

PROTECTIVE FILM FORMING APPARATUS AND LASER PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a protective film forming apparatus for forming a protective film on the subject surface of a wafer and also to a laser processing apparatus having such a protective film forming apparatus.

Description of the Related Art

As well known in the art, a plurality of devices such as ICs, LSIs, and LEDs are formed on the subject surface of a wafer such as a silicon wafer and a sapphire wafer so as to be partitioned by a plurality of streets. Such a wafer is separated into the individual devices by a laser processing apparatus, and these individual devices are widely used in electronic equipment such as a mobile phone and a personal computer (see Japanese Patent Laid-open No. 2004-322168). This publication discloses a technique such that a liquid resin is applied to the subject surface of a wafer to form a protective film prior to laser processing. That is, if a laser beam is applied to the subject surface of the wafer, thermal

energy is concentrated in a laser beam applied area, causing a problem that debris scatters to be deposited on the subject surface of the wafer, so that the quality of the devices may be remarkably reduced. To cope with this problem, the protective film mentioned above is formed on the subject surface of the wafer prior to laser processing.

However, if the subject surface of the wafer has steps or it is provided with metal bumps such as electrodes, the liquid resin cannot be uniformly applied to the subject surface of the wafer by a spin coating method as disclosed in the above publication, but a part of the subject surface of the wafer is not coated with the protective film. Furthermore, the liquid resin such as PVA (polyvinyl alcohol) and PEG (polyethylene glycol) is relatively expensive. However, in the case that the liquid resin is applied by the conventional spin coating method, substantially 90% or more of the liquid resin used scatters from the subject surface of the wafer and it is wasted, thus resulting in poor economy.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a protective film forming apparatus which can

form a protective film reliably and economically even when the subject surface of a wafer has steps or it is provided with metal bumps such as electrodes.

It is another object of the present invention to provide a laser processing apparatus having such a protective film forming apparatus.

In accordance with an aspect of the present invention, there is provided a protective film forming apparatus for forming a protective film on the subject surface of a wafer. The protective film forming apparatus includes: a spinner table for holding the wafer thereon under suction vacuum and rotating the wafer in a held condition thereof; and resin applying means for applying a liquid resin to the subject surface of the wafer held on the spinner table. The resin applying means includes spraying means for spraying the liquid resin, a first arm for supporting the spraying means, and first swinging means for horizontally swinging the spraying means supported to the first arm in a minimum required range from the center of rotation of the wafer to the outer circumference of the wafer.

Preferably, the spraying means includes a liquid resin supply passage, an air supply passage, and a nozzle opening for spraying the liquid resin supplied through

the liquid resin supply passage by using the air supplied through the air supply passage. Preferably, the protective film forming apparatus further includes cleaning means for cleaning the wafer after laser processed and drying means for drying the wafer after cleaned by the cleaning means. Each of the cleaning means and the drying means includes a nozzle for discharging water or air toward the subject surface of the wafer, an arm for supporting the nozzle, and means for horizontally swinging the nozzle supported to the arm in a minimum required range from the center of rotation of the wafer to the outer circumference of the wafer.

According to the protective film forming apparatus of the present invention, the protective film is formed on the subject surface of the wafer by spraying a liquid resin. Accordingly, even when the subject surface of the wafer has steps or it is provided with metal bumps such as electrodes, the protective film can be reliably formed on the subject surface of the wafer. Furthermore, as compared with the conventional spin coating method, the required amount of the liquid resin according to the spray coating method using the protective film forming apparatus of the present invention can be remarkably reduced to 10% to 15%, thereby greatly improving

economical efficiency. In an example of the spray coating method using the protective film forming apparatus of the present invention, 5 to 6 mL of liquid resin was required to form the protective film on the subject surface of a wafer having a diameter of 300 mm. In comparison therewith, 40 to 50 mL of liquid resin was required under the same conditions according to the conventional spin coating method.

The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing some preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing the appearance of a laser processing apparatus according to the present invention;

FIG. 2 is a perspective view of a wafer integrated with a frame;

FIG. 3 is a block diagram of a laser beam applying unit;

FIG. 4 is a partially cutaway, perspective view of a protective film forming apparatus according to the present invention;

FIG. 5 is a vertical sectional view of the protective film forming apparatus in the condition where a spinner table is lifted;

FIG. 6 is a vertical sectional view of the protective film forming apparatus in the condition where the spinner table is lowered;

FIG. 7 is a vertical sectional view of a spray nozzle;

FIG. 8 is a plan view for illustrating the range of swing motion of the spray nozzle;

FIG. 9 is an enlarged sectional view of the wafer whose subject surface is coated with a protective film;

FIG. 10 is an enlarged sectional view for illustrating a laser beam applying step; and

FIG. 11 is an enlarged sectional view of the wafer in the condition where the protective film has been removed by a cleaning step.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the present invention will now be described in detail with reference to the

drawings. FIG. 1 is a perspective view showing the appearance of a laser processing apparatus 2 including a protective film forming apparatus according to the present invention for laser processing a wafer to separate the wafer into individual chips (devices). Operation means 4 for allowing an operator to input instructions such as processing conditions to the laser processing apparatus 2 is provided at the front portion of the apparatus 2. Display means 6 such as a CRT for displaying a guide view to the operator or an image obtained by imaging means to be hereinafter described.

Referring to FIG. 2, there is shown a semiconductor wafer W as a workpiece to be laser processed. The wafer W has a subject surface (upper surface as viewed in FIG. 2) on which a plurality of first streets S1 and a plurality of second streets S2 orthogonal to the first streets S1 are formed to thereby partition the subject surface into a plurality of rectangular regions, wherein a device D is formed in each rectangular region. The wafer W is attached to a dicing tape T as an adhesive tape at its central portion, and the peripheral portion of the dicing tape T is attached to an annular frame F. Thus, the wafer W is supported through the dicing tape T to the annular frame F. A plurality of (e.g., 25) wafers W in such a

supported condition are stored in a wafer cassette 8. The wafer cassette 8 is placed on a vertically movable cassette elevator 9.

On the rear side of the wafer cassette 8, ejecting/inserting means 10 is provided for ejecting the wafer W before laser processed from the wafer cassette 8 and inserting the wafer W after laser processed into the wafer cassette 8. A temporary setting area 12 for temporarily setting the wafer W before or after laser processed is provided between the wafer cassette 8 and the ejecting/inserting means 10. Further, positioning means 14 for positioning the wafer W is provided in the temporary setting area 12.

Reference numeral 30 denotes a protective film forming apparatus according to a preferred embodiment of the present invention. The protective film forming apparatus 30 serves also as a cleaning apparatus for cleaning the wafer W after laser processed. First carrying means 16 having a pivotable arm for carrying the wafer W by using suction vacuum is provided in the vicinity of the temporary setting area 12. Thus, the wafer W is carried from the temporary setting area 12 to the protective film forming device 30 by the first carrying means 16 under suction vacuum. As described

later, a protective film is formed on the subject surface of the wafer W by the protective film forming apparatus 30.

The wafer W whose subject surface has been coated with the protective film is carried to a chuck table 18 by the first carrying means 16 under suction vacuum. The wafer W is held on the chuck table 18 under suction vacuum in the condition where the frame F supporting the wafer W is fixed by a plurality of fixing means (clamps) 19. The chuck table 18 is rotatable and reciprocable in the X direction. Alignment means 20 for detecting the street to be laser processed on the subject surface of the wafer W is provided above a path of movement of the chuck table 18 along the X direction. The alignment means 20 includes imaging means 22 for imaging the subject surface of the wafer W, so that the alignment means 20 can detect the street to be laser processed by image processing such as pattern matching according to an image obtained by the imaging means 22. The image obtained by the imaging means 22 is displayed by the display means 6.

On the left side of the alignment means 20 a laser beam applying unit 24 is provided for applying a laser beam to the wafer W held on the chuck table 18. The laser beam applying unit 24 has a casing 26 containing laser

beam oscillating means and the like to be hereinafter described. A condenser 28 for condensing the laser beam oscillated by the oscillating means onto the subject surface of the wafer W is mounted on the front end of the casing 26. As shown in FIG. 3, laser beam oscillating means 34 and laser beam modulating means 36 are provided in the casing 26 of the laser beam applying unit 24.

Examples of the laser beam oscillating means 34 include a YAG laser oscillator and a YVO4 laser oscillator. The laser beam modulating means 36 includes repetition frequency setting means 38, laser beam pulse width setting means 40, and laser beam wavelength setting means 42. The repetition frequency setting means 38, the laser beam pulse width setting means 40, and the laser beam wavelength setting means 42 constituting the laser beam modulating means 36 are known in the art, therefore the detailed description thereof will be omitted herein.

After ending the laser processing by the laser beam applying unit 24, the wafer W held on the chuck table 18 is moved in the X direction and next held and carried by second carrying means 32 movable in the Y direction to the protective film forming apparatus 30 serving also as the cleaning apparatus. In the protective film forming apparatus 30, a jet of water is supplied from a cleaning

water nozzle onto the wafer W during rotation of the wafer W at a low speed (e.g., 300 rpm), thereby cleaning the wafer W. After cleaning the wafer W, a jet of air is supplied from an air nozzle onto the wafer W during rotation of the wafer W at a high speed (e.g., 3000 rpm), thereby drying the wafer W. Thereafter, the wafer W is carried to the temporary setting area 12 by the first carrying means 16 under suction vacuum, and next returned to the original position in the wafer cassette 8 by the ejecting/inserting means 10.

Next, the protective film forming apparatus 30 will now be described in detail with reference to FIGS. 4 to 8. Referring first to FIG. 4, there is shown a partially cutaway, perspective view of the protective film forming apparatus 30. The protective film forming apparatus 30 includes a spinner table mechanism 44 and a cleaning water receiving mechanism 46 provided so as to surround the spinner table mechanism 44. The spinner table mechanism 44 includes a spinner table 48, an electric motor 50 for rotationally driving the spinner table 48, and a support mechanism 52 for vertically movably supporting the electric motor 50.

The spinner table 48 includes a vacuum chuck 48a formed of a porous material. The vacuum chuck 48a is

connected to suction means (not shown). Accordingly, the spinner table 48 functions to hold the wafer W placed on the vacuum chuck 48a by using a vacuum produced by the suction means. The electric motor 50 has an output shaft 50a, and the spinner table 48 is connected to the upper end of the output shaft 50a. The support mechanism 52 is composed of a plurality of (three in this preferred embodiment) support legs 54 and a plurality of (three in this preferred embodiment) air cylinders 56 operatively connected to the support legs 54, respectively. All of the air cylinders 56 are mounted on the electric motor 50.

The support mechanism 52 functions in such a manner that the air cylinders 56 are operated to vertically move the electric motor 50 and the spinner table 48 between the upper position shown in FIG. 5 as a load/unload position and the lower position shown in FIG. 6 as a working position. The cleaning water receiving mechanism 46 includes a cleaning water receptacle 58, three support legs 60 for supporting the cleaning water receptacle 58 (two of the three support legs 60 being shown in FIG. 4), and a cover member 62 mounted on the output shaft 50a of the electric motor 50. As shown in FIGS. 5 and 6, the cleaning water receptacle 58 is composed of a cylindrical outer wall 58a, a bottom wall 58b, and a cylindrical

inner wall 58c. The bottom wall 58b is formed with a central hole 51 for allowing the insertion of the output shaft 50a of the electric motor 50. The cylindrical inner wall 58c projects upward from the peripheral edge of the central hole 51.

As shown in FIG. 4, the bottom wall 58b is formed with a waste fluid outlet 59, and a drain hose 64 is connected to the waste fluid outlet 59. The cover member 62 is a cylindrical member having a closed top. The closed top of the cover member 62 is mounted to the upper end portion of the output shaft 50a of the electric motor 50, and a covering portion 62a (see FIG. 5) projects downward from the outer circumference of the closed top of the cover member 62. In the working position of the electric motor 50 and the spinner table 48 as shown in FIG. 6, the covering portion 62a of the cover member 62 is located so as to surround the cylindrical inner wall 58c of the cleaning water receptacle 58 with a given gap defined therebetween.

The protective film forming apparatus 30 further includes resin applying means 66 for applying a liquid resin to the wafer W held on the spinner table 48 before laser processing. The resin applying means 66 includes a spray nozzle 68 for spraying the liquid resin toward the

subject surface of the wafer W held on the spinner table 48 before laser processing, a substantially L-shaped arm 70 for supporting the spray nozzle 68, and an electric reversible motor 72 (see FIG. 5) for horizontally swinging the spray nozzle 68 supported to the arm 70 in a minimum required range from the center of rotation of the wafer W to the outer circumference of the wafer W. The spray nozzle 68 is connected through the arm 70 to a liquid resin supply source (not shown).

The protective film forming apparatus 30 serves also as the cleaning apparatus for cleaning the wafer W after laser processed. Accordingly, the protective film forming apparatus 30 further includes cleaning water supplying means 74 for cleaning the wafer W held on the spinner table 48 after laser processing and air supplying means 76 for drying the wafer W after cleaning. The cleaning water supplying means 74 includes a cleaning water nozzle 78 for supplying a jet of cleaning water toward the subject surface of the wafer W held on the spinner table 48 after laser processing, an arm 80 for supporting the cleaning water nozzle 78, and an electric reversible motor 82 (see FIG. 5) for horizontally swinging the cleaning water nozzle 78 supported to the arm 80. The cleaning water nozzle 78 is connected through

the arm 80 to a cleaning water supply source (not shown).

The air supplying means 76 includes an air nozzle 84 for supplying a jet of air toward the subject surface of the wafer W held on the spinner table 48 after cleaning, an arm 86 for supporting the air nozzle 84, and an electric reversible motor (not shown) for horizontally swinging the air nozzle 84 supported to the arm 86. The air nozzle 84 is connected through the arm 86 to an air supply source (not shown).

As shown in FIG. 7, the spray nozzle 68 and the arm 70 are integral with each other. The spray nozzle 68 includes a liquid resin supply passage 88 connected to a liquid resin supply source 90 for supplying a liquid resin under a pressure of 0.2 MPa, for example, an air supply passage 92 connected to an air supply source 94 for supplying air under a pressure of 0.4 MPa, for example, and a nozzle opening 96 for spraying the liquid resin supplied through the liquid resin supply passage 88 by using the air supplied through the air supply passage 92.

The operation of the protective film forming apparatus 30 will now be described. The semiconductor wafer W to be laser processed is carried to the spinner table 48 of the protective film forming apparatus 30 by

the swing motion of the first carrying means 16, and is held to the vacuum chuck 48a of the spinner table 48. At this time, the spinner table 48 is set at the load/unload position shown in FIG. 5, and all of the spray nozzle 68, the cleaning water nozzle 78, and the air nozzle 84 are set at a standby position where they are retracted from the spinner table 48 as shown in FIGS. 4 and 5.

After holding the wafer W on the spinner table 48 of the protective film forming apparatus 30 as mentioned above, a protective film forming step for forming a protective film on the subject surface of the wafer W by spraying a liquid resin is carried out in the following manner. First, the spinner table 48 is set to the working position as shown in FIGS. 6 and 8, and the spinner table 48 is next rotated in the direction shown by an arrow A in FIG. 8 at a rotational speed of 10 to 100 rpm (preferably, 30 to 50 rpm) by driving the electric motor 50. At the same time, the spray nozzle 68 is set above the outer circumference of the wafer W, and the liquid resin is sprayed by the spray nozzle 68 as driving the electric motor 72 to swing the spray nozzle 68 to a predetermined position just before the center of the wafer W (e.g., a position radially spaced apart from the outer circumference of the wafer W by the distance of

about $4/5$ of the radius of the wafer W) during a time period of about 40 seconds. Thereafter, the spray nozzle 68 is returned from this predetermined position near the center of the wafer W to the outer circumference of the wafer W during a time period of about 40 seconds as spraying the liquid resin. Thus, while the wafer W is being rotated, the liquid resin is sprayed onto the subject surface of the wafer W by the spray nozzle 68 as once oscillating the spray nozzle 68 between the outer circumference of the wafer W and the above predetermined position near the center of the wafer W as shown by an arrow B in FIG. 8, thereby forming a protective film on the subject surface of the wafer W. The reason for returning the spray nozzle 68 at the above predetermined position just before the center of the wafer W is to prevent an increase in thickness of the protective film at the center of the wafer W.

In an example of the spray coating method for the liquid resin according to this preferred embodiment, about 5 to 6 mL of liquid resin was required to form a protective film having a thickness of 10 μm on the subject surface of a wafer having a diameter of 300 mm. In comparison therewith, according to the conventional spin coating method, 40 to 50 mL of liquid resin was

required under the same conditions. Accordingly, the required amount of the liquid resin according to the spray coating method of the present invention can be remarkably reduced to 10% to 15% of that according to the conventional spin coating method, thereby greatly improving economical efficiency.

As a modification, the spraying of the liquid resin may be started at the outer circumference of the wafer W and ended at the center of the wafer W during a time period of about 80 seconds rather than once oscillating the spray nozzle 68 as shown by the arrow B. As another modification, the spraying of the liquid resin may be started at some position on the outer circumference of the wafer W, next passed through the center of the wafer W, and finally ended at another opposite position on the outer circumference of the wafer W during a time period of about 80 seconds. In this case, the spray nozzle 68 is preferably passed through the center of the wafer W at a relatively high speed.

The liquid resin sprayed onto the subject surface of the wafer W by the spray nozzle 68 is hardened with the elapse of time, thereby forming a protective film 98 on the subject surface of the wafer W as shown in FIG. 9. The thickness of the protective film 98 is preferably set

to about 0.5 to 10 μm . The liquid resin for forming the protective film 98 is preferably selected from a water-soluble resist such as PVA (polyvinyl alcohol), PEG (polyethylene glycol), and PEO (polyethylene oxide).

After performing this protective film forming step to form the protective film 98 on the subject surface of the wafer W, the spinner table 48 is lifted to the load/unload position shown in FIG. 5 and the vacuum chuck to the wafer W held on the spinner table 48 is canceled. Next, the wafer W is carried from the spinner table 48 to the chuck table 18 by the first carrying means 16 and is held to the chuck table 18 by suction vacuum. Next, the chuck table 18 holding the wafer W is moved in the X direction to a position directly below the imaging means 22.

At this position, a work area of the wafer W is imaged by the imaging means 22 to perform image processing such as pattern matching for aligning each street S and the condenser 28 of the laser beam applying unit 24 for applying a laser beam along each street S. Thus, the alignment of a laser beam spot to each street S is performed. After detecting each street S1 or S2 formed on the subject surface of the wafer W held on the chuck table 18 to perform the alignment of a laser beam spot to

each street S, the chuck table 18 is moved to a laser beam applying region where the condenser 28 is located, and a laser beam is next applied from the condenser 28 through the protective film 98 onto the subject surface of the wafer W along each street S1 or S2.

In such a laser beam applying step, a pulsed laser beam is applied from the condenser 28 of the laser beam applying unit 24 toward a predetermined one of the streets S formed on the subject surface (upper surface) of the wafer W so as to pass through the protective film 98 as moving the chuck table 18 in the X direction at a predetermined feed speed (e.g., 100 mm/sec).

For example, the laser beam applying step is performed under the following conditions.

Light source of laser beam: YAG laser

Wavelength: 355 nm (THG (third harmonic generation) of YAG laser)

Output: 3.0 W

Repetition frequency: 20 kHz

Condensation spot diameter: 1.0 μ m

Work feed speed: 100 mm/sec

By performing this laser beam applying step, the wafer W is separated along all of the streets S to obtain the individual devices D. Although debris 100 is

generated by the application of the laser beam as shown in FIG. 10, the debris 100 is blocked by the protective film 98, so that the debris 100 is prevented from sticking to electronic circuits, bonding pads or the like in each device D.

After separating the wafer W into the individual devices D as mentioned above, the chuck table 18 is returned to the initial position where the wafer W has been held and the vacuum chuck to the wafer W is canceled. Next, the wafer W is carried to the spinner table 48 of the protective film forming apparatus 30 by the second carrying means 32, and is held to the vacuum chuck 48a under suction vacuum. At this time, all of the spray nozzle 68, the cleaning water nozzle 78, and the air nozzle 84 are set at the standby position retracted from the spinner table 48 as shown in FIGS. 4 and 5.

Thereafter, a cleaning water composed of pure water and air is supplied to the wafer W by the cleaning water nozzle 78 connected to a pure water source and an air source (both not shown) as similar to the spray nozzle 68. At the same time, the wafer W is rotated at a low speed (e.g., 300 rpm). At this time, the cleaning water nozzle 78 is horizontally swung in a required range from the outer circumference of the wafer W to the center of the

wafer W as similar to the spray nozzle 68 shown in FIG. 8. Accordingly, when the cleaning water nozzle 78 reaches the center of the wafer W, the entire surface of the wafer W is cleaned by the cleaning water. Since the protective film 98 coating the subject surface of the wafer W is formed of a water-soluble resin, the protective film 98 can be easily cleaned off by the cleaning water as shown in FIG. 11. Further, the debris 100 generated in the laser beam applying step is also removed with the protective film 98 by the cleaning water.

After the cleaning step mentioned above, a drying step is performed. More specifically, the cleaning water nozzle 78 is returned to the standby position, and the air nozzle 84 is set to the work position above the outer circumference of the wafer W held on the spinner table 48. In this condition, the spinner table 48 is rotated at 3000 rpm, for example, and air is discharged from the air nozzle 84 toward the wafer W held on the spinner table 48. At this time, the air nozzle 84 is horizontally swung in a required range from the outer circumference of the wafer W to the center of the wafer W, so that the entire surface of the wafer W is dried. After this drying step, the wafer W is carried from the spinner table 48 to the temporary setting area 12 by the first carrying means 16.

Finally, the wafer W is carried from the temporary setting step 12 to the wafer cassette 8 and inserted into the original position in the wafer cassette 8 by the ejecting/inserting means 10.

The present invention is not limited to the details of the above described preferred embodiments. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the equivalence of the scope of the claims are therefore to be embraced by the invention.

WHAT IS CLAIMED IS:

1. A protective film forming apparatus for forming a protective film on the subject surface of a wafer, said protective film forming apparatus comprising:

a spinner table for holding said wafer under suction vacuum and rotating said wafer in a held condition; and

resin applying means for applying a liquid resin to the subject surface of said wafer held on said spinner table;

said resin applying means including spraying means for spraying said liquid resin, a first arm for supporting said spraying means, and first swinging means for horizontally swinging said spraying means supported to said first arm in a minimum required range from the center of rotation of said wafer to the outer circumference of said wafer.

2. The protective film forming apparatus according to claim 1, wherein said spraying means includes a liquid resin supply passage, an air supply passage, and a nozzle opening for spraying said liquid resin supplied through said liquid resin supply passage by using the air supplied through said air supply passage.

3. The protective film forming apparatus according

to claim 1 or 2, further comprising cleaning means having a cleaning water nozzle for spraying a cleaning water, a second arm for supporting said cleaning water nozzle, and second swinging means for horizontally swinging said cleaning water nozzle supported to said second arm in a minimum required range from the center of rotation of said wafer to the outer circumference of said wafer.

4. The protective film forming apparatus according to claim 3, further comprising drying means having an air nozzle for discharging air, a third arm for supporting said air nozzle, and third swinging means for horizontally swinging said air nozzle supported to said third arm in a minimum required range from the center of rotation of said wafer to the outer circumference of said wafer.

5. A laser processing apparatus comprising:

a chuck table for holding a wafer;

laser beam applying means for applying a laser beam to the subject surface of said wafer held on said chuck table; and

a protective film forming apparatus for forming a protective film on the subject surface of said wafer before laser processed by said laser beam applying means;

said protective film forming apparatus having a

configuration according to any one of claims 1 to 4.