

SEMICONDUCTOR WAFER PROCESSING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a semiconductor wafer processing method for forming a plurality of division grooves along a plurality of respective crossing streets of a semiconductor wafer.

Description of the Related Art

A plurality of crossing streets are formed on the front side of a semiconductor substrate constituting a semiconductor wafer to thereby define a plurality of separate regions where a plurality of devices such as ICs and LSIs are each formed. The semiconductor wafer is divided along the crossing streets by dicing to obtain a plurality of semiconductor chips corresponding to the individual devices. The semiconductor wafer has a stacked layer formed on the front side of the semiconductor substrate. The devices and the streets are formed by the stacked layer. The stacked layer includes a low-k film (low permittivity insulating film) and a functional film forming a circuit, for example.

There has recently been put into practical use a semiconductor wafer having a protective film called a passivation film on the front side thereof for the purpose of protecting the devices. The passivation film

is formed on the front side of a semiconductor substrate constituting the semiconductor wafer so as to cover the devices and the streets. The passivation film is formed of oxide such as SiO_2 , SiOF , SiON , and SiO (Si_xO_y). When a laser beam having an absorption wavelength (e.g., 355 nm) to the semiconductor substrate is applied to the semiconductor wafer, the energy of the laser beam absorbed by the semiconductor substrate reaches a bandgap energy to break the atomic bond in the semiconductor substrate, thereby performing the ablation. However, in the case that the passivation film of oxide is formed on the front side of the semiconductor substrate, there is a problem such that the laser beam passed through the passivation film may ablate the semiconductor substrate to break the passivation film from the inside surface thereof. To cope with this problem, Japanese Patent Laid-open No. 2013-102039 has proposed a processing method including the steps of applying a laser beam having an absorption wavelength to the passivation film to thereby remove the passivation film along each street and next dividing the semiconductor wafer.

SUMMARY OF THE INVENTION

However, in the case that a glass passivation film is formed on the stacked layer of a semiconductor wafer, the laser beam is transmitted through the glass

passivation film under the laser beam applying conditions described in Japanese Patent Laid-open No. 2013-102039. As a result, there is a problem such that the laser beam transmitted through the glass passivation film may ablate the stacked layer protected by the glass passivation film, causing the breakage of the glass passivation film from the inside surface thereof.

It is therefore an object of the present invention to provide a semiconductor wafer processing method which can suppress the breakage of the glass passivation film from the inside surface thereof due to the transmission of the laser beam in forming a division groove along each street.

In accordance with an aspect of the present invention, there is provided a semiconductor wafer processing method for processing a semiconductor wafer along a plurality of crossing streets formed on the front side of a semiconductor substrate of the semiconductor wafer to thereby define a plurality of separate regions where a plurality of devices are formed, the semiconductor wafer having a stacked layer formed on the front side of the semiconductor substrate, the stacked layer including an insulating film and a functional film to form the devices, the semiconductor wafer having a glass passivation film formed on the front side of the stacked layer so as to cover the devices and the streets,

the semiconductor wafer processing method including a first groove forming step of applying a CO₂ laser beam having an absorption wavelength to the glass passivation film along each street, thereby removing the glass passivation film along each street to form a first groove for dividing the glass passivation film along each street; and a second groove forming step of applying a laser beam having an absorption wavelength to the stacked layer along the first groove after performing the first groove forming step, thereby removing the stacked layer along each street to form a second groove for dividing the stacked layer along each street.

According to this method, the CO₂ laser beam having an absorption wavelength to only the glass passivation film is applied to the semiconductor wafer in the first groove forming step. Accordingly, it is possible to suppress the possibility that the CO₂ laser beam may be transmitted through the glass passivation film, so that it is possible to suppress the possibility that the stacked layer covered with the glass passivation film may be ablated by the application of the CO₂ laser beam. As a result, the breakage of the glass passivation film from the inside surface thereof can be prevented, and the glass passivation film can be removed along each street to form the first groove. Thereafter, the second groove can be formed along the first groove.

Preferably, the wavelength of the CO₂ laser beam to be applied in the first groove forming step is set in the range of 9.4 μm to 10.6 μm.

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 a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a processing apparatus suitable for use in performing a semiconductor wafer processing method according to a preferred embodiment of the present invention;

FIG. 2A is a perspective view of a semiconductor wafer to be processed by the semiconductor wafer processing method according to this preferred embodiment in the condition where the semiconductor wafer is supported to an annular frame;

FIG. 2B is an enlarged sectional view of an essential part of the semiconductor wafer shown in FIG. 2A;

FIG. 3A is a block diagram of first laser beam applying means constituting the processing apparatus

shown in FIG. 1;

FIG. 3B is a block diagram of second laser beam applying means constituting the processing apparatus shown in FIG. 1;

FIGS. 4A and 4B are sectional views for illustrating a first groove forming step in the semiconductor wafer processing method according to this preferred embodiment; and

FIGS. 5A and 5B are sectional views for illustrating a second groove forming step in the semiconductor wafer processing method according to this preferred embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

There will now be described a semiconductor wafer processing method according to a preferred embodiment of the present invention with reference to the attached drawings. FIG. 1 is a perspective view of a processing apparatus for use in the semiconductor wafer processing method according to this preferred embodiment. FIG. 2A is a perspective view of a semiconductor wafer supported to an annular frame, and FIG. 2B is an enlarged sectional view of an essential part of the semiconductor wafer shown in FIG. 2A. The configuration of a processing apparatus for use in the semiconductor wafer processing

method according to the present invention is not limited to that shown in FIG. 1, but any processing apparatus capable of processing the semiconductor wafer as in this preferred embodiment may be adopted.

As shown in FIG. 1, the processing apparatus denoted by reference numeral 1 includes a base 2, a chuck table 3 movably provided on the base 2 for holding a disk-shaped semiconductor wafer W thereon, first laser beam applying means 5 provided above the chuck table 3 for processing the semiconductor wafer W, and second laser beam applying means 6 provided above the chuck table 3 and arranged adjacent to the first laser beam applying means 5 for processing the semiconductor wafer W. That is, the semiconductor wafer W is processed by both the first laser beam applying means 5 and the second laser beam applying means 6.

The semiconductor wafer W as a workpiece to be processed by the processing apparatus 1 will now be described with reference to FIGS. 2A and 2B. As shown in FIG. 2A, the semiconductor wafer W is formed from a semiconductor substrate W1 of silicon. A plurality of crossing streets ST are formed on the front side W1a of the semiconductor substrate W1 to thereby define a plurality of separate regions where a plurality of devices D such as ICs and LSIs are each formed. As shown in FIG. 2B, a stacked layer W2 is formed on the front

side W1a of the semiconductor substrate W1 to form the streets ST and the devices D. The stacked layer W2 has an insulating film provided by a low-k film (low permittivity insulating film) and a functional film forming a circuit. Further, a glass passivation film W3 is formed on the front side W2a of the stacked layer W2 so as to fully cover the streets ST and the devices D. The glass passivation film W3 is formed of oxide such as SiO₂, SiOF, SiON, and SiO (Si_xO_y). Further, a water-soluble protective film W4 is formed on the front side W3a of the glass passivation film W3 to prevent scattered debris from sticking to the glass passivation film W3. Referring back to FIG. 2A, a protective tape T such as a synthetic resin sheet is attached to the back side W1b of the semiconductor substrate W1. The peripheral portion of the protective tape T is supported to an annular frame F. Accordingly, the semiconductor wafer W is supported through the protective tape T to the annular frame F.

Referring back to FIG. 1, a holding member 3a for holding the back side of the semiconductor wafer W under suction is formed on the upper surface of the chuck table 3. The holding member 3a is formed of a porous ceramic material. The holding member 3a is connected through a suction passage formed in the chuck table 3 to a vacuum source (not shown). The chuck table 3 has a circular shape and it is rotatable about its center by rotating

means (not shown). A pair of clamps 9 are provided on the outer circumference of the chuck table 3 so as to be supported by support arms. Each clamp 9 is driven by an air actuator to fix the annular frame F supporting the semiconductor wafer W at its diametrically opposite positions.

A cover 11 is provided below the chuck table 3 so as to be supported by a cylindrical member 10. The cylindrical member 10 is provided above indexing means 13. The indexing means 13 includes a pair of parallel guide rails 14 extending in the Y direction shown by an arrow Y in FIG. 1, a ball screw 15 provided between the guide rails 14 so as to extend parallel thereto, and a Y table 16 slidably mounted on the guide rails 14. A nut portion (not shown) is formed on the lower surface of the Y table 16, and the ball screw 15 is threadedly engaged with this nut portion. A drive motor 17 is connected to one end of the ball screw 15. Accordingly, when the drive motor 17 is operated, the Y table 16 is rotationally driven by the drive motor 17 to thereby move the Y table 16 along the guide rails 14 in the indexing direction (Y direction).

The indexing means 13 is provided above feeding means 20. The feeding means 20 includes a pair of parallel guide rails 22 extending in the X direction shown by an arrow X in FIG. 1, a ball screw 23 provided between the guide rails 22 so as to extend parallel

thereto, and an X table 21 slidably mounted on the guide rails 22. The guide rails 14 and the ball screw 15 of the indexing means 13 are provided on the X table 21, and the guide rails 22 and the ball screw 23 of the feeding means 20 are provided on the base 2. A nut portion (not shown) is formed on the lower surface of the X table 21, and the ball screw 23 is threadedly engaged with this nut portion. A drive motor 24 is connected to one end of the ball screw 23. Accordingly, when the drive motor 24 is operated, the ball screw 23 is rotationally driven by the drive motor 24 to thereby move the X table 21 along the guide rails 22 in the feeding direction (X direction).

The first laser beam applying means 5 is supported by a first support mechanism 27 so as to be movable in the Y direction and the Z direction shown by an arrow Z in FIG. 1 above the chuck table 3. The first support mechanism 27 includes a pair of parallel guide rails 28 extending in the Y direction and a motor-driven Y table 29 slidably mounted on the guide rails 28. The guide rails 28 are provided on the base 2. The Y table 29 has a rectangular shape as viewed in plan and a side wall portion 30 is formed at one end of the Y table 29 in the X direction so as to extend vertically.

The first support mechanism 27 further includes a pair of parallel guide rails 32 (one of which being shown) extending in the Z direction and a motor-driven Z

table 33 slidably mounted on the guide rails 32. The guide rails 32 are provided on one side surface of the side wall portion 30. A nut portion (not shown) is formed on the lower surface of the Y table 29, and another nut portion (not shown) is formed on one side surface of the Z table 33 opposed to the side surface of the side wall portion 30 where the guide rails 32 are provided. A ball screw 34 is threadedly engaged with the nut portion of the Y table 29, and another ball screw 35 is threadedly engaged with the nut portion of the Z table 33. A drive motor 36 is connected to one end of the ball screw 34, and another drive motor 37 is connected to one end of the ball screw 35. Accordingly, when the drive motor 36 is operated, the ball screw 34 is rotationally driven by the drive motor 36 to thereby move the Y table 29 along the guide rails 28 in the Y direction. Similarly, when the drive motor 37 is operated, the ball screw 35 is rotationally driven to thereby move the Z table 33 along the guide rails 32 in the Z direction.

The first laser beam applying means 5 includes a cylindrical casing 40 supported to the Z table 33 in a cantilever fashion. The first laser beam applying means 5 further includes first focusing means 41 mounted on the front end of the casing 40, pulsed laser beam oscillating means 42 (see FIG. 3A) provided in the casing 40, and power adjusting means 43 (see FIG. 3A) provided in the

casing 40. As shown in FIG. 3A, the pulsed laser beam oscillating means 42 is composed of a pulsed laser oscillator 42a provided by a CO₂ laser oscillator and repetition frequency setting means 42b connected to the pulsed laser oscillator 42a. The pulsed laser oscillator 42a functions to oscillate a CO₂ laser beam having a wavelength of 9.4 μm to 10.6 μm. The first focusing means 41 functions to apply the CO₂ laser beam oscillated from the pulsed laser beam oscillating means 42 toward the glass passivation film W3 of the semiconductor wafer W (the upper side as viewed in FIG. 1). The wavelength of the CO₂ laser beam to be applied from the first focusing means 41 is an absorption wavelength to the glass passivation film W3. The power adjusting means 43 functions to adjust the power of the CO₂ laser beam oscillated from the pulsed laser beam oscillating means 42 to a predetermined value.

Referring back to FIG. 1, imaging means 45 is provided at the front end portion of the casing 40. The imaging means 45 is capable of imaging a surface area of the semiconductor wafer W projected under predetermined magnification with a microscope. The imaging means 45 includes an imaging device (not shown) such as a CCD. The imaging device is composed of a plurality of pixels, wherein an electrical signal is obtained according to the quantity of light received by each pixel. Accordingly,

the imaging means 45 can image the front side of the semiconductor wafer W to thereby detect the streets ST.

The second laser beam applying means 6 is supported by a second support mechanism 48 so as to be movable in the Y direction and the Z direction above the chuck table 3. The second support mechanism 48 is provided on the base 2 so as to be juxtaposed to the first support mechanism 27 in the X direction, and the second laser beam applying means 6 is close arranged in line symmetry to the first laser beam applying means 5. In the second support mechanism 48, the components having substantially the same functions as those of the components of the first support mechanism 27 are denoted by the same reference numerals, and the description thereof will be omitted herein.

The second laser beam applying means 6 includes a cylindrical casing 50 supported to the Z table 33 of the second support mechanism 48 in a cantilever fashion. The second laser beam applying means 6 further includes second focusing means 51 mounted on the front end of the casing 50, pulsed laser beam oscillating means 52 (see FIG. 3B) provided in the casing 50, and power adjusting means 53 (see FIG. 3B) provided in the casing 50. The pulsed laser beam oscillating means 52 is composed of a pulsed laser oscillator 52a provided by a YAG laser oscillator and repetition frequency setting means 52b

connected to the pulsed laser oscillator 52a. The pulsed laser oscillator 52a functions to oscillate a pulsed laser beam having an absorption wavelength (e.g., 355 nm) to the stacked layer W2. The second focusing means 51 functions to apply the pulsed laser beam oscillated from the pulsed laser beam oscillating means 52 toward the stacked layer W2 of the semiconductor wafer W. The power adjusting means 53 functions to adjust the power of the pulsed laser beam oscillated from the pulsed laser beam oscillating means 52 to a predetermined value. No imaging means is provided at the front end portion of the casing 50 constituting the second laser beam applying means 6.

The processing method for the semiconductor wafer W by using the processing apparatus 1 mentioned above will now be described. Prior to performing the processing method, the semiconductor wafer W supported through the protective tape T to the annular frame F is taken out of a cassette (not shown). Thereafter, the semiconductor wafer W is transferred to the chuck table 3 and placed on the holding member 3a of the chuck table 3 in the condition where the stacked layer W2 is oriented upward through the films W3 and W4 and the protective tape T is in contact with the holding member 3a. Thereafter, the vacuum source (not shown) is operated to apply a suction force to the holding member 3a, thereby holding the semiconductor wafer W through the protective tape T on

the chuck table 3 under suction. Further, the annular frame F is fixed by the clamps 9. Thereafter, the first laser beam applying means 5 and the second laser beam applying means 6 are moved in the Y direction to position the first focusing means 41 and the second focusing means 51 so that the laser beam applying positions by the first and second focusing means 41 and 51 in the Y direction coincide with each other.

After holding the semiconductor wafer W on the chuck table 3 under suction, a target area of the semiconductor wafer W to be laser-processed is detected and the laser beam applying positions by the first and second focusing means 41 and 51 are set on a predetermined one of the streets ST according to a detection result obtained (alignment step). In this alignment step, the chuck table 3 is moved to a position directly below the imaging means 45 by the feeding means 20. Thereafter, the predetermined street ST of the semiconductor wafer W is imaged by the imaging means 45, and image processing such as pattern matching for aligning the predetermined street ST with the first and second focusing means 41 and 51 is performed by control means (not shown) by using an image obtained by the imaging means 45. According to the result of this image processing, the chuck table 3 is moved so that the laser beam applying positions by the first and second focusing

means 41 and 51 coincide with the center of the predetermined street ST in the direction of its width. After positioning the chuck table 3 in this manner, the first laser beam applying means 5 is moved in the Z direction so that the focal point of a CO₂ laser beam Lc (see FIG. 4A) to be applied from the first focusing means 41 is set on the glass passivation film W3. Similarly, the second laser beam applying means 6 is moved in the Z direction so that the focal point of a laser beam Ly (see FIG. 5A) to be applied from the second focusing means 51 is set on the stacked layer W2.

FIGS. 4A and 4B are sectional views for illustrating a passivation film dividing groove forming step (first groove forming step) according to this preferred embodiment. After performing the alignment step mentioned above, the first groove forming step is performed to form a passivation film dividing groove (first groove) M1 in the glass passivation film W3 along the predetermined street ST. In this first groove forming step, the first laser beam applying means 5 is operated to apply the CO₂ laser beam Lc having an absorption wavelength to the glass passivation film W3 from the first focusing means 41 toward the glass passivation film W3. As applying the CO₂ laser beam Lc, the chuck table 3 is moved at a predetermined feed speed in the feeding direction, i.e., in the X direction (perpendicular to the

sheet plane of FIG. 4A). Accordingly, the CO₂ laser beam Lc is applied to the glass passivation film W3 along the predetermined street ST. That is, ablation is performed to remove the glass passivation film W3 and the protective film W4 covering the front side W2a of the stacked layer W2 of the semiconductor wafer W along the predetermined street ST. As a result, the glass passivation film W3 is divided along the predetermined street ST to thereby form the first groove M1.

For example, the first groove forming step is performed under the following processing conditions.

Light source: CO₂ laser

Laser wavelength: 9.4 μ m

Focused spot diameter: 100 μ m

Average power: 1 W to 10 W

Repetition frequency: 20 kHz

Work feed speed: 600 mm/second

By setting the average power in the above range, the glass passivation film W3 can be well removed. If the average power exceeds 10 W, damage to the semiconductor wafer W by the ablation is large.

FIGS. 5A and 5B are sectional views for illustrating a stacked layer dividing groove forming step (second groove forming step) according to this preferred embodiment. After performing the first groove forming step mentioned above, the second groove forming step is

performed to remove the stacked layer W2 along the first groove M1 formed along the predetermined street ST, thereby forming a stacked layer dividing groove (second groove) M2 in the stacked layer W2 along the predetermined street ST. The second groove forming step is performed in sequential relationship with the first groove forming step. That is, when the predetermined street ST where the first groove M1 has been formed reaches the position directly below the second focusing means 51 as shown in FIG. 5A by feeding the semiconductor wafer W in the first groove forming step, the second laser beam applying means 6 is operated to perform the second groove forming step. By operating the second laser beam applying means 6, the laser beam Ly having an absorption wavelength to the stacked layer W2 is applied from the second focusing means 51 toward the stacked layer W2. As applying the laser beam Ly, the chuck table 3 is fed as similarly to the first groove forming step. Accordingly, the laser beam Ly is applied to the stacked layer W2 along the first groove M1 formed along the predetermined street ST. That is, ablation is performed to remove the stacked layer W2 exposed to the bottom of the first groove M1 along the predetermined street ST. As a result, the stacked layer W2 is divided along the predetermined street ST to thereby form the second groove M2.

For example, the second groove forming step is performed under the following processing conditions.

Light source: YAG pulsed laser

Laser wavelength: 355 nm

Focused spot diameter: 1 μ m

Average power: 3 W

Repetition frequency: 50 kHz

Work feed speed: 100 mm/second

The first groove forming step and the second groove forming step are performed similarly along all of the streets ST extending in a first direction on the semiconductor wafer W. Thereafter, the chuck table 3 is rotated 90° to thereby rotate the semiconductor wafer W held on the chuck table 3 by 90°. In this condition, the first groove forming step and the second groove forming step are similarly performed along all of the other streets ST extending in a second direction perpendicular to the first direction. Thus, the first grooves M1 and the second grooves M2 are formed along all of the streets ST of the semiconductor wafer W. Thereafter, the semiconductor wafer W is subjected to a dividing step as the next step.

According to this preferred embodiment described above, the CO₂ laser beam having an absorption wavelength to only the glass passivation film W3 is applied thereto to thereby form the first groove M1 in the glass

passivation film W3. Accordingly, it is possible to suppress the possibility that the CO₂ laser beam may be transmitted through the glass passivation film W3. As a result, it is possible to suppress the possibility that the stacked layer W2 may be ablated in the first groove forming step to cause the breakage of the glass passivation film W3 from the inside surface thereof.

The present invention is not limited to the above preferred embodiment, but various modifications may be made. The size, shape, etc. of the parts in the above preferred embodiment shown in the attached drawings are merely illustrative and they may be suitably changed within the scope where the effect of the present invention can be exhibited. Further, the above preferred embodiment may be suitably modified without departing from the scope of the object of the present invention.

For example, while the positions of the first and second focusing means 41 and 51 in the Y direction are made to coincide with each other in the first groove forming step and the second groove forming step in the above preferred embodiment, this configuration is illustrative. As a modification, the positions of the first and second focusing means 41 and 51 in the Y direction may be shifted from each other in the Y direction by the width of each street ST in performing the first groove forming step and the second groove

forming step. In this case, after forming the first groove M1, the semiconductor wafer W is moved in the indexing direction (Y direction) by the width of each street ST, and the second groove M2 is formed along the first groove M1.

The present invention is not limited to the details of the above described preferred embodiment. 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 semiconductor wafer processing method for processing a semiconductor wafer along a plurality of crossing streets formed on the front side of a semiconductor substrate of said semiconductor wafer to thereby define a plurality of separate regions where a plurality of devices are each formed, said semiconductor wafer having a stacked layer formed on the front side of said semiconductor substrate, said stacked layer including an insulating film and a functional film to form said devices, said semiconductor wafer having a glass passivation film formed on the front side of said stacked layer so as to cover said devices and said streets, said semiconductor wafer processing method comprising:

a first groove forming step of applying a CO₂ laser beam having an absorption wavelength to said glass passivation film along each street, thereby removing said glass passivation film along each street to form a first groove for dividing said glass passivation film along each street; and

a second groove forming step of applying a laser beam having an absorption wavelength to said stacked layer along said first groove after performing said first groove forming step, thereby removing said stacked layer along each street to form a second groove for dividing

said stacked layer along each street.

2. The semiconductor wafer processing method according to claim 1, wherein the wavelength of said CO₂ laser beam to be applied in said first groove forming step is set in the range of 9.4 μm to 10.6 μm.