suction pressure is maintained at the third pressure.

4. The semiconductor die pick-up apparatus according to claim 1, wherein

the opening pressure switch mechanism switches the opening pressure for a plurality of times between the first pressure and the second pressure, before any of the moving elements is first moved from the first position to the second position.

5. The semiconductor die pick-up apparatus according to claim 2, wherein

when the semiconductor die is picked up, at least one of the moving elements is moved from the first position to the second position every time the suction pressure is switched from the third pressure to the fourth pressure and the opening pressure is switched from the first pressure to the second pressure after the opening pressure is switched from the second pressure to the first pressure in a state in which the suction pressure is switched from the fourth pressure to the third pressure.

6. The semiconductor die pick-up apparatus according to claim 1, comprising:

a separation detection means configured to detect whether or not a portion of the semiconductor die facing against any of the tip end surfaces of the moving elements that has moved from the first position to the second position is separated from the front surface of the dicing sheet, wherein

when the separation detection means has detected that the portion of the semiconductor die is unseparated from the dicing sheet, the opening pressure is switched from the first pressure to the second pressure without moving the moving elements from the first position to the second position, and then again the

opening pressure is switched from the second pressure to the first pressure.

7. The semiconductor die pick-up apparatus according to claim 6, comprising:

a collet configured to suction a semiconductor die;
a suctioning mechanism connected to the collet, and configured to suction air from a surface of the collet; and
a flow rate sensor configured to detect an amount of air flow suctioned by the suctioning mechanism, wherein
the separation detection means determines that separation is successful when a number of times that a derivative signal changes over a predetermined threshold range is an even number, and determines that the separation is unsuccessful when the number of times is an odd number, the derivative signal being obtained by derivation of a signal of the amount of suctioned air flow detected by the flow rate sensor.

8. The semiconductor die pick-up apparatus according to claim 1, comprising:

a sheet displacement detection sensor configured to detect displacement of the dicing sheet between an inner surface of the opening of the stage and an outer circumference surface of the stepped-surface forming mechanism, the displacement

being in an approaching and departing direction with respect to the suction surface, wherein

if the sheet displacement detected by the sheet displacement detection sensor is a predetermined threshold value or smaller when the opening pressure is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure, the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is separated from the semiconductor chip by switching the suction pressure from the third pressure to the fourth pressure and the opening pressure from the first pressure to the second pressure, and thereafter switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is again switched from the fourth pressure to the third pressure.

9. The semiconductor die pick-up apparatus according to claim 8, wherein

the sheet displacement detection sensor uses, as a light source, light of a wavelength whose light transmission rate through the dicing sheet is in a range from 0% to 30%.

10. The semiconductor die pick-up apparatus according to claim 9, wherein

the sheet displacement detection sensor employs a reflection-type optical fiber using an LED of a short wavelength from 0 nm to 300 nm as a light source.

11. The semiconductor die pick-up apparatus according to claim 1, wherein

the stepped-surface forming mechanism includes:

a columnar moving element that is disposed in a center;

a plurality of annular moving elements arranged around the columnar moving element in a telescopical manner; and

a slider movable in a direction along the suction surface within the opening of the stage,

each of the annular moving elements includes an inclined surface that is in contact with the slider, and with which corresponding one of the annular moving elements moves between the first position and the second position based on movement of the slider, and

the inclined surface of one of the annular moving elements on an outer circumference side and a different inclined surface of a different one of the annular moving elements on an inner circumference side are arranged in a displaced manner in a

moving direction of the slider so that when the slider moves, a tip end surface of the annular moving element on the outer circumference side moves from the first position to the second position before a tip end surface of the different annular moving element on the inner circumference sided moves.

12. The semiconductor die pick-up apparatus according to claim 11, wherein

the columnar moving element includes an inclined surface that is in contact with the slider, and with which the columnar moving element moves between the first position and the second position, and the inclined surface is disposed in a displaced manner in the moving direction of the slider so that when the slider moves, the tip end surface of the annular moving element on the inner circumference side moves from the first position to the second position before a tip end surface of the columnar moving element moves.

13. The semiconductor die pick-up apparatus according to claim 1, wherein

the stepped-surface forming mechanism includes:

a slider movable in a direction along the suction surface within the opening of the stage,

a plurality of plated moving elements arranged side by side in a moving direction of the slider,

each of the plated moving elements includes an inclined surface that is in contact with the slider, and with which corresponding one of the plated moving elements moves between the first position and the second position based on movement of the slider, and

the inclined surfaces of the plated moving elements are arranged in a displaced manner in the moving direction of the slider so that the corresponding plated moving elements sequentially move from the first position to the second position along the moving direction of the slider.

14. A semiconductor die pick-up method comprising:

a step of preparing a semiconductor die pick-up apparatus including: a stage having a suction surface for suctioning a back surface of a dicing sheet with a front surface to which a semiconductor die to be picked up is applied; a stepped-surface forming mechanism configured to form a stepped surface for the suction surface, the stepped-surface forming mechanism having a plurality of moving elements disposed in an opening provided in the suction surface of the stage, the moving elements being movable between a first position and a second position, the first position being a position at which tip end surfaces of the moving elements are higher than the suction surface, the second position being a position at which the tip end surfaces of the moving elements are lower than the first

position; an opening pressure switch mechanism configured to switch an opening pressure of the opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure; and a suction pressure switch mechanism configured to switch a suction pressure of the suction surface between a third pressure that is near vacuum and a fourth pressure that is near the atmospheric pressure;

a positioning step of, assuming that a tip end surface of each of the moving elements of the stepped-surface forming mechanism is at the first position, moving the stage in a direction along the suction surface so that the semiconductor die to be picked up comes immediately above the stepped surface of the stepped-surface forming mechanism;

a first-separation step of separating the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism from the semiconductor chip by switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure; and

a second-separation step of separating a portion of the semiconductor die from the surface of the dicing sheet by moving at least one of the moving elements from the first position to the second position every time the opening pressure is switched from the first pressure to the second pressure in a state in

which the suction pressure is maintained at the third pressure, the portion of the semiconductor die facing against the tip end surface of the at least one moving element.

15. A semiconductor die pick-up method comprising:

a step of preparing a semiconductor die pick-up apparatus including: a stage having a suction surface for suctioning a back surface of a dicing sheet with a front surface to which a semiconductor die to be picked up is applied; a stepped-surface forming mechanism configured to form a stepped surface for the suction surface, the stepped-surface forming mechanism having a plurality of moving elements disposed in an opening provided in the suction surface of the stage, the moving elements being movable between a first position and a second position, the first position being a position at which tip end surfaces of the moving elements are higher than the suction surface, the second position being a position at which the tip end surfaces of the moving elements are lower than the first position; an opening pressure switch mechanism configured to switch an opening pressure of the opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure; and a suction pressure switch mechanism configured to switch a suction pressure of the suction surface between a third pressure that is near vacuum and a fourth pressure that is near the atmospheric pressure;

a positioning step of, assuming that a tip end surface of each of the moving elements of the stepped-surface forming mechanism is at the first position, moving the stage in a direction along the suction surface so that the semiconductor die to be picked up comes immediately above the stepped surface of the stepped-surface forming mechanism;

a first-separation step of separating the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism from the semiconductor chip by switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure; and

a third-separation step of separating a portion of the semiconductor die from the surface of the dicing sheet by moving at least one of the moving elements from the first position to the second position every time the suction pressure is switched from the third pressure to the fourth pressure and the opening pressure is switched from the first pressure to the second pressure after the opening pressure is switched from the second pressure to the first pressure in a state in which the suction pressure is switched from the fourth pressure to the third pressure, the portion of the semiconductor die facing against the tip end surface of the at least one moving element.

16. The semiconductor die pick-up method according to claim 14 or 15, wherein

the semiconductor die pick-up apparatus includes a sheet displacement detection sensor configured to detect displacement of the dicing sheet between an inner surface of the opening of the stage and an outer circumference surface of the stepped-surface forming mechanism, the displacement being in an approaching and departing direction with respect to the suction surface, and

the first separation step includes:

a first separation determination step of determining when the opening pressure is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is switched from the fourth pressure to the third pressure, that the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is separated from the semiconductor chip if the sheet displacement detected by the sheet displacement detection sensor exceeds a predetermined threshold value, and that the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is unseparated from the semiconductor chip if the sheet displacement detected by the

sheet displacement detection sensor is the predetermined threshold value or smaller; and

a first retry step of separating the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism from the semiconductor chip, when the dicing sheet between the inner surface of the opening of the stage and the outer circumference surface of the stepped-surface forming mechanism is determined to be unseparated from the semiconductor chip in the first determination step, by switching the suction pressure from the third pressure to the fourth pressure and the opening pressure from the first pressure to the second pressure, and thereafter switching the opening pressure from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is again switched from the fourth pressure to the third pressure.

17. The semiconductor die pick-up method according to claim 14, wherein

the semiconductor die pick-up apparatus includes: a collet configured to suction a semiconductor die; a suctioning mechanism connected to the collet, and configured to suction air from a surface of the collet; and a flow rate sensor configured to detect an amount of air flow suctioned by the suctioning mechanism, and

the second-separation step includes:

a second separation determination step of determining that the portion of the semiconductor die facing against the tip end surface of the moving element that has moved from the first position to the second position is separated from the front surface of the dicing sheet when a number of times that a derivative signal changes over a predetermined threshold range is an even number, and determining that the portion of the semiconductor die is unseparated from the front surface of the dicing sheet when the number of times is an odd number, the derivative signal being obtained by derivation of a signal of the amount of suctioned air flow detected by the flow rate sensor; and

a second retry step of separating the portion of the semiconductor die from the front surface of the dicing sheet, when the portion of the semiconductor die is determined to be unseparated from the front surface of the dicing sheet in the second separation determination step, by switching the opening pressure from the first pressure to the second pressure without moving the moving element from the first position to the second position, and again switching the opening pressure from the second pressure to the first pressure.

18. The semiconductor die pick-up method according to claim 15, wherein

the semiconductor die pick-up apparatus includes: a collet configured to suction a semiconductor die; a suctioning mechanism connected to the collet, and configured to suction air from a surface of the collet; and a flow rate sensor configured to detect an amount of air flow suctioned by the suctioning mechanism, and

the third-separation step includes:

a third separation determination step of determining that the portion of the semiconductor die facing against the tip end surface of the moving element that has moved from the first position to the second position is separated from the front surface of the dicing sheet when a number of times that a derivative signal changes over a predetermined threshold range is an even number, and determining that the portion of the semiconductor die is unseparated from the front surface of the dicing sheet when the number of times is an odd number, the derivative signal being obtained by derivation of a signal of the amount of suctioned air flow detected by the flow rate sensor; and

a third retry step of separating the portion of the semiconductor die from the front surface of the dicing sheet, when the portion of the semiconductor die is determined to be unseparated from the front surface of the dicing sheet in the third separation determination step, by switching the suction pressure from the third pressure to the fourth pressure and the

opening pressure from the first pressure to the second pressure without moving the moving element from the first position to the second position, and again switching the suction pressure from the fourth pressure to the third pressure and the opening pressure from the second pressure to the first pressure.

19. The semiconductor die pick-up method according to claim 16, wherein

the sheet displacement detection sensor uses, as a light source, light of a wavelength whose light transmission rate through the dicing sheet is in a range from 0% to 30%.

20. The semiconductor die pick-up method according to claim 19, wherein

the sheet displacement detection sensor employs a reflection-type optical fiber using an LED of a short wavelength from 0 nm to 300 nm as a light source.

21. The semiconductor die pick-up method according to claim 14 or 15, wherein

the opening pressure switch mechanism switches the opening pressure for a plurality of times between the first pressure and the second pressure, before any of the moving elements is first moved from the first position to the second position.