

METHOD OF PROCESSING WAFER

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of processing a wafer.

Description of the Related Art

For performing plasma dicing on a wafer including a functional layer disposed on a substrate, a wafer pretreatment is initially carried out by forming a protective film on a face side of the wafer and applying a laser beam to the wafer along projected dicing lines on the wafer to remove portions of the protective film and the functional layer, exposing portions of the substrate. Thereafter, plasma dicing is carried out on the wafer using the remaining portions of the protective film as a mask (see, for example, JP 2022-052821A).

SUMMARY OF THE INVENTION

However, heat of the laser beam applied to the wafer tends to melt side surfaces of the functional layer and the exposed portions of the face side of the substrate, forming surface irregularities, miniscule cracks, and modified layers that are more brittle than

other regions.

If plasma etching is carried out on the wafer with those defective regions being exposed, then the surface irregularities etc. are etched so as to elongate depthwise, forming surface irregularities on the side surfaces of the etched substrate. As a result, the quality of the processed wafer is lowered.

It is therefore an object of the present invention to provide a method of processing a wafer by way of plasma etching such that the processed wafer will be of increased quality.

In accordance with an aspect of the present invention, there is provided a method of processing a wafer along a grid of projected dicing lines thereon, the wafer including a substrate and a functional layer disposed on a face side of the substrate, the functional layer including a plurality of devices disposed in respective areas demarcated by the projected dicing lines, including a first processed groove forming step of applying a laser beam to the wafer from a face side thereof along the projected dicing lines to form first processed grooves in the functional layer, after the first processed groove forming step, a masking protective film forming step of forming a masking protective film

covering the face side of the wafer and filling the first processed grooves, after the masking protective film forming step, a second processed groove forming step of applying a laser beam to the wafer along the first processed grooves to form second processed grooves that are narrower than the first processed grooves, exposing the substrate through the second processed grooves, and after the second processed groove forming step, a plasma etching step of carrying out plasma etching on the wafer along the second processed grooves using the masking protective film as a mask.

Preferably, the laser beam applied in the second processed groove forming step has a smaller output power level than the laser beam applied in the first processed groove forming step.

Preferably, the plasma etching step includes the step of dividing the wafer into a plurality of device chips including the respective devices.

Preferably, the method further includes, before the first processed groove forming step, a first protective film forming step of forming a first protective film on the face side of the wafer, and after the first processed groove forming step, a first protective film removing step of washing away the first

protective film.

Preferably, the first processed grooves have respective widths that are identical to each other, and the second processed grooves have respective widths that are identical to each other.

Preferably, the wafer includes metal parts disposed on the face side thereof at the projected dicing lines, the first processed grooves being wider than the metal parts.

The present invention is advantageous in that the quality of the processed wafer is increased in plasma etching.

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 schematically illustrating a wafer to be processed by a method of processing a wafer according to a first embodiment of the

present invention;

FIG. 2 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer illustrated in FIG. 1;

FIG. 3 is a flowchart of the sequence of the method of processing a wafer according to the first embodiment;

FIG. 4 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a first protective film forming step of the method of processing a wafer illustrated in FIG. 3;

FIG. 5 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a first processed groove forming step of the method of processing a wafer illustrated in FIG. 3;

FIG. 6 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a first protective film removing step of the method of processing a wafer illustrated in FIG. 3;

FIG. 7 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a masking protective film forming step of the method of processing a wafer illustrated in FIG. 3;

FIG. 8 is an enlarged fragmentary cross-sectional

view schematically illustrating a portion of the wafer after a second processed groove forming step of the method of processing a wafer illustrated in FIG. 3;

FIG. 9 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer during a plasma etching step of the method of processing a wafer illustrated in FIG. 3;

FIG. 10 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a masking protective film removing step of the method of processing a wafer illustrated in FIG. 3;

FIG. 11 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of a wafer after a first protective film forming step of a method of processing a wafer according to a modification of the first embodiment;

FIG. 12 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a first processed groove forming step of the method of processing a wafer according to the modification of the first embodiment;

FIG. 13 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of

the wafer after a first protective film removing step of the method of processing a wafer according to the modification of the first embodiment;

FIG. 14 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a masking protective film forming step of the method of processing a wafer according to the modification of the first embodiment;

FIG. 15 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a second processed groove forming step of the method of processing a wafer according to the modification of the first embodiment;

FIG. 16 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer during a plasma etching step of the method of processing a wafer according to the modification of the first embodiment;

FIG. 17 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer after a masking protective film removing step of the method of processing a wafer according to the modification of the first embodiment;

FIG. 18 is a fragmentary plan view schematically

illustrating a portion of a wafer to be processed by a method of processing a wafer according to a second embodiment of the present invention;

FIG. 19 is a cross-sectional view taken along line XIX-XIX of FIG. 18;

FIG. 20 is a cross-sectional view taken along line XX-XX of FIG. 18;

FIG. 21 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to a first projected dicing line after a first protective film forming step of the method of processing a wafer according to the second embodiment;

FIG. 22 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to a second projected dicing line after the first protective film forming step of the method of processing a wafer according to the second embodiment;

FIG. 23 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first processed groove forming step of the method of processing a wafer

according to the second embodiment;

FIG. 24 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first processed groove forming step of the method of processing a wafer according to the second embodiment;

FIG. 25 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first protective film removing step of the method of processing a wafer according to the second embodiment;

FIG. 26 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first protective film removing step of the method of processing a wafer according to the second embodiment;

FIG. 27 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film forming step of the method of processing a wafer

according to the second embodiment;

FIG. 28 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film forming step of the method of processing a wafer according to the second embodiment;

FIG. 29 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a second processed groove forming step of the method of processing a wafer according to the second embodiment;

FIG. 30 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the second processed groove forming step of the method of processing a wafer according to the second embodiment;

FIG. 31 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line during a plasma etching step of the method of processing a wafer according to the

second embodiment;

FIG. 32 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line during the plasma etching step of the method of processing a wafer according to the second embodiment;

FIG. 33 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film forming step of the method of processing a wafer according to the second embodiment;

FIG. 34 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film forming step of the method of processing a wafer according to the second embodiment;

FIG. 35 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of a wafer along a sectional plane perpendicular to a first projected dicing line after a first protective film forming step of a method of processing a wafer according

to a modification of the second embodiment;

FIG. 36 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to a second projected dicing line after the first protective film forming step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 37 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first processed groove forming step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 38 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first processed groove forming step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 39 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first protective film removing step of the method of processing a wafer

according to the modification of the second embodiment;

FIG. 40 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first protective film removing step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 41 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film forming step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 42 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film forming step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 43 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a second processed groove forming step of the method of processing a wafer

according to the modification of the second embodiment;

FIG. 44 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the second processed groove forming step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 45 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line during a plasma etching step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 46 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line during the plasma etching step of the method of processing a wafer according to the modification of the second embodiment;

FIG. 47 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film removing step of the method of processing a wafer

according to the modification of the second embodiment;
and

FIG. 48 is an enlarged fragmentary cross-sectional view schematically illustrating a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film removing step of the method of processing a wafer according to the modification of the second embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings. The present invention is not limited to the details of the embodiments described below. The components described below cover those which could easily be anticipated by those skilled in the art and those which are essentially identical to those described below. Furthermore, the arrangements described below can be combined in appropriate manners. Various omissions, replacements, or changes of the arrangements may be made without departing from the scope of the present invention. In the description below, those components that are identical to each other are denoted by identical reference signs.

[First embodiment]

A method of processing a wafer according to a first embodiment of the present invention will be described below with reference to the drawings. FIG. 1 schematically illustrates, in perspective, a wafer to be processed by the method of processing a wafer according to the first embodiment. FIG. 2 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer illustrated in FIG. 1. FIG. 3 is a flowchart of the sequence of the method of processing a wafer according to the first embodiment.

(Wafer)

The method of processing a wafer according to the first embodiment represents a method of processing the wafer, denoted by 1, illustrated in FIG. 1. According to the first embodiment, the wafer 1 includes a wafer such as a semiconductor wafer shaped as a circular plate including a substrate 2 made of silicon, glass, silicon carbide (SiC), sapphire, gallium arsenide, or the like. As illustrated in FIG. 1, the wafer 1 has a plurality of devices 5 constructed in respective areas demarcated on a face side 3 thereof by a grid of projected dicing lines 4 established on the face side 3.

The devices 5 may include integrated circuits

(ICs), large-scale-integration (LSI) circuits, charge-coupled devices (CCDs), memories (semiconductor storage devices), or the like.

According to the first embodiment, as illustrated in FIGS. 1 and 2, the wafer 1 includes a functional layer 6 disposed on a face side of the substrate 2 and having a face side as the face side 3 of the wafer 1. The functional layer 6 includes a plurality of low-dielectric-constant insulating films (hereinafter referred to as "low-k films") made of inorganic film of SiOF, BSG (SiOB), or the like, organic film as polymer film of polyimide-based material, parylene-based material, or the like, or carbon-containing silicon oxide (SiOCH), and a circuit layer including an electrically conductive metal pattern or film.

The low-k films and the circuit layer as they are combined together make up the devices 5. The circuit layer provides the circuits of the devices 5. Specifically, the devices 5 are constructed of the low-k films stacked in the functional layer 6 on the substrate 2 and the circuit layer disposed between the low-k films. At the projected dicing lines 4, the functional layer 6 is made up of the low-k layers disposed on the substrate 2.

The functional layer 6 including the low-k films tend to be peeled off from the substrate 2 when the wafer 1 is cut by a cutting blade from the face side 3 thereof. According to the first embodiment, as described above, the devices 5 are made up of the functional layer 6 disposed on the substrate 2 and are disposed in the face side 3.

According to the first embodiment, the projected dicing lines 4 include a plurality of first projected dicing lines 7 extending parallel to each other and a plurality of second projected dicing lines 8 extending parallel to each other and crossing the first projected dicing lines 7. The wafer 1 thus includes the devices 5 in the face side 3 and the first and second projected dicing lines 7 and 8 on the face side 3 that demarcate the areas where the devices 5 are disposed. According to the first embodiment, the width of each of the first projected dicing lines 7 and the width of each of the second projected dicing lines 8 are equal to each other. (Method of processing a wafer)

The method of processing a wafer according to the first embodiment represents a method of processing the wafer 1 where the devices 5 are constructed in the functional layer 6 disposed on the face side of the

substrate 2, along the first and second projected dicing lines 7 and 8 demarcating the areas where the devices 5 are disposed. According to the first embodiment, the method of processing a wafer is also a method of dividing, which represents a form of "processing," the wafer 1 into individual device chips 10 (see FIG. 1) along the first and second projected dicing lines 7 and 8. Each of the device chips 10 includes a portion of the substrate 2 and one of the devices 5.

As illustrated in FIG. 3, the method of processing a wafer includes first protective film forming step 101, a first processed groove forming step 102, a first protective film removing step 103, a masking protective film forming step 104, a second processed groove forming step 105, a plasma etching step 106, and a masking protective film removing step 107. In preparation for the method of processing a wafer according to the first embodiment, as illustrated in FIG. 1, a circular tape 11 that is larger in diameter than the wafer 1 is affixed to a reverse side 9 of the wafer 1 that is opposite the face side 3, and an annular frame 12 is affixed to an outer circumferential edge portion of the tape 11. In the method of processing a wafer according to the first embodiment, the wafer 1 that is

supported by the frame 12 through the tape 11 is processed. Although the frame 12 is combined with wafers according to the first embodiment and all other embodiments of the present invention as described below, the frame 12 is not indispensable and may not be combined with wafers.

(First protective film forming step 101)

FIG. 4 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 after the first protective film forming step 101 of the method of processing a wafer illustrated in FIG. 3. The first protective film forming step 101 represents a step of forming a first protective film 13 (see FIG. 4) on the face side 3 of the wafer 1 before the first processed groove forming step 102.

According to the first embodiment, in the first protective film forming step 101, a resin film coating apparatus, not illustrated, operates to hold the reverse side 9 of the wafer 1 under suction on a holding surface of a spinner table, not illustrated, with the tape 11 interposed therebetween, clamp the frame 12 in position with clamps, not illustrated, rotate the spinner table about its central axis, and drop a water-soluble resin in a liquid phase from a water-soluble resin supply nozzle,

not illustrated, onto a central portion of the face side 3 of the wafer 1. Under centrifugal forces produced by the rotation of the spinner table, the dropped water-soluble resin flows and spreads radially outwardly from the central portion of the face side 3 of the wafer 1 toward an outer circumferential edge portion of the wafer 1, thereby coating the face side 3 in its entirety.

The water-soluble resin may include polyvinyl alcohol (PVA), polyvinylpyrrolidone (PVP), or the like, for example. In the first protective film forming step 101, the water-soluble resin applied to the entire face side 3 of the wafer 1 is dried into a first protective film 13 covering the entire face side 3, as illustrated in FIG. 4. According to the first embodiment, as described above, the first protective film 13 is made of the water-soluble resin. The water-soluble resin as it is dried into the first protective film 13 is resistant to a plasmatized etching gas 18 (see FIG. 9) used in the plasma etching step 106 because it is etched at a lower rate than the substrate 2 is etched by the plasmatized etching gas 18.

(First processed groove forming step 102)

FIG. 5 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 after

the first processed groove forming step 102 of the method of processing a wafer illustrated in FIG. 3. The first processed groove forming step 102 represents a step of applying a laser beam, not illustrated, to the wafer 1 from the face side 3 side along the first and second projected dicing lines 7 and 8, forming first processed grooves 14 (see FIG. 5) in the functional layer 6.

According to the first embodiment, in the first processed groove forming step 102, a laser processing apparatus, not illustrated, operates to hold the reverse side 9 side of the wafer 1 under suction on a holding surface of a holding table, not illustrated, with the tape 11 interposed therebetween, and clamp the frame 12 in position with clamps, not illustrated. Then, the laser processing apparatus performs an alignment process by capturing an image of the face side 3 of the wafer 1 with an image capturing unit, not illustrated, detecting the first and second projected dicing lines 7 and 8 from the captured image, and positioning a laser beam applying unit, not illustrated, in alignment with selected ones of the first and second projected dicing lines 7 and 8.

According to the first embodiment, in the first processed groove forming step 102, the laser processing apparatus operates to apply a laser beam having a

wavelength absorbable by the wafer 1 from the laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8. The laser processing apparatus sets the focused spot of the laser beam on a face side of the first protective film 13 or the face side of the substrate 2 in applying the laser beam to the wafer 1 along the first and second projected dicing lines 7 and 8.

According to the first embodiment, in the first processed groove forming step 102, the laser beam applied by the laser processing apparatus to the wafer ablates portions of the first protective film 13, the functional layer 6, and the substrate 2 that are aligned with the first and second projected dicing lines 7 and 8, removing them to form first processed grooves 14 (one illustrated in FIG. 5) through the functional layer 6 along the first and second projected dicing lines 7 and 8, as illustrated in FIG. 5. The first processed grooves 14 extend depthwise through and hence divide the functional layer 6.

Specifically, the laser beam is applied to two transversely opposite edges of each of the first and

second projected dicing lines 7 and 8 to abrade portions of the first protective film 13, the functional layer 6, and the substrate 2 along the transversely opposite edges of each of the first and second projected dicing lines 7 and 8, forming processed grooves along those transversely opposite edges, and then applied between the processed grooves along those transversely opposite edges to abrade portions of the first protective film 13, the functional layer 6, and the substrate 2 between the processed grooves along the transversely opposite edges, thereby forming the first processed grooves 14. The laser beam applied to the wafer 1 in the first processed groove forming step 102 has a wavelength of 355 nm and a repetitive frequency ranging from 200 to 2000 kHz. However, the wavelength of the laser beam is not limited to 355 nm, but may preferably be in the ultraviolet range.

More specifically, when the laser beam is applied to the two transversely opposite edges of each of the first and second projected dicing lines 7 and 8 to abrade the portions of the first protective film 13, the functional layer 6, and the substrate 2 along the two transversely opposite edges, forming the processed grooves along the two transversely opposite edges, the

laser beam is branched into two laser beams that are applied respectively to the two transversely opposite edges and has an average output power level of 0.5 W, the laser beam applying unit and the wafer 1 are moved relatively to each other at a speed (hereinafter referred to as "processing-feed speed") ranging from 100 to 400 mm/sec, and the focused spot of the laser beam is of a circular shape having a diameter of 5 μm . Furthermore, when the laser beam is applied between the processed grooves along the two transversely opposite edges to abrade the portions of the first protective film 13, the functional layer 6, and the substrate 2 between the processed grooves along the two transversely opposite edges, the laser beam has an average output power level of 10.0 W, the processing-feed speed ranges from 200 to 1000 mm/sec., and the focused spot of the laser beam is of a rectangular shape having a width of 60 μm .

According to the first embodiment, all the first processed grooves 14 have respective widths 14-1 that are identical to each other.

(First protective film removing step 103)

FIG. 6 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 after the first protective film removing step 103 of the method

of processing a wafer illustrated in FIG. 3. The first protective film removing step 103 represents a step of washing away the first protective film 13 after the first processed groove forming step 102 has been carried out.

According to the first embodiment, in the first protective film removing step 103, a cleaning apparatus, not illustrated, operates to hold the reverse side 9 of the wafer 1 under suction on a holding surface of a spinner table, not illustrated, with the tape 11 interposed therebetween, clamp the frame 12 in position with clamps, not illustrated, rotate the spinner table about its central axis, and supply cleaning water from a cleaning water supply nozzle, not illustrated, onto a central portion of the face side 3 of the wafer 1. Under centrifugal forces produced by the rotation of the spinner table, the cleaning water supplied to the face side 3 of the wafer 1 flows and spreads radially outwardly from the central portion of the face side 3 of the wafer 1 toward an outer circumferential edge portion of the wafer 1, thereby removing the first protective film 13 including the water-soluble resin together with foreign matter such as debris from the wafer 1, as illustrated in FIG. 6.

(Masking protective film forming step 104)

FIG. 7 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 after the masking protective film forming step 104 of the method of processing a wafer illustrated in FIG. 3. The masking protective film forming step 104 represents a step of forming a masking protective film 15 (see FIG. 15) covering the face side 3 of the wafer 1 and filling the first processed grooves 14 after the first processed groove forming step 102 has been carried out.

According to the first embodiment, in the masking protective film forming step 104, a resin film coating apparatus, not illustrated, operates to hold the reverse side 9 of the wafer 1 under suction on a holding surface of a spinner table, not illustrated, with the tape 11 interposed therebetween, clamp the frame 12 in position with clamps, not illustrated, rotate the spinner table about its central axis, and drop a water-soluble resin in a liquid phase from a water-soluble resin supply nozzle, not illustrated, onto a central portion of the face side 3 of the wafer 1. Under centrifugal forces produced by the rotation of the spinner table, the dropped water-soluble resin flows and spreads radially outwardly from the central portion of the face side 3 of the wafer 1 toward the outer circumferential edge portion of the

wafer 1, thereby coating the face side 3 in its entirety and filling the first processed grooves 14.

The water-soluble resin may include polyvinyl alcohol (PVA), polyvinylpyrrolidone (PVP), or the like, for example. In the masking protective film forming step 104, the water-soluble resin applied to the entire face side 3 of the wafer 1 is dried into a masking protective film 15 covering the entire face side 3 and filling the first processed grooves 14, as illustrated in FIG. 7.

According to the first embodiment, as described above, the masking protective film 15 is made of the water-soluble resin. The water-soluble resin as it is dried into the masking protective film 15 is resistant to the plasmatized etching gas 18 (see FIG. 9) used in the plasma etching step 106 because it is etched at a lower rate than the substrate 2 is etched by the plasmatized etching gas 18. According to the first embodiment, the water-soluble resin of the masking protective film 15 is identical to the water-soluble resin of the first protective film 13 formed in the first protective film forming step 101. According to the present invention, however, the water-soluble resin of the masking protective film 15 may be different from the water-soluble resin of the first protective film 13 formed in

the first protective film forming step 101 providing the water-soluble resin of the masking protective film 15 is resistant to the etching gas 18.

(Second processed groove forming step 105)

FIG. 8 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 after the second processed groove forming step 105 of the method of processing a wafer illustrated in FIG. 3. The second processed groove forming step 105 represents a step of applying a laser beam to the wafer 1 along the first processed grooves 14 to form second processed grooves 16 (see FIG. 8) having a width 16-1 smaller than the first processed grooves 14, through the masking protective film 15 along the first processed grooves 14, thereby exposing portions of the substrate 2 along the second processed grooves 16.

According to the first embodiment, in the second processed groove forming step 105, a laser processing apparatus, not illustrated, operates to hold the reverse side 9 side of the wafer 1 under suction on a holding surface of a holding table, not illustrated, with the tape 11 interposed therebetween, and clamp the frame 12 in position with clamps, not illustrated. Then, the laser processing apparatus performs an alignment process

by capturing an image of the face side 3 of the wafer 1 with an image capturing unit, not illustrated, detecting the first and second projected dicing lines 7 and 8 from the captured image, and positioning a laser beam applying unit, not illustrated, in alignment with selected ones of the first and second projected dicing lines 7 and 8.

According to the first embodiment, in the second processed groove forming step 105, the laser processing apparatus operates to apply a laser beam having a wavelength absorbable by the wafer 1 from the laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8. The laser processing apparatus sets the focused spot of the laser beam on a face side of the masking protective film 15 or the face side of the substrate 2 in applying the laser beam to the wafer 1 along the first processed grooves 14 at the first and second projected dicing lines 7 and 8.

According to the first embodiment, in the second processed groove forming step 105, the laser beam applied by the laser processing apparatus to the wafer 1 ablates portions of the masking protective film 15 on bottom

surfaces 17 of the first processed grooves 14 and the substrate 2 that are aligned with the first and second projected dicing lines 7 and 8, removing them to form second processed grooves 16 (one illustrated in FIG. 8) through the functional layer 6 along the first and second projected dicing lines 7 and 8, as illustrated in FIG. 8. The second processed grooves 16 have bottom portions defined in the bottom surfaces 17 of the first processed grooves 14 and have widths 16-1 smaller than the widths 14-1 of the first processed grooves 14.

Specifically, the laser beam is applied to transversely central portions of the first processed grooves 14a along the first and second projected dicing lines 7 and 8 to ablate portions of the masking protective film 15 on the bottom surfaces 17 of the first processed grooves 14 and the substrate 2, forming the second processed grooves 16. The laser beam applied to the wafer 1 in the second processed groove forming step 105 has a wavelength of 355 nm and a repetitive frequency ranging from 200 to 1000 kHz. However, the wavelength of the laser beam is not limited to 355 nm, but may preferably be in the ultraviolet range.

More specifically, the laser beam has an average output power level of 1.0 W, the laser beam applying unit

and the wafer 1 are moved relatively to each other at a processing-feed speed of 200 mm/sec., and the focused spot of the laser beam is of a circular shape having a diameter in the range from 25 to 40 μm . The average output power level of the laser beam applied in the second processed groove forming step 105 should be lower than the average output power level of the laser beam applied in the first processed groove forming step 102. The laser beam applied in the second processed groove forming step 105 thus has an output power level smaller than the output power level of the laser beam applied in the first processed groove forming step 102. Moreover, the energy density of one spot of the laser beam applied in the second processed groove forming step 105 is lower than the energy density of one spot of the laser beam applied in the first processed groove forming step 102. According to the first embodiment, the widths 16-1 of all the second processed grooves 16 are identical to each other.

(Plasma etching step 106)

FIG. 9 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 during the plasma etching step 106 of the method of processing a wafer illustrated in FIG. 3. The plasma

etching step 106 represents a step of performing plasma etching on the wafer 1 along the second processed grooves 16 using the masking protective film 15 as a mask after the second processed groove forming step 105 has been carried out.

According to the first embodiment, in the plasma etching step 106, a plasma etching step, not illustrated, operates to hold the reverse side 9 of the wafer 1 under suction on a holding surface of a spinner table, not illustrated, with the tape 11 interposed therebetween, apply high-frequency electric power for generating and maintaining a plasma to an upper electrode, and apply high-frequency electric power for drawing ions to the holding table that functions a lower electrode, while supplying an etching gas 18 to the face side 3 side of the wafer 1.

The etching gas 18 in a space between the holding table and the upper electrode is plasmatized and then drawn to the wafer 1, etching, i.e., plasma-etching, the portions of the substrate 2 that are exposed on bottom surfaces of the second processed grooves 16 in the masking protective film 15. The second processed grooves 16 are progressively etched through the substrate 2 toward the reverse side 9 of the wafer 1.

In the plasma etching step 106, the plasma etching apparatus plasma-etches the wafer 1 until the second processed grooves 16 reach and become open at the reverse side 9 of the wafer 1, dividing the wafer 1 into the device chips 10. According to the first embodiment, in the plasma etching step 106, therefore, the wafer 1 is divided into the device chips 10.

(Masking protective film removing step 107)

FIG. 10 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer 1 after the masking protective film removing step 107 of the method of processing a wafer illustrated in FIG. 3. The masking protective film removing step 107 represents a step of washing away of the masking protective film 15 after the plasma etching step 106 has been carried out.

According to the first embodiment, in the masking protective film removing step 107, a cleaning apparatus, not illustrated, operates to hold the reverse side 9 of the wafer 1 under suction on a holding surface of a spinner table, not illustrated, with the tape 11 interposed therebetween, clamp the frame 12 in position with clamps, not illustrated, rotate the spinner table about its central axis, and supply cleaning water such as pure water or pure water containing a surfactant from a

cleaning water supply nozzle, not illustrated, onto a central portion of the masking protective film 15 on the face side 3 of the wafer 1. Under centrifugal forces produced by the rotation of the spinner table, the cleaning water supplied to the central portion of the masking protective film 15 flows and spreads radially outwardly from the central portion toward an outer circumferential edge portion of the wafer 1, thereby dissolving and removing the masking protective film 15 including the water-soluble resin together with foreign matter such as debris from the wafer 1, as illustrated in FIG. 10.

According to the conventional processing method, before plasma etching is performed on the portions of the substrate 2 at the bottom surfaces of the first processed grooves 14, the portions of the first protective film 13 and the functional layer 6 are removed to form the first processed grooves 14. Therefore, a laser beam having a large output power level needs to be applied to the wafer 1, tending to cause large thermal damage to the functional layer 6 and hence develop surface irregularities on inner side surfaces of the first processed grooves 14, particularly those of the functional layer 6. Consequently, when plasma etching is

performed on the portions of the substrate 2 at the bottom surfaces of the first processed grooves 14 by the conventional processing method, the portions of the substrate 2 along the first processed grooves 14 are etched along the surface irregularities developed on the inner side surfaces of the first processed grooves 14, particularly those of the functional layer 6. As a result, the resultant device chips 10 are likely to have surface irregularities on their side surfaces and to have a reduced flexural strength.

By contrast, the method of processing a water according to the first embodiment fills the first processed grooves 14 with the masking protective film 15 and then removes the masking protective film 15 from the first processed grooves 14, forming the second processed grooves 16. Since the masking protective film 15 is processed with a smaller amount of energy than the functional layer 6, the output power level of the laser beam applied to form the second processed grooves 16 may be smaller than the output power level of the laser beam applied to form the first processed grooves 14. With the method of processing a water according to the first embodiment, therefore, the thermal damage caused to the masking protective film 15 when the second processed

grooves 16 are formed may be smaller than the thermal damage caused to the functional layer 6 when the first processed grooves 14 are formed, thereby making the surface irregularities formed on the inner side surfaces of the second processed grooves 16 by the masking protective film 15 smaller than the surface irregularities formed on the inner side surfaces of the first processed grooves 14 by the functional layer 6.

With the method of processing a water according to the first embodiment, furthermore, inasmuch as the masking protective film 15 is processed with a smaller amount of energy than the functional layer 6, the output power level of the laser beam applied to form the second processed grooves 16 may be smaller than the output power level of the laser beam applied to form the first processed grooves 14, so that, whereas it is possible to form the second processed grooves 16, the surface irregularities formed on the inner side surfaces of the second processed grooves 16 can be reduced. While the side surfaces of the device chips 10 that are formed by plasma etching represent surface irregularities transferred from the side surfaces of the processed grooves 16 in the mask, the surface irregularities of the side surfaces of the device chips 10 are small because

the surface irregularities of the side surfaces of the processed grooves 16 in the mask are small.

As a result, since the method of processing a wafer according to the first embodiment etches the portions of the substrate 2 on the bottom surfaces of the second processed grooves 16 along the second processed grooves 165 in the plasma etching step 106, the quality of the processed wafer is increased in the plasma etching step 106, and the surface irregularities of the side surfaces of the device chips 10 are reduced, thereby restraining a reduction in the flexural strength of the device chips 10.

[Modification of the first embodiment]

A method of processing a wafer according to a modification of the first embodiment will be described below with reference to the drawings. FIG. 11 schematically illustrates, in enlarged fragmentary cross section, a portion of a wafer after a first protective film forming step of the method of processing a wafer according to the modification of the first embodiment. FIG. 12 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer after a first processed groove forming step of the method of processing a wafer according to the modification of the

first embodiment. FIG. 13 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer after a first protective film removing step of the method of processing a wafer according to the modification of the first embodiment. FIG. 14 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer after a masking protective film forming step of the method of processing a wafer according to the modification of the first embodiment. FIG. 15 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer after a second processed groove forming step of the method of processing a wafer according to the modification of the first embodiment. FIG. 16 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer during a plasma etching step of the method of processing a wafer according to the modification of the first embodiment. FIG. 17 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer after a masking protective film removing step of the method of processing a wafer according to the modification of the first embodiment. Those parts illustrated in FIGS. 11, 12, 13, 14, 15, 16, and 17 that are identical to those according

to the first embodiment are denoted by identical reference signs, and will be omitted from detailed description.

The method of processing a wafer according to the modification of the first embodiment represents a method of dividing a wafer 1 into individual device chips 10 along first and second projected dicing lines 7 and 8, as with the first embodiment. As with the first embodiment, the method of processing a wafer according to the modification of the first embodiment includes the first protective film forming step 101, the first processed groove forming step 102, the first protective film removing step 103, the masking protective film forming step 104, the second processed groove forming step 105, the plasma etching step 106, and the masking protective film removing step 107.

According to the modification of the first embodiment, in the first protective film forming step 101, as illustrated in FIG. 11, the entire face side 3 of the wafer 1 is covered with the first protective film 13 including the water-soluble resin, as with the first embodiment.

According to the modification of the first embodiment, in the first processed groove forming step

102, a laser processing apparatus, not illustrated, operates to apply a laser beam having a wavelength absorbable by the wafer 1 from a laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8, as with the first embodiment.

Then, in the first processed groove forming step 102, as illustrated in FIG. 12, the laser beam applied by the laser processing apparatus to the wafer 1 ablates portions of the first protective film 13 and the functional layer 6 that are aligned with the first and second projected dicing lines 7 and 8, removing them to form first processed grooves 14 (one illustrated in FIG. 12) in the functional layer 6 along the first and second projected dicing lines 7 and 8. As illustrated in FIG. 12, the first processed grooves 14 in the functional layer 6 along the first and second projected dicing lines 7 and 8 are recessed from the face side of the functional layer 6 and do not extend depthwise through and hence do not divide the functional layer 6.

Then, in the first protective film removing step 103, cleaning water is supplied to the first protective

film 13 on the face side 3 of the wafer 1, washing away the first protective film 13 from the face side 3 of the wafer 1, as illustrated in FIG. 13, as with the first embodiment.

Then, in the masking protective film forming step 104, as illustrated in FIG. 14, the entire face side 3 of the wafer 1 is covered with the masking protective film 15 including the water-soluble resin, and the first processed grooves 14 are filled with the masking protective film 15, as with the first embodiment.

Then, in the second processed groove forming step 105, a laser processing apparatus, not illustrated, operates to apply a laser beam having a wavelength absorbable by the wafer 1 from a laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8, as with the first embodiment.

Specifically, the laser processing apparatus ablates portions of the masking protective film 15 on bottom surfaces 17 of the first processed grooves 14, the functional layer 6, and the substrate 2 that are aligned with the first and second projected dicing lines 7 and 8,

removing them to form second processed grooves 16 (one illustrated in FIG. 15) through the functional layer 6 along the first and second projected dicing lines 7 and 8, as illustrated in FIG. 15. The second processed grooves 16 have bottom portions defined in the bottom surfaces 17 of the first processed grooves 14 and have widths 16-1 smaller than the widths 14-1 of the first processed grooves 14. The second processed grooves 16 extend depthwise through and hence divide the functional layer 6.

According to the modification of the first embodiment, the output power level of the laser beam applied in the second processed groove forming step 105 is smaller than the output power level of the laser beam applied in the first processed groove forming step 102. Moreover, the energy density of one spot of the laser beam applied in the second processed groove forming step 105 is lower than the energy density of one spot of the laser beam applied in the first processed groove forming step 102. According to the modification of the first embodiment, furthermore, the widths 14-1 of all the first processed grooves 14 are identical to each other, and the widths 16-1 of all the second processed grooves 16 are identical to each other.

Then, in the plasma etching step 106, the portions of the substrate 2 that are exposed on bottom surfaces of the second processed grooves 16 in the masking protective film 15 are etched, i.e., plasma-etched, by the plasmatized etching gas 18. The second processed grooves 16 are progressively etched through the substrate 2 toward the reverse side 9 of the wafer 1, until the wafer 1 is divided into the device chips 10, as illustrated in FIG. 16, as with the first embodiment.

Then, in the masking protective film removing step 107, cleaning water is supplied to the masking protective film 15 on the face side 3 of the wafer 1, washing away the masking protective film 15 including the water-soluble resin together with foreign matter such as debris from the face side 3 of the wafer 1, as illustrated in FIG. 17, as with the first embodiment.

The method of processing a wafer according to the modification of the first embodiment, as with the first embodiment, is advantageous in that, since the first processed grooves 14 are filled with the masking protective film 15 and then the masking protective film 15 is removed from the first processed grooves 14, forming the second processed grooves 16, the surface irregularities formed on the inner side surfaces of the

second processed grooves 16 are smaller than the surface irregularities formed on the inner side surfaces of the first processed grooves 14, so that the surface irregularities formed on the side surfaces of the wafer-dividing grooves by plasma etching are reduced. As a consequence, the quality of the processed wafer 1 is increased, resulting in an increase in the flexural strength of the device chips 10 fabricated from the wafer 1. In addition, inasmuch as the method of processing a wafer according to the modification of the first embodiment forms the first processed grooves 14 that are deep enough to divide the functional layer 6 separately in the first processed groove forming step 102 and the second processed groove forming step 105, unlike the method of processing a wafer according to the first embodiment that forms the first processed grooves 14 that are deep enough to divide the functional layer 6 altogether in the first processed groove forming step 102, any thermal damaged caused to the functional layer 6 and the substrate 2 is reduced, increasing the flexural strength of the device chips 10. According to the method of processing a wafer according to the modification of the first embodiment, in the second processed groove forming step 105, because the portions of the substrate 2

are exposed by removing the remaining portions of the functional layer 6 and the masking protective film 15, the output power level of the laser beam is higher than in the second processed groove forming step 105 according to the first embodiment. However, the surface irregularities on the side surfaces of the second processed grooves 16 are smaller than the related art in which the functional layer 6 is exposed as a mask on the entire inner side surfaces of the second processed grooves 16, resulting in an increase in the quality of the processed wafer 1 in plasma etching.

(Second embodiment)

A method of processing a wafer according to a second embodiment of the present invention will be described below with reference to the drawings. FIG. 18 schematically illustrates, in plan, a portion of a wafer to be processed by the method of processing a wafer according to the second embodiment. FIG. 19 is a cross-sectional view taken along line XIX-XIX of FIG. 18. FIG. 20 is a cross-sectional view taken along line XX-XX of FIG. 18. FIG. 21 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to a first projected dicing line after a first protective film forming step of the

method of processing a wafer according to the second embodiment. FIG. 22 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to a second projected dicing line after the first protective film forming step of the method of processing a wafer according to the second embodiment.

FIG. 23 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first processed groove forming step of the method of processing a wafer according to the second embodiment. FIG. 24 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first processed groove forming step of the method of processing a wafer according to the second embodiment. FIG. 25 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first protective film removing step of the method of processing a wafer according to the second embodiment. FIG. 26 schematically illustrates, in enlarged

fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first protective film removing step of the method of processing a wafer according to the second embodiment.

FIG. 27 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film forming step of the method of processing a wafer according to the second embodiment. FIG. 28 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film forming step of the method of processing a wafer according to the second embodiment. FIG. 29 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a second processed groove forming step of the method of processing a wafer according to the second embodiment. FIG. 30 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected

dicing line after the second processed groove forming step of the method of processing a wafer according to the second embodiment.

FIG. 31 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line during a plasma etching step of the method of processing a wafer according to the second embodiment.

FIG. 32 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line during the plasma etching step of the method of processing a wafer according to the second embodiment.

FIG. 33 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film forming step of the method of processing a wafer according to the second embodiment. FIG. 34 schematically illustrates, in

enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film forming step of the method of processing a wafer according to the second embodiment. Those parts

illustrated in FIGS. 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, and 34 that are identical to those according to the first embodiment are denoted by identical reference signs, and will be omitted from detailed description.

As illustrated in FIG. 18, the wafer 1 to be processed by the method of processing a wafer according to the second embodiment has first projected dicing lines 7 and second projected dicing lines 8, the first projected dicing lines 7 being narrower than the second projected dicing lines 8. As illustrated in FIGS. 18 and 20, test elementary group (TEG) chips 21 that include metal parts are disposed on the face side 3 of the wafer 1 at the second projected dicing lines 8. Furthermore, as illustrated in FIGS. 18 and 19, TEG chips 22 are also disposed on the face side 3 of the wafer 1 at the first projected dicing lines 7. According to the present invention, however, no TEG chips 22 may be disposed on the face side 3 of the wafer 1 at the first projected dicing lines 7.

The TEG chips 21 and 22 represent evaluation devices for discovering design and fabrication problems that have occurred on the devices 5. On the wafer 1 to be processed by the method of processing a wafer

according to the second embodiment, the TEG chips 21 are slightly narrower than the second projected dicing lines 8 and wider than the first projected dicing lines 7, and the TEG chips 22 are slightly narrower than the first projected dicing lines 7.

The method of processing a wafer according to the second embodiment represents a method of dividing a wafer 1 into individual device chips 10 along first and second projected dicing lines 7 and 8, as with the first embodiment. As with the first embodiment, the method of processing a wafer according to the second embodiment includes the first protective film forming step 101, the first processed groove forming step 102, the first protective film removing step 103, the masking protective film forming step 104, the second processed groove forming step 105, the plasma etching step 106, and the masking protective film removing step 107.

According to the second embodiment, in the first protective film forming step 101, as illustrated in FIGS. 21 and 22, the entire face side 3 of the wafer 1 is covered with the first protective film 13 including the water-soluble resin, as with the first embodiment.

According to the second embodiment, in the first processed groove forming step 102, a laser processing

apparatus, not illustrated, operates to apply a laser beam having a wavelength absorbable by the wafer 1 from a laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8, forming first processed grooves 14 in the wafer 1 along the first and second projected dicing lines 7 and 8, as with the first embodiment.

In order to prevent burrs from developing on the TEG chips 21 and 22 to maintain the quality of the device chips 10 fabricated from the wafer 1, it is necessary to remove the TEG chips 21 and 22 in their entirety from the face side 3 of the wafer 1 along the first and second projected dicing lines 7 and 8 in the first processed groove forming step 102. As described above, on the wafer 1 to be processed by the method of processing a wafer according to the second embodiment, the TEG chips 21 are slightly narrower than the second projected dicing lines 8 and wider than the first projected dicing lines 7.

The first processed grooves 14, also denoted by 141 in FIG. 23, defined in the wafer 1 along the first projected dicing lines 7 have a width 141-1, and the

first processed grooves 14, also denoted by 142 in FIG. 24, defined in the wafer 1 along the second projected dicing lines 8 have a width 141-2, the width 141-1 being smaller than the width 141-2. The widths 141-1 and 141-2 are larger than the respective widths of the TEG chips 22 and 21. Accordingly, the width 141-1 of the first processed grooves 141 along the first projected dicing lines 7 and the width 142-1 of the first processed grooves 142 along the second projected dicing lines 8 are not identical to each other. According to the second embodiment, the width 141-1 of the first processed grooves 141 is of 60 mm, whereas the width 142-1 of the first processed grooves 142 is of 120 mm.

According to the second embodiment, in the first processed groove forming step 102, specifically, the laser processing apparatus ablates portions of the first protective film 13 on the first and second projected dicing lines 7 and 8, the TEG chips 21 and 22, the functional layer 6, and the substrate 2 that are aligned with the first and second projected dicing lines 7 and 8, removing them to form first processed grooves 141 and 142 through the functional layer 6 along the first and second projected dicing lines 7 and 8, as illustrated in FIGS. 23 and 24. The first processed grooves 141 and 142

extend depthwise through and hence divide the functional layer 6.

According to the second embodiment, in the first protective film removing step 103, cleaning water is supplied to the first protective film 13 on the face side 3 of the wafer 1, washing away the first protective film 13 from the face side 3 of the wafer 1, as illustrated in FIGS. 25 and 26, as with the first embodiment.

Then, in the masking protective film forming step 104, the entire face side 3 of the wafer 1 is covered with the masking protective film 15 including the water-soluble resin, and the first processed grooves 141 and 142 are filled with the masking protective film 15, as illustrated in FIGS. 27 and 28, as with the first embodiment.

Then, in the second processed groove forming step 105, a laser processing apparatus, not illustrated, operates to apply a laser beam having a wavelength absorbable by the wafer 1 from a laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8, as with the first embodiment.

Then, in the second processed groove forming step 105, the laser processing apparatus ablates portions of the masking protective film 15 on bottom surfaces 17 of the first processed grooves 141 and 142 and the substrate 2 that are aligned with the first and second projected dicing lines 7 and 8, removing them to form second processed grooves 16 through the functional layer 6 along the first and second projected dicing lines 7 and 8, as illustrated in FIGS. 29 and 30. The second processed grooves 16 have bottom portions defined in the bottom surfaces 17 of the first processed grooves 141 and 142 and have widths 16-1 smaller than the widths 141-1 and 141-2 of the first processed grooves 141 and 142. The second processed grooves 16 extend depthwise through and hence divide the functional layer 6.

According to the second embodiment, the output power level of the laser beam applied in the second processed groove forming step 105 is smaller than the output power level of the laser beam applied in the first processed groove forming step 102. Furthermore, the widths 16-1 of all the second processed grooves 16 are identical to each other.

According to the second embodiment, in the plasma etching step 106, as illustrated in FIGS. 31 and 32, the

portions of the substrate 2 that are exposed on bottom surfaces of the second processed grooves 16 in the masking protective film 15 are etched, i.e., plasma-etched, by the plasmatized etching gas 18. The second processed grooves 16 are progressively etched through the substrate 2 toward the reverse side 9 of the wafer 1, until the wafer 1 is divided into the device chips 10, as illustrated in FIGS. 31 and 32, as with the first embodiment.

Then, in the masking protective film removing step 107, cleaning water is supplied to the masking protective film 15 on the face side 3 of the wafer 1, washing away the masking protective film 15 including the water-soluble resin together with foreign matter such as debris from the face side 3 of the wafer 1, as illustrated in FIGS. 33 and 34, as with the first embodiment.

The method of processing a wafer according to the modification of the first embodiment, as with the second embodiment, is advantageous in that, since the first processed grooves 141 and 142 are filled with the masking protective film 15 and then the masking protective film 15 is removed from the first processed grooves 14, forming the second processed grooves 16, the surface

irregularities formed on the inner side surfaces of the second processed grooves 16 are smaller than the surface irregularities formed on the inner side surfaces of the first processed grooves 14. As a consequence, the quality of the processed wafer 1 is increased in plasma etching.

Inasmuch as the TEG chips 21 and 22 are removed in their entity in the first processed groove forming step 102 in order to prevent burrs from developing on the TEG chips 21 and 22, the widths 141-1 and 141-2 of the first processed grooves 141 and 142 are different from each other. Therefore, if the wafer 1 is then plasma-etched according to the conventional processing method, then the wafer 1 is processed irregularly, i.e., is not processed uniformly, when it is plasma-etched. In the method of processing a wafer according to the second embodiment, however, since the second processed grooves 16 have the same width 16-1 even though the widths 141-1 and 141-2 of the first processed grooves 141 and 142 are different from each other, the wafer 1 is prevented from being processed irregularly when it is plasma-etched.

[Modification of the second embodiment]

A method of processing a wafer according to a modification of the second embodiment will be described

below with reference to the drawings. FIG. 35 schematically illustrates, in enlarged fragmentary cross section, a portion of a wafer along a sectional plane perpendicular to a first projected dicing line after a first protective film forming step of the method of processing a wafer according to the modification of the second embodiment. FIG. 36 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to a second projected dicing line after the first protective film forming step of the method of processing a wafer according to the modification of the second embodiment.

FIG. 37 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first processed groove forming step of the method of processing a wafer according to the modification of the second embodiment. FIG. 38 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first processed groove forming step of the method of processing a wafer according to the modification of the second embodiment. FIG. 39 schematically illustrates, in

enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a first protective film removing step of the method of processing a wafer according to the modification of the second embodiment.

FIG. 40 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the first protective film removing step of the method of processing a wafer according to the modification of the second embodiment.

FIG. 41 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a masking protective film forming step of the method of processing a wafer according to the modification of the second embodiment. FIG. 42

schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film forming step of the method of processing a wafer according to the modification of the second embodiment. FIG. 43 schematically illustrates, in enlarged fragmentary cross section, a portion of the

wafer along a sectional plane perpendicular to the first projected dicing line after a second processed groove forming step of the method of processing a wafer according to the modification of the second embodiment. FIG. 44 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the second processed groove forming step of the method of processing a wafer according to the modification of the second embodiment.

FIG. 45 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line during a plasma etching step of the method of processing a wafer according to the modification of the second embodiment. FIG. 46 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line during the plasma etching step of the method of processing a wafer according to the modification of the second embodiment. FIG. 47 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the first projected dicing line after a

masking protective film removing step of the method of processing a wafer according to the modification of the second embodiment. FIG. 48 schematically illustrates, in enlarged fragmentary cross section, a portion of the wafer along a sectional plane perpendicular to the second projected dicing line after the masking protective film removing step of the method of processing a wafer according to the modification of the second embodiment. Those parts illustrated in FIGS. 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, and 48 that are identical to those according to the first embodiment and the second embodiment are denoted by identical reference signs, and will be omitted from detailed description.

The wafer 1 to be processed by the method of processing a wafer according to the modification of the second embodiment, as with the second embodiment, has first projected dicing lines 7 and second projected dicing lines 8, the first projected dicing lines 7 being narrower than the second projected dicing lines 8, and TEG chips 21 that include metal parts are disposed on the face side 3 of the wafer 1 at the second projected dicing lines 8. Furthermore, TEG chips 22 are also disposed on the face side 3 of the wafer 1 at the first projected dicing lines 7. According to the present invention,

however, no TEG chips 22 may be disposed on the face side 3 of the wafer 1 at the first projected dicing lines 7. On the wafer 1 to be processed by the method of processing a wafer according to the modification of the second embodiment, the TEG chips 21 are narrower than the second projected dicing lines 8 and wider than the first projected dicing lines 7.

The method of processing a wafer according to the modification of the second embodiment represents a method of dividing a wafer 1 into individual device chips 10 along first and second projected dicing lines 7 and 8, as with the first embodiment and the second embodiment. As with the first embodiment and the second embodiment, the method of processing a wafer according to the modification of second embodiment includes the first protective film forming step 101, the first processed groove forming step 102, the first protective film removing step 103, the masking protective film forming step 104, the second processed groove forming step 105, the plasma etching step 106, and the masking protective film removing step 107.

According to the modification of the second embodiment, in the first protective film forming step 101, as illustrated in FIGS. 35 and 36, the entire face

side 3 of the wafer 1 is covered with the first protective film 13 including the water-soluble resin, as with the first embodiment.

According to the modification of the second embodiment, in the first processed groove forming step 102, a laser processing apparatus, not illustrated, operates to apply a laser beam having a wavelength absorbable by the wafer 1 from a laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8, as with the first embodiment and the second embodiment.

According to the modification of the second embodiment, in the first processed groove forming step 102, the width 141-1 of the first processed grooves 141 along the first projected dicing lines 7 is smaller than the width 142-1 of the first processed grooves 142 along the second projected dicing lines 8. Accordingly, the widths 141-1 and 141-2 of the first processed grooves 141 and 142 formed in the first processed groove forming step 102 are not identical to each other.

According to the modification of the second

embodiment, in the first processed groove forming step 102, specifically, the laser processing apparatus ablates portions of the first protective film 13 on the first and second projected dicing lines 7 and 8, the TEG chips 21 and 22, and the functional layer 6 that are aligned with the first and second projected dicing lines 7 and 8, removing the portions of the first protective film 13 and the functional layer 6 and all of the TEG chips 21 and 22 to form first processed grooves 141 and 142 along the first and second projected dicing lines 7 and 8, as illustrated in FIGS. 37 and 38. The first processed grooves 141 and 142 in the functional layer 6 along the first and second projected dicing lines 7 and 8 are recessed from the face side of the functional layer 6 and do not extend depthwise through and hence do not divide the functional layer 6.

According to the modification of the second embodiment, in the first protective film removing step 103, cleaning water is supplied to the first protective film 13 on the face side 3 of the wafer 1, washing away the first protective film 13 from the face side 3 of the wafer 1, as illustrated in FIGS. 47 and 48, as with the first embodiment and the second embodiment.

According to the modification of the second

embodiment, the entire face side 3 of the wafer 1 is covered with the masking protective film 15 including the water-soluble resin, and the first processed grooves 141 and 142 are filled with the masking protective film 15, as illustrated in FIGS. 41 and 42, as with the first embodiment and the second embodiment.

According to the modification of the second embodiment, in the second processed groove forming step 105, a laser processing apparatus, not illustrated, operates to apply a laser beam having a wavelength absorbable by the wafer 1 from a laser beam applying unit to the wafer 1 along the first and second projected dicing lines 7 and 8 while moving the wafer 1 and the laser beam applying unit relatively to each other along the first and second projected dicing lines 7 and 8, as with the first embodiment and the second embodiment.

According to the modification of the second embodiment, in the second processed groove forming step 105, the laser processing apparatus ablates portions of the masking protective film 15 on bottom surfaces 17 of the first processed grooves 141 and 142, the functional layer 6, and the substrate 2 that are aligned with the first and second projected dicing lines 7 and 8, removing them to form second processed grooves 16 through the

functional layer 6 along the first and second projected dicing lines 7 and 8, as illustrated in FIGS. 43 and 44. The second processed grooves 16 have bottom portions defined in the bottom surfaces 17 of the first processed grooves 141 and 142 and have widths 16-1 smaller than the widths 141-1 and 141-2 of the first processed grooves 141 and 142. The second processed grooves 16 extend depthwise through and hence divide the functional layer 6.

According to the modification of the second embodiment, the output power level of the laser beam applied in the second processed groove forming step 105 is smaller than the output power level of the laser beam applied in the first processed groove forming step 102. Moreover, the energy density of one spot of the laser beam applied in the second processed groove forming step 105 is lower than the energy density of one spot of the laser beam applied in the first processed groove forming step 102. According to the modification of the second embodiment, furthermore, the widths 16-1 of all the second processed grooves 16 are identical to each other.

According to the modification of the second embodiment, in the plasma etching step 106, as illustrated in FIGS. 45 and 46, the portions of the

substrate 2 that are exposed on bottom surfaces of the second processed grooves 16 in the masking protective film 15 are etched, i.e., plasma-etched, by the plasmatized etching gas 18. The second processed grooves 16 are progressively etched through the substrate 2 toward the reverse side 9 of the wafer 1, until the wafer 1 is divided into the device chips 10, as illustrated in FIGS. 45 and 46, as with the first embodiment and the second embodiment.

According to the modification of the second embodiment, in the masking protective film removing step 107, cleaning water is supplied to the masking protective film 15 on the face side 3 of the wafer 1, washing away the masking protective film 15 including the water-soluble resin together with foreign matter such as debris from the face side 3 of the wafer 1, as illustrated in FIGS. 47 and 48, as with the first embodiment and the second embodiment.

The method of processing a wafer according to the modification of the second embodiment, as with the first embodiment and the second embodiment, is advantageous in that, since the first processed grooves 141 and 142 are filled with the masking protective film 15 and then the masking protective film 15 is removed from the first

processed grooves 141 and 142, forming the second processed grooves 16, the surface irregularities formed on the inner side surfaces of the second processed grooves 16 are smaller than the surface irregularities formed on the inner side surfaces of the first processed grooves 14. As a consequence, the quality of the processed wafer 1 is increased in plasma etching.

Moreover, in the method of processing a wafer according to the modification of the second embodiment, since the second processed grooves 16 have the same width 16-1 even though the widths 141-1 and 141-2 of the first processed grooves 141 and 142 are different from each other, the wafer 1 is prevented from being processed irregularly when it is plasma-etched.

The present invention is not limited to the above embodiments and modifications thereof. In other words, various changes and modifications may be made therein without departing from the scope of the invention. For example, according to the present invention, the first protective film forming step 101 and the first protective film removing step 103 may not be carried out. Furthermore, the wafer 1 may not be divided into individual device chips 10 in the plasma etching step 106.

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 method of processing a wafer along a grid of projected dicing lines thereon, the wafer including a substrate and a functional layer disposed on a face side of the substrate, the functional layer including a plurality of devices disposed in respective areas demarcated by the projected dicing lines, the method comprising:

a first processed groove forming step of applying a laser beam to the wafer from a face side thereof along the projected dicing lines to form first processed grooves in the functional layer;

after the first processed groove forming step, a masking protective film forming step of forming a masking protective film covering the face side of the wafer and filling the first processed grooves;

after the masking protective film forming step, a second processed groove forming step of applying a laser beam to the wafer along the first processed grooves to form second processed grooves that are narrower than the first processed grooves, exposing the substrate through the second processed grooves; and

after the second processed groove forming step, a plasma etching step of carrying out plasma etching on the

wafer along the second processed grooves using the masking protective film as a mask.

2. The method of processing a wafer according to claim 1, wherein the laser beam applied in the second processed groove forming step has a smaller output power level than the laser beam applied in the first processed groove forming step.

3. The method of processing a wafer according to claim 1, wherein the plasma etching step includes the step of dividing the wafer into a plurality of device chips including the respective devices.

4. The method of processing a wafer according to claim 1, further comprising:

before the first processed groove forming step, a first protective film forming step of forming a first protective film on the face side of the wafer; and

after the first processed groove forming step, a first protective film removing step of washing away the first protective film.

5. The method of processing a wafer according to claim 1, wherein the first processed grooves have respective widths that are identical to each other, and the second processed grooves have respective widths that are identical to each other.

6. The method of processing a wafer according to claim 5, wherein the wafer includes metal parts disposed on the face side thereof at the projected dicing lines, the first processed grooves being wider than the metal parts.