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 portion around 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 can likely be destroyed. Therefore, there is proposed a method, as illustrated in Fig. 31 of PTL 1, in which flection 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.

[0006]

Further, there is also proposed a method in which when a semiconductor die is picked up, a tip end of a cap on a side for closing a suctioning opening is caused to advance from a close-contact surface in a state in which a semiconductor die to be picked up is suctioned by a collet, the cap is caused to slide while a dicing sheet and a semiconductor die are moved upward to provide a gap between the suctioning opening and the tip end of the cap, then a rear end of the cap which is on a side for opening the cap is caused to advance from the close-contact surface, so that a surface of the cap is substantially parallel with the close-contact surface, the cap is caused to slide by moving the dicing sheet and the semiconductor die upward on the surface of the cap to sequentially open the suctioning opening, the dicing sheet is caused to sequentially suctioned to the opened suctioning opening, and thus the dicing sheet is sequentially separated from the semiconductor die to be picked up (cf.,PTL 3).

Citation List

Patent Literature

[0007]

PTL 1: Japanese Patent No. 4945339

PTL 2: US Patent No. 8092645

PTL 3: Japanese Patent No. 4397429

Summary of Invention

Technical Problem

[0008]

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 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 any of PTLs 1-3 has a problem that a semiconductor die is more likely damaged when the semiconductor die is picked up from a dicing sheet.

[0009]

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

Solution to Problem

[0010]

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 suctioning opening provided in the suction surface of the stage; a cap configured to slide along the suction surface to open and close the suctioning opening; and an opening pressure switch mechanism configured to switch a pressure of the suctioning opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure, and when the semiconductor die is picked up, the cap is caused to slide by a predetermined distance in an opening direction, every time the pressure of the suctioning opening is switched from the first pressure to the second pressure after the pressure of the suctioning opening is switched from the second pressure to the first pressure.

[0011]

Preferably, the semiconductor die pick-up apparatus according to the present invention is configured such that when the semiconductor die is picked up, the cap is caused to slide by the predetermined distance in the opening direction while a suction pressure of the suction surface is maintained to be vacuum.

[0012]

Preferably, the semiconductor die pick-up apparatus according to the present invention is configured such that the cap is provided for the stage such that a surface of the cap is allowed to freely advance from the suction surface, and when the semiconductor die is picked up, the dicing sheet is separated from the semiconductor die by causing the cap to

slightly slide to slightly open the suctioning opening, causing the surface of the cap to advance up to a predetermined height higher than the suction surface, then setting the suction pressure to be vacuum, and switching, after a predetermined time elapses, the pressure of the suctioning opening from the second pressure to the first pressure, the dicing sheet being positioned above the slightly opened suction opening.

[0013]

Preferably, the semiconductor die pick-up apparatus according to the present invention is configured such that the opening pressure switch mechanism switches the pressure of the suctioning opening between the first pressure and the second pressure more than once before causing the cap to slide by the predetermined distance in the opening direction.

[0014]

Preferably, the semiconductor die pick-up apparatus according to the present invention is configured such that the cap is provided for the stage such that a surface of the cap is allowed to freely advance from the suction surface, and when the semiconductor die is picked up, the cap is caused to slide in a state in which the surface of the cap advances up to a predetermined height higher than the suction surface.

[0015]

It is also preferable that the semiconductor die pick-up apparatus according to the present invention includes:

separation detection means configured to detect whether or not a portion of the semiconductor die positioned immediately above the suctioning opening opened by causing the cap to slide is separated from the front surface of the dicing sheet, and when the separation detection means has detected that the portion of the semiconductor die is unseparated from the dicing sheet, the pressure of the suctioning opening is switched from the first pressure to the second pressure without causing the cap to slide, and then again the pressure of the suctioning opening is switched from the second pressure to the first pressure.

[0016]

It is also 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, and 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.

[0017]

It is also preferable that the semiconductor die pick-up apparatus according to the present invention includes: a sheet displacement detection sensor provided near an end surface of the suctioning opening with which a tip end of the cap is brought into contact when the suctioning opening is closed, and configured to detect displacement of the dicing sheet with respect to the suction surface in an approaching and departing direction when the cap is caused to slightly slide to slightly open the suctioning opening, the dicing sheet being positioned above the suction opening that is slightly opened, and if the sheet displacement detected by the sheet displacement detection sensor is a predetermined threshold value or smaller when the pressure of the suctioning opening is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is set to vacuum, the dicing sheet is separated from the semiconductor chip die by making the suction pressure open to air and switching the pressure of the suctioning opening from the first pressure to the second pressure, and again setting the suction pressure to vacuum and switching the pressure of the suctioning opening from the second pressure to the first pressure after the predetermined time elapses, the dicing sheet being positioned above the slightly opened suction opening. 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%, and 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.

[0018]

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 having a front surface to which a semiconductor die to be picked up is applied; a suctioning opening provided in the suction surface of the stage; a cap provided for the stage such that a surface of the cap is allowed to freely advance from the suction surface, and configured to slide along the suction surface to open and close the suctioning opening; and an opening pressure switch mechanism configured to switch a pressure of the suctioning opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure; a positioning step of moving the stage in a direction along the suction surface, so that a tip end of the cap in a closed state aligns with one end of a semiconductor die to be picked up, and that a position of the cap in a width direction aligns with a position of the semiconductor die in the width direction; a first separation step of separating the dicing sheet from the semiconductor die

by causing the cap to slightly slide to slightly open the suctioning opening, causing the surface of the cap to advance up to a predetermined height higher than the suction surface, then setting the suction pressure to be vacuum, and switching, after a predetermined time elapses, the pressure of the suctioning opening from the second pressure to the first pressure, the dicing sheet being positioned above the slightly opened suction opening; and a second-separation step of separating a portion of the semiconductor die from the front surface of the dicing sheet by causing the cap to slide, in a state in which a surface of the cap advances up to a predetermined height higher than the suction surface, by a predetermined distance in the opening direction every time the pressure of the suctioning opening is switched from the first pressure to the second pressure after a suction pressure of the suction surface is maintained to be vacuum and the pressure of the suctioning opening is switched from the second pressure to the first pressure, the portion of the semiconductor die being positioned immediately above the suctioning opening opened by the sliding.

[0019]

Preferably, in the semiconductor die pick-up method according to the present invention, the opening pressure switch mechanism switches the pressure of the suctioning opening between the first pressure and the second pressure more than

once before causing the cap to slide by the predetermined distance in the opening direction.

[0020]

Preferably, in the semiconductor die pick-up method according to the present invention, the semiconductor die pick-up apparatus includes: a sheet displacement detection sensor provided near an end surface of the suctioning opening with which a tip end of the cap is brought into contact when the suctioning opening is closed, and configured to detect displacement of the dicing sheet with respect to the suction surface in an approaching and departing direction when the cap is caused to slightly slide to slightly open the suctioning opening, the dicing sheet being positioned above the suction opening that is slightly opened, and the first separation step includes: a first separation determination step of determining, when the pressure of the suctioning opening is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is set to vacuum, that the dicing sheet positioned above the slightly opened suction opening is separated from the semiconductor die if the sheet displacement detected by the sheet displacement detection sensor exceeds a predetermined threshold value, and that the dicing sheet positioned above the slightly opened suction opening is unseparated from the semiconductor die 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, when the dicing sheet positioned above the slightly opened suction opening is determined to be unseparated from the semiconductor die in the first separation determination step, the dicing sheet from the semiconductor chip by making the suction pressure open to air and switching the pressure of the suctioning opening from the first pressure to the second pressure, and again setting the suction pressure to vacuum and switching the pressure of the suctioning opening from the second pressure to the first pressure after the predetermined time elapses, the dicing sheet being positioned above the slightly opened suction opening. 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%, and 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.

[0021]

Preferably, in the semiconductor die pick-up method according to the present invention, 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 a portion of the semiconductor die positioned immediately above the suctioning opening opened by sliding the cap 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 positioned immediately above the suctioning opening opened by sliding the cap 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, 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, the portion of the semiconductor die from the front surface of the dicing sheet by switching the pressure of the suctioning opening from the first pressure to the second pressure without causing the cap to slide, and again switching the pressure of the suctioning opening from the second pressure to the first pressure.

Advantageous Effects of Invention

[0022]

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

Brief Description of Drawings

[0023]

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. 3 is a plan view illustrating the stage of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 4A is a detailed view illustrating the stage of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 4B is a detailed view of a portion A in Fig. 4A.

Fig. 5A is a plan view illustrating a cap of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 5B is an elevational view illustrating the cap of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 5C is a detailed view of a portion B in Fig. 5B.

Fig. 6 is a sectional view of the stage and the cap of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 7 is a diagram illustrating a wafer applied to a dicing sheet.

Fig. 8 is a diagram illustrating a semiconductor die applied to the dicing sheet.

Fig. 9A is a plan view illustrating a configuration of a wafer holder.

Fig. 9B is an elevational view illustrating the configuration of the wafer holder.

Fig. 10A is an elevational view for illustration of an operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 10B is a plan view 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. 12A is an elevational view for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 12B is a plan view 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. 20 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 21 is a diagram for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22A is an elevational view for illustration of the operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 22B is a plan view for illustration of the 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 the 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 an opening width during the 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 suction pressure during the 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 pressure of a suctioning opening during the 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 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. 24A 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. 24B 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. 24C 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. 24D 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. 25A 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. 25B is a chart showing a temporal change in an opening width during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 25C is a chart showing a temporal change in a suction pressure during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 25D is a chart showing a temporal change in a pressure of a suctioning opening during the different operation of the semiconductor die pick-up apparatus according to the embodiment of the present invention.

Fig. 25E 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.

Description of Embodiment

[0024]

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 suctioning opening 40 provided for the suction surface 22 of the stage 20 as shown in Fig. 2; a cap 23 for opening and closing the suctioning opening 40; a slider drive mechanism 300 for causing a slider 332 to which the cap 23 is rotatably applied to slide as shown in Fig. 1; a collet 18 for picking up one of the semiconductor dies 15; an opening pressure switch mechanism 80 for switching a pressure of the suctioning opening 40 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.

[0025]

As illustrated in Fig. 1, the slider drive mechanism 300 disposed within the stage 20 is configured by: a first link 326 driven in a forward-backward direction with respect to the suction surface 22 by a drive unit 25 attached to a base unit 24 of the stage 20; a piston 370 slidably provided for a housing 21 of the stage 20 in the forward-backward direction with respect to the suction surface 22; a stopper 321a provided within the housing 21, and engaged with a flange 371 of the piston 370 so as to limit an operation of the piston 370 in the forward-backward direction with respect to the suction surface 22; a spring 373 that connects the first link 326 and the piston 370 in the forward-backward direction with respect to the suction surface 22; a guide rail 331 attached to the piston 370, and extending along a direction in which a groove 22a extends that is substantially parallel to the suction surface 22; the slider 332 slidably attached to the guide rail 331; and a second link 329 that is rotatably attached to the piston 370 via a pin 328, that connects the slider 332 and the first link 326, and that converts, upon contact of the piston 370 with the stopper 321a, a movement of the first link 326 in the forward-backward direction with respect to the suction surface 22 into a movement in a direction along the guide rail 331 of the slider 332. To

the slider 332, a cylindrical pin 330 extending along a width direction of the groove 22a is attached. As illustrated in Fig. 5A and Fig. 5B, the pin 330 is rotatably engaged with an inverted U-shaped cutout provided in an arm 23f overhanging from a tip end 23a of the cap 23 toward a side of an end surface 22e. Further, the second link 329 connects the slider 332 and the first link 326 by a pin 327 disposed on one end fitted into an engagement groove 326a of the first link 326, and by an engagement groove 329a provided on the other end sandwiching a pin 330a of the slider 332. Within the drive unit 25, a motor 381 for operating the slider drive mechanism 300 is attached. To a rotational axis of the motor 381, a cam 383 in contact with a roller 326c provided at a tip end of a shaft 326b of the first link 326 is attached. When the motor 381 rotates in a direction indicated by an arrow a illustrated in Fig. 1, the slider drive mechanism 300 causes the slider 332 to slide rightward along the suction surface 22 by an upward movement of the first link 326 indicated by an arrow b illustrated in Fig. 1 and a rotating movement of the second link 329 indicated by an arrow d illustrated in Fig. 1.

[0026]

As illustrated in Fig. 1, the opening pressure switch mechanism 80 for switching a pressure of the suctioning opening 40 of the stage 20 (cf., Fig. 2) or a pressure within the housing 21 communicated with the suctioning opening 40 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 housing 21 communicated with the suctioning opening 40 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 suctioning opening 40 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 suctioning opening 40 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 suctioning opening 40 between the first pressure P_1 and the second pressure P_2.

[0027]

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 a suction groove 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 suction groove 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 suction 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 suction groove 26 or the suction surface 22 between the third pressure P_3 and the fourth pressure P_4.

[0028]

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.

[0029]

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, near the end surface 22e of the suctioning opening 40 with which the tip end 23a of the cap 23 is brought into contact when the suctioning opening 40 is closed, 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 are used as long as light

having a high reflection rate through the dicing sheet is emitted.

[0030]

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, and a second-separation program 159 are stored.

[0031]

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 381 of the slider drive 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. It should be noted that alternate long and short dash lines in Fig. 1 represent signal

lines from the device/sensor interface 153 of the controller 150 to 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 381 of the slider drive mechanism 300, the horizontal wafer-holder-drive unit 110, the vertical stage-drive unit 120, the collet drive unit 130, the vacuum apparatus 140, the flow rate sensor 106, and the sheet displacement detection sensor 107.

[0032]

Next, the stage 20 and the cap 23 are described in detail with reference to Fig. 2 through Fig. 6. Referring to Fig. 2, the stage 20 includes the cylindrical housing 21 having the suction surface 22 for suctioning the dicing sheet 12 on its upper surface, the base unit 24 provided on a side opposite of the suction surface 22 of the housing 21, and the drive unit 25 attached to the base unit 24 and driving the slider drive mechanism 300 disposed within the housing 21. The base unit 24 of the stage 20 is attached to a stage fixation unit that is not illustrated. The suction surface 22 is provided with the groove 22a that is recessed into the stage 20 from the suction surface 22, a projected portion 22b disposed within the groove 22a on a side close to the stage 20 and projecting from a bottom surface of the groove 22a. Side surfaces 22f of the groove 22a

are flush with guide surfaces 22g on both sides of the projected portion 22b, and extend linearly from an inner circumference side to an outer circumference side of the stage. The projected portion 22b is a step having a flat surface between the guide surfaces 22g, and a height of the projected portion 22b is smaller than a depth of the groove 22a. The bottom surface of the groove 22a and the surface of the projected portion 22b are connected by an inclined surface 22c extending from the bottom surface of the groove 22a to the surface of the projected portion 22b. The bottom surface of the groove 22a is provided with two holes 41 that are communicated with an interior of the stage 20, and a rib 22d is provided in a center of each of the holes 41 and on a side of an outer surface of the stage of each of the holes 41.

[0033]

To the groove 22a, the cap 23 is attached. The cap 23 has a substantially identical width with a width of the groove 22a and a width between and the guide surfaces 22g, and slides along a direction from the groove 22a toward the projected portion 22b. The cap 23 is configured such that along the sliding direction, the tip end 23a is on a side facing toward the end surface 22e of the groove 22a, and a rear end 23c is on a side at which the cap 23 defines an opening. The cap 23 is in a flat-plated shape, and includes a flat portion 23h on which the semiconductor dies 15 are placed with the dicing sheet

12 interposed therebetween, and an inclined surface 23g that continues from the flat portion 23h and is inclined downward from the suction surface. A length of the sliding direction of the cap 23 is shorter than a length of the sliding direction of the groove 22a, and a thickness of the flat portion 23h of the cap 23 is the same as the depth of the groove 22a. Therefore, when the cap 23 is fitted into the groove 22a, so that the tip end 23a of the cap 23 is in contact with the end surface 22e of the groove 22a, the flat portion 23h on a surface of the cap 23 becomes flush with the suction surface 22. Side surfaces 23b of the cap 23 and the side surfaces 22f of the groove 22a constitute a sliding surface. Further, at both corners of the groove 22a on a side with which the tip end 23a of the cap 23 is brought into contact, vertical grooves 364 for suctioning the dicing sheet 12 are respectively provided outside of the side surfaces 22f of the groove 22a in a width direction of the groove 22a so as to extend in the vertical direction into the stage 20 from the suction surface 22.

[0034]

Thus configured, the suction surface 22 is provided with the suctioning opening 40 defined in a U shape enclosed by the side surfaces 22f, the end surface 22e, and the guide surfaces 22g of the groove 22a. The suctioning opening 40 is communicated with an interior of the housing 21. Further, as illustrated in Fig. 2, there are three suction grooves 26

substantially in a U shape provided so as to triply surround the U-shaped suctioning opening 40. On each side of the suction grooves 26, two or three suction holes 27 are provided. The suction holes 27 are connected to the suction pressure switch mechanism 90 via the piping 93 as illustrated in Fig. 1.

[0035]

As illustrated in Fig. 3, Fig. 4A, and Fig. 4B, when the tip end 23a of the cap 23 is pressed against the end surface 22e of the groove 22a on the inner circumference side of the stage 20, the suctioning opening 40 is closed. The suctioning opening 40 is opened when he cap 23 slides along the side surfaces 22f and the guide surfaces 22g of the groove 22a from the inner circumference side toward the outer circumference side of the stage 20 and the tip end 23a of the cap 23 is moved away from the end surface 22e of the groove 22a. Therefore, the end surface 22e is an end surface of the suctioning opening 40 with which the tip end 23a of the cap 23 is brought into contact when the suctioning opening 40 is closed.

[0036]

As illustrated in Fig. 4A and Fig. 4B, as the tip end 23a of the cap 23 is brought into contact with the end surface 22e when the cap 23 is closed. Therefore, in a state in which the cap 23 is closed, the vertical grooves 364 having an about 180-degree fan-shaped cylindrical surface runs between the

suction surface 22 and the interior of the housing 21 at the both corners of the cap 23 and the groove 22a.

[0037]

As illustrated in Fig. 5B and Fig. 5C, the cap 23 is in a flat-plated shape on a side of the tip end 23a, a thickness of the flat portion 23h on which the semiconductor dies 15 are placed with the dicing sheet 12 interposed therebetween is substantially uniform, a curved surface 23d that rounds a corner between a back surface of the cap 23 and a surface of the rear end 23c is provided on the back surface of the cap 23 on a side of the rear end 23c, and the inclined surface 23g whose inclination increases from the flat portion 23h toward the rear end 23c is provided on a side of the surface. The inclined surface 23g is provided in a region where any of the semiconductor dies 15 is not placed thereupon, and a length of the flat portion 23h is longer than a length of each of the semiconductor dies 15. On the side of the back surface, the cap 23 has a flat surface. Further, the both side surfaces 23b of the cap 23 are respectively provided with chamfers 23e. On the back surface of the cap 23 on the side of the tip end 23a, there are two arms 23f that project toward the tip end 23a. The arms 23f are attached so as to respectively be inserted through the holes 41 in the stage 20 illustrated in Fig. 2. Each of the arms 23f has a U-shaped engagement groove, and as illustrated in Fig. 1, the cap 23 is rotatably attached to the

slider 332 by having the engagement grooves be engaged with the pin 330 of the slider 332.

[0038]

As illustrated in Fig. 6, when the suctioning opening 40 is closed by the cap 23 such that the tip end 23a of the cap 23 is brought into contact with the end surface 22e of the groove 22a, a surface of the flat portion 23h of the cap 23 is flush with the suction surface 22. Further, when the suctioning opening 40 is closed such that the tip end 23a of the cap 23 is in contact with the end surface 22e of the groove 22a, a small V-shaped groove is provided between the suction surface 22 and the cap 23. Moreover, the width of the groove 22a, that is, a width of the suctioning opening 40, a width of the cap 23, a width of each of the semiconductor dies 15 are substantially identical, and the side surfaces 22f of the groove 22a are slidably in contact with the side surfaces 23bof the cap 23.

[0039]

An operation of the semiconductor die pick-up apparatus 500 thus configured will be described with reference to Fig. 7 through Fig. 23A to Fig. 23E. 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.

[0040]

Referring to Fig. 7, 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. 8, 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.

[0041]

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. 9A and Fig. 9B. 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 is smoothly expanded when the dicing sheet 12 is attached to the expanded ring 16. As illustrated in Fig. 9B, 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.

[0042]

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.

[0043]

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. As illustrated in Fig. 10A and Fig. 10B, the controller 150 starts positioning between the cap 23 and the semiconductor die 15 in a state in

which the cap 23 is closed. As the cap 23 is at a position to close the suctioning opening 40, the tip end 23a of the cap 23 is in contact with the end surface 22e of the groove 22a, and the back surface of the cap 23 on the side of the rear end 23c is on a surface of the groove 22a and supported by the groove 22a. Further, the flat portion 23h on a surface of the cap 23 and is substantially flush with the suction surface 22. The controller 150 causes the horizontal wafer-holder-drive unit 110 illustrated in Fig. 1 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, and causes the vertical stage-drive unit 120 illustrated in Fig. 1 to move the stage 20 upward until the suction surface 22 of the stage 20 and the flat portion 23h on the surface of the cap 23 are brought into close contact with a lower surface of the dicing sheet 12. When the suction surface 22 of the stage 20 and the flat portion 23h on the surface of the cap 23 are brought into close contact with the lower surface of the dicing sheet 12, the controller 150 stops upward movement of the stage 20. Then, the controller 150 again makes adjustment by causing the horizontal wafer-holder-drive unit 110 to bring one end 15a of the semiconductor die 15 to be picked up to contact with the tip end 23a of the cap 23 at a closed

position, to align an across-the-width position of the cap 23 with an across-the-width position of the semiconductor die 15, and to align side surfaces the semiconductor die 15 with the side surfaces 23b of the cap 23. The width of the cap 23 is substantially the same as the width of the semiconductor die 15 to be picked up, and therefore it is possible to make positioning between the side surfaces of the semiconductor die 15 and the side surfaces 23b of the cap 23 by aligning one of the side surfaces 23b with a corresponding one of the side surfaces of the semiconductor dies 15. At this time, the dicing sheet 12 is applied with tension by the expanded ring 16 of the wafer holder 10.

[0044]

Fig. 10B is a plan view of the suction surface 22 of the stage 20 and the surface of the cap 23, and illustrates positional relation between the dicing sheet 12 and the semiconductor die 15 placed on the suction surface 22 of the stage 20 and the surface of the cap 23 by an alternate long and short dash line. In Fig. 10B, the cap 23 is shown slightly larger than the semiconductor die 15 in order to distinguish the semiconductor die 15 and the cap 23 having substantially the same width. This also applies to Fig. 12B and Fig. 22B. As illustrated in Fig. 10B, upon positioning of the cap 23 and the semiconductor die 15, the semiconductor die 15 is positioned on the flat portion 23h of the cap 23.

[0045]

Upon completion of advancement and adhesion of the stage 20 to the lower surface of the dicing sheet 12 and positioning of the semiconductor die 15, 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 as to communicate the suction hole 19 of the collet 18 with the vacuum apparatus 140. With this, air in the suction hole 19 is suctioned to the vacuum apparatus 140 as indicated by an arrow 301 in Fig. 11 to vacuumize the suction hole 19, and the collet 18 suctions and fixes the semiconductor die 15 to the surface 18a. At this time, a height of the surface 18a of the collet 18 is an initial height that is a total value of a height of the suction surface 22, a thickness of the dicing sheet 12, and a thickness of the semiconductor die 15. Further, in a state in which execution of the positioning program 157 is completed, a pressure of the suctioning opening 40, the suction groove 26, or the suction surface 22 corresponds to an atmospheric pressure (completion of the positioning program 157).

[0046]

Next, the controller 150 executes the first-separation program 158 illustrated in Fig. 1. First, at time t_0 shown in Fig. 23A through Fig. 23E, the controller 150 outputs a command for causing the slider drive mechanism 300 to cause the flat portion 23h on the surface of the cap 23 to advance from the suction surface 22 by a predetermined height H_1, and to slightly slide the cap 23 toward the outer circumference side of the stage 20 to slightly open the suctioning opening 40. As illustrated in Fig. 12A, as the motor 381 of the drive unit 25 of the slider drive mechanism 300 rotates based on the command from the controller 150, the cam 383 attached to an axis of the motor 381 rotates. The cam 383 is in an elliptical shape, and a cam surface of the cam is in contact with the roller 326c attached to a tip end of the shaft 326b of the first link 326. When rotated in a direction indicated by an arrow a in Fig. 12A, the cam surface of the cam 383 moves the roller 326c up toward the suction surface 22. This operation moves the shaft 326b upward as indicated by an arrow b in Fig. 12A, and the first link 326 as a whole moves upward toward the suction surface 22. When the first link 326 as a whole moves upward, the piston 370 connected to a side of the suction surface 22 via the spring 373 is moved upward by the first link 326, and the piston 370 as a whole moves upward toward the suction surface 22 as indicated by an arrow c in Fig. 12A. As the piston 370 as a whole moves upward toward the suction surface 22, the guide rail

331 attached to a side of the suction surface 22 also moves upward along with the piston 370 toward the suction surface 22. As the guide rail 331 moves upward, the slider 332 attached along an upper surface the guide rail 331 also moves upward toward the suction surface 22. Then, the tip end 23a of the cap 23 rotatably engaged with the slider 332 via the arm 23f advances up from the suction surface 22 along with the upward movement of the slider 332.

[0047]

When the tip end 23a of the cap 23 advances up from the suction surface 22 as indicated by an arrow 201 in Fig. 13, the tip end 23a of the cap 23 moves the dicing sheet 12 and the one end 15a of the semiconductor die 15 upward. Then, the tip end 23a is applied with a downward force by the dicing sheet 12, and the cap 23 rotates centering the pin 330 in a clockwise direction. The lower surface of the cap 23 on the side of the rear end 23c is supported by the bottom surface of the groove 22a, and the flat portion 23h of the surface of the cap 23 pressing the dicing sheet 12 upward is inclined downward to the rear end 23c from the tip end 23a of the cap 23. The controller 150 causes the collet drive unit 130 to move the collet 18 upward as the cap 23 advances up from the suction surface 22 as indicated by an arrow 302 in Fig. 13. As the dicing sheet 12 is inclined following an inclination of the flat portion 23h on the surface of the cap 23, the semiconductor die 15 applied to the dicing

sheet 12 is also inclined with respect to the suction surface 22. Accordingly, while a side of the one end 15a of the semiconductor die 15 moves upward while being suctioned to the collet 18, a side of the other end 15b of the semiconductor die 15 is applied to the dicing sheet 12 and spaced apart from the surface 18a of the collet 18. In this state, the semiconductor die 15 is slightly deformed and flexed between the side of the one end 15a and the side of the other end 15b. Further, as the side of the other end 15b of the semiconductor die 15 is spaced apart from the surface 18a of the collet 18, air flows into the suction hole 19 through a gap between the other end 15b of the semiconductor die 15 and the surface 18a as indicated by an arrow 303 in Fig. 13.

[0048]

As illustrated in Fig. 12A, as the cam 383 of the slider drive mechanism 300 further rotates based on the command from the controller 150, and the first link 326 is moved up toward the suction surface 22, the spring 373 between the piston 370 that cannot move toward the suction surface 22 and the first link 326 is compressed in the forward-backward direction with respect to the suction surface 22 by the motor 381 and the cam 383. Upon compression of the spring 373, the piston 370 does not advance toward the suction surface 22, and only the first link 326 advances toward the suction surface 22. Accordingly, the pin 328 of the piston 370 does not move up toward the suction

surface 22, but only the pin 327 of the second link 329 in the engagement groove 326a of the first link 326 moves up toward the suction surface 22. Then, the second link 329 starts rotating about the pin 328. By this rotating movement, the engagement groove 329a of the second link 329 on the other end moves toward the outer circumference side of the stage 20, and the slider 332 to which the pin 330a in the engagement groove 329a is fixed and the cap 23 rotatably engaged with the pin 330of the slider 332 via the arm 23f start sliding toward the outer circumference side of the stage 20.

[0049]

As illustrated in Fig. 14, when the cap 23 starts sliding toward the outer circumference side of the stage 20, the curved surface 23d provided at the rear end 23c on the back surface of the cap 23 is brought into contact with the inclined surface 22c that connects the projected portion 22b and the bottom surface of the groove 22a. Then, as the cap 23 further slides, as shown by an arrow 203 in Fig. 14, the curved surface 23d of the cap 23 moves up toward the inclined surface 22c. With this, a surface of the flat portion 23h of the cap 23 on the side of the rear end 23c starts advancing from the suction surface 22. Then, as the cap 23 further slides, the curved surface 23d of the cap 23 moves over the inclined surface 22c, and the back surface of the cap 23 is brought into contact with the surface of the projected portion 22b. A projecting height of the

projected portion 22b projecting from the bottom surface of the groove 22a is substantially equal to an advancing height H_1 of the surface of the cap 23 from the suction surface 22. Therefore, when the bottom surface of the cap 23 is brought into contact with the surface of the projected portion 22b, the flat portion 23h on the surface of the cap 23 becomes substantially parallel with the suction surface 22. As the lower surface of the cap 23 is supported by the surface of the projected portion 22b illustrated in Fig. 14, the lower surface of the cap 23 is apart from the bottom surface of the groove 22a. After this, the cap 23 slides in a state in which the flat portion 23h on the surface of the cap 23 is substantially parallel with the suction surface 22.

[0050]

When the flat portion 23h on the surface of the cap 23 becomes substantially parallel with the suction surface 22, the surface of the flat portion 23h is also substantially parallel with the surface 18a of the collet 18. Therefore, the side of the other end 15b of the semiconductor die 15 that is apart from the collet 18 while the flat portion 23h of the cap 23 is inclined is again suctioned to the surface 18a of the collet 18. As illustrated in Fig. 14, when the flat portion 23h as a whole on which is the semiconductor dies 15 placed advances from the suction surface 22 by the height H_1, so that the cap 23 becomes substantially parallel with the suction surface 22, a gap of

a width D_1 is provided between the tip end 23a of the cap 23 and the end surface 22e. The gap is a minute opening 42, and the width D_1 is an opening width D_1 of the minute opening 42. Further, as illustrated in Fig. 14, the height of the surface 18a of the collet 18 is a height Hc obtained by adding the thickness of the dicing sheet 12 and the thickness of the semiconductor dies 15 to the advancing height H_1 of the flat portion 23h of the cap 23.

[0051]

Next, at time t_1 in Fig. 23C, the controller 150 outputs a command for setting the suction pressure to be the third pressure P_3 that is near vacuum. By this command, the drive unit 92 of the suction pressure switch mechanism 90 illustrated in Fig. 1 switches the three-way valve 91 so as to communicate the suction hole 27 with the vacuum apparatus 140. Then, as indicated by an arrow 202 in Fig. 14, air in the suction groove 26 is suctioned by the vacuum apparatus 140 through the suction hole 27, and as illustrated in Fig. 23D, 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 a circumferential edge of the suctioning opening 40 is vacuumized and suctioned to the suction surface 22 as illustrated in Fig. 14. As the flat portion 23h of the cap 23 as a whole advances from the suction surface 22 by the height H_1, when the dicing sheet 12 is vacuumized and suctioned to the

suction surface 22, as illustrated in Fig. 14, the dicing sheet 12 is applied with an obliquely downward tension F_1. The tension F_1 is 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 a near-field region of the one end 15a 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 near-field region of the one end 15a of the semiconductor die 15. After the suction pressure is set to the third pressure P_3 that is near vacuum at time t_2 as illustrated in Fig. 23C, the controller 150 maintains the suction pressure to be the third pressure P_3 that is near vacuum.

[0052]

As illustrated in Fig. 23D, at time t_3 at which a predetermined time has elapsed after time t_2, the controller 150 outputs a command for switching the pressure of the suctioning opening 40 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 as to communicate either the suctioning opening 40 or the

interior of the housing 21 with the vacuum apparatus 140. Then, as indicated by an arrow 204 in Fig. 15, air in the suctioning opening 40 and the minute opening 42 is suctioned by the vacuum apparatus 140, as illustrated in Fig. 23D, the pressure of the suctioning opening 40 reaches the first pressure P_1 that is near vacuum at time t_4. With this, as indicated by an arrow 205 in Fig. 15, the dicing sheet 12 immediately above the minute opening 42 is pulled downward. Here, as indicated by a dotted line in Fig. 23D, during a period from time t3 to t6, the drive unit 82 of the opening pressure switch mechanism 80 can output a command for switching the pressure of the suctioning opening 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. Further, the near-field region of the one end 15a of the semiconductor die 15 immediately above the minute opening 42 deformed and flexed downward by being pulled by the dicing sheet 12 as indicated by an arrow 206. With this, the near-field region of the one end 15a of the semiconductor die 15 moves away from the surface 18a of the collet 18. Due to the displacement that has occurred between the near-field region of the one end 15a of the semiconductor die 15 and the front surface 12a of the dicing sheet 12 at time t_2 when the suction pressure becomes the third pressure P_3 that is near

vacuum, the near-field region of the one end 15a of the semiconductor die 15 is provided with a trigger for separation from the front surface 12a of the dicing sheet 12. Therefore, as indicated by the arrow 206 in Fig. 15, the near-field region of the one end 15a of the semiconductor die 15 starts to be separated from the front surface 12a of the dicing sheet 12, while being deformed and flexed.

[0053]

As illustrated in Fig. 15, as the near-field region of the one end 15a 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 being vacuumized as indicated by an arrow 207 in Fig. 15. 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. 23D, as the pressure of the suctioning opening 40 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 near-field region of the one end 15a of 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. 23E, the amount of leaked air entering the suction hole 19 of the collet 18 increases from time t_3 to time t_4.

[0054]

As illustrated in Fig. 23D, in a state in which the suction pressure is maintained at the third pressure P_3 that is near vacuum, the controller 150 maintains the suctioning opening 40 or the minute opening 42 of the stage 20 to be at the first pressure P_1 that is near vacuum from time t_4 to time t_5. During this time period, as indicated by an arrow 208 in Fig. 16, the near-field region of the one end 15a 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 near-field region of the one end 15a 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. 23E, the amount of leaked air entering the suction hole 19 of the collet 18 decreases. As illustrated in Fig. 16, when the semiconductor die 15 is vacuumized and suctioned to the surface 18a of the collet 18 at time t_5, the amount of leaked air becomes zero. At this time, the near-field region of the one end 15a of the semiconductor die 15 is separated from the front surface 12a of the dicing sheet 12 positioned immediately above the minute opening 42 (initial separation). When initial separation of the near-field region of the one end 15a of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 occurs, as illustrated in Fig. 15 and Fig. 16, the dicing sheet 12 positioned immediately above the minute opening 42 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 near-field region of the one end 15a of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 positioned immediately above the minute opening 42 has occurred. Further, if the detected displacement is smaller than the predetermined threshold value, the controller 150 determines that initial separation of the near-field region of the one end 15a of the semiconductor die 15 from the front surface 12a of the dicing sheet 12 positioned immediately above the minute opening 42 has not occurred (first separation determination step). If it is determined that the initial separation of the near-field region of the one end 15a 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 near-field region of the one end 15a of the semiconductor die 15 has not occurred, the controller 150 performs a first retry step.

[0055]

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 suctioning opening 40 or the minute opening 42, and the suction groove 26, and sets the pressure of the suctioning opening 40 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 suctioning opening 40 or the minute opening 42, and the suction groove 26, switches the pressure of the suctioning opening 40 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).

[0056]

Next, the controller 150 executes the second-separation program 159 illustrated in Fig. 1. As illustrated in Fig. 23C and Fig. 23D, in the state in which the suction pressure is

maintained at the third pressure P_3 that is near vacuum, the controller 150 maintains the pressure of the suctioning opening 40 to be at the first pressure P_1 that is near vacuum for a predetermined time period. Then, at time t_5, the controller 150 outputs a command for switching the pressure of the suctioning opening 40 from the first pressure P_1 that is near vacuum to the second pressure P_2 that is 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 as to communicate the piping 85 open to air with the suctioning opening 40. With this, as indicated by an arrow 210 in Fig. 17, air enters the suctioning opening 40. Therefore, as illustrated in Fig. 23D, from time t_5 to time t_6, the pressure of the suctioning opening 40 increases from the first pressure P_1 that is near vacuum to the second pressure P_2 that is near the atmospheric pressure. Upon the pressure of the suctioning opening 40 reaching the second pressure P_2 that is near the atmospheric pressure, the dicing sheet 12 positioned immediately above the minute opening 42 and pulled in the downward direction by vacuum moves back upward as indicated by an arrow 209 in Fig. 17.

[0057]

As illustrated in Fig. 23D, when the pressure of the suctioning opening 40 becomes the second pressure P_2 that is near the atmospheric pressure at time t_6, the controller 150

outputs a command for having the cap 23 slide to increase an opening width of the suctioning opening 40 from the opening width D_1 of the minute opening 42 to an opening width D_2 as illustrated in Fig. 23B. By this command, the motor 381 of the slider drive mechanism 300 illustrated in Fig. 1 rotates in the direction indicated by the arrow a illustrated in Fig. 1, the slider 332 slides rightward along the suction surface 22 by the upward movement of the first link 326 indicated by the arrow b illustrated in Fig. 1 and the rotating movement of the second link 329 indicated by the arrow d illustrated in Fig. 1, and the cap 23 slides as indicated by an arrow 211 in Fig. 17 in a state in which the flat portion 23h on the surface of the cap 23 is substantially parallel with the suction surface 22. Then, when the opening width reaches d_2, the controller 150 stops the motor 381 to stop sliding of the cap 23. As illustrated in Fig. 17, this operation opens the suctioning opening 40, and a portion between the tip end 23a of the cap 23 and the end surface 22e becomes an opening portion 43 having the opening width D_2.

[0058]

As illustrated in Fig. 23D, at time t_7, the controller 150 outputs a command for switching the pressure of the suctioning opening 40 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 suctioning opening 40 is communicated with the vacuum apparatus 140. With this, as indicated by an arrow 212 in Fig. 18, air in the suctioning opening 40 or the opening portion 43 is suctioned to the vacuum apparatus 140, and at time t_8, and as illustrated in Fig. 23D, the pressure of the suctioning opening 40 or the opening portion 43 becomes the first pressure P_1 that is near vacuum. When the pressure of the suctioning opening 40 or the opening portion 43 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 opening portion 43 is suctioned into the opening portion 43 as indicated by an arrow 213 in Fig. 18. With this, as indicated by an arrow 214 in Fig. 18, the near-field region of the one end 15a of the semiconductor die 15 is deformed and flexed in the downward direction and moves apart from the surface 18a of the collet 18, and as indicated by an arrow 215 in Fig. 18, 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. 23E, the amount of leaked air increases from time t_7 to time t_8 during which the pressure of the suctioning opening 40 or the opening portion 43 decreases.

[0059]

As illustrated in Fig. 23D, at time t_8, the controller 150 outputs a command for increasing the pressure of the

suctioning opening 40 from the first pressure P_1 that is near vacuum to the second pressure P_2 that is 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 suctioning opening 40 is communicated with the piping 85 open to air. With this, as indicated by an arrow 216 in Fig. 19, air enters the suctioning opening 40 or the opening portion 43, and as illustrated in Fig. 23D, the pressure of the suctioning opening 40 or the pressure of the opening portion 43 increases up to the second pressure P_2 that is near the atmospheric pressure. With this, as indicated by an arrow 217 in Fig. 19, the dicing sheet 12 immediately above the opening portion 43 is displaced upward. Further, along with the upward displacement of the dicing sheet 12, the near-field region of the one end 15a of the semiconductor die 15 in a region positioned immediately above the opening portion 43 moves back to the surface 18a of the collet 18 as indicated by an arrow 218 in Fig. 19. 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. 23E, and becomes zero at time t_9 in Fig. 23E. At this time, the near-field region of the one end 15a of the semiconductor die 15 is vacuumized and suctioned to the surface 18a of the collet 18, and the near-field region of the one end 15a of the semiconductor die 15 positioned

immediately above the opening portion 43 is separated from the front surface 12a of the dicing sheet 12 (end of first second-separation step).

[0060]

At time t_9, the controller 150 performs a second second-separation step. As illustrated in Fig. 23B, the controller 150 outputs a command for having the cap 23 slide to increase the opening width of the suctioning opening 40 from the opening width D_2 to an opening width D_3. By this command, the slider drive mechanism 300 illustrated in Fig. 1 is driven, and the cap 23 slides as indicated by an arrow 219 in Fig. 20 in a state in which the flat portion 23h on the surface of the cap 23 is substantially parallel with the suction surface 22. Then, when the opening width reaches d_3, the controller 150 stops the motor 381 to stop sliding of the cap 23. As illustrated in Fig. 17, this operation further opens the suctioning opening 40, and a portion between the tip end 23a of the cap 23 and the end surface 22e becomes an opening portion 44 having the opening width D_3.

[0061]

Further, as illustrated in Fig. 23D, at time t_{10}, the controller 150 outputs a command for switching the pressure of the suctioning opening 40 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 suctioning opening 40 is communicated with the vacuum apparatus 140. With this, as indicated by a dashed arrow 220 in Fig. 17, air in the suctioning opening 40 or the opening portion 43 is suctioned to the vacuum apparatus 140, and the pressure of the suctioning opening 40 or the pressure of the opening portion 44 becomes the first pressure P_1 that is near vacuum at time t_{11}. Then, as indicated by a dashed line arrow 221 in Fig. 20, the dicing sheet 12 is suctioned into the opening portion 44. At this time, as about a half of an entire region of the semiconductor die 15 is separated from the dicing sheet 12, the semiconductor die 15 is susceptible to separation from the dicing sheet 12. Therefore, even when the dicing sheet 12 moves in the downward direction, the semiconductor die 15 can not be displaced in the downward direction along with the dicing sheet 12, and remains vacuumized and suctioned to the collet 18, and a portion of the semiconductor die 15 positioned immediately above the opening portion 44 is separated from the front surface 12a of the dicing sheet 12. Therefore, air can not enter the suction hole 19 of the collet 18, and the amount of leaked air is zero during a period from time t_{10} to t_{11} in Fig. 23E.

[0062]

As illustrated in Fig. 23D, at time t_{11}, the controller 150 outputs a command for increasing the pressure of the

suctioning opening 40 from the first pressure P_1 that is near vacuum to the second pressure P_2 that is 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 suctioning opening 40 is communicated with the piping 85 open to air. With this, as indicated by an arrow 222 in Fig. 20, air enters the suctioning opening 40 or the opening portion 44, and as illustrated in Fig. 23D, the pressure of the suctioning opening 40 or the pressure of the opening portion 44 increases up to the second pressure P_2 that is near the atmospheric pressure. With this, as indicated by an arrow 223 in Fig. 20, the dicing sheet 12 immediately above the opening portion 44 is displaced upward. Then, when the pressure of the suctioning opening 40 or the pressure of the opening portion 44 becomes the second pressure P_2 that is near the atmospheric pressure at time t_{12}, the second second-separation step is terminated.

[0063]

Hereinafter, the controller 150 similarly performs a third second-separation step at time t_{12} shown in Fig. 23B. The controller 150 has the cap 23 slide as indicated by an arrow 224 in Fig. 21 to set the suctioning opening 40 to be an opening portion 45 having an opening width D_4 (a width between the tip end 23a of the cap 23 and the end surface 22e), then switches the pressure of the opening portion 45 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_{13} shown in Fig. 23D as indicated by an arrow 225 in Fig. 21, and separates a portion of the semiconductor die 15 positioned immediately above the opening portion 45 from the front surface 12a of the dicing sheet 12 as indicated by an arrow 226 in Fig. 21. Then, at t_{14} shown in Fig. 23D, the controller 150 switches the pressure of the opening portion 45 from the first pressure P_1 that is near vacuum to the second pressure P_2 that is near the atmospheric pressure, and terminates the third second-separation step when the pressure of the suctioning opening 40 or the pressure of the opening portion 45 becomes the second pressure P_2 that is near the atmospheric pressure at time t_{15}. Similarly, the controller 150 performs a fourth second-separation step during a period from time t_{15} to time t_{18} shown in Fig. 23A through Fig. 23E. The controller 150 opens the cap 23 to an opening width D_5, and separates a portion of the semiconductor die 15 positioned immediately above the opening portion from the front surface 12a of the dicing sheet 12.

[0064]

When the cap 23 is slid and the width becomes the opening width D_5, the semiconductor die 15 is almost separated from the dicing sheet 12. Therefore, the controller 150 has the cap 23 slide to increase the opening width from d_5 to d_7 at time t_{18} as illustrated in Fig. 23B, and picks up the semiconductor die

15 by moving the collet 18 upward as illustrated in Fig. 22A. After picking up the semiconductor die 15, the controller 150 moves the cap 23 back to an initial position at time t_{20}, resumes the pressure of the suctioning opening 40 and the suction pressure to the atmospheric pressure, and terminates the pick-up operation.

[0065]

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 from the semiconductor die 15 step-by-step by repeatedly performing the second-separation step in which the cap 23 is slid to open the suctioning opening 40 step-by-step every time the pressure of the suctioning opening 40 is switched from the first pressure P_1 that is near vacuum to the second pressure P_2 that is near the atmospheric pressure, and therefore it is possible to provide an effect of suppressing damage to semiconductor dies during pick up.

[0066]

In the second-separation step previously described, the controller 150 performs the second separation determination step for determining whether or not the region of the semiconductor die 15 positioned immediately above the opening portion 43 is separated from the front surface 12a of the dicing sheet 12, and performs the second retry step if it is determined

in the second separation determination step that the region of the semiconductor die 15 positioned immediately above the opening portion 43 is not separated from the front surface 12a of the dicing sheet 12. Hereinafter, the second separation determination step and the second retry step will be described. It should be noted that in the pick-up operation illustrated by Fig. 25a through Fig. 25E to which the following description refers, only an operation for the second retry step from time t_8 to time t_{11} is different form the operation illustrated by Fig. 23A through Fig. 23E. An operation for time t_0 to time t_8 is the same as that in Fig. 23A through Fig. 23E, and an operation for time t_{11} to time t_{23} is the same as the operation for time t_8 to t_{20} in Fig. 23A through Fig. 23E.

[0067]

As described above with reference to Fig. 18, when the pressure of the suctioning opening 40 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. 23E, 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. 23D, when the pressure of the suctioning opening 40 starts increasing from the first pressure P_1 that is near vacuum to the second pressure P_2 that

is 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. 19, 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 semiconductor die 15 in a region positioned immediately above the opening portion 43 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, as illustrated in Fig. 23A through Fig. 23E, even when the pressure of the suctioning opening 40 increases up from the first pressure P_1 that is near vacuum to the second pressure P_2 that is 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 vacuumized and suctioned to the surface of the collet 18.

[0068]

In this manner, when the semiconductor die 15 is separated well from the dicing sheet 12, as illustrated in Fig. 24A, 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. 24C, 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 order to correctly detect separation, in the second separation determination step, a signal of the amount of leaked air shown in Fig. 24A and Fig. 24C is differentiated to calculate a derivative value for the amount of leaked air shown in Fig. 24B and Fig. 24D.

[0069]

As illustrated in Fig. 24B, 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. 24D, 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. 24B and Fig. 24D, 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. 24B. 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. 24D. Therefore, in the second separation determination step, when the derivative value for the amount of leaked air during a time period from time t_7 to time t_9 in Fig. 23E changes over the range of the predetermined threshold value twice (even number), it is determined that the semiconductor die 15 has been separated, and the process moves to the next separation step. When the derivative value for the amount of leaked air changes over the range of the predetermined threshold value once (odd number), it is determined that the semiconductor die 15 has not been separated, and the process moves to the second retry step described next.

[0070]

In the second retry step, as illustrated in Fig. 25B, the controller 150 decreases the pressure of the suctioning opening 40 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} as illustrated in Fig. 25D, without causing the cap 23 to slide. Then, as illustrated in Fig. 25D, at time t_{11}, the controller 150 increases the pressure of the suctioning opening 40 from the first pressure P_1 that is near vacuum to the second pressure P_2 that is near the atmospheric pressure (second retry step). In the second retry step, if the amount of leaked air decreases down to zero during a time period from time t_{11} to time t_{12} in Fig. 25E, 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_{12} shown in Fig. 25E 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 positioned immediately above the opening portion 43 has been separated from the front surface 12a of the dicing sheet 12, terminates the second retry step, and resets the number of times to 0 before the next second-separation step (clears a counter).

[0071]

Further, in a region in Fig. 24B 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 $-S_1$ (at time t_1 in Fig. 24A and Fig. 24B), an actual amount of leaked collet air starts decreasing as illustrated in Fig. 24A, after reaching a maximum leaked amount. Accordingly, after time t_1 in Fig. 24A and Fig. 24B, 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 $-S_1$ is 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 $-S_1$, and thus to reduce separation time and damage to the semiconductor die 15.

[0072]

Here, when the second-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 second-separation step when the count is an even number, and to the second 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 second-separation step, a count number of the derivative value is 2 (odd number), and therefore the operation moves to the second second-separation step. If the predetermined portion of the semiconductor die 15 is not separated in the second second-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 second-separation step, but to the second retry step. If the predetermined portion of the semiconductor die 15 is separated in the second retry step, a number 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 second-separation step. As described above, by determining whether or not the process moves to the next second-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 second-separation step is performed and whether or not the separation of the semiconductor die is performed.

[0073]

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.

[0074]

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

[0075]

10: wafer holder

11: wafer

12: dicing sheet

12a: front surface

12b: back surface

13: ring

14: gap

15: semiconductor die

15a: one end

15b: the other end

16: expanded ring

18: collet

18a: surface

19: suction hole

20: stage

21: housing

22: suction surface

22a: groove

22b: projected portion

22c: inclined surface

22d: rib

22e: end surface

22f: side surface

22g: guide surface

23: cap

23a: tip end

23b: side surface

23c: rear end

23d: curved surface

23e: chamfer

23f: arm

23g: inclined surface

23h: flat portion

24: base unit

25: drive unit

26: suction groove

27: suction hole

40: suctioning opening

41: hole

42: minute opening

43-45: opening portion

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

300: slider drive mechanism

321a: stopper

326: first link

326a, 329a: engagement groove

326b: shaft

326c: roller

327, 328, 330, 330a: pin

329: second link

331: guide rail

332: slider

364: vertical groove

370: piston

371: flange

381: motor

383: cam

500: pick-up apparatus

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 suctioning opening provided in the suction surface of the stage;

a cap configured to slide along the suction surface to open and close the suctioning opening; and

an opening pressure switch mechanism configured to switch a pressure of the suctioning 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, the cap is caused to slide by a predetermined distance in an opening direction, every time the pressure of the suctioning opening is switched from the first pressure to the second pressure after the pressure of the suctioning opening is switched from the second pressure to the first pressure.

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

when the semiconductor die is picked up, the cap is caused to slide by the predetermined distance in the opening direction while a suction

pressure of the suction surface is maintained to be vacuum.

3. The semiconductor die pick-up apparatus according to claim 1 or 2, wherein

the cap is provided for the stage such that a surface of the cap is allowed to freely advance from the suction surface, and

when the semiconductor die is picked up, the dicing sheet is separated from the semiconductor die by causing the cap to slightly slide to slightly open the suctioning opening, causing the surface of the cap to advance up to a predetermined height higher than the suction surface, then setting the suction pressure to be vacuum, and switching, after a predetermined time elapses, the pressure of the suctioning opening from the second pressure to the first pressure, the dicing sheet being positioned above the slightly opened suction opening.

4. The semiconductor die pick-up apparatus according to claim 1 or 2, wherein

the opening pressure switch mechanism switches the pressure of the suctioning opening between the first pressure and the second pressure more than once before causing the cap to slide by the predetermined distance in the opening direction.

5. The semiconductor die pick-up apparatus according to claim 1 or 2, wherein

the cap is provided for the stage such that a surface of the cap is allowed to freely advance from the suction surface, and

when the semiconductor die is picked up, the cap is caused to slide in a state in which the surface of the cap advances up to a predetermined height higher than the suction surface.

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

separation detection means configured to detect whether or not a portion of the semiconductor die positioned immediately above the suctioning opening opened by causing the cap to slide 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 pressure of the suctioning opening is switched from the first pressure to the second pressure without causing the cap to slide, and then again the pressure of the suctioning opening 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 or 2, comprising:

a sheet displacement detection sensor provided near an end surface of the suctioning opening with which a tip end of the cap is brought into contact when the suctioning opening is closed, and configured to detect displacement of the dicing sheet with respect to the suction surface in an approaching and departing direction when the cap is caused to slightly slide to slightly open the suctioning opening, the dicing sheet being positioned above the suction opening that is slightly opened, wherein

if the sheet displacement detected by the sheet displacement detection sensor is a predetermined threshold value or smaller when the pressure of the suctioning opening is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is set to vacuum, the dicing sheet is separated from the semiconductor die by making the suction pressure open to air and switching the pressure of the suctioning opening from the first pressure to the second pressure, and again setting the suction pressure to vacuum and switching the pressure of the suctioning opening from the second pressure to the first pressure after the predetermined time elapses, the dicing sheet being positioned above the slightly opened suction opening.

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. 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 having a front surface to which a semiconductor die to be picked up is applied; a suctioning opening provided in the suction surface of the stage; a cap provided for the stage such that a surface of the cap is allowed to freely advance from the suction surface, and configured to slide along the suction surface to open and close the suctioning opening; and an opening pressure switch mechanism configured to switch a pressure of the suctioning opening between a first pressure that is near vacuum and a second pressure that is near an atmospheric pressure;

a positioning step of moving the stage in a direction along the suction surface, so that a tip end of the cap in a closed state aligns with one end of a semiconductor die to be picked up, and that a position of the cap in a width direction aligns with a position of the semiconductor die in the width direction;

a first separation step of separating the dicing sheet from the semiconductor die by causing the cap to slightly slide to slightly open the suctioning opening, causing the surface of the cap to advance up to a predetermined height higher than the suction surface, then setting the suction pressure to be vacuum, and switching, after a predetermined time elapses, the pressure

of the suctioning opening from the second pressure to the first pressure, the dicing sheet being positioned above the slightly opened suction opening; and

a second-separation step of separating a portion of the semiconductor die from the front surface of the dicing sheet by causing the cap to slide, in a state in which a surface of the cap advances up to a predetermined height higher than the suction surface, by a predetermined distance in the opening direction every time the pressure of the suctioning opening is switched from the first pressure to the second pressure after a suction pressure of the suction surface is maintained to be vacuum and the pressure of the suctioning opening is switched from the second pressure to the first pressure, the portion of the semiconductor die being positioned immediately above the suctioning opening opened by the sliding.

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

the opening pressure switch mechanism switches the pressure of the suctioning opening between the first pressure and the second pressure more than once before causing the cap to slide by the predetermined distance in the opening direction.

13. The semiconductor die pick-up method according to claim 11, wherein

the semiconductor die pick-up apparatus includes: a sheet displacement detection sensor provided near an end surface of the suctioning opening with which a tip end of the cap is brought into contact when the suctioning opening is closed, and configured to detect displacement of the dicing sheet with respect to the suction surface in an approaching and departing direction when the cap is caused to slightly slide to slightly open the suctioning opening, the dicing sheet being positioned above the suction opening that is slightly opened, and

the first separation step includes:

a first separation determination step of determining, when the pressure of the suctioning opening is switched from the second pressure to the first pressure after a predetermined time elapses after the suction pressure is set to vacuum, that the dicing sheet positioned above the slightly opened suction opening is separated from the semiconductor die if the sheet displacement detected by the sheet displacement detection sensor exceeds a predetermined threshold value, and that the dicing sheet positioned above the slightly opened suction opening is unseparated from the semiconductor die 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, when the dicing sheet positioned above the slightly opened suction opening is determined to be unseparated from the semiconductor die in the

first separation determination step, the dicing sheet from the semiconductor die by making the suction pressure open to air and switching the pressure of the suctioning opening from the first pressure to the second pressure, and again setting the suction pressure to vacuum and switching the pressure of the suctioning opening from the second pressure to the first pressure after the predetermined time elapses, the dicing sheet being positioned above the slightly opened suction opening.

14. The semiconductor die pick-up method according to claim 11, 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 a portion of the semiconductor die positioned immediately above the suctioning opening opened by sliding the cap 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

positioned immediately above the suctioning opening opened by sliding the cap 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, 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, the portion of the semiconductor die from the front surface of the dicing sheet by switching the pressure of the suctioning opening from the first pressure to the second pressure without causing the cap to slide, and again switching the pressure of the suctioning opening from the second pressure to the first pressure.

15. The semiconductor die pick-up method according to claim 13, 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%.

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