DESCRIPTION

MANUFACTURING METHOD FOR SEMICONDUCTOR CHIPS, AND SEMICONDUCTOR CHIP

Technical Field

The present invention relates to a manufacturing method for semiconductor chips for forming semiconductor devices arranged in a plurality of device-formation-regions defined by dividing regions on a first surface of a semiconductor wafer and individually separating the device-formation-regions of the semiconductor wafer along the dividing regions, thereby manufacturing semiconductor chips that include the individualized semiconductor devices and to a semiconductor chip.

Background Art

Conventionally, as a method for dividing a semiconductor wafer into individual semiconductor chips by such a manufacturing method for semiconductor chips, various methods have been known. For example, a method for dividing a semiconductor wafer by mechanically cutting the wafer by means of a rotary blade called the dicer blade, i.e., mechanical dicing is known.

However, semiconductor wafers have recently been

made thinner and thinner, and a semiconductor wafer susceptible to external forces is subjected to the mechanical dicing described above, it is often the case where the semiconductor wafer is damaged at the time of cutting. This leads to a problem that a reduction in the processing yield cannot be avoided. As such damage, there is, for example, the occurrence of chipping that the corner portions (edges) of the semiconductor chips become chipped due to the sharply cut shape.

In recent years, plasma dicing that uses plasma etching has been attracting attention in place of the conventional mechanical dicing described above (reference should be made to, for example, Japanese unexamined patent publication No. 2004-172365 A). A method for dividing a semiconductor wafer into individual semiconductor chips by the conventional plasma dicing is described herein with reference to the schematic explanatory views shown in Figs. 27A through 27C and Figs. 28A and 28B.

First of all, as shown in Fig. 27A, a semiconductor wafer 501 is put into a state in which semiconductor devices 502 are formed in the respective device-formation-regions R1 defined by dividing regions R2 on its circuit-formation-face 501a. Each of the semiconductor devices 502 includes devices such as a MOS (Metal-Oxide-Semiconductor) structure transistor

constructed of a semiconductor wafer 501 (Semiconductor), a silicon oxide 551 (Oxide) formed directly on the circuit-formation-face 501a and a metal film (Metal) formed on the silicon oxide 551. Further, the semiconductor device 502 further includes connection terminals 552 (also called the bonding pads) for electrically connecting the devices to external electronic apparatuses. Moreover, a surface protection film 553 is formed on the surfaces of the semiconductor devices 502, so that the surfaces of the semiconductor devices 502 are protected. The connection terminals 552 are exposed outside without being covered with the surface protection film 553. Neither the silicon oxide 551 nor the surface protection film 553 is formed in portions that correspond to the dividing regions R2 of the circuit-formation-face 501a.

Next, as shown in Fig. 27B, a protective sheet 504 is peelably adhesively stuck to the circuit-formation-face 501a via an adhesive so that the circuit-formation-face 501a of the semiconductor wafer 501 does not suffer damages. Subsequently, a mask (mask pattern) 505 is placed on a surface 501b to be processed (that is, a processing-target-face), or the surface opposite from the circuit-formation-face 501a so that the portions that correspond to the dividing regions R2 are exposed.

Next, by performing plasma etching on the

semiconductor wafer 501 on which the mask 505 is thus formed, the exposed surface of the surface 501b that is not covered with the mask 505 is etched, removing the portions that correspond to the dividing regions R2. Through this process, as shown in Fig. 27C, the device-formation-regions R1 are individually separated, forming the individual pieces of the semiconductor chips 510 that include the semiconductor devices 502. Consequently, the semiconductor wafer 501 is divided into the individual pieces of the semiconductor chips 510 that include the respective semiconductor devices 502 along the dividing regions R2.

Subsequently, as shown in Fig. 28A, the mask 505 that is remaining on the surface 501b to be processed of the separated semiconductor chips 510 is removed by carrying out, for example, an ashing process. Subsequently, as shown in Fig. 28B, an adhesive sheet (dicing sheet) 506 is stuck to the surface 501b to be processed of the semiconductor wafer 501, and the protective sheet 504 that has protected the circuit-formation-face 501a of the semiconductor wafer 501 is peeled off. As a result, the semiconductor chips 510 are arranged on the adhesive sheet 506 in a state in which they are separated into individual pieces.

By dividing the semiconductor wafer 501 using the conventional plasma dicing described above, damages given

to the manufactured semiconductor chips 510 can be reduced in comparison with the aforementioned mechanical dicing.

Disclosure of Invention

However, even the semiconductor chips 510, which are divided into the individual pieces by the conventional plasma dicing described above, are to have sharp corner portions 554 (edges) formed by the separation as shown in Figs. 27C, 28A and 28B. There is a problem that the occurrence of chipping cannot be avoided when the sharp corner portions 554 are formed on the semiconductor chips 510 as described above.

In particular, the conventional plasma dicing described above has a characteristic that the ions in the plasma have increasing difficulties in reaching the etching bottom portion as getting closer to the bottom portion. Therefore, it is sometimes the case where the protrusive sharp corner portions 554 are formed at the lower end portions of the separated semiconductor chips 510 as shown in, for example, the partially enlarged schematic view of the etched dividing region R2 shown in Fig. 29. In such a case, there is a problem that the corner portions 554 become more easily chipped and the transverse rupture strength of the semiconductor chip is reduced.

Further, in the semiconductor chips 510, as shown

in Fig. 29, not only the formation of the sharp corner portions 554 on the circuit-formation-face 501a but also the formation of sharp corner portions 555 on the surface 501b to be processed result, and this leads to a problem that the reduction in the transverse rupture strength of the semiconductor chips 510 becomes more significant.

An object of the present invention is to solve the aforementioned problems and provide a manufacturing method for semiconductor chips for forming individualized semiconductor chips by dividing a semiconductor wafer, so as to make the semiconductor chips have high transverse rupture strength without damaging the semiconductor chips and a semiconductor chip that has such a high transverse rupture strength.

In order to achieve the object, the present invention is constituted as follows.

According to a first aspect of the present invention, there is provided a manufacturing method for semiconductor chips comprising:

performing plasma etching on a second surface of a semiconductor wafer that has a first surface on which semiconductor devices placed in a plurality of device-formation-regions defined by dividing regions and an insulating film placed in the dividing regions are formed and the second surface on which a mask for defining the

dividing regions is placed, the second surface being located opposite from the first surface, whereby portions that correspond to the dividing regions are removed and the insulating film is exposed from etching bottom portions;

removing corner portions on the first surface side put in contact with the insulating film in the device-formation-regions by performing the plasma etching in a state in which exposed surfaces of the insulating film are charged with electric charge due to ions in plasma; and

subsequently, removing the exposed insulating film so that the device-formation-regions are separated into individual semiconductor chips, whereby the semiconductor chips each of which includes the individualized semiconductor device are manufactured,

wherein isotropic plasma etching is further performed from the second surface on the semiconductor wafer or the individual semiconductor chips with the mask placed at any timing before or after exposure of the insulating film, removal of the corner portions or removal of the insulating film is carried out.

According to a second aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the first aspect, wherein corner portions put in contact with the mask placed on the second surface side are removed in the device-

formation-regions of the semiconductor wafer or the semiconductor chips by carrying out the isotropic plasma etching.

According to a third aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the first aspect, wherein

the exposure of the insulating film is performed by carrying out anisotropic plasma etching on the semiconductor wafer,

the corner portions are removed by continuously performing the anisotropic etching,

the corner portions brought in contact with the mask are removed by carrying out the isotopic etching by switching over from the anisotropic etching to the isotopic etching, and

then the insulator is removed.

According to a fourth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the third aspect, wherein

the switchover between the anisotropic etching and the isotopic etching is performed by switching over between plasma conditions for the anisotropic etching and plasma conditions for the isotopic etching determined by

combining one parameter or a plurality of parameters including a pressure of a gas for plasma generation, a gas composition, a high-frequency output or a discharge frequency.

According to a fifth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the first aspect, wherein, in the plasma etching from the second surface, the insulating film formed of silicon oxide (SiO_2) on the first surface of the semiconductor wafer is exposed from the etching bottom portion.

According to a sixth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the first aspect, wherein, in the plasma etching from the second surface, a surface protection film formed of polyimide (PI) to protect surfaces of the semiconductor devices formed on the first surface of the semiconductor wafer is exposed from the etching bottom portion as the insulating film.

According to a seventh aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the first aspect, wherein, after the removal of the insulating film, the mask is removed by performing ashing on the second surface of the semiconductor wafer.

According to an eighth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in any one of the first through seventh aspects, wherein, the plasma etching is performed from the second surface of the semiconductor wafer, on which the mask is placed, the mask having roughly convex curved portions formed in portions that correspond to the corner portions of each of the device-formation-regions, each of the device-formation-regions having a roughly rectangular region.

According to a ninth aspect of the present invention, there is provided a manufacturing method for semiconductor chips comprising:

performing plasma etching on a second surface of a semiconductor wafer that has a first surface on which semiconductor devices placed in a plurality of device-formation-regions defined by dividing regions and an insulating film placed in the dividing regions are formed and the second surface on which a mask for defining the dividing regions is placed, the second surface being located opposite from the first surface, whereby portions that correspond to the dividing regions are removed and the insulating film is exposed from etching bottom portions; and

removing the exposed insulating film while

removing corner portions on the first surface side put in contact with the insulating film in the device-formation-regions by performing the plasma etching in a state in which exposed surfaces of the insulating film are charged with electric charge due to ions in plasma, whereby the device-formation-regions are separated into individual semiconductor chips and consequently the semiconductor chips each of which includes individualized semiconductor device are manufactured,

wherein isotropic plasma etching is further performed from the second surface on the semiconductor wafer or the individual semiconductor chips with the mask placed at any timing before or after exposure of the insulating film, removal of the corner portions or removal of the insulating film is carried out.

According to a tenth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the ninth aspect, wherein corner portions put in contact with the mask placed on the second surface side is removed in the device-formation-regions of the semiconductor wafer or the semiconductor chips by carrying out the isotropic plasma etching.

According to an eleventh aspect of the present invention, there is provided the manufacturing method for

the semiconductor chips as defined in the ninth aspect, wherein

the exposure of the insulating film is performed by carrying out anisotropic plasma etching on the semiconductor wafer,

the corner portions are removed by continuously performing the anisotropic etching, and

then the corner portions brought in contact with the mask are removed by carrying out the isotopic etching by switching over from the anisotropic etching to the isotopic etching

According to a twelfth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the eleventh aspect, wherein

the switchover between the anisotropic etching and the isotopic etching is performed by switching over between plasma conditions for the anisotropic etching and plasma conditions for the isotopic etching determined by combining one parameter or a plurality of parameters including a pressure of a gas for plasma generation, a gas composition, a high-frequency output or a discharge frequency.

According to a thirteenth aspect of the present invention, there is provided the manufacturing method for

the semiconductor chips as defined in the ninth aspect, wherein, in the plasma etching from the second surface, a surface protection film formed of silicon nitride (Si_3N_4) to protect surfaces of the semiconductor devices formed on the first surface of the semiconductor wafer is exposed from the etching bottom portion as the insulating film.

According to a fourteenth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the ninth aspect, wherein, after removing the corner portions put in contact with the mask by performing the isotopic etching, the mask is removed by performing ashing on the second surface of the semiconductor wafer.

According to a fifteenth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in any one of the ninth through fourteenth aspects, wherein, the plasma etching is performed from the second surface of the semiconductor wafer on which the mask is placed, the mask having roughly convex curved portions formed in portions that correspond to the corner portions of each of the device-formation-regions, each of the device-formation-regions having a roughly rectangular region.

According to a sixteenth aspect of the present invention, there is provided a manufacturing method for

semiconductor chips comprising:

performing plasma etching on a second surface of a semiconductor wafer that has a first surface on which semiconductor devices placed in a plurality of device-formation-regions defined by dividing regions are formed and onto which a protective sheet having an insulating property is stuck and a second surface on which a mask for defining the dividing regions is placed, the second surface being located opposite from the first surface, whereby portions that correspond to the dividing regions are removed and the insulating protective sheet is exposed from etching bottom portions, and then the device-formation-regions are separated into individual semiconductor chips; and

removing corner portions put in contact with the insulating protective sheet at each of the semiconductor chips by performing the plasma etching in a state in which the exposed surfaces of the insulating film are charged with electric charge due to ions in plasma, whereby semiconductor chips including individualized semiconductor devices are consequently manufactured,

wherein isotropic plasma etching is further performed from the second surface on the semiconductor wafer or the individual semiconductor chips with the mask placed at any timing before or after exposure of the

protective sheet or removal of the corner portions is carried out.

According to a seventeenth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in claim the sixteenth aspect, wherein the corner portions put in contact with the mask placed on the second surface side are removed in the device-formation-regions of the semiconductor wafer or the semiconductor chips by carrying out the isotropic plasma etching.

According to an eighteenth aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in claim the sixteenth aspect, wherein

the exposure of the protective sheet is performed by carrying out anisotropic plasma etching on the semiconductor wafer,

the corner portion removal processing is carried out by continuously performing the anisotropic etching, and

then the corner portions brought in contact with the mask are removed by carrying out the isotopic etching by switching over from the anisotropic etching to the isotopic etching.

According to a nineteenth aspect of the present invention, there is provided the manufacturing method for

the semiconductor chips as defined in the eighteenth aspect, wherein

the switchover between the anisotropic etching and the isotopic etching is performed by switching over between plasma conditions for the anisotropic etching and plasma conditions for the isotopic etching determined by combining one parameter or a plurality of parameters including a pressure of a gas for plasma generation, a gas composition, a high-frequency output or a discharge frequency.

According to a 20th aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in the sixteenth aspect, wherein, after the corner portions brought in contact with the mask are removed by performing the isotopic etching, the insulating protective sheet is removed by being peeled off from the first surface of the semiconductor wafer.

According to a 21st aspect of the present invention, there is provided the manufacturing method for the semiconductor chips as defined in any one of the sixteenth through 20th aspects, wherein, the plasma etching is performed from the second surface of the semiconductor wafer on which the mask is placed, the mask having roughly convex curved portions formed in portions that correspond to the corner portions of each of the device-formation-

regions, each of the device-formation-regions having a roughly rectangular region.

According to a 22nd aspect of the present invention, there is provided a semiconductor chip having a roughly rectangular shape obtained by dividing a semiconductor wafer in which a plurality of semiconductor devices are formed into individual pieces of the semiconductor devices, wherein

the rectangular shape of the chip is defined by rounded ridgelines thereof.

According to a 23rd aspect of the present invention, there is provided the semiconductor chip as defined in the 22nd aspect, wherein a curved convex surface portion is formed in portions that correspond to the rounded ridgelines of the rectangular shape.

According to a 24th aspect of the present invention, there is provided a semiconductor chip comprising:

a first surface on which semiconductor devices are formed;

a second surface located parallel to the first surface on a side opposite from the first surface; and

a connection surface, which is located at peripheries of the first surface and the second surface and connects an outer end portion of the first surface and an

outer end portion of the second surface, wherein

the connection surface has a curved convex surface portion so that no ridgeline is formed at the outer end portions of the first and the second surfaces.

According to a 25th aspect of the present invention, there is provided the semiconductor chip as defined in the 24th aspect, wherein the connection surface is comprised of the curved convex surface portion.

According to the present invention, by employing a semiconductor wafer on which the insulating film is placed in the portions that correspond to the dividing regions of the first surface as the semiconductor wafer, and removing the corner portions of the formed semiconductor chips by performing plasma etching process on the second surface, a manufacturing method for semiconductor chips capable of forming, for example, R-portions (rounded portions or curved convex surface portions) at the removed corner portions and improving the transverse rupture strength can be achieved.

In concrete, by removing the portions that correspond to the dividing regions by carrying out the plasma etching process on the semiconductor wafer, the insulating film is exposed from the etching bottom portion. Subsequently, by continuing the plasma etching process, the exposed insulating film can be charged with positive charge

due to the ions in the plasma. By bending the trajectory of the applied ions by the electric charge described above, the sharp corner portions or ridgelines of the semiconductor chips put in contact with the insulating film can be removed.

By removing the sharp corner portions of the semiconductor chips, semiconductor chips, which can suppress the occurrence of chipping in the manufactured semiconductor chips and of which the transverse rupture strength is improved, can be manufactured.

Further, by performing the isotropic plasma etching on the semiconductor wafer or the individual semiconductor chips in a state in which the mask is placed at any timing before or after the insulator exposure processing, the corner portion removal processing or the insulator removal processing is carried out, etching can be performed in the direction along the surface of the semiconductor wafer, i.e., the widthwise direction of the dividing regions. By thus performing the isotopic etching, the corner portions brought in contact with the mask placed on the second surface side are removed in each of the device-formation-regions, and the structural strength of the formed semiconductor chips can be improved.

Therefore, all the ridgelines can be removed from the formed semiconductor chips, and the curved convex

surface portions can be formed in the positions that correspond to the ridgelines. Moreover, the curved convex surface portions described above can be formed not by the mechanical processing of cutting, abrading or the like but by plasma etching processing, and this therefore enables the prevention of the occurrence of a residual stress and a damaged layer. Therefore, semiconductor chips, of which the configurational structural strength is improved and the transverse rupture strength is improved can be provided.

Moreover, when the exposed insulating film is formed of silicon oxide or polyimide, the insulating film can be positively etched by performing the plasma etching by changing, for example, the kind of the gas, and the removal can reliably be achieved.

Moreover, when the exposed insulating film is formed of silicon nitride, the exposed insulating film can be etched concurrently with the etching performed for the removal of the corner portions.

Furthermore, by employing an insulating protective sheet as a protective sheet adhesively placed to protect the first surface of the semiconductor wafer, removing the portions that correspond to the dividing regions for the exposure of the insulating protective sheet and thereafter continuing the plasma etching in a state in which the exposed insulating protective sheet is

electrically charged, the corner portions of the semiconductor chips can be removed, meaning that an effect similar to the aforementioned effect can be obtained.

Brief Description of Drawings

These and other aspects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, in which:

Fig. 1 is a schematic structural view showing the construction of a plasma processing apparatus according to a first embodiment of the present invention;

Fig. 2 is a partially enlarged sectional view of the lower electrode of the plasma processing apparatus of Fig. 1;

Figs. 3A and 3B are schematic structural views of the plasma processing apparatus of Fig. 1, where:

Fig. 3A is a schematic structural view showing a state in which the surface of the lower electrode is charged with negative charge by driving a power unit for electrostatic attraction, and

Fig. 3B is a schematic structural view showing a state in which plasma is generated in a processing chamber by driving a high-frequency power unit;

Fig. 4 is a control block diagram showing the construction of the control system of the plasma generating apparatus of Fig. 1;

Fig. 5 is a schematic explanatory view for explaining the principle of a plasma dicing process method used in the first embodiment, showing a state in which the insulating film is not exposed from an etching bottom portion;

Fig. 6 is a schematic explanatory view for explaining the principle of the plasma dicing process method used in the first embodiment, showing a state in which notch formation is performed with the insulating film exposed from the etching bottom portion;

Fig. 7 is a flow chart showing the procedure of a semiconductor wafer dividing method according to the first embodiment;

Figs. 8A through 8C are schematic explanatory views of a semiconductor wafer showing the processes of a manufacturing method for semiconductor chips according to the first embodiment, where:

Fig. 8A is a view of a state before processing is started,

Fig. 8B is a view of a state in which a protective sheet is adhesively placed, and

Fig. 8C is a view of a state in which a

resist film is formed;

Figs. 9A through 9C are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 8C, where:

Fig. 9A is a view of a state in which a mask pattern for defining dividing regions is formed,

Fig. 9B is a view of a state in which a plasma dicing process for exposing the silicon oxide is carried out, and

Fig. 9C is a view of a state in which a plasma dicing process for notch formation is carried out;

Figs. 10A through 10C are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 9C, where:

Fig. 10A is a view of a state in which rounded portions are formed by isotopic etching,

Fig. 10B is a view of a state in which a silicon oxide removing process is carried out, and

Fig. 10C is a view of a state in which an ashing processing is carried out;

Figs. 11A and 11B are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig.

10C, where:

Fig. 11A is a view of a state in which an adhesive sheet is adhesively stuck to mask-placement-faces of semiconductor chips, and

Fig. 11B is a view of a state in which the protective sheet is peeled off from a circuit-formation-face;

Fig. 12 is a data table showing the plasma processing conditions used for the plasma dicing process of a semiconductor wafer;

Fig. 13 is a schematic sectional view of the plasma processing apparatus in a state in which a semiconductor wafer is loaded;

Fig. 14 is a schematic sectional view of the plasma processing apparatus in a state in which a plasma dicing processing is carried out;

Fig. 15 is a schematic sectional view of the plasma processing apparatus in a state in which a plasma ashing processing is carried out;

Figs. 16A through 16C are schematic explanatory views of a semiconductor wafer showing the processes of a semiconductor chip manufacturing method according to a second embodiment of the present invention, where:

Fig. 16A is a view of a state before processing is started,

Fig. 16B is a view of a state in which a protective sheet is adhesively placed, and

Fig. 16C is a view of a state in which a resist film is formed;

Figs. 17A through 17C are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 16C, where:

Fig. 17A is a view of a state in which a mask pattern for defining dividing regions is formed,

Fig. 17B is a view of a state in which a plasma dicing process for exposing a polyimide film is carried out, and

Fig. 17C is a view of a state in which a plasma dicing process for notch formation is carried out;

Figs. 18A through 18C are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 17C, where:

Fig. 18A is a view showing a state in which rounded portions are formed by isotopic etching,

Fig. 18B is a view of a state in which a polyimide film removing process is carried out, and

Fig. 18C is a view of a state in which an ashing process is carried out;

Figs. 19A and 19B are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 18C, where:

Fig. 19A is a view of a state in which an adhesive sheet is placed on mask-placement-faces of semiconductor chips, and

Fig. 19B is a view of a state in which the protective sheet is peeled off from a circuit-formation-face;

Fig. 20 is a flow chart showing the procedure of a semiconductor wafer dividing method according to a modification example of the second embodiment;

Fig. 21 is a schematic sectional view of a semiconductor wafer showing a semiconductor chip manufacturing method according to the modification example of the second embodiment;

Fig. 22 is a flow chart showing the procedure of a semiconductor wafer dividing method according to a third embodiment of the present invention;

Figs. 23A through 23C are schematic explanatory views of a semiconductor wafer showing the processes of the semiconductor chip manufacturing method according to the third embodiment, where:

Fig. 23A is a view of a state before

processing is started,

Fig. 23B is a view of a state in which a protective sheet is adhesively placed, and

Fig. 23C is a view of a state in which a resist film is formed;

Figs. 24A through 24C are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 23C, where:

Fig. 24A is a view of a state in which a mask pattern for defining dividing regions is formed,

Fig. 24B is a view of a state in which a plasma dicing process for exposing an insulating protective sheet is carried out, and

Fig. 24C is a view of a state in which a plasma dicing process for notch formation is carried out;

Figs. 25A and 25B are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 24C, where:

Fig. 25A is a view showing a state in which rounded portions are formed by isotopic etching, and

Fig. 25B is a view of a state in which an ashing process is carried out;

Figs. 26A and 26B are schematic explanatory views

of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 25B, where:

Fig. 26A is a view of a state in which an adhesive sheet is placed on mask-placement-faces of semiconductor chips, and

Fig. 26B is a view of a state in which the insulating protective sheet is peeled off from the circuit-formation-face;

Figs. 27A through 27C are schematic explanatory views of a semiconductor wafer showing a conventional semiconductor chip manufacturing method, where:

Fig. 27A is a view of a state before processing is started,

Fig. 27B is a view of a state in which a mask pattern for defining dividing regions is formed, and

Fig. 27C is a view of a state in which a plasma dicing process is carried out;

Figs. 28A and 28B are schematic explanatory views of the semiconductor wafer showing the processes of the semiconductor chip manufacturing method continued from Fig. 27C, where:

Fig. 28A is a view of a state in which an ashing process is carried out, and

Fig. 28B is a view showing a state in which

the insulating protective sheet is peeled off from the circuit-formation-face;

Fig. 29 is a partially enlarged schematic view in the neighborhood of dividing regions of the semiconductor wafer in a state in which the plasma dicing process of the conventional semiconductor wafer is carried out;

Fig. 30 is a schematic perspective view (including a partial removal cross section) showing the appearance of the semiconductor chip formed by the semiconductor chip manufacturing method of the first embodiment; and

Fig. 31 is a schematic plan view showing the placement of a resist film in a state in which rounded portions are formed at corner portions by the semiconductor chip manufacturing method of the first embodiment.

Best Mode for Carrying Out the Invention

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

Hereinbelow, one embodiment of the present invention is described in detail with reference to the accompanying drawings.

FIRST EMBODIMENT

CONSTRUCTION OF PLASMA PROCESSING APPARATUS

Fig. 1 shows a schematic structural view that schematically shows the construction of a plasma processing apparatus 101 used for dividing a semiconductor wafer by a manufacturing method for semiconductor chips of the first embodiment of the present invention. It is noted that Fig. 1 is a schematic structural view showing a longitudinal sectional view of the plasma processing apparatus 101. The plasma processing apparatus 101 is the apparatus that manufactures semiconductor chips by dividing a semiconductor wafer, on the circuit-formation-face (first surface) of which a plurality of semiconductor devices are formed, into individual pieces of the semiconductor chips that include the semiconductor devices.

In a series of manufacturing processes of the semiconductor chips as described above, a protective sheet, which is made of a material that is less etchable than, for example, silicon that is the principal material of the semiconductor wafer, is stuck to the circuit-formation-face (i.e., the surface on which the devices are formed) of the semiconductor wafer where the semiconductor devices are formed in device-formation-regions defined by dividing regions arranged in a roughly grating-like shape, and a mask for defining the dividing regions for separating the device-formation-regions into individual pieces from the

semiconductor wafer is formed on a mask-placement-face (second surface) that is the surface opposite from the circuit-formation-face. Then, a plasma etching process (plasma processing) such as plasma dicing is carried out by the present plasma processing apparatus 101 on the objective semiconductor wafer in the state.

The construction of the plasma processing apparatus 101 is concretely described with reference to Fig. 1.

In the plasma processing apparatus 101 of Fig. 1, the inside of a vacuum chamber 1 serves as a processing chamber 2 for carrying out processing of the objective semiconductor wafer and is able to form a sealed space for generating plasma under a reduced pressure. A lower electrode 3 (first electrode) is placed on the lower side inside the processing chamber 2, and an upper electrode 4 (second electrode) is placed above the lower electrode 3 and oppositely to the lower electrode 3. The electrode 3 and the upper electrode 4 have a roughly cylindrical shape and are concentrically arranged in the processing chamber 2.

The lower electrode 3 is placed in a state in which its periphery is surrounded by insulating members 5A and 5B that are two layers mounted to fill up the bottom portion of the processing chamber 2 and its upper surface for retaining the object to be processed is fixed exposed

at the center portion of the bottom portion of the processing chamber 2. The lower electrode 3 is made of a conductor such as aluminum and includes a disk-shaped electrode portion 3a for retaining the object to be processed and a columnar support portion 3b that protrudes downward from the lower surface of the electrode portion 3a and whose one end is formed exposed outside the vacuum chamber 1 in an integrated state. Moreover, the support portion 3b is held by the vacuum chamber 1 via an insulating member 5C, and the lower electrode 3 is attached to the vacuum chamber 1 in a state in which it is electrically insulated by being thus retained.

The upper electrode 4 is made of a conductor such as aluminum similar to the lower electrode 3 and includes a disk-shaped electrode portion 4a and a columnar support portion 4b that protrudes upward from the upper surface of the electrode portion 4a and whose one end is formed exposed outside the vacuum chamber 1 in an integrated state. Moreover, the support portion 4b is electrically continued to the vacuum chamber 1 and made elevatable by an electrode elevation unit 24 (see Fig. 13). By the electrode elevation unit 24, the upper electrode 4 is made elevatable between a wafer loading/unloading position that is the upper end position of the elevation and where a large space for loading and unloading a semiconductor wafer between it

and the lower electrode 3 is formed and a discharge space formation position that is the lower end position of the elevation and where a discharge space for generating plasma discharge for plasma processing is formed between the upper electrode 4 and the lower electrode 3. The electrode elevation unit 24 functions as an interelectrode distance changing means and is able to change an interelectrode distance D (see Fig. 2) between the lower electrode 3 and the upper electrode 4 by moving up and down the upper electrode 4.

The detailed structure of the lower electrode 3 and the semiconductor wafer of the object to be processed are described next. As shown in Fig. 1, the upper surface of the electrode portion 3a of the lower electrode 3 is a planar retention surface (one example of the retention portion) on which a semiconductor wafer 6 is placed, and an insulating coating layer 3f is provided around the entire circumference of the outer edge portion of the retention surface. The insulating coating layer 3f is formed of ceramic such as alumina, and the outer edge portion of the insulating coating layer 3f is partially covered with an insulating member 5A as shown in Fig. 1 in a state in which the lower electrode 3 is mounted inside the vacuum chamber 1. The outer edge portion of the lower electrode 3 is insulated from the plasma generated in the discharge space

by having the structure, and abnormal electrical discharge can be prevented from being generated.

Fig. 2 is a partial schematic sectional view showing a state in which the semiconductor wafer 6 is placed on the lower electrode 3 before plasma dicing is started. The semiconductor wafer 6 is a semiconductor substrate made of a principal material of, for example, silicon, and a protective sheet 30 is adhesively stuck to a circuit-formation-face 6a (first surface) of the surface (lower surface side in Fig. 2) of the semiconductor wafer 6. In a state in which the semiconductor wafer 6 is placed on a retention surface 3g of the electrode portion 3a that is the upper surface of the lower electrode 3, the protective sheet 30 is to closely adhere to the retention surface 3g.

The protective sheet 30 has a construction that includes an insulating layer obtained by forming an insulating film such as polyimide into a film of a thickness of about 100 μm and is peelably stuck to the circuit-formation-face 6a of the semiconductor wafer 6 with an adhesive material. When the semiconductor wafer 6 to which the protective sheet 30 is stuck is retained on the lower electrode 3, the insulating layer functions as a dielectric in electrostatically attracting the semiconductor wafer 6 by the retention surface 3g of the electrode portion 3a as described later.

Moreover, with regard to the material of the protective sheet 30, it is preferable to select a material that is less etchable than silicon that is the principal material of the semiconductor wafer 6 during the plasma dicing described later.

Moreover, a mask-placement-face 6b (second surface) on which the mask for defining dividing regions (dividing lines) in the plasma dicing stage described later is placed is provided on the opposite side (upper side in Fig. 2) of the circuit-formation-face 6a. The mask is formed by abrading the surface on the side that becomes the mask-placement-face 6b by, for example, machining as described later and thereafter patterning the surface with a resist film 31a, by which regions excluding the portions that correspond to the dividing regions to be subjected to the plasma etching are covered with the resist film 31a. That is, the portions that correspond to the device-formation-regions are covered with the resist film 31a on the mask-placement-face 6b of the semiconductor wafer 6, so that mask slit portions 31b are arranged in the portions that correspond to the dividing regions.

Moreover, as shown in Fig. 2, the lower electrode 3 has a plurality of attraction holes 3e that open on the retention surface 3g, and the attraction holes 3e communicate with a suction hole 3c provided in the lower

electrode 3. As shown in Fig. 1, the suction hole 3c is connected to a vacuum suction pump 12 via a gas line switchover valve 11, and the gas line switchover valve 11 is connected to an N_2 gas supply unit 13 that supplies N_2 gas. By switching the gas line switchover valve 11, the suction hole 3c can be selectively connected to the vacuum suction pump 12 or the N_2 gas supply unit 13.

In concrete, by selecting the vacuum suction pump 12 by the gas line switchover valve 11 and driving the vacuum suction pump 12 in a state in which the suction hole 3c communicates with the vacuum suction pump 12, the semiconductor wafer 6 placed on the lower electrode 3 can be held by vacuum attraction by effecting vacuum suction through the attraction holes 3e. Therefore, the attraction holes 3e, the suction hole 3c and the vacuum suction pump 12 serve as vacuum suction means for retaining the semiconductor wafer 6 by vacuum attraction in a state in which the protective sheet 30 is closely fit to the retention surface 3g of the electrode portion 3a by effecting suction through the attraction holes 3e that open on the retention surface 3g of the lower electrode 3.

Moreover, by selecting the N_2 gas supply unit 13 by the gas line switchover valve 11 and connecting the suction hole 3c to the N_2 gas supply unit 13, the N_2 gas can be gushed through the attraction holes 3e against the

lower surface of the protective sheet 30. The N_2 gas is the gas for blowing purpose intended for compulsorily separating the protective sheet 30 from the retention surface 3g as described later.

Moreover, as show in Fig. 1, a refrigerant passage 3d for cooling use is provided in the lower electrode 3, and the refrigerant passage 3d is connected to a cooling unit 10. By driving the cooling unit 10, a refrigerant such as cooling water circulates in the refrigerant passage 3d, by which the semiconductor wafer 6 is cooled via the lower electrode 3 and the protective sheet 30 on the lower electrode 3 of which the temperatures are raised by heat generated during the plasma processing. It is noted that the refrigerant passage 3d and the cooling unit 10 serve as cooling means for cooling the lower electrode 3.

Moreover, in the plasma processing apparatus 101 of Fig. 1, a vacuum pump 8 is connected via an exhaust switchover valve 7 to an exhaust port 1a provided communicating with the processing chamber 2. By driving the vacuum pump 8 by switching the exhaust switchover valve 7 to the exhaust side, the processing chamber 2 of the vacuum chamber 1 is internally evacuated, allowing the processing chamber 2 to be internally decompressed. Moreover, the processing chamber 2 has a pressure sensor 28

(not shown in Fig. 1, see Fig. 4), and by controlling the vacuum pump 8 by a control unit 33 (see Fig. 4) described later on the basis of the pressure measurement result of the pressure sensor 28, the processing chamber 2 can be internally decompressed to the desired pressure. The vacuum pump 8 for decompression to the desired pressure can be controlled by directly controlling the evacuation ability of the vacuum pump 8 itself by using, for example, a variable capacity type as the vacuum pump 8 or providing an opening regulating valve (butterfly valve etc.) in the evacuation path and indirectly controlling the evacuation ability by controlling the opening. It is noted that the vacuum pump 8 and the exhaust switchover valve 7 serve as an evacuation unit (decompression means) that internally decompresses the processing chamber 2 to the desired pressure. Moreover, by switching the exhaust switchover valve 7 to the atmospheric open side, the atmosphere is introduced into the processing chamber 2 through the exhaust port 1a, allowing the internal pressure of the processing chamber 2 to be restored to the atmospheric pressure.

The detailed structure of the upper electrode 4 is described next. The upper electrode 4 has a center electrode portion 4a and an annular member 4f constructed of an insulating film provided fixed to the outer

peripheral portion of the electrode so as to surround the electrode portion 4a. The annular member 4f has an inside diameter made approximately equal to the outside diameter of the electrode portion 4a of the upper electrode 4 and is concentrically arranged in a shape that expands outwardly of the circumferential surface of the lower electrode 3. The annular member 4f plays the role of holding a disk-shaped gas blowing portion 4e placed in a lower center portion of the upper electrode 4.

The gas blowing portion 4e supplies a plasma generating gas for generating plasma discharge in the discharge space formed between the upper electrode 4 and the lower electrode 3. The gas blowing portion 4e is a member obtained by processing a porous material that internally has many micropores into a disk-like shape and is able to supply in a uniform state the plasma generating gas supplied into a gas retention space 4g, which is surrounded by the lower surface of the electrode portion 4a of the upper electrode 4, the upper surface of the gas blowing portion 4e and the inner peripheral surface of the annular member 4f, by making the gas uniformly blow into the discharge space via the micropores.

A gas supply hole 4c that communicates with the gas retention space 4g is provided in the support portion 4b, and the gas supply hole 4c is connected to a plasma

generating gas supply unit placed outside the vacuum chamber 1. The plasma generating apparatus has a first gas supply unit 20A, a second gas supply unit 20B, a third gas supply unit 20C and a fourth gas supply unit 20D as a plurality of gas supply units that individually supply gases of different kinds, a gas mixing portion (junction of piping) 19 to mix the gasses supplied from the gas supply units 20A, 20B, 20C and 20D and put the gas composition into a uniform state, and a gas flow rate regulating section 21 that is placed between the gas mixing portion 19 and the gas supply units 20A, 20B, 20C and 20D and individually regulates the supply flow rates of the gases supplied to the gas mixing portion 19.

The gas flow rate regulating section 21 has a first flow rate control valve 23A that independently regulates the flow rate of the gas supplied from the first gas supply unit 20A, a first on/off valve 22A capable of interrupting the gas supply, a second flow rate control valve 23B that independently regulates the flow rate of the gas supplied from the second gas supply unit 20B, a second on/off valve 22B capable of interrupting the gas supply, a third flow rate control valve 23C that independently regulates the flow rate of the gas supplied from the third gas supply unit 20C, a third on/off valve 22C capable of interrupting the gas supply, a fourth flow rate control

valve 23D that independently regulates the flow rate of the gas supplied from the fourth gas supply unit 20D and a fourth on/off valve 22D capable of interrupting the gas supply. The opening control and the on/off control of the valves are executed by the control unit 33 described later.

The plasma processing apparatus 101 of the present first embodiment is able to supply, for example, a sulfur hexafluoride gas (SF_6) from the first gas supply unit 20A, helium (He) from the second gas supply unit 20B, oxygen (O_2) from the third gas supply unit 20C and trifluoromethane (CHF_3) from the fourth gas supply unit 20D. The plasma generating gas supply units constructed as above makes it possible to individually regulate the flow rate of the gas(es) supplied from one or a plurality of gas supply units selected from the gas supply units 20A, 20B, 20C and 20D by the gas flow rate regulating section 21, supply a mixed gas (or single gas) of the desired gas composition and flow rate to the gas mixing portion 19 and supply the gas (mixed gas) mixed in the gas mixing portion 19 into the discharge space through a gas supply hole 4c, a gas retention space 4g and a gas blowing portion 4e.

Moreover, by changing only the supply flow rate without changing the gas composition, i.e., the gas supply ratio by using the function of the gas flow rate regulating section 21 that can individually regulate the flow rate of

each gas, the internal pressure of the processing chamber 2 can be controlled. In concrete, by controlling the gas flow rate regulating section 21 by the control unit 33 on the basis of a preset pressure condition and the internal pressure of the processing chamber 2 detected by the pressure sensor 28, the internal pressure of the processing chamber 2 can be regulated to coincide with the pressure condition. Therefore, the gas flow rate regulating section 21 concurrently has the function of regulating the composition of the gas supplied into the processing chamber 2 and the function of controlling the internal pressure of the processing chamber 2.

Moreover, as shown in Fig. 1, the lower electrode 3 is electrically connected to a high-frequency power unit 17 via a matching circuit 16. By driving the high-frequency power unit 17, a high-frequency voltage is applied between the upper electrode 4 that is electrically continued to the vacuum chamber 1 grounded to a grounding portion 9 and the lower electrode 3. As a result, plasma discharge is generated in the discharge space between the upper electrode 4 and the lower electrode 3 in the processing chamber 2, and the plasma generating gas supplied into the processing chamber 2 makes a transition to the plasma state. Moreover, the matching circuit 16 has the function of matching the impedance of the plasma

discharge circuit in the processing chamber 2 with the high-frequency power unit 17 at the time of generating plasma. In the present embodiment, the high-frequency power unit 17 and the matching circuit 16 serve as one example of the high-frequency power applying device.

Further, a DC power unit 18 for electrostatic attraction is connected to the lower electrode 3 via an RF filter 15. By driving the DC power unit 18 for electrostatic attraction, the surface of the lower electrode 3 is charged with negative charge (indicated by "-" in the figure) as shown in the schematic view of the plasma processing apparatus 101 of Fig. 3A. As shown in the schematic view of the plasma processing apparatus 101 of Fig. 3B, if a plasma 34 (indicated by the dotted portion in the figure) is generated in the processing chamber 2 by driving the high-frequency power unit 17 in this state, a direct current application circuit 32 that connects the semiconductor wafer 6 placed on the retention surface 3g via the protective sheet 30 to the grounding portion 9 is formed via the plasma 34 in the processing chamber 2. As a result, a closed circuit that sequentially connects the lower electrode 3, the RF filter 15, the DC power unit 18 for electrostatic attraction, the grounding portion 9, the plasma 34 and the semiconductor wafer 6 is formed, and the semiconductor wafer 6 is charged with positive charge

(indicated by "+" in the figure).

Then, a Coulomb force takes effect between the negative charge "-" in the retention surface 3g of the lower electrode 3 formed of a conductor and the positive charges "+" in the semiconductor wafer 6 via the protective sheet 30 that includes an insulating layer as a dielectric, so that the semiconductor wafer 6 is retained on the lower electrode 3 by the Coulomb force. At this time, the RF filter 15 prevents the radio-frequency voltage of the radio-frequency power unit 17 from being applied directly to the DC power unit 18 for electrostatic attraction. It is noted that the polarity of the DC power unit 18 for electrostatic attraction may be reversed. As described above, in the plasma processing apparatus 101, the components that substantially contribute to the generation of the plasma can also be referred to as a plasma generating apparatus.

Moreover, in the above construction, the DC power unit 18 for electrostatic attraction serves as an electrostatic attraction means for electrostatically attracting the semiconductor wafer 6 by utilizing the Coulomb force that takes effect between the semiconductor wafer 6 and the retention surface 3g of the lower electrode 3, which are separated by the protective sheet 30, by applying a DC voltage to the lower electrode 3. That is,

with regard to the retention means for retaining the semiconductor wafer 6 on the lower electrode 3, the two types of the vacuum suction means for vacuum attraction of the protective sheet 30 via the plurality of attraction holes 3e that open on the retention surface 3g and the electrostatic attraction means can properly be used.

Moreover, a refrigerant passage 4d for cooling use is provided in the upper electrode 4 as in the lower electrode 3, and the refrigerant passage 4d is connected to the cooling unit 10. A refrigerant such as cooling water circulates in the refrigerant passage 4d by driving the cooling unit 10, and this makes it possible to cool the upper electrode 4 whose temperature has been elevated by heat generated during the plasma processing.

Moreover, an opening 1b for loading and unloading the semiconductor wafer 6 that is the object to be processed is provided on the side surface of the processing chamber 2 (see Fig. 13). A door 25 that is moved up and down by a door opening/closing unit 26 is provided outside the opening 1b, and the opening 1b is opened and closed by moving up and down the door 25. Fig. 7 shows a state in which the semiconductor wafer 6 is loaded and unloaded with the opening 1b opened by moving down the door 25 by the door opening/closing unit 26.

Moreover, as shown in Fig. 13, a space for

conveyance use is secured between the upper electrode 4 and the lower electrode 3 by moving up the upper electrode 4 by the electrode elevation unit 24 to position the electrode in the wafer loading/unloading position during the loading and unloading of the semiconductor wafer 6. In this state, a suction head 27 that is sucking and holding the semiconductor wafer 6 is made to enter the processing chamber 2 via the opening 1b by operating an arm 27a. By this operation, the loading of the semiconductor wafer 6 onto the lower electrode 3 and the unloading of the processed semiconductor wafer 6 (semiconductor devices) are performed.

CONSTRUCTION OF CONTROL SYSTEM

The construction of the control system of the plasma processing apparatus 101 that has the above construction is described next with reference to the block diagram of the control system shown in Fig. 4.

As shown in Fig. 4, the control unit 33 has a storage section 92 that stores various data and a processing program and a process control section 91 that executes control of the plasma processing by executing the operation control of the components of the plasma processing apparatus 101 on the basis of these data and processing program. The storage section 92 stores plasma processing conditions 81 (allowed to be plasma conditions

or operating conditions) and an operation program 82 of the plasma processing, and the process control section 91 executes control of the plasma processing on the basis of the operation program 82 and the plasma processing conditions 81. An operation/input section 94 is the input means such as a keyboard and executes data input of the plasma processing conditions and so on and input of operating commands. A display section 93 is a display device, which displays a guide screen and so on at the time of operation input. Although not shown, it may be a case where the control unit 33 has an external input/output interface and exchange of information with the outside of the device is performed.

In this case, the plasma processing conditions used in the plasma processing apparatus 101 of the present first embodiment are herein described. The plasma processing steps carried out in the present first embodiment roughly include three steps, which are a plasma dicing processing (or a plasma etching processing), an insulator removal processing and a mask removal processing as described later. Moreover, during the plasma dicing processing described above, the three plasma processing steps of an insulator exposure processing, a corner portion removal processing and an isotropic etching processing are carried out by performing the plasma etching, as described

later, and the plasma processing conditions 81 for carrying out the processing steps are preliminarily individually determined. In concrete, the plasma processing conditions 81 are determined by combinational conditions of, for example, the gas composition of the plasma generating gases, the internal pressure of the processing chamber 2 and the frequency (discharge frequency) of the high frequency applied between the upper electrode 4 and the lower electrode 3.

Moreover, in the plasma processing apparatus 101 of the present first embodiment, two types of etching of mutually different etching characteristics of anisotropic etching that has a more intense etching characteristic in the direction of thickness than in the direction along the surface of the semiconductor wafer 6 (i.e., etching characteristic principally effected in the direction of thickness) and isotopic etching that has a roughly equivalent etching characteristic in the direction along the surface and the direction of thickness are used as the plasma etching. In concrete, in the plasma dicing processing, the insulator exposure processing and the corner portion removal processing are carried out by performing the anisotropic etching on the same plasma processing conditions, and the isotopic etching is carried out by switching the anisotropic etching to the isotopic

etching. Here, intensity of the etching characteristic in the direction of thickness is expressed as "A", and intensity of the etching characteristic in the direction along the surface of the semiconductor wafer 6 is expressed as "B", it is desirable to set ratios between "A" and "B" for the respective types of etching as follows,

For the anisotropic etching: $A/B \geq 10$

For the isotopic etching: $2 \geq A/B \geq 1$

One example of the plasma processing conditions 81 as described above is shown in the data table of Fig. 12. As shown in Fig. 12, plasma processing conditions 81A for the anisotropic etching of the insulator exposure processing and the corner portion removal processing are provided by the combinational conditions that the gas composition of the mixed gas (i.e., mixture ratio of the gases) is constituted of SF_6 and O_2 at a ratio of 10 : 2, the pressure is 100 Pa and the frequency is 60 MHz. Moreover, plasma processing conditions 81B for the isotropic etching are provided by the combinational conditions that the gas composition is constituted of SF_6 and He at a ratio of 10 : 30, the pressure is 500 Pa and the frequency is 13.56 MHz. As conditions other than those of the plasma dicing process, there is an interelectrode distance D between the upper electrode 4 and the lower electrode 3, and, for example, a value (assumed to be an

interelectrode distance D1) considered to be optimum within a range of 5 to 50 mm as the interelectrode distance D is set as the plasma processing conditions 81A and 81B.

Moreover, plasma processing conditions 81C for the insulating film removing process are provided by the combinational conditions that the gas composition is constituted of CHF_3 at a ratio of 20, the pressure is 50 Pa and the frequency is 13.56 MHz when silicon oxide (SiO_2) is used as the insulator as described later. Further, plasma processing conditions 81D for the mask removal process are provided by the combinational conditions that the gas composition is constituted of O_2 at a ratio of 20, the pressure is 50 Pa and the frequency is 13.56 MHz. Moreover, a value (assumed to be an interelectrode distance D2) considered to be optimum within a range of 50 to 100 mm as the interelectrode distance D is set for the plasma processing conditions 81D for the mask removal process. Moreover, the plasma processing conditions 81 include the condition of a processing time.

Moreover, although the switchover between the anisotropic etching and the isotropic etching in the plasma dicing processing, i.e., the switchover of the etching characteristic should preferably be achieved by switchover between the plasma processing conditions 81A and the plasma processing conditions 81B determined by the combinations of

the gas composition, the pressure and the frequency as described above, the present invention is not limited to the switchover of conditions. Instead of the above case, the switchover of the etching characteristic can be achieved even when only one parameter of, for example, the gas composition, the pressure and the frequency is switched. For the switchover of the etching characteristic, the gas composition is the most effective parameter, and the second and third most effective parameters are the pressure and the frequency, respectively. For example, when the switchover of the etching characteristic is performed by only changing the gas composition, the switchover from the anisotropic etching to the isotropic etching can be achieved by changing the gas composition of SF_6 : O_2 : He from 10 : 2 : 0 to 10 : 0 : 30. Moreover, when the switchover of the etching characteristic is performed by only changing the internal pressure of the processing chamber 2, switchover from the anisotropic etching to the isotropic etching can be achieved by increasing the pressure (e.g., from 100 Pa to 500 Pa). Moreover, when the switchover of the etching characteristic is performed by only changing the frequency of the high frequency, switchover from the anisotropic etching to the isotropic etching can be achieved by lowering the frequency (e.g., from 60 MHz to 13.56 MHz). It is noted that, for example,

a high-frequency output (e.g., set within a range of 500 to 3000 W) and a gas supply flow rate are also used as a parameter besides these parameters.

Moreover, as the gas composition for the anisotropic etching, it is preferable to use a gas composition such that a reaction product that easily deposits (deposition: vapor deposition or deposition). For example, a fluorine oxide of silicon ($Si_xF_yO_z$) (x, y and z are integers in this case) can be generated as the reaction product by using a gas composition that includes oxygen as the gas composition for the anisotropic etching. The fluorine oxide has a characteristic that it is less etchable than silicon. Taking advantage of the characteristic allows the groove portions to be formed on the surface of the semiconductor wafer by performing the anisotropic etching and allows the film to be formed on the inner surface side of the formed groove portions by making the generated fluorine oxide adhere to the surface (sidewall deposition). On the other hand, the fluorine oxide does not easily adhere to the bottom surfaces of the groove portions by physical etching with accelerated ions. For the above reasons, the inner surfaces of the groove portions can be made less etchable than the bottom surfaces, and this consequently allows the etching to produce an intense effect in the direction of thickness of the

semiconductor wafer, so that more ideal anisotropic etching can be achieved. Therefore, it is preferable to use the gas composition that promotes the anisotropic etching, i.e., the gas composition that easily causes sidewall deposition as the gas composition for the anisotropic etching.

The plasma processing conditions 81A for the anisotropic etching, the plasma processing conditions 81B for the isotropic etching, the plasma processing conditions 81C for the insulator removing process and the plasma processing conditions 81D for the mask removing process are stored in the storage section 92 of the control unit 33. The plasma processing conditions 81 necessary for each step are selected on the basis of the operation program 82, and the plasma processing is carried out by the process control section 91 on the basis of the selected plasma processing conditions 81.

During the plasma processing carried out on the basis of the operation program 82, as shown in Fig. 4, the components, which are the gas flow rate regulating section 21, the gas line switchover valve 11, the high-frequency power unit 17, the DC power unit 18 for electrostatic attraction, the exhaust switchover valve 7, the vacuum pump 8, the vacuum suction pump 12, the door opening/closing unit 26 and the electrode elevation unit 24, are controlled by the process control section 91.

Moreover, by regulating the total supply amount of the gases by controlling the gas flow rate regulating section 21 by the process control section 91 on the basis of the pressure detection result by the pressure sensor 28, the internal pressure of the processing chamber 2 can be controlled to coincide with the plasma processing conditions 81.

Further, as shown in Fig. 4, the control unit 33 has a processing time measurement section 95, which measures the processing time of the plasma processing and executes control such that, when the measurement result reaches the condition of the processing time included in the plasma processing conditions 81, control to end the processing is by the process control section 91 can be performed.

The principle of the plasma etching processing method used in the present first embodiment is described next with reference to the partially enlarged schematic explanatory views of the neighborhood of the dividing regions of the semiconductor wafer 6 shown in Figs. 5 and 6.

Fig. 5 is a view showing a state in which the plasma etching process is carried out on the portion that corresponds to the mask slit portion (or mask cutout portion) 31b, i.e., the dividing region from the mask-placement-face 6b side on the semiconductor wafer 6 to the

circuit-formation-face 6a of which the protective sheet 30 is adhesively stuck and on which the resist film 31a is placed to define the dividing region on the mask-placement-face 6b. Moreover, as shown in Fig. 5, the semiconductor wafer 6 used in the present first embodiment is the semiconductor wafer on the circuit-formation-face 6a of which the silicon oxide film 35 formed of silicon oxide (SiO_2) of one example of the insulating film (that is, insulating thin film or insulating layer) is formed also in the portion that corresponds to the dividing region. The semiconductor wafer has a construction different from that of the conventional semiconductor wafer on which no such silicon oxide is formed in the portion that corresponds to the dividing region. It is noted that the protective sheet 30 is adhesively stuck to the circuit-formation-face 6a located on the thus-formed silicon oxide film 35 side.

As shown in Fig. 5, the ions in the plasma are made roughly perpendicularly incident on the semiconductor wafer 6 by an electric field generated in the plasma processing apparatus 101, and the incident ions reach the bottom portion (etching bottom portion) of a groove portion formed by an etching process, promoting the etching. The ions (having positive charge) that have reached the etching bottom portion are recombined with electrons in the semiconductor wafer 6 formed of silicon that is the

semiconductor material. That is, since the silicon material also has characteristics as a conductor, the ions that have reached the etching bottom portion and have positive charge are recombined with the electrons in the semiconductor wafer 6 due to an electric continuity between the etching bottom portion and the inside of the semiconductor wafer 6. The etching bottom portion is not charged with positive charge so long as the electric continuity is achieved.

On the other hand, as shown in Fig. 6, when a state in which the etching progresses to remove the etching bottom portion and expose the surface of the silicon oxide film 35, no electric continuity is achieved between the exposed silicon oxide film 35 and the inside of the semiconductor wafer 6, and therefore, the silicon oxide film 35 exposed by the reach of the ions is surface charged (electrically charged) with positive charge for the charging of the positive charge. When the state in which the thus exposed silicon oxide film 35 is charged with the positive charge, ions that enter next looses the straightness thereof due to the electric fields of positive charges, and the track (trajectory) thereof is to be bent. Consequently, as shown in Fig. 6, the ions reach both corner portions of the groove portion, so that etching is performed at both the corner portions, and removed portions

of a shape that is called "notch" where the groove portion is sharply expanded in the widthwise direction at the bottom portions are formed. This is the principle of the plasma etching process method used in the present first embodiment.

By thus forming the notches at the bottom portions of the groove portion, removal of the corner portions of the separated semiconductor chips, or, for example, formation of rounded (R) portions that are curved convex surface portions when viewed from the semiconductor wafer 6 side, or the side to be etched can be achieved (corner portion removal processing). Moreover, with regard to the principle of the plasma processing method as described above, it is preferable to perform anisotropic etching so that the ions in the applied plasma easily reach the etching bottom portions in the state shown in Fig. 5, i.e., in the state in which the silicon oxide film 35 is not exposed, and the anisotropic etching is also performed in the insulator exposure processing of the first embodiment. Moreover, a processing time necessary for exposing the silicon oxide film 35 (i.e., processing time of the insulator exposure processing) and a processing time necessary for forming notches of a prescribed size (i.e., removing the corner portions, such as chamfering and rounded portion formation) after the exposure of the

silicon oxide film 35 in the plasma dicing process are included in the plasma processing conditions 81A.

SEMICONDUCTOR CHIP MANUFACTURING METHOD

Next, a manufacturing method for semiconductor chips carried out by the plasma processing apparatus 101 that has the construction described above and a semiconductor wafer dividing method (plasma dicing process) carried out through the process of the manufacturing method for semiconductor chips are described below. A flow chart showing a series of procedure of the semiconductor wafer dividing method is shown in Fig. 7, and schematic explanatory views for explaining a series of processing contents of the manufacturing method for semiconductor chips are shown in Figs. 8A through 8C, Figs. 9A through 9C, Figs. 10A through 10C and Figs. 11A and 11B. Reference is made with reference to mainly these figures.

The semiconductor wafer 6 has a disk-like shape, and a plurality of device-formation-regions R1 are arranged in a matrix form on its circuit-formation-face 6a. The size of the device-formation-regions R1 are determined according to the size of the semiconductor chips to be manufactured and arranged in, for example, rectangular regions. Fig. 8A shows a partially enlarged schematic sectional view of the semiconductor wafer 6. As shown in Fig. 8A, dividing regions R2, which are roughly belt-shaped

regions that have a prescribed width dimension (i.e., a region that has a width dimension sufficiently smaller than that in the lengthwise direction thereof), are arranged between the mutually adjacent device-formation-regions R1. The dividing regions R2 serve as the regions that are arranged in a roughly grating-like shape on the circuit-formation-face 6a of the semiconductor wafer 6 defining the device-formation-regions R1 and also serve as the frame-shaped regions arranged outside the peripheries of the device-formation-regions R1 with regard to the relation thereof to one device-formation-region R1. Further, the dividing regions R2 are located in dividing positions where the device-formation-regions R1 are separated into individual pieces in the plasma dicing process. Moreover, the semiconductor devices 44 are formed in the respective device-formation-regions R1.

In concrete, as shown in Fig. 8A, the semiconductor wafer 6 is formed of a silicon substrate 45 that has a disk-like shape, and the silicon oxide film 35 formed of SiO_2 is formed on the entire circuit-formation-face 6a thereof. Further, the semiconductor devices 44 are formed in portions that correspond to the device-formation-regions R1 of the circuit-formation-face 6a. The semiconductor devices 44 include devices of MOS (Metal-Oxide-Semiconductor) structure transistors constructed of a

silicon substrate 45 (Semiconductor), a silicon oxide 35 (Oxide) formed directly on the circuit-formation-face 6a and a metal film (Metal) formed on the silicon oxide 35. Further, the semiconductor devices 44 have connection terminals 43 (also called the bonding pads) for electrically connecting the devices to external electronic apparatuses. It is noted that a surface protection film 46 (e.g., formed of polyimide) is formed on the surfaces of the semiconductor devices 44 for the protection of the surfaces of the semiconductor devices 44. The connection terminals 43 are not covered with the surface protection film 35 but exposed outside.

As shown in Fig. 8B, in order that the circuit-formation-face 6a might not suffer damages during each process subsequently carried out on the semiconductor wafer 6, the protective sheet 30 is peelably stuck to the circuit-formation-face 6a via an adhesive. With regard to the protective sheet 30, one that is shaped into the same shape as the exterior shape of the semiconductor wafer 6 is used so that the sheet covers the entire surface of the circuit-formation-face 6a and does not protrude from the semiconductor wafer 6. By using the protective sheet 30 of the shape, damage that the protective sheet 30 protruding from the semiconductor wafer 6 is damaged by the plasma can be prevented from occurring in the subsequent processing

such as plasma processing.

Next, as shown in Fig. 8C, a mask for defining the dividing regions R2 for dividing the semiconductor wafer 6 into individual pieces of semiconductor chips are formed on the mask-placement-face 6b that is the back surface of the circuit-formation-face 6a of the semiconductor wafer 6. In concrete, a resist film 31 made of, for example, a resin is formed as the mask to cover the entire surface of the mask-placement-face 6b of the semiconductor wafer 6. Subsequently, as shown in Fig. 9A, mask slit portions 31b are formed by patterning the resist film 31 by photolithography and removing only the portions that correspond to the dividing regions R2 by a width of, for example, 20 μm. As a result, a mask pattern such that the portions that correspond to the device-formation-regions R1 are covered with the resist film 31a and the portions that correspond to the dividing regions R2 are exposed at the mask slit portions (or mask cutout portions) 31b is formed on the mask-placement-face 6b of the semiconductor wafer 6. The semiconductor wafer 6 provided with the mask in the state becomes the object to be subjected to the plasma processing described later.

A method for dividing the semiconductor wafer 6 provided with the mask into individual pieces of semiconductor chips is described according to the flow

chart of Fig. 7 with reference to the schematic views of the plasma processing apparatus 101 shown in Figs. 13 through 15. It is noted that the control of each subsequent operation in the plasma processing apparatus 101 is executed by controlling the components by the process control section 91 on the basis of the operation program 82 stored in the storage section 92 of the control unit 33.

First of all, in step S1 of the flow chart of Fig. 7, the semiconductor wafer 6 provided with the mask is loaded into the processing chamber 2 as shown in Fig. 13. During the loading operation, the semiconductor wafer 6 held by the suction head 27 via the mask is loaded through the opening 1b into the processing chamber 2 by operating the arm 27a in a state in which the upper electrode 4 is moved up by the electrode elevation unit 24, and the semiconductor wafer 6 is placed on the lower electrode 3 via the protective sheet 30.

Next, the vacuum suction pump 12 is driven to effect vacuum suction through the attraction holes 3e to turn on the vacuum attraction of the semiconductor wafer 6, and the DC power unit 18 for electrostatic attraction is turned on (step S2). By the vacuum attraction, the semiconductor wafer 6 is held by the lower electrode 3 in a state in which the protective sheet 30 closely adhere to the retention surface 3g of the lower electrode 3 in the

processing chamber 2.

Subsequently, the door 25 is closed as shown in Fig. 14, and the upper electrode 4 is moved down by the electrode elevation unit 24 (step S3). At this time, the plasma processing conditions 81A for the anisotropic etching is selected and taken out of the plasma processing conditions 81 stored in the storage section 92 of the control unit 33 by the process control section 91 on the basis of the operation program 82, and the interelectrode distance D between the upper electrode 4 and the lower electrode 3 is set to a prescribed condition (i.e., interelectrode distance D1) within a range of, for example, 5 to 50 mm based on the condition of the interelectrode distance D included in the plasma processing conditions 81A for the anisotropic etching.

Next, the vacuum pump 8 is operated to start decompression in the processing chamber 2 (step S4). When the inside of the processing chamber 2 reaches a prescribed degree of vacuum, the gasses selected by the gas flow rate regulating section 21 are regulated to a prescribed gas composition and a prescribed flow rate based on the selected plasma processing conditions 81A for the anisotropic etching and supplied into the processing chamber 2 (step S5). In concrete, the first on/off valve 22A is opened on the basis of the plasma processing

conditions 81A for the anisotropic etching, and SF_6 is supplied from the first gas supply unit 20A to the gas mixing portion 19 with the supply flow rate thereof regulated by the first flow rate control valve 23A. In addition, the third on/off valve portion 22C is opened, and O_2 is supplied from the third gas supply unit 20C to the gas mixing portion 19 with the supply flow rate thereof regulated by the third flow rate control valve 23C. At this time, the second on/off valve 22B and the fourth on/off valve 22D are put in a closed state, and neither He nor CHF_3 is supplied. Moreover, SF_6 and O_2 are mixed together so as to have a gas composition of 10 : 2 at the gas mixing portion 19 and supplied into the processing chamber 2.

Then, in the gas supply process, the internal pressure of the processing chamber 2 is detected by the pressure sensor 28 and compared with the pressure condition (e.g., 100 Pa) in the plasma processing conditions 81A, and it is confirmed that the detected pressure has reached the pressure expressed by the pressure condition. That is, the interelectrode distance D between the lower electrode 3 and the upper electrode 4, the composition of the gases to be supplied to the processing chamber 2 and the internal pressure of the processing chamber 2 are set on the basis of the plasma processing conditions 81A for the anisotropic

etching.

Then, after the condition setting is completed, a high-frequency voltage that agrees with the condition is applied between the upper electrode 4 and the lower electrode 3 by driving the high-frequency power unit 18 on the basis of the frequency (e.g., 60 MHz) and the output condition of the high-frequency of the plasma processing conditions 81A, and plasma discharge is started (step S6). As a result, the supplied mixed gas makes a transition to the plasma state in the discharge space between the upper electrode 4 and the lower electrode 3. By the plasma generation, ions in the plasma are applied from the mask side (resist film 31a side) to the semiconductor wafer 6. By the application of ions, only the portions corresponding to the dividing regions R2 that are not covered with the resist film 31a of the silicon (i.e., silicon substrate 45) that is the principal material of the semiconductor wafer 6 are etched.

Concurrently with this, a direct current application circuit 32 is formed in the discharge space between the upper electrode 4 and the lower electrode 3 by the plasma (see Figs. 3A and 3B). As a result, an electrostatic attraction force is generated between the lower electrode 3 and the semiconductor wafer 6, and the semiconductor wafer 6 is held by the lower electrode 3 with

the electrostatic attraction force. Therefore, the protective sheet 30 satisfactorily adheres close to the retention surface 3g of the lower electrode 3, and the semiconductor wafer 6 is stably retained in the plasma processing process. In addition, the protective sheet 30 is satisfactorily cooled by the cooling function provided for the lower electrode 3, and a thermal damage due to heat generated by the plasma discharge is prevented.

Moreover, since anisotropic etching is performed on the basis of the plasma processing conditions 81A in the plasma dicing process (insulator exposure processing) by the anisotropic etching, the etching characteristic has an increase in the thickness direction of the semiconductor wafer 6. Therefore, as shown in Fig. 9B, the surface of the semiconductor wafer 6 corresponding to the mask slit portions 31b is etched in the thickness direction, so that groove portions 6c of a width that is roughly equal to the width of the mask slit portions 31b, i.e., the width of the dividing regions R2 are formed.

Moreover, in step S7, the plasma dicing process (insulator exposure processing) in step S6 is carried out until the etching bottom portion that is the bottom portion of the groove portion 6c is removed by etching and the surface of the silicon oxide film 35 is exposed from the bottom portion (i.e., until the surface of the insulator is

exposed), or, for example, until the time measured by the processing time measurement section 95 reaches the condition of the processing time necessary for exposing the silicon oxide film 35 included in the plasma processing conditions 81A. By thus providing a state in which the silicon oxide film 35 is exposed at the groove portions 6c, the portions that correspond to the dividing regions R2 are removed from the silicon substrate 45.

When it is determined in step S7 that it reaches the prescribed time, the plasma dicing process under the same condition is continuously carried out by anisotropic etching in step S8 as a plasma dicing process for performing the notch formation (i.e., notch formation processing or corner portion removal processing). As a result, the exposed silicon oxide film 35 becomes electrically charged with the positive charge of the ions applied from inside the plasma to the bottom portions of the groove portions 6c, and the trajectory of the incident ions in the groove portions 6c are consequently bent, performing the etching of the divided silicon substrate 45 so that the bottom portions of the groove portions 6c are expanded in the widthwise direction. Consequently, as shown in Fig. 9C, notches 42 are formed at both corner portions of the bottom portions of the groove portions 6c, i.e., the corner portions of the portions put in contact

with the silicon oxide film 35 of each piece of the divided silicon substrate 45 are removed, forming rounded (R) portions 40a.

The plasma dicing process for notch formation in step S8 is carried out in step S9 until the notches 42 and the rounded portions 40a of the prescribed sizes are formed, e.g., the time measured by the processing time measurement section 95 reaches the condition of the processing time necessary for forming the notches of the prescribed size included in the plasma processing conditions 81A.

If it is determined that it has reached the processing time in step S9, then the plasma dicing process (notch formation processing) by the anisotropic etching is ended, and the plasma processing conditions 81B for the isotropic etching are selected by the process control section 91, and the gases selected by the gas flow rate regulating section 21 are regulated to a prescribed gas composition and a prescribed flow rate based on the conditions and supplied into the processing chamber 2 (step S10). In concrete, the first on/off valve 22A is opened on the basis of the plasma processing conditions 81B for the isotropic etching, so that SF_6 is supplied from the first gas supply unit 20A to the gas mixing portion 19 with its supply flow rate controlled by the first flow rate control valve 23A. Concurrently, the second on/off valve 22B is

opened, so that He is supplied from the second gas supply unit 20B to the gas mixing portion 19 with its supply flow rate controlled by the second flow rate control valve 23B. It is noted that the third on/off valve 22C and the fourth on/off valve 22D are put in a closed state at this time, and neither O_2 nor CHF_3 is supplied. Moreover, SF_6 and He are mixed so as to have a gas composition of 10 : 30 in the gas mixing portion 19 and supplied into the processing chamber 2.

Then, it is confirmed that the internal pressure of the processing chamber 2 detected by the pressure sensor 28 has reached a pressure condition (e.g., 500 Pa) in the plasma processing conditions 81B in the gas supply process (step S10). It is noted that the interelectrode distance D1 between the lower electrode 3 and the upper electrode 4 is kept as it is.

Subsequently, on the basis of the frequency (e.g., 13.56 MHz) and the output condition of the plasma processing conditions 81B, by starting plasma discharge by applying a high-frequency voltage that agrees with the conditions between the upper electrode 4 and the lower electrode 3 by driving the high-frequency power unit 18, the plasma dicing process by the isotropic etching is started (step S11).

Since the isotopic etching has a feature that the

etching characteristic in the direction along the surface of the semiconductor wafer 6 and the etching characteristic in the direction of thickness are roughly equal to each other, etching is performed roughly equally in each of the directions in the portions to which the plasma is applied. Although the etching characteristic in the direction of thickness actually tends to become slightly more intense than the etching characteristic in the direction along the surface also by the isotropic etching, it is unchanged that an etching characteristic obviously different from that of the anisotropic etching is exhibited.

If the plasma etching is carried out by the isotropic etching, as shown in Fig. 10A, the groove portions 6c formed by the plasma dicing process by the anisotropic etching are etched in the direction along the surface of the semiconductor wafer 6 in the neighborhood of the entrance (i.e., in the neighborhood of the upper portion in the figure). Therefore, the groove portions 6c are etched so as to be slightly expanded in the widthwise direction thereof. Moreover, the etching characteristic tends to become more intense in the neighborhood of the entrance of the groove portions 6c and weaker as approaching the bottom portions. Therefore, by performing the isotropic etching, as shown in Fig. 10A, the rounded (R) portions 40b that are curved convex surface portions

can be formed at the end portions put in contact with the dividing regions R2 on the mask-placement-face 6b of the device-formation-regions R1. That is, the rounded portions 40b are formed at the end portions (corner portions) located on the mask-placement-face 6b side of the device-formation-regions R1 and the four corner portions of the rectangular plane.

It is noted that the plasma dicing process by the isotropic etching in step S11 is carried out until the rounded portions 40b are formed into a prescribed size, or, for example, until the time measured by the processing time measurement section 95 elapses over the processing time of the plasma processing conditions 81B for the isotropic etching.

When it is determined in step S12 that it has reached the prescribed time, the plasma dicing process by the isotropic etching is ended. In addition, the plasma processing conditions 81C for the insulating film removing process are selected by the process control section 91, and the gas selected by the gas flow rate regulating section 21 is supplied into the processing chamber 2 by being regulated to the prescribed gas composition and the prescribed gas flow rate on the basis of the conditions (step S13). In concrete, the fourth on/off valve 22D is opened on the basis of the plasma processing conditions 81C

for the insulating film removing process, so that CHF_3 is supplied from the fourth gas supply unit 20D to the gas mixing portion 19 with its supply flow rate regulated by the fourth flow rate control valve 23D.

Then, it is confirmed that the internal pressure of the processing chamber 2 detected by the pressure sensor 28 has reached the pressure condition (e.g., 50 Pa) in the plasma processing conditions 81C in the gas supply step. It is noted that the interelectrode distance D1 between the lower electrode 3 and the upper electrode 4 is kept as it is.

Subsequently, by starting the plasma discharge by applying a high-frequency voltage that agrees with the conditions between the upper electrode 4 and the lower electrode 3 with the high-frequency power unit 18 driven on the basis of the frequency (e.g., 13.56 MHz) and the output condition of the high-frequency of the plasma processing conditions 81C, the plasma etching for removing the silicon oxide 35 exposed at the groove portions 6c is started (insulator removal processing in step S14).

By performing the plasma etching, as shown in Fig. 10B, the exposed silicon oxide 35, i.e., the silicon oxide 35 in the portions that correspond to the dividing regions R2 is positively etched to remove the silicon oxide 35 in the portions. As a result, the portions that correspond to

the dividing regions R2 are completely removed from the semiconductor wafer 6, and the device-formation-regions R1 are separated into individual pieces, forming the semiconductor chips 40 that include the semiconductor devices 44. It is noted that the plasma etching is carried out until the time measured by the processing time measurement section 95 reaches the processing time included in the plasma processing conditions 81C (step S15).

If it is determined in step S15 that it has reached the prescribed time, then the plasma etching process for the insulating film removing process, i.e., the insulator removal processing is ended. When the processing is ended, the supply of the mixed gas and the application of the high-frequency voltage are stopped. Subsequently, an interelectrode distance change for making a transition to the plasma ashing processing (mask removal processing) is performed (step S16). In concrete, the plasma processing conditions 81D for mask removing process are selected by the process control section 91, and the upper electrode 4 is moved up by the electrode elevation unit 24 as shown in Fig. 15 on the basis of the conditions, setting the interelectrode distance between the upper electrode 4 and the lower electrode 3 to the interelectrode distance D2. The interelectrode distance D2 when the mask is removed by plasma ashing as described above is set wider than the

interelectrode distance D1 in the plasma dicing process.

Subsequently, the third gas supply unit 20C is selected on the basis of the plasma processing conditions 81D, and the plasma ashing gas (e.g., oxygen) is supplied from the third gas supply unit 20C with its supply flow rate being regulated (step S17). Then, by detecting the internal gas pressure of the processing chamber 2 in the gas supply process and comparing the pressure with that of the plasma processing conditions, it is confirmed that the pressure has reached the pressure expressed by the conditions.

Subsequently, by applying the high-frequency voltage between the upper electrode 4 and the lower electrode 3 by driving the high-frequency power unit 18, the plasma discharge is started (step S18). As a result, the supplied gas makes a transition to the plasma state in the discharge space between the upper electrode 4 and the lower electrode 3. The thus generated plasma takes effect on the mask-placement-face 6b of the semiconductor wafer 6, thereby ashing (incinerating) the resist film 31a made of an organic substance by the plasma.

Then, with the progress of the ashing, the resist film 31a gradually disappears, and finally, the mask is completely removed from the semiconductor wafer 6, i.e., the mask-placement-face 6b of the semiconductor chips 40

formed into individual pieces as shown in Fig. 10C. The output of the high-frequency power source in the mask removing process is set to a prescribed value set within a range of, for example, 100 to 1000 W based on the plasma processing conditions 81D. Then, after the mask is completely removed, the plasma discharge is stopped.

Subsequently, the operation of the vacuum pump 8 is stopped (step S19), and the exhaust switchover valve 7 is switched for release to the atmosphere (step S20). As a result, the internal pressure of the processing chamber 2 is restored into the atmospheric pressure. Then, the vacuum attraction is turned off, and the DC power unit for electrostatic attraction is turned off (step S21). As a result, the retention by attraction of the semiconductor wafer 6 in a state in which it is divided into individual pieces of the semiconductor chips 40 and retained by the protection tape 30 is released.

Yet subsequently, the semiconductor wafer 6 that has undergone the plasma processing is unloaded (step S22). That is, the semiconductor wafer 6 is sucked and held by the suction head 27 and unloaded to the outside of the processing chamber 2 with the N_2 gas blown through the attraction holes 3e. As a result, the plasma processing for continuously carrying out the insulator removal processing, the notch formation processing, the isotropic

etching processing, the insulating film removing process and the mask removal processing is ended in the plasma processing apparatus 101.

Then, the semiconductor wafer 6 unloaded together with the protective sheet 30 is transferred to a sheet peeling process, in which the protective sheet 30 is peeled off from the circuit-formation-faces 6a of the semiconductor chips 40. As shown in Figs. 11A and 11B, the sheet peeling is performed after the semiconductor chips 40 are retained on the adhesive sheet 37 by sticking an adhesive sheet 37 for retention use to the mask-placement-face 6b of the semiconductor chips 40. As a result, the manufacturing process of the semiconductor chips is completed.

In this case, Fig. 30 shows a schematic perspective view (including partial removal cross section) showing the appearance of the thus-formed semiconductor chips 40. As shown in Fig. 30, the rounded portions 40a that are curved convex surface portions can be formed so as to remove the sharp corner portions (or ridgelines) at the end portions (i.e., at the end portions in all of the four directions) on the circuit-formation-face 6a side of the semiconductor chips 40. Further, the rounded portions 40b that are curved convex surface portions can be formed so as to remove the sharp corner portions (or ridgelines) at the

end portions (i.e., at the end portions in all of the four directions) on the mask-placement-face 6b side of the semiconductor chips 40. That is, all the corner portions and the ridgelines of the semiconductor chips 40 can be removed. As a result, chipping due to the corner portions and the like that become chipped can be suppressed from occurring on the manufactured semiconductor chip 40, and the transverse rupture strength can be improved.

Moreover, the thus-formed semiconductor chip 40 is, for example, a semiconductor chip of a reduced thickness such that the thickness dimension thereof is sufficiently smaller than the width dimension thereof. Concretely describing the structure of the semiconductor chip 40, the semiconductor chip 40 has a first surface (circuit-formation-face) 40c which has a roughly rectangular flat surface and on which the semiconductor device 44 is formed, a second surface 40d which is a roughly rectangular flat surface parallel to the first surface 40c located on the side opposite from the first surface 40c, and a connection surface 40e which is located at the periphery of the first surface 40c and the second surface 40d and connects the end portion of the first surface 40c with the end portion of the second surface 40d. Furthermore, the semiconductor chip 40 is constructed so that the connection surface 40e includes the respective

rounded portions 40a and 40b that are curved convex surface portions so that no ridgelines are formed at the end portions of the first surface 40c and the second surface 40d. Therefore, in the manufactured semiconductor wafer 40, the portions where the ridgelines have been located by the conventional manufacturing method can be constructed of curved convex surface portions, and the transverse rupture strength can be improved. Considering the fact that the thickness dimension is sufficiently smaller than the width dimension in the semiconductor chip 40 as described above, it is also possible to form all the connection surfaces 40e of the curved convex surface portions.

Moreover, when curved convex surface portions, i.e., rounded portions 31c are formed at the four corner portions of the resist films 31a that have a roughly rectangular shape in plane and are arranged on the mask-placement-faces 6b of the semiconductor wafer 6 as shown in the schematic explanatory view of Fig. 31, the configuration of the formed semiconductor chip 40 can be formed into a smoother configuration, and this is preferable. In the thus-formed semiconductor chips 40, the width dimension of the dividing regions R2 is, for example, about 5 to 20 μm, the width dimension of the removed corner portions, i.e., the diameter dimension of the rounded portions 40a and 40b is about 0.5 to 20 μm, and further the

width dimension of the removed silicon oxide film 35 is not greater than about 50 μm. Although the curved convex surface portions come to have a configuration that unlimitedly resembles chamfered portions (inclined flat surface portion or a tapered portion) if a curvature of the "rounded portions", or the "curved convex surface portions" becomes unlimitedly small, such chamfered portions are included in the curved convex surface portions of the present embodiment so long as the portions are convex surface portions curved even a little.

Although the case where the rounded portions 40a are formed by forming notches at the corner portions of the semiconductor chip 40 has been described above, the manufacturing method for semiconductor chips of the present first embodiment is not limited only to this case, and it may be a case where chamfer portions obtained by removing the sharp portions are formed at the corner portions. This is because the occurrence of chipping can be suppressed even if the chamfer portions are formed as described above.

Moreover, although the case where the principal portion of the semiconductor wafer 6 is the silicon substrate 45 formed of silicon has been described above, the notch formation of the present first embodiment can be similarly carried out and a similar effect can be obtained even when the semiconductor wafer is formed of a GaAs based

material in place of the above case. It is noted that a gas constituted mainly of chlorine based gas should preferably be used as the plasma processing gas in place of the fluorine based gas (SF_6, CF_4) for etching the silicon material. When the GaAs based material is used as described above, the silicon oxide can be used as the insulating film.

Moreover, although the case where the semiconductor chips 40 are manufactured in order of the insulator exposure processing, the notch formation processing, the isotopic etching processing, the insulator removal processing and the mask removal processing has been described above, the present embodiment is not limited to the case. It may be a case where the isotopic etching processing is carried out at any timing before or after the insulator exposure processing, the notch formation processing or the insulator removal processing is carried out. It is noted that the insulator exposure processing and the notch formation processing are carried out on the identical plasma processing conditions 81A, and therefore, it is efficient to continuously carry out both the processes.

According to the first embodiment, various effects can be obtained as follows.

By using the semiconductor wafer, on which the

silicon oxide film 35 is placed as the insulating film in the portions that correspond to the dividing regions R2 of the circuit-formation-face 6a, as the semiconductor wafer 6 and carrying out the plasma dicing process from the mask-placement-face 6b, the semiconductor chip manufacturing capable of forming the rounded portions 40a at the corner portions of the formed semiconductor chips 40 and improving the transverse rupture strength can be achieved.

In concrete, the groove portions 6c are formed in the portions that correspond to dividing regions R2 by carrying out the plasma dicing process on the semiconductor wafer 6, and the silicon oxide film 35 is exposed from the etching bottom portions in accordance with the progress of the etching. Subsequently, the exposed silicon oxide film 35 can be charged with the positive charge due to the ions in the plasma by continuing the plasma dicing process, and the rounded portions 40a can be formed by removing the corner portions of the semiconductor chips 40 put in contact with the silicon oxide film 35 by bending the trajectory of the applied ions by the charging.

By thus forming the rounded portions 40a on the semiconductor chips 40, the semiconductor chips which are able to suppress the occurrence of chipping of the manufactured semiconductor chips 40 and of which the transverse rupture strength is improved can be manufactured.

Moreover, with regard to the exposed silicon oxide film 35, the silicon oxide film 35 can be positively etched by performing the plasma etching while switching, for example, the kind of the gas, and the removal can reliably be achieved. Therefore, the silicon oxide film 35, which is not formed in the portions that correspond to the dividing regions R2 in the conventional semiconductor wafer 501 to be subjected to the plasma dicing process, can be removed by carrying out the plasma etching process by switching the kind of the gas in the case where the silicon oxide film 35 is formed in the portions that correspond to the dividing regions R2, and the semiconductor wafer 6 can reliably be divided into the individual pieces of the semiconductor chips 40.

Further, by performing the etching on the inner side surface of the formed groove portions 6c in the direction along the surface of the semiconductor wafer 6 by switching the etching characteristic to the isotopic etching, etching can be achieved in the widthwise direction in the neighborhood of the entrance of the groove portions 6c. By thus performing the etching, the rounded portions 40b that are curved convex surface portions can be formed at the end portions and the corner portions on the mask-placement-face 6b side of the semiconductor chips 40.

Therefore, all the ridgelines can be removed from

the semiconductor chips 40 separated by the plasma dicing process, so that the smooth curved convex surface portions can be formed at the portions where the ridgelines and corner portions have originally been located, and the transverse rupture strength can be improved.

SECOND EMBODIMENT

The present invention is not limited to the above embodiment but allowed to be put into practice in various modes. For example, a manufacturing method for semiconductor chips according to the second embodiment of the present invention is described below with reference to the schematic explanatory views shown in Figs. 16A through 16C, Figs. 17A through 17C, Figs. 18A through 18C and Figs. 19A and 19B.

The manufacturing method for semiconductor chips of the present second embodiment differs from the first embodiment in the point that a polyimide (PI) film is used as the insulating film instead of using the silicon oxide film 35 as the insulating film formed in the portions that correspond to the dividing regions R2 as in the semiconductor wafer 6 of the first embodiment. Only the different point is described below. The fact that the plasma processing apparatus 101 used in the first embodiment is similarly used by the manufacturing method for semiconductor chips of the present second embodiment is

same, and therefore, no description is provided for the apparatus. Moreover, the flow chart showing the procedure of the manufacturing method for the semiconductor chips of the present second embodiment is similar to the flow chart used for the first embodiment, no description is provided therefor.

First of all, as shown in Fig. 16A, semiconductor devices 144 are formed in portions that correspond to the respective device-formation-regions R1 on a circuit-formation-face 106a of a semiconductor wafer 106. Each of the semiconductor devices 144 includes devices such as a MOS (Metal-Oxide-Semiconductor) structure transistor constructed of a silicon substrate 45 (Semiconductor), a silicon oxide 135 (Oxide) formed directly on the circuit-formation-face 106a and a metal film (Metal) formed on the silicon oxide 135. Further, the semiconductor devices 144 further includes a connection terminal 143 (also called the bonding pad) for electrically connecting the devices to external electronic apparatuses. In the portions that correspond to the dividing regions R2, the silicon oxide 135 is not formed unlike the first embodiment.

Moreover, as shown in Fig. 16A, on the circuit-formation-face 106a of the semiconductor wafer 106, a polyimide film 146 is formed as a surface protection film covering the formed semiconductor devices 144. The

polyimide film 146 has a function to protect the semiconductor devices 144 formed on the circuit-formation-face 106a and placed formed also covering the portions that correspond to the dividing regions R2 on the circuit-formation-face 106a. In the semiconductor devices 144, the surfaces of the connection terminals 143 are not entirely covered with the polyimide film 146 but exposed for electrical connection. Moreover, the main body of the semiconductor wafer 106 is similar to that of the first embodiment in the point that it is formed of the silicon substrate 45.

A protective sheet 30 is adhesively stuck to the semiconductor wafer 106 so as to protect the entire circuit-formation-face 106a as shown in Fig. 16B. Subsequently, as shown in Figs. 16C and 17A, a mask pattern of a resist film 31a and mask slit portions 31b is formed to define dividing regions R2 on the mask-placement-face 106b of the semiconductor wafer 106.

The semiconductor wafer 106 provided with the mask formed as above is subjected to plasma processing by using the plasma processing apparatus 101.

In concrete, a plasma dicing process is first carried out by anisotropic etching from the mask-placement-face 106b of the semiconductor wafer 106, removing by anisotropic etching the silicon substrate 45 in the

portions that correspond to the dividing regions R2. Through this process, as shown in Fig. 17B, groove portions 106c are to be formed in the portions that correspond to the dividing regions R2. With the progress of the etching, the polyimide film 146 becomes exposed from the etching bottom portion (insulator exposure processing in step S6 of Fig. 7). When the polyimide film 146 that is the insulating film is exposed as described above, the exposed polyimide film 146 is charged with the positive charge of the ions in the plasma, and the trajectory of the applied ions is to be bent. Consequently, as shown in Fig. 17C, notches 142 are formed at the corner portions of groove portions 106c, and rounded portions 140a are formed at the corner portions of the separated silicon substrate 45 put in contact with the polyimide film 146 (notch formation processing in step S8 of Fig. 7). When the rounded portions 140a of the prescribed size are formed, the plasma dicing process by the anisotropic etching is ended.

Subsequently, the etching characteristic is switched from the anisotropic etching to the isotopic etching, and a plasma dicing process by the isotopic etching is started (isotopic etching processing in step S11 of Fig. 7). By the plasma dicing process using the isotropic etching, as shown in Fig. 18A, the groove portions 106c formed by the plasma dicing process using the

anisotropic etching are etched in the direction along the surface of the semiconductor wafer 6 in the neighborhood of the entrance thereof (i.e., in the neighborhood of the upper portion in the figure), and the groove portions 6c are etched so as to be slightly expanded in the widthwise direction thereof. As a result, rounded (R) portions 140b that are curved convex surface portions put in contact with the dividing regions R2 can be formed on the mask-placement-face 106b of the device-formation-regions R1. That is, the rounded portions 140b are formed at the end portions (corner portions) located on the mask-placement-face 106b side of the device-formation-regions R1 and the four corner portions of the rectangular plane.

Next, removal of the polyimide film 146 exposed on the dividing regions R2, i.e., the insulator removal processing is started (step S14 of Fig. 7). However, due to the polyimide film 146 used as the insulating film for the semiconductor wafer 106 of the present second embodiment, an etching gas capable of positively effecting plasma etching on the polyimide film 146 is used. For example, a gas that contains oxygen is used as the etching gas. In the plasma processing apparatus 101, the gases of the kinds used in each processing are stored in the gas supply units 20A, 20B, 20C and 20D. By thus carrying out the insulating film removing process, as shown in Fig. 18B,

the exposed polyimide film 146 is removed from the portions that correspond to the dividing regions R2. Consequently, the semiconductor wafer 106 is divided into individual pieces of device-formation-regions R1, and the individual pieces of the semiconductor chips 140 are to be formed.

Subsequently, the resist film 31a is removed from the mask-placement-face 106b of the semiconductor chips 140 separated as shown in Fig. 18C by carrying out plasma ashing (mask removal processing in step S18 of Fig. 7). Further, as shown in Figs. 19A and 19B, the adhesive sheet 37 is stuck to the mask-placement-face 106b, and the protective sheet 30 is peeled off from the circuit-formation-face 106a. As a result, the manufacturing process of the semiconductor chips 140 is completed.

As described above, even when the semiconductor wafer 106 uses the polyimide film 146 that is the surface protection film as the insulating film placed in the dividing regions R2, the rounded portions 140a can be formed at the end portions on the circuit-formation-face 106a side by performing the notch formation as in the first embodiment during the plasma dicing process, and the rounded portions 140b can be formed at the end portions on the mask-placement-face 106b side by using the isotropic etching. Therefore, semiconductor chips 140 that have corner portions formed of smooth curved convex surface

portions with all the ridgelines removed can be formed, and semiconductor chips of which the transverse rupture strength can be improved can be manufactured.

MODIFICATION EXAMPLE OF SECOND EMBODIMENT

Although the case where the polyimide film 146 formed as the surface protection film is used as the insulating film placed in the dividing regions R2 has been described above, the present second embodiment is not limited only to the case. It may be a case where, for example, a silicon nitride film formed of silicon nitride (Si_3N_4) is used as the surface protection film in place of such a case. The case where the silicon nitride film is used is described below as a semiconductor chip manufacturing method according to a modification example of the present second embodiment is described below. Moreover, for the description, a flow chart showing the procedure of the semiconductor chip manufacturing method is shown in Fig. 20, and a schematic explanatory view showing a state in which a notch formation processing and a silicon-nitride film (insulator) removal processing are concurrently carried out is shown in Fig. 21.

First of all, as shown in the flow chart of Fig. 20, the loading of a semiconductor wafer 206 in step S31 to the completion of the insulator exposure processing in step S37 are similar to the procedure of the first embodiment of

Fig. 7. Subsequently, the exposed silicon-nitride film 246 is to be removed by anisotropic etching in step S38. With regard to the gas for etching the silicon nitride film 246, the same gas as the sulfur hexafluoride gas (SF_6) that is the gas for etching the silicon substrate 145 is used. Therefore, in the schematic explanatory view of Fig. 21 showing a plasma dicing processing state of the semiconductor wafer 206 where the silicon nitride film 246 is formed as the insulating film, when the silicon nitride film 246 is exposed from the bottom portions of the formed groove portions 206c by etching the silicon substrate 245 in the portions that correspond to the dividing regions R2 by using SF_6, notch formation is carried out by bending the trajectory of the incident ions by charging the exposed silicon nitride film 246 with positive charge, and the exposed silicon nitride film 246 is concurrently etched. Consequently, by carrying out the plasma dicing process by the anisotropic etching for notch formation, the exposed silicon nitride film 246 can be removed (notch formation and insulator removal processing).

As described above, in order to concurrently carry out the formation of rounded portions 240a on the semiconductor chips 240 by notch formation and the removal of the exposed silicon nitride film 246, it is preferable to determine the formation thickness of the silicon nitride

film 246 in consideration of the plasma processing time necessary for forming the desired notches.

In the flow chart of Fig. 20, the isotropic etching is carried out in steps S40 through S42, subsequently the mask removal processing is carried out in steps S43 through S45, the plasma dicing processing is completed by the prescribed procedure in steps S46 through S49, and semiconductor chips 240 are formed.

THIRD EMBODIMENT

Next, a manufacturing method for semiconductor chips according to the third embodiment of the present invention is described below with reference to the flow chart of the procedure shown in Fig. 22 and the schematic explanatory views shown in Figs. 23A through 23C, Figs. 24A through 24C, Figs. 25A and 25B and Figs. 26A and 26B. By the manufacturing method for semiconductor chips of the present third embodiment, notch formation and so on are carried out by using a protective sheet that has an insulating property as the insulating film to be placed in the dividing regions R2 unlike the first embodiment and the second embodiment. Only the different point is described below. Moreover, the manufacturing method for semiconductor chips of the third embodiment can be carried out by the processing apparatus 101 used in the first embodiment. Therefore, no description is provided for the

construction and so on of the plasma processing apparatus 101.

As shown in Fig. 23A, a semiconductor device 344 is formed in each of the device-formation-regions R1 on a circuit-formation-face 306a of a semiconductor wafer 306. The semiconductor device 344 include devices such as a MOS structure transistor constructed of a silicon substrate 45, a silicon oxide 335 formed directly on the circuit-formation-face 306a, and a metal film formed on the silicon oxide 335. Further, the semiconductor device 344 also has connection terminals 343 for electrically connecting the devices to external electronic apparatuses. Moreover, the surface of the semiconductor device 344 is covered with a surface protection film 346. The connection terminal 343 is not covered with the surface protection film 335 but exposed outside. Moreover, neither the silicon oxide 335 nor the surface protection film 346 is formed in the portions that correspond to dividing regions R2.

First, as shown in Fig. 23B, a protective sheet is adhesively stuck to the circuit-formation-face 306a of the semiconductor wafer 306 for the protection of the surface. In the present third embodiment, an insulating protective sheet 330 that has an electrical insulation property is used as such a protective sheet. Moreover, the insulating protective sheet 330 described above serves as

one example of the insulating film to be placed in the dividing regions R2.

Subsequently, a resist film 31 is formed covering the mask-placement-face 306b of the semiconductor wafer 306 as shown in Fig. 23C, and a mask pattern constructed of the mask slit portions 31b and resist film 31a is formed so that the portions corresponding to the dividing regions R2 are exposed as shown in Fig. 24A.

The semiconductor wafer 306 provided with the thus-formed mask is subjected to plasma processing by using the plasma processing apparatus 101. In concrete, a prescribed procedure is carried out in steps S51 through S55 shown in Fig. 22, and subsequently, as shown in Fig. 24B, the portions that correspond to the dividing regions R2 are removed by carrying out a plasma dicing process by anisotropic etching (protective sheet exposure processing in steps S56 and S57 of Fig. 22). As a result, the semiconductor wafer 306 is divided into individual pieces of the device-formation-regions R1, so that the individual pieces of the semiconductor chips 340 are formed.

Moreover, if the portions that correspond to the dividing regions R2 are removed as described above, the surface of the insulating protective sheet 330 is to be exposed (i.e., the insulating film is exposed) in the dividing regions R2. When the insulating protective sheet

330 is exposed as described above, the exposed insulating protective sheet 330 is charged with the positive charge of the ions in the plasma, the trajectory of the subsequently incident ions is bent, and the notches 342 are formed at the corner portions located on the illustrated lower side of the semiconductor chips 340, i.e., the rounded portions 340a are formed as shown in Fig. 24C. When the rounded portions 340a of the desired size are formed (notch formation processing in steps S58 and 59 of Fig. 22), the plasma dicing process by the anisotropic etching is ended.

Subsequently, the etching characteristic is switched from the anisotropic etching to the isotopic etching, and the isotopic etching processing is carried out (steps S60 through S62 of Fig. 22). By carrying out the isotopic etching processing, rounded portions 340b are formed at the corner portions on the mask-placement-face 306b side of the separated semiconductor chips 340 as shown in Fig. 25A.

Subsequently, plasma ashing (mask removal processing in steps S63 through S65 of Fig. 22) is carried out to remove the resist films 31a as shown in Fig. 25B, and the separating process of the semiconductor chips 340 by the plasma dicing is completed by carrying out a prescribed procedure in steps S66 through S69. Further, as shown in Figs. 26A and 26B, an adhesive sheet 37 is stuck

to the mask-placement-face 306b of the semiconductor wafer 306, and the insulating protective sheet 330 is peeled off from the circuit-formation-face 306a. As a result, the semiconductor chips 340, where the rounded portions 340a are formed at the corner portions of the circuit-formation-face 306a and the rounded portions 340b are formed at the corner portions of the mask-placement-face 306b, are manufactured.

Since the notch formation is performed as described above, the semiconductor chips, which can form the rounded portions 340a on the manufactured semiconductor chips 340 even when the insulating protective sheet 330 is used as the insulating film placed in the dividing regions R2 and of which the transverse rupture strength is improved, can be manufactured.

Moreover, a manufacturing method for semiconductor chips, which can obviate the need for carrying out the plasma etching process for removing the insulating film by using the insulating protective sheet 330 that can freely be adhesively stuck to or peeled off from the semiconductor wafer 306 as the insulating film and of which the efficiency is improved, can be provided.

The semiconductor chips manufactured by the semiconductor chip manufacturing method of the present invention can improve the transverse rupture strength by

virtue of the curved convex surface portions formed in the portions that correspond to the positions where the ridgelines are formed so that all the ridgelines are removed. Therefore, it is particularly effective to use the semiconductor chips for IC cards with built-in semiconductor chips such as personal authentication cards. The above is because such IC cards have the features that they are often portably used and often contain important information separated inside, and the reliability can be improved by using the semiconductor chips of the present invention of which the strength against bending is improved.

It is to be noted that, by properly combining the arbitrary embodiments of the aforementioned various embodiments, the effects possessed by them can be produced.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

The disclosure of Japanese Patent Application No.2005-117221 filed on April 14, 2005 including specification, drawing and claims are incorporated herein

by reference in its entirety.

CLAIMS

1. A manufacturing method for semiconductor chips comprising:

performing plasma etching on a second surface of a semiconductor wafer that has a first surface on which semiconductor devices placed in a plurality of device-formation-regions defined by dividing regions and an insulating film placed in the dividing regions are formed and the second surface on which a mask for defining the dividing regions is placed, the second surface being located opposite from the first surface, whereby portions that correspond to the dividing regions are removed and the insulating film is exposed from etching bottom portions;

removing corner portions on the first surface side put in contact with the insulating film in the device-formation-regions by performing the plasma etching in a state in which exposed surfaces of the insulating film are charged with electric charge due to ions in plasma; and

subsequently, removing the exposed insulating film so that the device-formation-regions are separated into individual semiconductor chips, whereby the semiconductor chips each of which includes the individualized semiconductor device are manufactured,

wherein isotropic plasma etching is further

performed from the second surface on the semiconductor wafer or the individual semiconductor chips with the mask placed at any timing before or after exposure of the insulating film, removal of the corner portions or removal of the insulating film is carried out.

2. The manufacturing method for the semiconductor chips as defined in claim 1, wherein corner portions put in contact with the mask placed on the second surface side are removed in the device-formation-regions of the semiconductor wafer or the semiconductor chips by carrying out the isotropic plasma etching.

3. The manufacturing method for the semiconductor chips as defined in claim 1, wherein

the exposure of the insulating film is performed by carrying out anisotropic plasma etching on the semiconductor wafer,

the corner portions are removed by continuously performing the anisotropic etching,

the corner portions brought in contact with the mask are removed by carrying out the isotopic etching by switching over from the anisotropic etching to the isotopic etching, and

then the insulator is removed.

4. The manufacturing method for the semiconductor chips as defined in claim 3, wherein

the switchover between the anisotropic etching and the isotopic etching is performed by switching over between plasma conditions for the anisotropic etching and plasma conditions for the isotopic etching determined by combining one parameter or a plurality of parameters including a pressure of a gas for plasma generation, a gas composition, a high-frequency output or a discharge frequency.

5. The manufacturing method for the semiconductor chips as defined in claim 1, wherein, in the plasma etching from the second surface, the insulating film formed of silicon oxide (SiO_2) on the first surface of the semiconductor wafer is exposed from the etching bottom portion.

6. The manufacturing method for the semiconductor chips as defined in claim 1, wherein, in the plasma etching from the second surface, a surface protection film formed of polyimide (PI) to protect surfaces of the semiconductor devices formed on the first surface of the semiconductor wafer is exposed from the etching bottom portion as the

insulating film.

7. The manufacturing method for the semiconductor chips as defined in claim 1, wherein, after the removal of the insulating film, the mask is removed by performing ashing on the second surface of the semiconductor wafer.

8. The manufacturing method for the semiconductor chips as defined in any one of claims 1 through 7, wherein, the plasma etching is performed from the second surface of the semiconductor wafer, on which the mask is placed, the mask having roughly convex curved portions formed in portions that correspond to the corner portions of each of the device-formation-regions, each of the device-formation-regions having a roughly rectangular region.

9. A manufacturing method for semiconductor chips comprising:

performing plasma etching on a second surface of a semiconductor wafer that has a first surface on which semiconductor devices placed in a plurality of device-formation-regions defined by dividing regions and an insulating film placed in the dividing regions are formed and the second surface on which a mask for defining the dividing regions is placed, the second surface being

located opposite from the first surface, whereby portions that correspond to the dividing regions are removed and the insulating film is exposed from etching bottom portions; and

removing the exposed insulating film while removing corner portions on the first surface side put in contact with the insulating film in the device-formation-regions by performing the plasma etching in a state in which exposed surfaces of the insulating film are charged with electric charge due to ions in plasma, whereby the device-formation-regions are separated into individual semiconductor chips and consequently the semiconductor chips each of which includes individualized semiconductor device are manufactured,

wherein isotropic plasma etching is further performed from the second surface on the semiconductor wafer or the individual semiconductor chips with the mask placed at any timing before or after exposure of the insulating film, removal of the corner portions or removal of the insulating film is carried out.

10. The manufacturing method for the semiconductor chips as defined in claim 9, wherein corner portions put in contact with the mask placed on the second surface side is removed in the device-formation-regions of the

semiconductor wafer or the semiconductor chips by carrying out the isotropic plasma etching.

11. The manufacturing method for the semiconductor chips as defined in claim 9, wherein

the exposure of the insulating film is performed by carrying out anisotropic plasma etching on the semiconductor wafer,

the corner portions are removed by continuously performing the anisotropic etching, and

then the corner portions brought in contact with the mask are removed by carrying out the isotopic etching by switching over from the anisotropic etching to the isotopic etching.

12. The manufacturing method for the semiconductor chips as defined in claim 11, wherein

the switchover between the anisotropic etching and the isotopic etching is performed by switching over between plasma conditions for the anisotropic etching and plasma conditions for the isotopic etching determined by combining one parameter or a plurality of parameters including a pressure of a gas for plasma generation, a gas composition, a high-frequency output or a discharge frequency.

13. The manufacturing method for the semiconductor chips as defined in claim 9, wherein, in the plasma etching from the second surface, a surface protection film formed of silicon nitride (Si_3N_4) to protect surfaces of the semiconductor devices formed on the first surface of the semiconductor wafer is exposed from the etching bottom portion as the insulating film.

14. The manufacturing method for the semiconductor chips as defined in claim 9, wherein, after removing the corner portions put in contact with the mask by performing the isotopic etching, the mask is removed by performing ashing on the second surface of the semiconductor wafer.

15. The manufacturing method for the semiconductor chips as defined in any one of claims 9 through 14, wherein, the plasma etching is performed from the second surface of the semiconductor wafer on which the mask is placed, the mask having roughly convex curved portions formed in portions that correspond to the corner portions of each of the device-formation-regions, each of the device-formation-regions having a roughly rectangular region.

16. A manufacturing method for semiconductor chips

comprising:

performing plasma etching on a second surface of a semiconductor wafer that has a first surface on which semiconductor devices placed in a plurality of device-formation-regions defined by dividing regions are formed and onto which a protective sheet having an insulating property is stuck and a second surface on which a mask for defining the dividing regions is placed, the second surface being located opposite from the first surface, whereby portions that correspond to the dividing regions are removed and the insulating protective sheet is exposed from etching bottom portions, and then the device-formation-regions are separated into individual semiconductor chips; and

removing corner portions put in contact with the insulating protective sheet at each of the semiconductor chips by performing the plasma etching in a state in which the exposed surfaces of the insulating film are charged with electric charge due to ions in plasma, whereby semiconductor chips including individualized semiconductor devices are consequently manufactured,

wherein isotropic plasma etching is further performed from the second surface on the semiconductor wafer or the individual semiconductor chips with the mask placed at any timing before or after exposure of the

protective sheet or removal of the corner portions is carried out.

17. The manufacturing method for the semiconductor chips as defined in claim 16, wherein the corner portions put in contact with the mask placed on the second surface side are removed in the device-formation-regions of the semiconductor wafer or the semiconductor chips by carrying out the isotropic plasma etching.

18. The manufacturing method for the semiconductor chips as defined in claim 16, wherein

the exposure of the protective sheet is performed by carrying out anisotropic plasma etching on the semiconductor wafer,

the corner portion removal processing is carried out by continuously performing the anisotropic etching, and

then the corner portions brought in contact with the mask are removed by carrying out the isotopic etching by switching over from the anisotropic etching to the isotopic etching.

19. The manufacturing method for the semiconductor chips as defined in claim 18, wherein

the switchover between the anisotropic etching

and the isotopic etching is performed by switching over between plasma conditions for the anisotropic etching and plasma conditions for the isotopic etching determined by combining one parameter or a plurality of parameters including a pressure of a gas for plasma generation, a gas composition, a high-frequency output or a discharge frequency.

20. The manufacturing method for the semiconductor chips as defined in claim 16, wherein, after the corner portions brought in contact with the mask are removed by performing the isotopic etching, the insulating protective sheet is removed by being peeled off from the first surface of the semiconductor wafer.

21. The manufacturing method for the semiconductor chips as defined in any one of claims 16 through 20, wherein, the plasma etching is performed from the second surface of the semiconductor wafer on which the mask is placed, the mask having roughly convex curved portions formed in portions that correspond to the corner portions of each of the device-formation-regions, each of the device-formation-regions having a roughly rectangular region.

22. A semiconductor chip having a roughly rectangular shape obtained by dividing a semiconductor wafer in which a plurality of semiconductor devices are formed into individual pieces of the semiconductor devices, wherein

the rectangular shape of the chip is defined by rounded ridgelines thereof.

23. The semiconductor chip as defined in claim 22, wherein a curved convex surface portion is formed in portions that correspond to the rounded ridgelines of the rectangular shape.

24. A semiconductor chip comprising:

a first surface on which semiconductor devices are formed;

a second surface located parallel to the first surface on a side opposite from the first surface; and

a connection surface, which is located at peripheries of the first surface and the second surface and connects an outer end portion of the first surface and an outer end portion of the second surface, wherein

the connection surface has a curved convex surface portion so that no ridgeline is formed at the outer end portions of the first and the second surfaces.

25. The semiconductor chip as defined in claim 24, wherein the connection surface is comprised of the curved convex surface portion.