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(54) MANUFACTURING METHOD OF CHIPS

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CPC ***H01L 21/78*** (2013.01); ***H01L 21/30655*** (2013.01); *H01L 21/3081* (2013.01)

(57) **ABSTRACT**

Provided is a manufacturing method of a plurality of chips by dividing a workpiece that is defined into a plurality of regions by scribe lines. The manufacturing method includes the following steps of forming a mask by supplying a plasmatic deposition gas to a side of a front surface or a side of a back surface of the workpiece, forming cut grooves, with the mask being removed along the scribe lines, by causing a cutting blade to cut into the workpiece at a predetermined cut-in depth along the scribe lines on a side of the surface on which the mask has been formed, and then removing the workpiece along the scribe lines to divide the workpiece into the chips by applying plasma etching to the workpiece while supplying a plasmatic etching gas to the side of the surface of the workpiece in which the cut grooves have been formed.

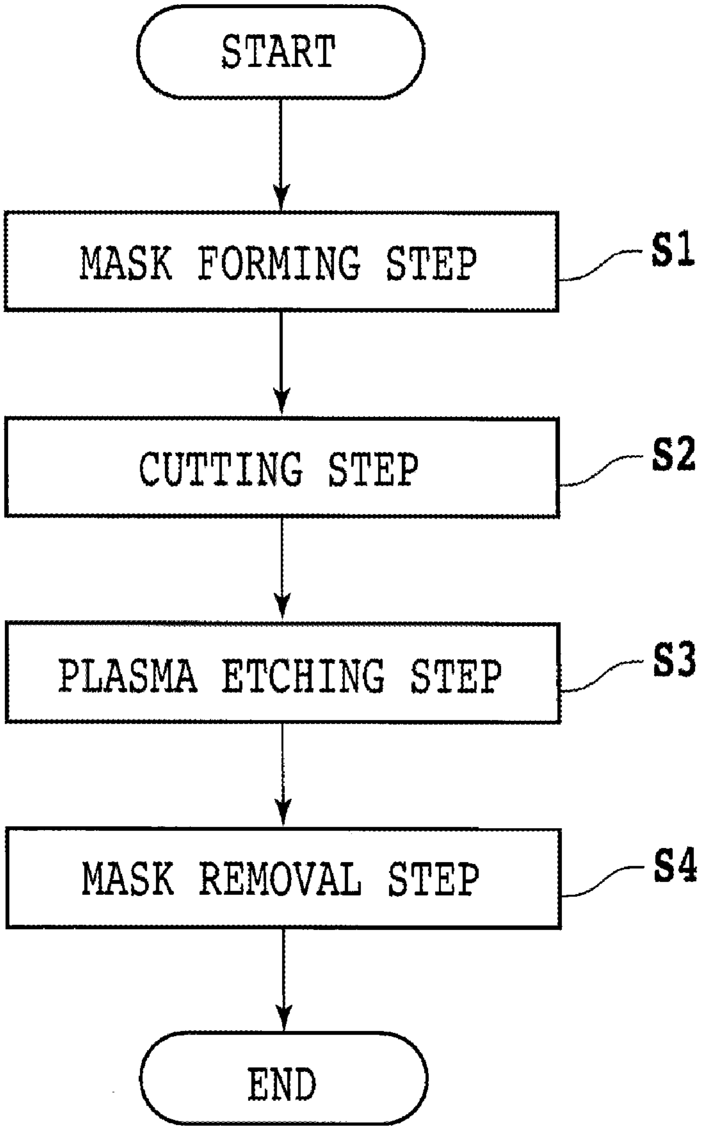


FIG.1A

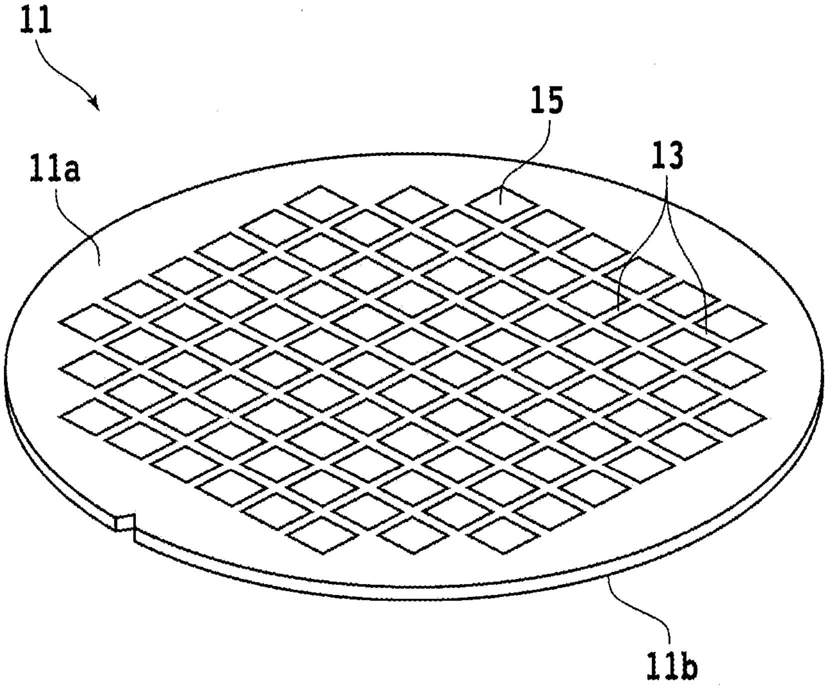


FIG.1B

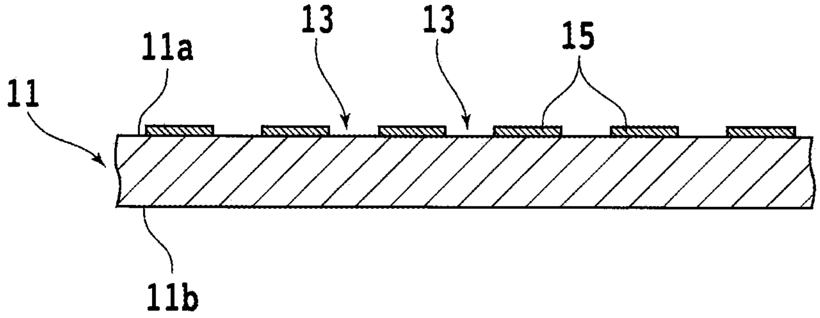


FIG.2

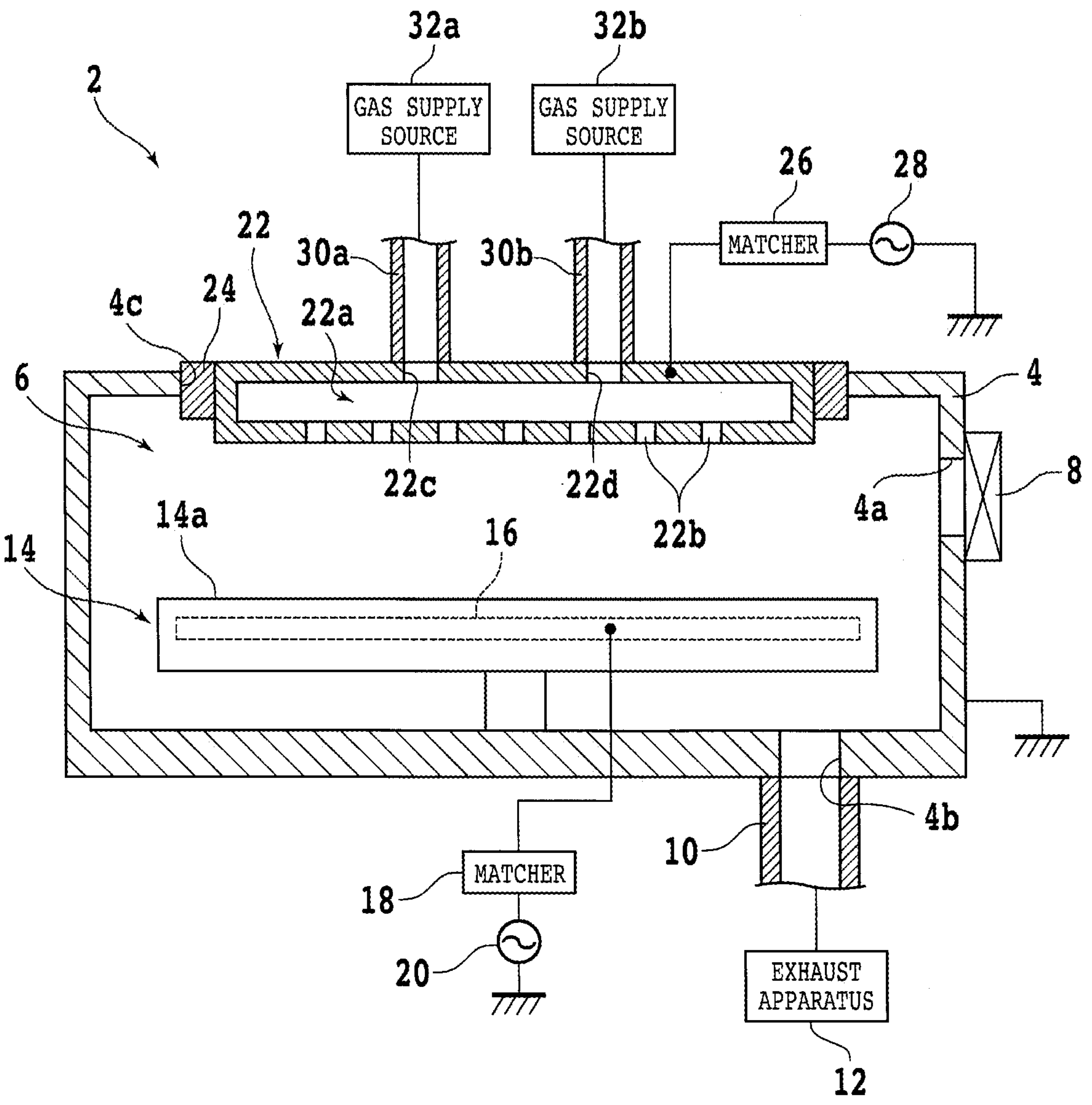

32a
32b
GAS SUPPLY SOURCE
GAS SUPPLY SOURCE
2
26
28
MATCHER
22
30a
30b
4c
24
22a
4
6
8
22c
22d
22b
4a
14a
16
14
4b
10
MATCHER
18
20
EXHAUST APPARATUS
12

FIG.3

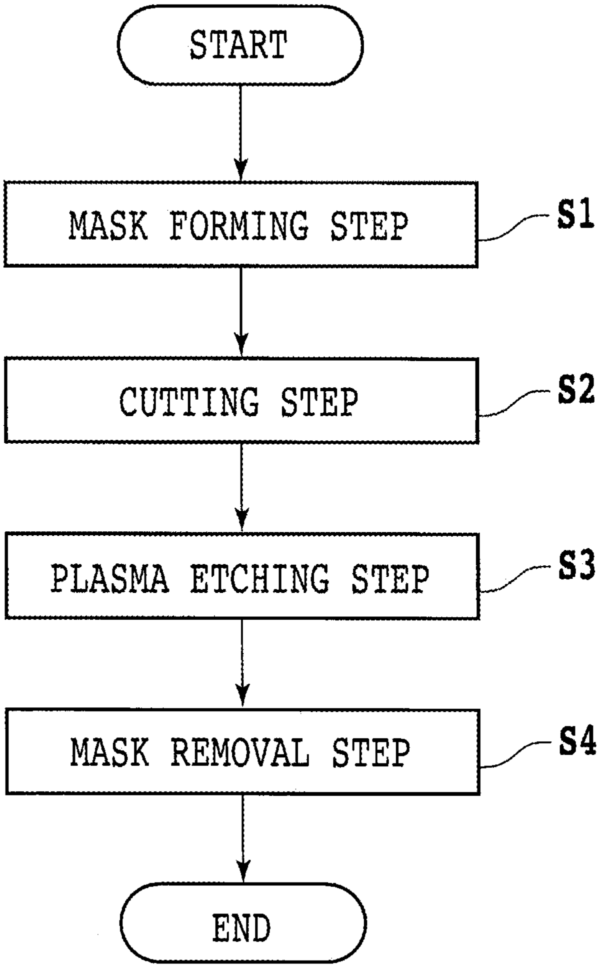

START
MASK FORMING STEP
S1
CUTTING STEP
S2
PLASMA ETCHING STEP
S3
MASK REMOVAL STEP
S4
END

FIG.4A

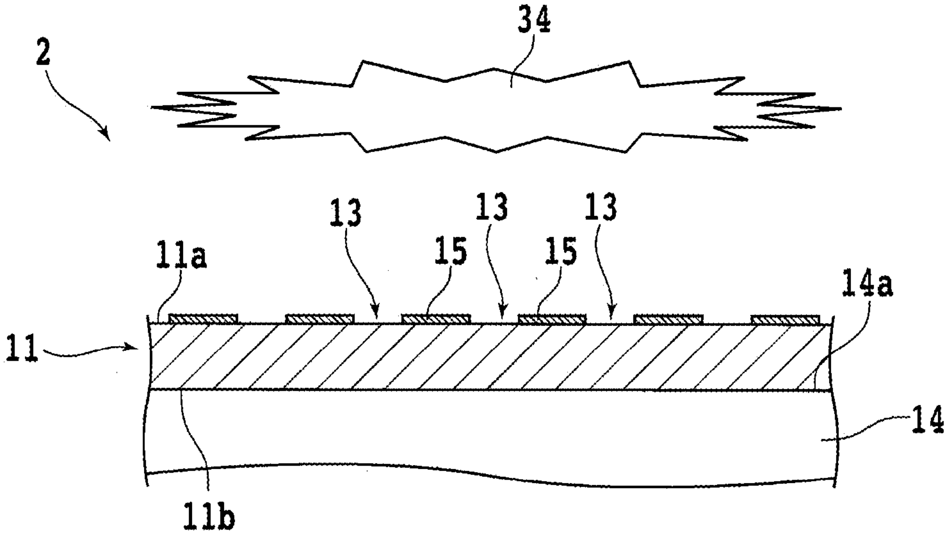


FIG.4B

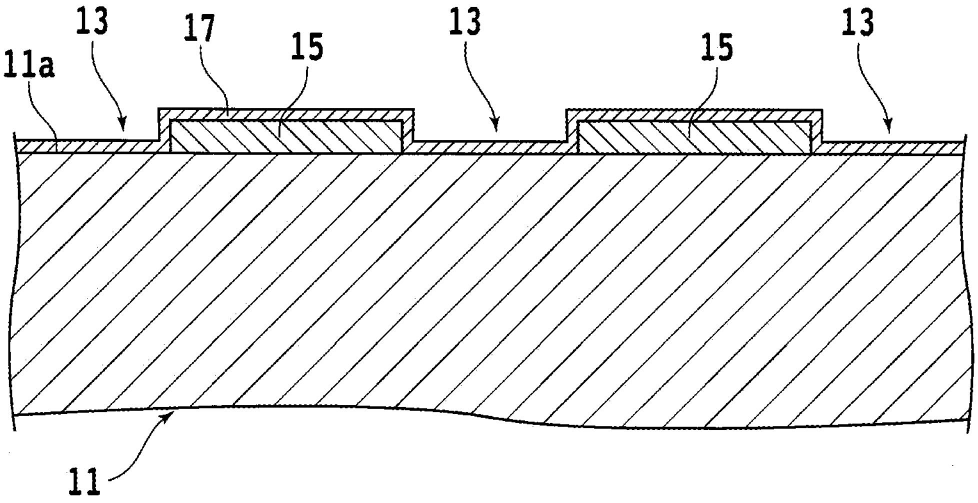


FIG.5A

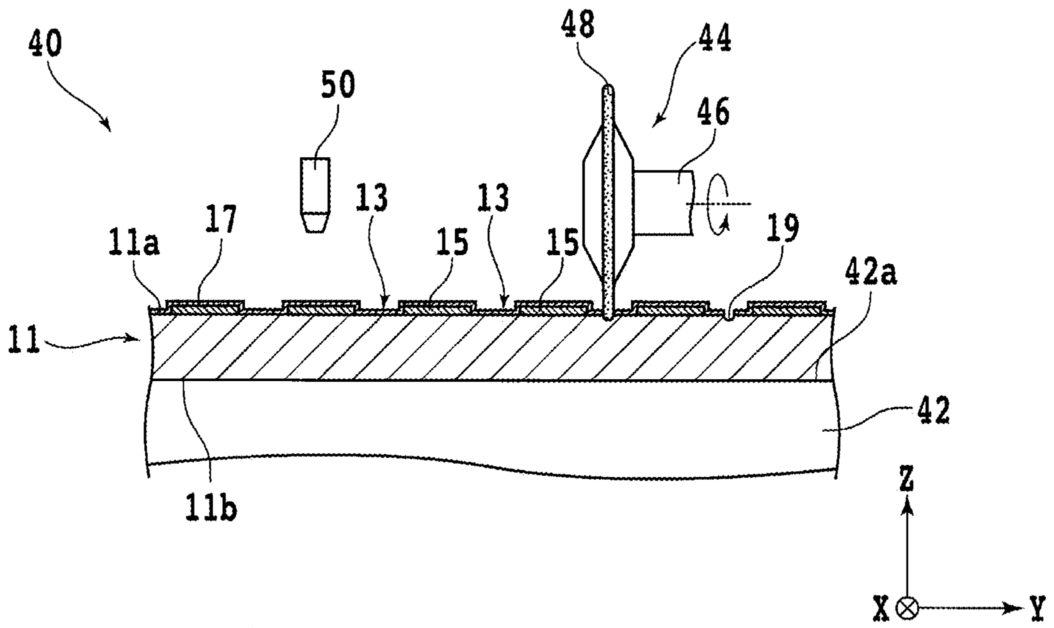


FIG.5B

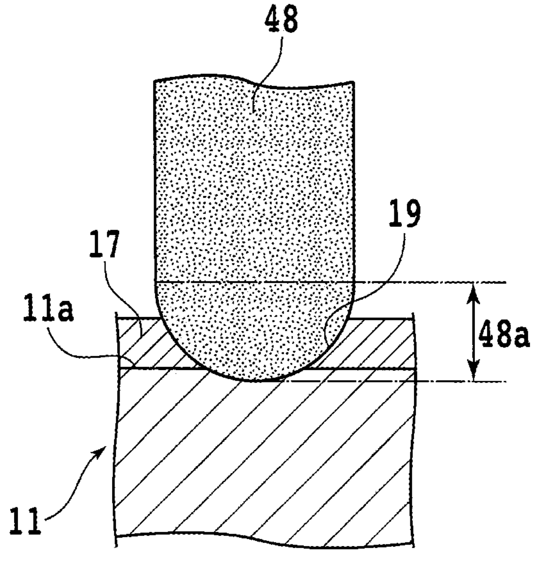


FIG.5C

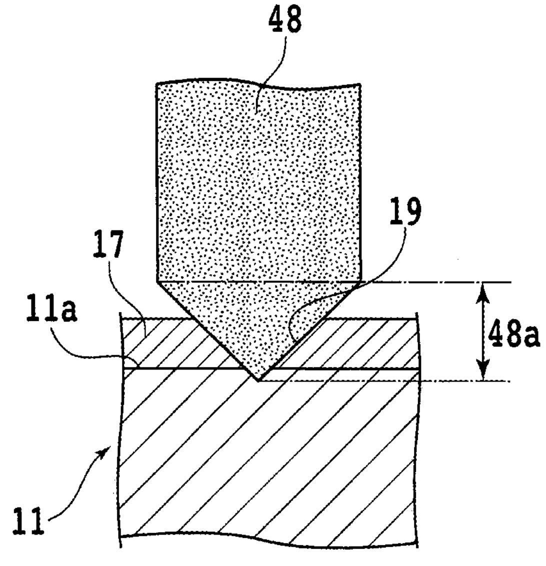


FIG.6

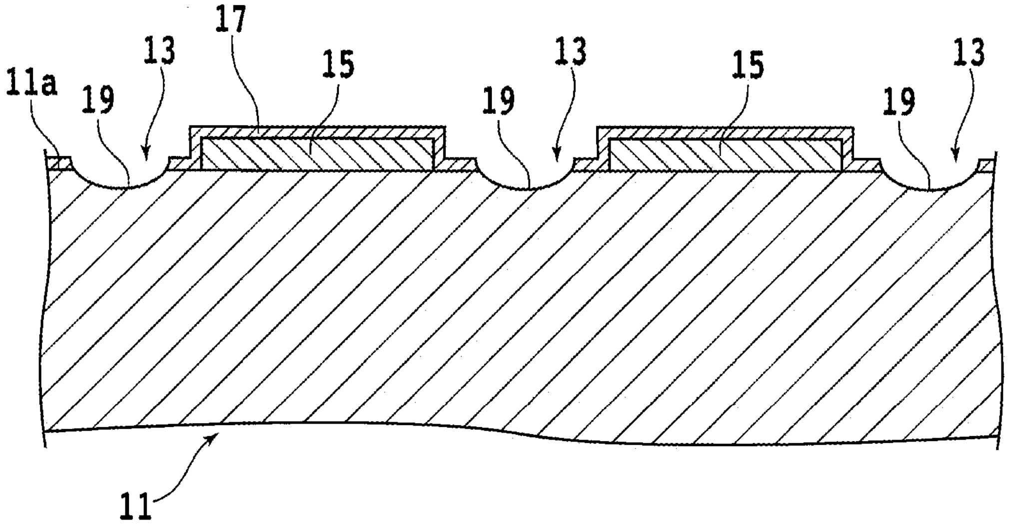


FIG.7

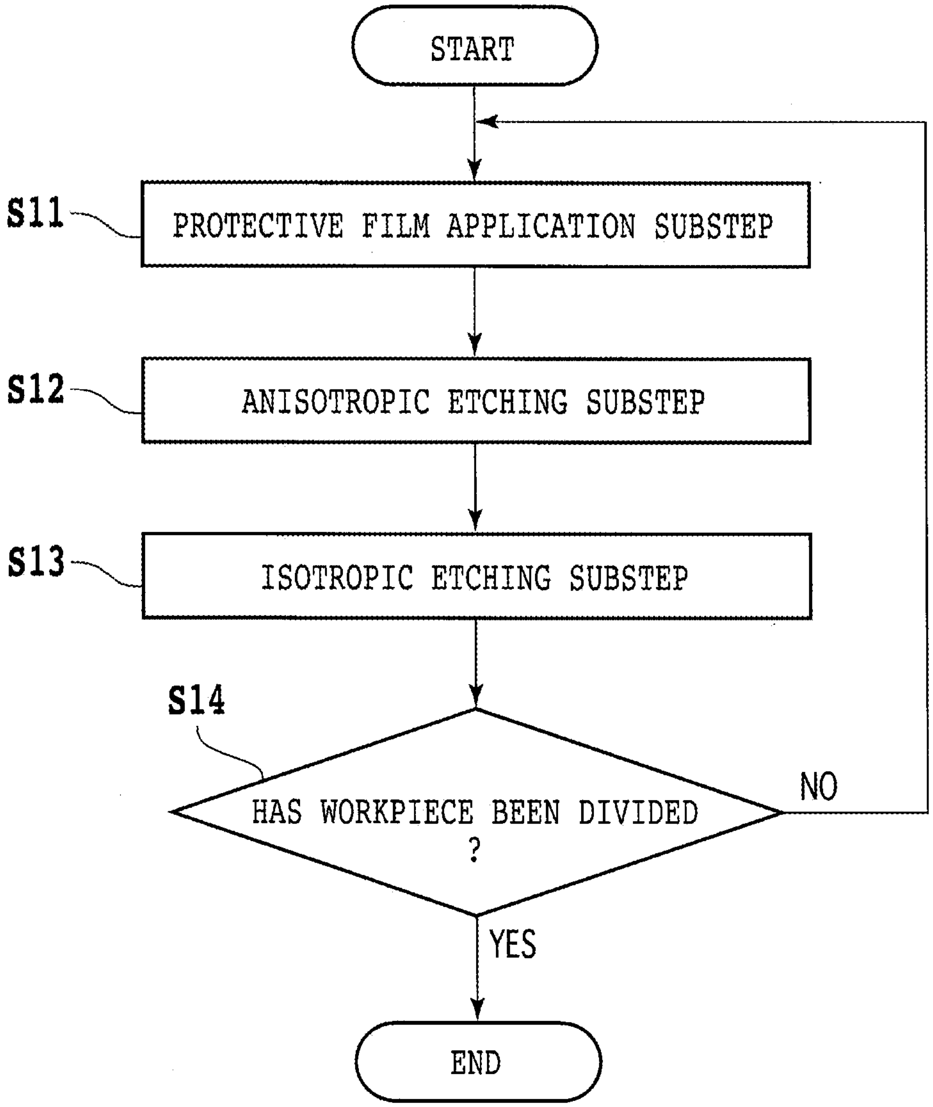

START
S11
PROTECTIVE FILM APPLICATION SUBSTEP
S12
ANISOTROPIC ETCHING SUBSTEP
S13
ISOTROPIC ETCHING SUBSTEP
S14
HAS WORKPIECE BEEN DIVIDED ?
NO
YES
END

FIG.8A

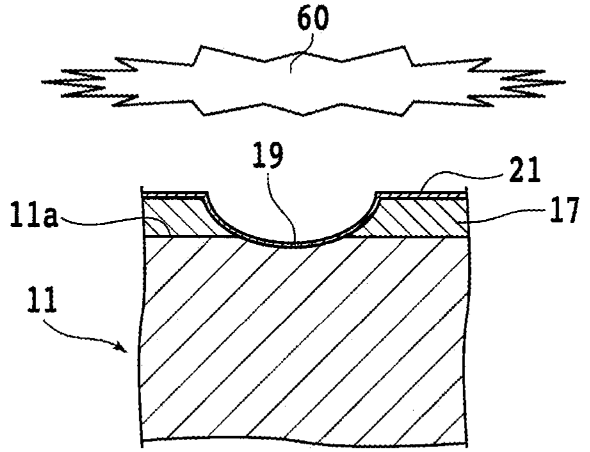


FIG.8B

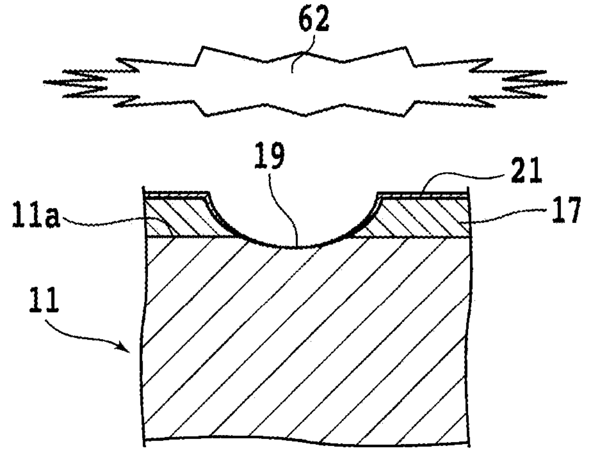


FIG.8C

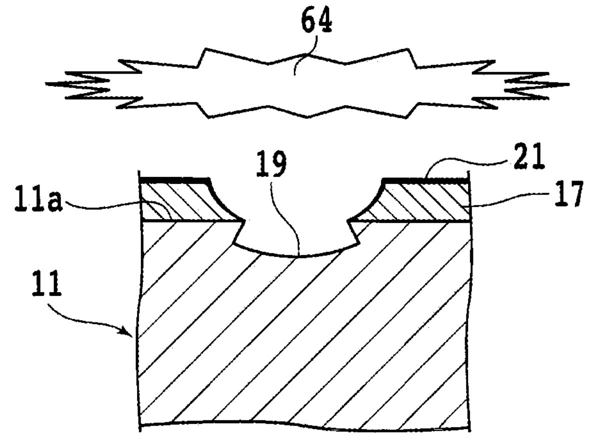


FIG.9

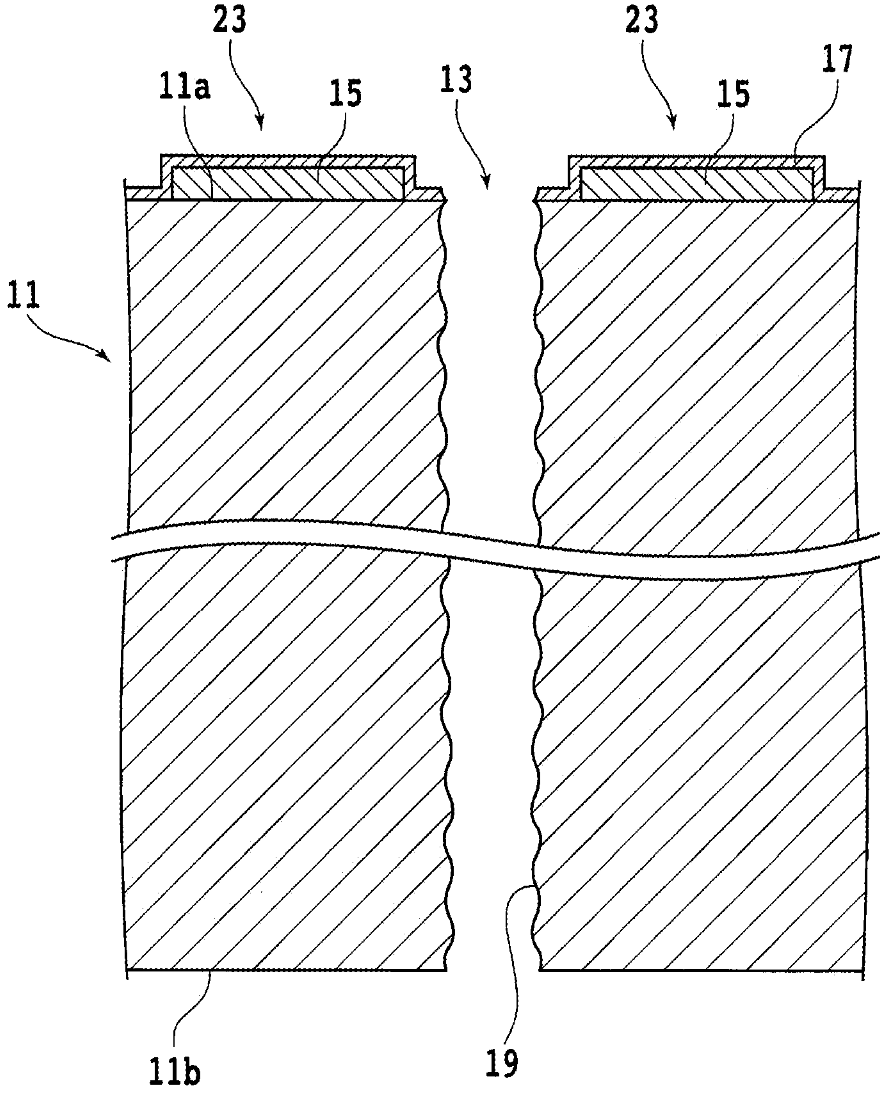


FIG.10A

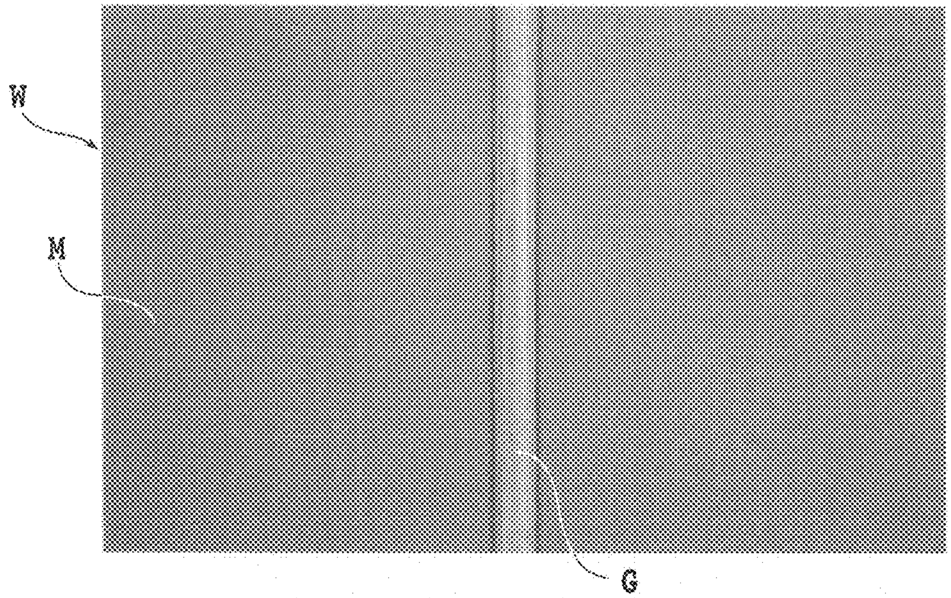


FIG.10B

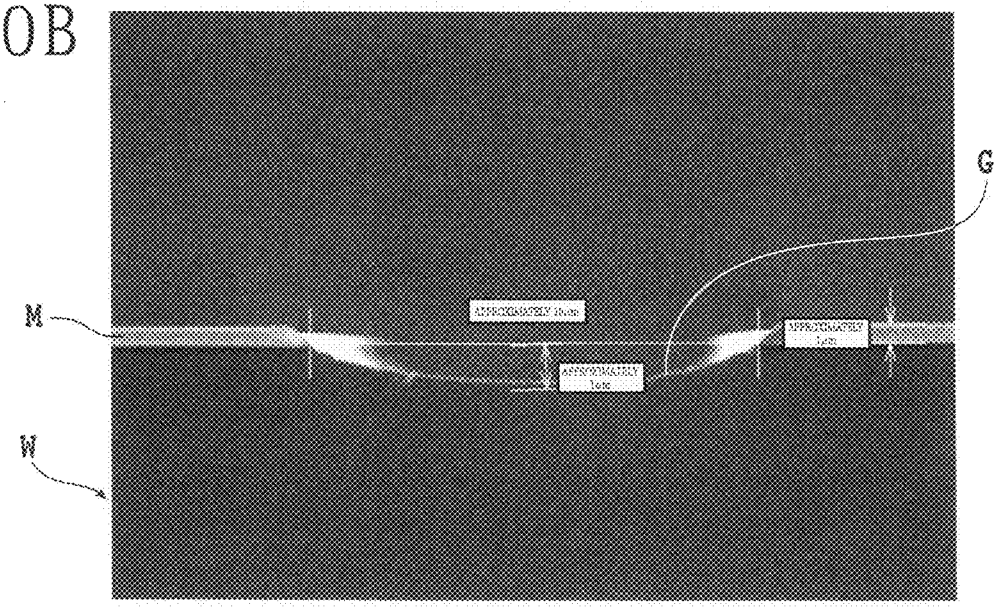


FIG.11A

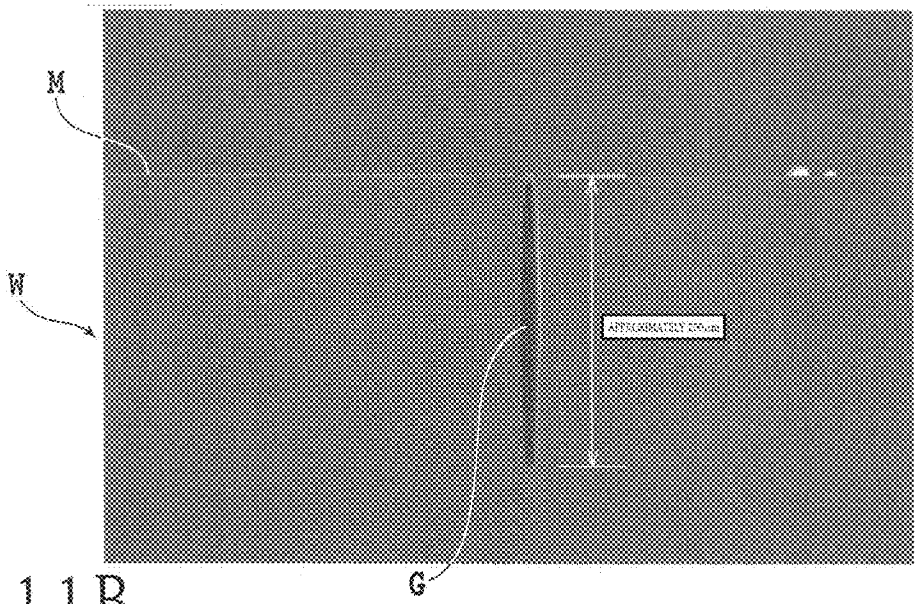
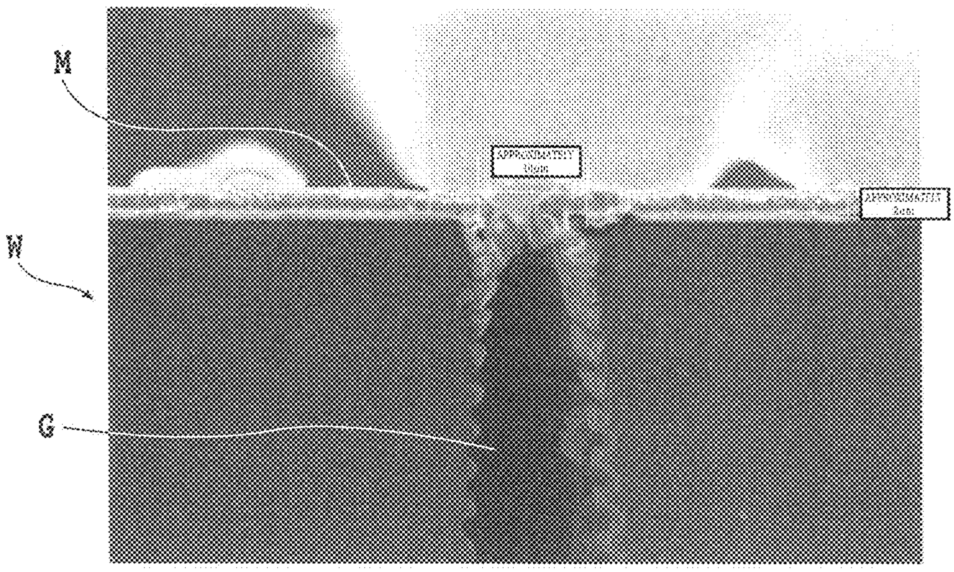


FIG.11B



MANUFACTURING METHOD OF CHIPS

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a manufacturing method of a plurality of chips, in which the chips are manufactured by dividing a workpiece.

Description of the Related Art

[0002] In a manufacturing process of device chips, a wafer is used with respective devices formed in a plurality of regions defined by a plurality of scribe lines (streets) arrayed in a grid pattern. By dividing this wafer along the scribe lines, a plurality of device chips with the respective devices included therein are obtained. These device chips are incorporated in various pieces of electronic equipment such as mobile phones or personal computers.

[0003] For the division of a wafer, a cutting apparatus that cuts the workpiece with an annular cutting blade, a laser processing apparatus that applies laser processing to the workpiece, or the like is used. In recent years, development of processing that divides a wafer by applying plasma etching and is called plasma dicing is also under way. In plasma dicing, a mask that is patterned such that scribe lines are exposed is first formed on a wafer. An etching gas in a plasma state is then supplied to the wafer through the mask, so that plasma etching is applied along the scribe lines to divide the wafer.

[0004] A mask for plasma etching is formed by patterning, for example, a photoresist along scribe lines. A method that forms a mask with a laser processing apparatus has also been proposed to achieve simplification of processing steps and cost reduction. Disclosed in JP 2016-207737A, for example, is a method for forming an etching mask, with scribe lines exposed, by forming a water-soluble protective film on a wafer and then emitting a laser beam to the water-soluble protective film along the scribe lines.

SUMMARY OF THE INVENTION

[0005] When applying plasma etching to a workpiece such as a wafer, a photoresist or a water-soluble protective film is formed as a mask on the wafer, as described above. However, the formation of the mask with the photoresist needs steps for application, exposure, and development of the resist, thereby taking time and effort for the formation of the mask. On the other hand, the use of the method that performs the patterning of the water-soluble protective film by the irradiation of the laser beam can form the mask through a smaller number of steps compared with the use of the photoresist. Moreover, the laser processing apparatus allows to easily change the irradiation conditions for the laser beam, so that even if a workpiece to which plasma etching is to be applied is changed, design changes can be promptly made to the mask according to the kind of the changed workpiece.

[0006] When performing the patterning of the water-soluble protective film by the laser processing apparatus, however, elaborate laser processing that uses a short pulsed laser is needed such that heat produced by the irradiation of a laser beam does not cause deleterious effects on the workpiece. This increases costs required for the implementation and operation of the laser processing apparatus, and therefore prevents the cost reduction of plasma etching.

[0007] With the foregoing problems in view, the present invention has as an object thereof the provision of a manufacturing method of chips, which can reduce costs of plasma etching.

[0008] In accordance with an aspect of the present invention, there is provided a manufacturing method of a plurality of chips, the method manufacturing the chips by dividing a workpiece that is defined into a plurality of regions by scribe lines, including a mask forming step of forming a mask by supplying a plasmatic deposition gas to a side of a front surface or a side of a back surface of the workpiece, a cutting step of forming cut grooves, with the mask being removed along the scribe lines, by causing a cutting blade to cut into the workpiece at a predetermined cut-in depth along the scribe lines on the side of a surface on which the mask has been formed, and a plasma etching step of removing the workpiece along the scribe lines to divide the workpiece into the chips by applying plasma etching to the workpiece while supplying a plasmatic etching gas to the side of the surface of the workpiece in which the cut grooves have been formed.

[0009] Preferably, the cutting blade may have a tip end portion having a width tapering toward a tip end, and in the cutting step, the cutting blade may be caused to cut into the mask such that only the tip end portion comes into contact with the mask. Also preferably, in the cutting step, the cut-in depth of the cutting blade may be set to smaller than 10 μm.

[0010] Also preferably, in the plasma etching step, the workpiece may be divided into the chips along the scribe lines by repeating a protective film application substep of applying a protective film to the cut grooves by supplying a plasmatic deposition gas to the side of the surface of the workpiece in which the cut grooves have been formed, an anisotropic etching substep of, after the protective film application substep, removing portions of the protective film covering corresponding bottoms of the cut grooves, through anisotropic plasma etching of the protective film by supplying a plasmatic gas for anisotropic etching to the cut grooves, and an isotropic etching substep of, after the anisotropic etching substep, subjecting the bottoms of the cut grooves to isotropic plasma etching by supplying a plasmatic gas for isotropic etching to the cut grooves. Also preferably, the manufacturing method may further include a mask removal step of removing the mask after the plasma etching step.

[0011] In the manufacturing method for chips according to the aspect of the present invention, the patterning of the mask formed on the workpiece is performed through the removal of the mask along the scribe lines by causing the cutting blade to cut into the mask. Accordingly, it is possible to form a mask for plasma etching with an inexpensive cutting machine instead of a costly laser processing apparatus or the like, thereby reducing the costs of plasma etching.

[0012] The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1**A is a perspective view depicting a workpiece usable in a manufacturing method for chips according to an embodiment of an aspect of the present invention;

[0014] FIG. **1**B is a fragmentary cross-sectional view depicting the workpiece of FIG. **1**A;

[0015] FIG. **2** is a partial cross-sectional front view depicting a plasma processing apparatus for use in the manufacturing method according to the embodiment;

[0016] FIG. **3** is a flow chart illustrating the manufacturing method of chips according to the embodiment;

[0017] FIG. **4**A is a fragmentary partial cross-sectional front view depicting the workpiece in a mask forming step of the manufacturing method according to the embodiment;

[0018] FIG. **4**B is a fragmentary cross-sectional view depicting the workpiece after the mask forming step of FIG. **4**A;

[0019] FIG. **5**A is a fragmentary partial cross-sectional front view depicting the workpiece in a cutting step of the manufacturing method according to the embodiment;

[0020] FIG. **5**B is a fragmentary partial cross-sectional front view depicting a tip end portion of a cutting blade for use in the cutting step of FIG. **5**A;

[0021] FIG. **5**C is a fragmentary partial cross-sectional front view depicting a modification of the tip end portion of the cutting blade in FIG. **5**B;

[0022] FIG. **6** is a fragmentary cross-sectional view depicting the workpiece after the cutting step of FIG. **5**A;

[0023] FIG. **7** is a flow chart illustrating an example of a plasma etching step in the manufacturing method according to the embodiment;

[0024] FIG. **8**A is a fragmentary cross-sectional view depicting the workpiece in a protective film application substep of the plasma etching step of FIG. **7**;

[0025] FIG. **8**B is a fragmentary cross-sectional view depicting the workpiece in an anisotropic etching substep of the plasma etching step of FIG. **7**;

[0026] FIG. **8**C is a fragmentary cross-sectional view depicting the workpiece in an isotropic etching substep of the plasma etching step of FIG. **7**;

[0027] FIG. **9** is a fragmentary cross-sectional view depicting the workpiece after the plasma etching step illustrated in FIG. **7**;

[0028] FIG. **10**A is a micrograph depicting a side of an upper surface of a wafer after formation of a mask and cut grooves in an Example of the embodiment;

[0029] FIG. **10**B is a micrograph depicting a cross-section of the wafer after the formation of the mask and cut grooves in the Example;

[0030] FIG. **11**A is a micrograph depicting a cross-section of the wafer after plasma etching in the Example; and

[0031] FIG. **11**B is a micrograph depicting on an enlarged scale a cut groove formed in the wafer in the Example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0032] With reference to the attached drawings, an embodiment of an aspect of the present invention will hereinafter be described. A description will first be made of a configuration example of a workpiece usable in a manufacturing method for chips according to this embodiment. FIG. **1**A is a perspective view depicting a workpiece **11**, and FIG. **1**B is a cross-sectional view depicting the workpiece **11**.

[0033] The workpiece **11** is, for example, a disk-shaped wafer made from a semiconductor material such as a single crystal silicon, and includes a front surface (first surface) **11***a* and a back surface (second surface) **11***b*, which are substantially parallel to each other. The workpiece **11** is defined into a plurality of rectangular regions by a plurality of scribe lines (streets) **13** arrayed and set such that they intersect. On a side of the front surface **11***a* of the regions defined by the scribed lines **13**, devices **15** such as integrated circuits (ICs), large scale integrations (LSIs), light emitting diodes (LEDs), or micro electro mechanical systems (MEMS) devices are formed individually. By dividing the workpiece **11** along the scribe lines **13**, a plurality of chips (device chips) each including the device **15** are manufactured. However, no limitations are imposed on the material, shape, structure, size, and the like of the workpiece **11**. The workpiece **11** may be, for example, a wafer (substrate) made from a semiconductor (GaAs, InP, GaN, SiC, or the like) other than silicon, sapphire, a glass, a ceramic, a resin, a metal, or the like. No limitations are imposed either on the kind, number, shape, structure, size, arrangement, and the like of the devices **15**, and no devices **15** may be formed on the workpiece **11**.

[0034] In this embodiment, the workpiece **11** is divided along the scribe lines **13** by applying plasma etching to the workpiece **11** (plasma dicing). For the plasma etching of the workpiece **11**, a plasma processing apparatus is used to supply a plasmatic gas to the workpiece **11**.

[0035] FIG. **2** is a partial cross-sectional front view depicting a plasma processing apparatus **2**. The plasma processing apparatus **2** includes a chamber **4**, in which the workpiece **11** is to be placed. The chamber **4** is made from an electrically conductive material such as a metal and is grounded. An inside of the chamber **4** corresponds to a processing space **6**, in which plasma processing for the workpiece **11** is to be performed.

[0036] In a side wall of the chamber **4**, an opening **4***a* is disposed to transfer the workpiece **11**. On an outer side of the opening **4***a*, a gate (openable door) **8** is disposed to open or close the opening **4***a*. A moving mechanism (not depicted) such as an air cylinder is coupled with the gate **8**, and the moving mechanism causes the gate **8** to be raised or lowered along the side wall of the chamber **4**. By lowering the gate **8** and exposing the opening **4***a*, the workpiece **11** can be loaded into the processing space **6** through the opening **4***a*, or can be unloaded from the processing space **6** through the opening **4***a*. Further, the processing space **6** is hermetically closed by raising the gate **8** and closing the opening **4***a*.

[0037] Through a bottom wall of the chamber **4**, an opening **4***b* is disposed to communicate the inside and an outside of the chamber **4** with each other. The opening **4***b* is communicated to an exhaust apparatus **12** such as a vacuum pump via a piping **10**. When the exhaust apparatus **12** is activated with the processing space **6** kept hermetically closed, the processing space **6** is exhausted and depressurized.

[0038] In the processing space **6**, a holding table (chuck table) **14** is disposed to hold the workpiece **11**. The holding table **14** has an upper surface, which is a planar surface substantially parallel to a horizontal plane and constitutes a holding surface **14***a* on which the workpiece **11** is to be held. An electrostatic chuck that holds the workpiece **11** by an electric force can be used as the holding table **14**. The holding table **14** is made, for example, from a dielectric material such as a ceramic, and a disk-shaped electrode **16** is disposed inside the holding table **14**. The electrode **16** is arranged substantially in parallel to the holding surface **14***a*, and is connected to a radio frequency power supply **20** via a matcher **18**. It is to be noted that a cooling path (not depicted) may also be disposed inside the holding table **14** to allow flowing of a coolant such as water. The holding table **14** is cooled by allowing the coolant to flow through the cooling path.

[0039] Above the holding table **14**, a gas ejection head **22** is disposed. The gas ejection head **22** is made from an electrically conductive material such as a metal, and is inserted in an opening **4***c* disposed through a top wall of the chamber **4**. It is to be noted that an annular bearing **24** made from an electrically insulating material is disposed between the top wall of the chamber **4** and the gas ejection head **22**. The bearing **24** is disposed so as to surround the gas ejection head **22**, and insulates the chamber **4** and the gas ejection head **22**.

[0040] The gas ejection head **22** is connected to a radio frequency power supply **28** via a matcher **26**. To the gas ejection head **22**, a lift mechanism (not depicted) is connected to raise or lower the gas ejection head **22** in a vertical direction. The distance between the holding table **14** and the gas ejection head **22** is adjusted by raising or lowering the gas ejection head **22** with the lift mechanism.

[0041] Disposed inside the gas ejection head **22** is a gas diffusion space **22***a* to which two gases of different types for plasma processing are supplied. On a side of a lower surface of the gas ejection head **22**, a plurality of gas supply paths **22***b* are disposed, communicating the processing space **6** of the chamber **4** and the gas diffusion space **22***a* to each other. On a side of an upper surface of the gas ejection head **22**, a pair of gas supply paths **22***c* and **22***d* is disposed. The gas supply path **22***c* is connected to a gas supply source **32***a* via a piping **30***a*, while the gas supply path **22***d* is connected to a gas supply source **32***b* via a piping **30***b*. The gas supply source **32***a* supplies one of the two gases of different types for plasma processing to the gas diffusion space **22***a* via the piping **30***a* and the gas supply path **22***c*. Similarly, the gas supply source **32***b* supplies the other one of the two gases of different types for plasma processing to the gas diffusion space **22***a* via the piping **30***b* and the gas supply path **22***d*. As a consequence, these two gases of different types are mixed in the gas diffusion space **22***a*. It is to be noted that FIG. **2** depicts a configuration in which the two gases of different types for plasma processing are supplied to the gas ejection head **22** from the two gas supply sources **32***a* and **32***b*. However, the number of gas supply sources connected to the gas ejection head **22** may be 1, or 3 or more.

[0042] When applying plasma processing to the workpiece **11** using the plasma processing apparatus **2**, the gate **8** is first lowered, so that the opening **4***a* is exposed. The workpiece **11** is then loaded by a transfer mechanism (not depicted) into the processing space **6** through the opening **4***a*, and is arranged on the holding surface **14***a* of the holding table **14**. It is to be noted that, upon loading of the workpiece **11**, the gas ejection head **22** may preferably be raised in advance to widen the distance between the holding table **14** and the gas ejection head **22**.

[0043] The gate **8** is next raised to close the opening **4***a*, whereby the processing space **6** is hermetically closed. A predetermined voltage is then applied to the electrode **16** by the radio frequency power supply **20**. This causes dielectric polarization to occur on a side of the holding surface **14***a* of the holding table **14**, and an electrostatic attraction force acts between the holding surface **14***a* and the workpiece **11**. As a result, the workpiece **11** is held under suction on the holding surface **14***a*. Further, the height of the gas ejection head **22** is adjusted such that the holding table **14** and the gas ejection head **22** are arranged at a distance suited for plasma processing. Furthermore, the exhaust apparatus **12** is activated, and the processing space **6** is depressurized.

[0044] Both or one or the other of the two gases of different types for plasma processing are/is next supplied from the gas supply source **32***a* and/or the gas supply source **32***b* to the gas diffusion space **22***a*. Further, radio frequency power is applied by the radio frequency power supply **28** to the gas ejection head **22**. As a result, a gas or a gas mixture in the gas diffusion space **22***a* is transformed into a plasma, and the resulting plasmatic gas is supplied to and spread in the processing space **6** through the gas supply paths **22***b*. As a consequence, the plasmatic gas is supplied to the workpiece **11** on the holding table **14**, so that predetermined plasma processing (deposition processing, etching treatment, or the like) is applied to the workpiece **11**.

[0045] A description will next be made regarding the manufacturing method for chips according to this embodiment. In this embodiment, the workpiece **11** (see FIGS. **1**A and **1**B) is divided into a plurality of chips by applying plasma processing to the workpiece **11** by use of the plasma processing apparatus **2** (see FIG. **2**). FIG. **3** is a flow chart illustrating the manufacturing method for chips according to the embodiment.

[0046] When dividing the workpiece **11**, a mask is first formed by supplying a plasmatic deposition gas to the side of the front surface **11***a* or a side of the back surface **11***b* (mask forming step **S1**). It is to be noted that a description will hereinafter be made taking as a representative example a case in which the mask is to be formed on the side of the front surface **11***a* of the workpiece **11**, but the mask may be formed on the side of the back surface **11***b* of the workpiece **11**. FIG. **4**A is a fragmentary partial cross-sectional front view depicting the workpiece **11** in the mask forming step **S1**. In the mask forming step **S1**, the mask is formed on the workpiece **11** by the plasma processing apparatus **2**.

[0047] Described specifically, the workpiece **11** is first held on the holding surface **14***a* of the holding table **14** such that the workpiece **11** is upwardly exposed on the side of the surface on which the mask is to be formed (on the side of the front surface **11***a*) and the workpiece **11** faces the holding surface **14***a* on the side of the opposite surface (the side of the back surface **11***b*). A protective film forming gas is then supplied to the gas diffusion space **22***a* (see FIG. **2**) of the gas ejection head **22** and at the same time, radio frequency power is applied to the gas ejection head **22**. As a consequence, the gas in the gas diffusion space **22***a* is transformed into a plasma, and a gas **34** (deposition gas) that is in a plasma state and contains ions and radicals is produced. If this carbon-containing deposition gas **34** (a C_4F_8-containing gas, a CH_4-containing gas, or the like) is supplied to the workpiece **11**, a film that contains carbon is formed on the workpiece **11**. For example, the C_4F_8-containing gas supplied from the gas supply source **32***a* and the Ar gas supplied from the gas supply source **32***b* are mixed, and the deposition gas **34** in the plasma state is produced. The deposition gas **34** is then supplied to the workpiece **11**, and CF radicals contained in the deposition gas **34** deposit on the side of the front surface **11***a* of the workpiece **11**. As a consequence, an insulating film with carbon fluoride contained therein (fluorocarbon film) is formed on the side of the front surface **11***a* of the workpiece **11**. This film with carbon fluoride contained therein is used as the mask in plasma etching.

[0048] FIG. **4**B is a fragmentary cross-sectional view depicting the workpiece **11** after the mask forming step S**1**. CF radicals are deposited, for example, on the side of the front surface **11***a* of the workpiece **11**, so that a mask **17** (a film with carbon fluoride contained therein) is formed on the side of the front surface **11***a* of the workpiece **11**. It is to be noted that the CF radicals uniformly deposit on the front surface **11***a* of the workpiece **11** and on surfaces of the devices **15**. As a result, the mask **17** having a uniform thickness, to which the shapes of the front surface **11***a* of the workpiece **11** and the surfaces of the devices **15** are reflected, is formed. The thickness of the mask **17** is appropriately set taking into consideration the below-mentioned conditions and the like for plasma etching. However, the thinner the mask **17**, the shorter the deposition time. It is therefore preferred to form the mask **17** to be thin within a range that it functions as a mask for plasma etching. For example, the thickness of the mask **17** is smaller than 10 μm, preferably smaller than 5 μm.

[0049] While removing the mask **17** along the scribe lines **13**, cut grooves are next formed by causing an annular cutting blade **48** (see FIG. **5**A) to cut to a predetermined cut-in depth into the workpiece **11** on the side of a surface on which the mask **17** is formed (on the side of the front surface **11***a*) (cutting step S**2**). FIG. **5**A is a fragmentary partial cross-sectional front view depicting the workpiece **11** in the cutting step S**2**. In the cutting step S**2**, the mask **17** is cut by use of a cutting apparatus **40**. It is to be noted that, in FIG. **5**A, an X-axis direction (processing feed direction, first horizontal direction) and a Y-axis direction (indexing feed direction, second horizontal direction) are perpendicular to each other. On the other hand, a Z-axis direction (cut-in depth direction, height direction, vertical direction, up-down direction) is perpendicular to the X-axis direction and Y-axis direction.

[0050] The cutting apparatus **40** has a holding table (chuck table) **42** that holds the workpiece **11**. The holding table **42** has an upper surface, which is a planar surface substantially parallel to a horizontal plane (XY plane), and constitutes a circular holding surface **42***a* that holds the workpiece **11**. The holding surface **42***a* is communicated to a suction source (not depicted) such as an ejector via a flow passage (not depicted) formed inside the holding table **42**, a valve (not depicted), and the like.

[0051] The holding table **42** has a moving unit (not depicted) and a rotary drive source (not depicted) coupled therewith. The moving unit is configured, for example, with a ball screw type moving mechanism, and moves the holding table **42** along the X-axis direction. On the other hand, the rotary drive source is configured with a motor or the like, and rotates the holding table **42** about an axis of rotation that is substantially parallel to the Z-axis direction.

[0052] The cutting apparatus **40** also includes a cutting unit **44** that cuts the workpiece **11**. The cutting unit **44** is arranged above the holding table **42**, and includes a cylindrical spindle **46** arranged along the Y-axis direction. On a distal end portion (one end portion) of the spindle **46**, the annular cutting blade **48** is mounted. A proximal end portion (the other end portion) of the spindle **46**, on the other hand, has a rotary drive source (not depicted) such as a motor is coupled therewith. The cutting blade **48** is rotated about an axis of rotation, which is substantially parallel to the Y-axis direction, by power transmitted from the rotary drive source via the spindle **46**. As the cutting blade **48**, a cutting blade of, for example, the hub type (hub blade) is used. The hub blade includes an annular hub base made from a metal or the like, and an annular cutting edge formed along an outer peripheral edge of the hub base. The cutting edge of the hub blade is configured with an electroformed grinding stone which includes abrasive grits of diamond or the like and a binding material such as a nickel plating layer that fixedly secures the abrasive grits. However, a washer type cutting blade (washer blade) can also be used as the cutting blade **48**. The washer blade is configured with only an annular cutting edge, which includes abrasive grits of diamond or the like and a binding material that is formed of a metal, a ceramic, a resin, or the like and fixedly secures the abrasive grits.

[0053] The cutting unit **44** has a moving unit (not depicted) coupled therewith. The moving unit is configured, for example, with a ball screw type moving mechanism, and moves the cutting unit **44** in the Y-axis direction and the Z-axis direction. The position in the indexing direction of the cutting blade **48**, the cut-in depth of the cutting blade **48** into the workpiece **11**, and the like are adjusted by the moving mechanism.

[0054] When cutting the workpiece **11** by the cutting apparatus **40**, the workpiece **11** is first held on the holding table **42**. Described specifically, the workpiece **11** is arranged on the holding table **42** such that the workpiece **11** is upwardly directed on the side of the surface on which the mask **17** is formed (on the side of the front surface **11***a*) and faces the holding surface **42***a* on the side of the opposite surface (on the side of the back surface **11***b*). When a suction force (negative pressure) of the suction source is allowed to act on the holding surface **42***a* with the workpiece **11** arranged as described above, the workpiece **11** is held under suction on the holding table **42**.

[0055] The holding table **42** is next rotated to bring the length direction of a predetermined one of the scribe lines **13** into alignment with the X-axis direction. Further, the position in the Y-axis direction of the cutting unit **44** is adjusted such that the positions in the Y-axis direction of the cutting blade **48** and the predetermined one scribe line **13** are brought into coincidence with each other. Furthermore, the height position (the position in the Z-axis direction) of the cutting unit **44** is adjusted such that the cutting blade **48** is positioned at a lower end thereof slightly lower than the front surface **11***a* of the workpiece **11** (a lower surface of the mask **17**). With the cutting blade **48** kept rotating, the holding table **42** is then moved along the X-axis direction. As a consequence, the holding table **42** and the cutting blade **48** are relatively moved along the X-axis direction, and the cutting blade **48** is caused to cut into the workpiece **11** and the mask **17** along the predetermine one scribe line **13**. The difference in height position between a surface (upper surface) of the mask **17** and a tip end (lower end) of the cutting blade **48** at this time corresponds to the cut-in depth of the cutting blade **48**. The cut-in depth of the cutting blade **48** is set equal to or greater than the thickness of the mask **17**.

[0056] When cutting the workpiece **11** and the mask **17** by the cutting blade **48**, a liquid (cutting fluid) such as pure water is supplied to the cutting blade **48**. As a consequence, the cutting blade **48** is cooled, and at the same time, debris occurring by cutting processing is washed away.

[0057] When the cutting blade **48** is caused to cut in as described above, cut grooves **19** are formed along the scribe lines **13** in the workpiece **11** on the side of the front surface **11***a* and also in the mask **17**. The cut grooves **19** are formed so as to split the mask **17** and extend to the front surface **11***a* of the workpiece **11**.

[0058] It is to be noted that the cutting blade **48** preferably has a tip end portion **48***a* (see FIG. **5**B) of a width tapering toward a tip end. In the cutting step S**2**, the cutting blade **48** is preferably caused to cut into the mask **17** so as to come into contact with the mask **17** at only the tip end portion **48***a* thereof.

[0059] FIG. **5**B is a fragmentary partial cross-sectional front view depicting the tip end portion **48***a* of the cutting blade **48**. The cutting blade **48** has the tip end portion **48***a* having a surface formed in an arc shape extending from one side toward the other side thereof. Described specifically, the surface of the tip end portion **48***a* is curved (has a rounded shape), and the tip end portion **48***a* is formed such that its width becomes gradually narrower toward the tip end (lower end). FIG. **5**C is a fragmentary partial cross-sectional front view depicting a modification of the tip end portion **48***a* of the cutting blade **48**. As depicted in FIG. **5**C, the tip end portion **48***a* of the cutting blade **48** may include a pair of planar side surfaces formed so as to be inclined with respect to a radial direction of the cutting blade **48**. In this case, the surface of the tip end portion **48***a* has a V-shape as seen in a cross-section, and the tip end portion **48***a* is formed such that its width becomes gradually narrower toward the tip end (lower end).

[0060] In the cutting step S**2**, the cutting blade **48** is caused to cut into the mask **17** such that only the tip end portion **48***a* (tapered area) of the cutting blade **48** comes into contact with the mask **17**. As a consequence, an area of the mask **17**, in which the cutting blade **48** comes into contact with the mask **17**, is cut such that the mask **17** is pressed toward the side of the front surface **11***a* of the workpiece **11** by the surface of the tip end portion **48***a* of the cutting blade **48**. As a result, peeling of the mask **17** due to the contact between the cutting blade **48** and the mask **17** is hardly generated, even if the cutting blade **48** which is rotating at high speed is caused to cut into the mask **17**.

[0061] The mask **17** is then removed along all the scribe lines **13** by repeating similar procedures. As a result, the workpiece **11** is obtained with the cut grooves **19** formed in a grid pattern along the scribed lines **13**.

[0062] FIG. **6** is a fragmentary cross-sectional view depicting the workpiece **11** after the cutting step S**2**. The cut grooves **19** are formed in regions of the mask **17**, where the mask **17** overlaps the scribe lines **13**, so that the cut grooves **19** reach the front surface **11***a* of the workpiece **11**. As a result, the mask **17** is split along the scribe lines **13**, and at the same time, portions (lower end portions) of the cut grooves **19** are formed in the workpiece **11** on the side of the front surface **11***a*, so that the front surface **11***a* of the workpiece **11** is exposed along the scribe lines **13**. It is to be noted that the shape of the tip end portion **48***a* of the cutting blade **48** is reflected in the profile of the cut grooves **19**. Described specifically, if the tip end portion **48***a* of the cutting blade **48** has the rounded shape (see FIG. **5**B), the cut grooves **19** are formed in a curved shape. If the tip end portion **48***a* of the cutting blade **48** has the V-shape (see FIG. **5**C), on the other hand, the cut grooves **19** are formed each including a pair of inner walls inclined with respect to the front surface **11***a* of the workpiece **11** and also with the surface of the mask **17**.

[0063] The cut-in depth of the cutting blade **48** in the cutting step S**2** is appropriately set according to the thickness of the mask **17**, the length of the tip end portion **48***a* of the cutting blade **48**, and the like. It is however to be noted that the tip end portion **48***a* (tapered area) of the cutting blade **48** is often formed especially in a range of approximately 10 μm from the tip end of the cutting blade **48**. It is therefore preferred to set the cut-in depth of the cutting blade **48** to smaller than 10 μm.

[0064] In the cutting step S**2**, the cut grooves **19** may be formed while adjusting the height position of the cutting blade **48** according to the height position of the surface of the mask **17**. Described specifically, the cutting apparatus **40** may include a measurement unit **50** to measure displacements of the height position of the surface of an object, specifically the mask **17** as depicted in FIG. **5**A. The measurement unit **50** is configured, for example, with a non-contact displacement meter such as a laser displacement meter, and measures the height position of the surface of the mask **17**. When the workpiece **11** is held on the holding table **42**, the height position of the surface of the mask **17** in each area where the mask **17** is to be cut by the cutting blade **48** (the area that overlaps each scribe line **13**) is measured by the measurement unit **50**. When causing the cutting blade **48** to cut into the workpiece **11** and the mask **17** along each scribe line **13**, the height position of the cutting blade **48** is sequentially adjusted according to the height position of the surface of the mask **17** as measured by the measurement unit **50** such that the cut-in depth of the cutting blade **48** remains constant.

[0065] By adjusting the cut-in depth of the cutting blade **48** according to the height position of the surface of the actual mask **17** as described above, the cut-in depth of the cutting blade **48** can be maintained constant even if there are variations in the height position of the surface of the mask **17**. This ensures that the mask **17** can be split without causing the cutting blade **48** to cut into the workpiece **11** unnecessarily. It is to be noted that, if thickness variations of the workpiece **11** and the mask **17** are small, the height position of the holding surface **42***a* (see FIG. **5**A) of the holding table **42** may be measured by the measurement unit **50**. In this case, the height position of the cutting blade **48** is sequentially adjusted according to the height position of the holding surface **42***a* measured by the measurement unit **50** when causing the cutting blade **48** to cut into the workpiece **11** and the mask **17** along each scribe line **13**. This can maintain the cut-in depth of the cutting blade **48** constant even if there are irregularities on the holding surface **42***a*.

[0066] The workpiece **11** is next removed along the scribe lines **13** and divided into the chips by applying plasma etching to the workpiece **11** (plasma etching step S**3**). In the plasma etching step S**3**, a plasmatic etching gas is supplied to the side of the surface (the side of the front surface **11***a*, the side of the mask **17**) of the workpiece **11**, where the cut grooves **19** have been formed in the workpiece **11**, thereby applying plasma etching to the workpiece **11**.

[0067] FIG. **7** is a flow chart illustrating an example of the plasma etching step S**3**. In the plasma etching step S**3**, the workpiece **11** is divided along the scribe lines **13** by use of, for example, the Bosch process to allow the cut grooves **19** to extend to the surface (back surface **11***b*) on a side opposite to the surface, on which the mask **17** is formed, of the workpiece **11**. Described specifically, the cut grooves **19** are allowed to reach the back surface **11***b* of the workpiece **11** by repeating work that etches the bottoms of the cut grooves **19** by performing a protective film application substep S**11**, an anisotropic etching substep S**12**, and an isotropic etching substep S**13** in this order. The plasma processing apparatus **2** depicted in FIG. **2** can be used for the plasma etching.

[0068] FIG. **8**A is a fragmentary cross-sectional view depicting the workpiece **11** in the protective film application substep S**11**. In the protective film application substep S**11**, a protective film **21** is applied to the cut grooves **19** by supplying a plasmatic deposition gas **60** to the side of the surface (the side of the front surface **11***a*, the side of the mask **17**) of the workpiece **11**, where the cut grooves **19** have been formed.

[0069] Described specifically, the workpiece **11** is held on the holding surface **14***a* (see FIG. **2**) of the holding table **14** such that the workpiece **11** is upwardly exposed on the side of the front surface **11***a* (on the side of the mask **17**, on the side of the cut grooves **19**), and on the side of the back surface **11***b*, faces the holding surface **14***a*. A deposition gas, specifically a protective film forming gas is then supplied to the gas diffusion space **22***a* (see FIG. **2**) of the gas ejection head **22**, and at the same time, radio frequency power is applied to the gas ejection head **22**. As a consequence, the plasmatic protective film forming gas **60** is supplied to the side of the front surface **11***a* of the workpiece **11**. When the protective film forming gas **60** is supplied to the workpiece **11**, ions and radicals which are both contained in the protective film forming gas **60** deposit on the mask **17**, and at the same time, enter the cut grooves **19** and deposit on the inner walls of the cut grooves **19**. As a result, the protective film **21** is formed on the surface of the mask **17** and the inner walls of the cut grooves **19**, whereby the protective film **21** is applied to the cut grooves **19**. For example, in the gas diffusion space **22***a* (see FIG. **2**), the C_4F_8-containing gas supplied from the gas supply source **32***a* and the Ar gas supplied from the gas supply source **32***b* are mixed and are transformed into a plasma. In this case, CF radicals contained in the protective film forming gas **60** deposit on the side of the front surface **11***a* of the workpiece **11**, whereby the insulating protective film **21** with carbon fluoride contained therein is formed on the surface of the mask **17** and the inner walls of the cut grooves **19**. For example, the supply time of the protective film forming gas **60** is set to six seconds or longer and eight seconds or shorter, and the protective film **21** is formed to have a thickness of 10 nm or smaller.

[0070] FIG. **8**B is a fragmentary cross-sectional view depicting the workpiece **11** in the anisotropic etching substep S**12**. In the anisotropic etching substep S**12**, the protective film **21** applied to the bottoms of the cut grooves **19** is removed through anisotropic plasma etching of the protective film **21** resulting from supplying a plasmatic gas **62** for anisotropic etching to the cut grooves **19**.

[0071] Described specifically, a gas mixture **62** for anisotropic etching is supplied to the gas diffusion space **22***a* (see FIG. **2**) of the gas ejection head **22**. For example, a fluorinated gas (CF_4, SF_6, or the like) supplied from the gas supply source **32***a* and an inert gas (He, Ar, or the like) supplied from the gas supply source **32***b* are mixed into the gas mixture **62** for anisotropic etching in the gas diffusion space **22***a*. Respective radio frequency powers are then applied to the electrode **16** (see FIG. **2**) and the gas ejection head **22**. As a consequence, the gas mixture **62** for anisotropic etching in the gas diffusion space **22***a* is transformed into a plasma, and the resulting plasmatic etching gas **62** for anisotropic etching is accelerated toward the holding table **14**, so that anisotropic plasma etching is applied to the workpiece **11**. When this anisotropic plasma etching is continued for a certain period of time (for example, approximately three seconds), portions of the protective film **21** covering the bottoms of the cut grooves **19** are removed, and the bottoms of the cut grooves **19** are hence exposed, with remaining portions of the protective film **21** covering the upper ends of the cut grooves **19** being left.

[0072] FIG. **8**C is a fragmentary cross-sectional view depicting the workpiece **11** in the isotropic etching substep S**13**. In the isotropic etching substep S**13**, the bottoms of the cut grooves **19** are isotropically subjected to plasma etching by supplying a plasmatic gas **64** for isotropic etching to the cut grooves **19**.

[0073] Described specifically, a gas mixture **64** for isotropic etching is supplied to the gas diffusion space **22***a* (see FIG. **2**) of the gas ejection head **22**. In a case in which the workpiece **11** is a single crystal silicon wafer, for example, a fluorinated gas (CF_4, SF_6, or the like) supplied from the gas supply source **32***a* and an inert gas (He, Ar, or the like) supplied from the gas supply source **32***b* are mixed into the gas mixture **64** for isotropic etching in the gas diffusion space **22***a*. Radio frequency power is then applied to the gas ejection head **22**. As a consequence, the gas mixture **64** for isotropic etching supplied to the gas diffusion space **22***a* is transformed into a plasma, and the resulting plasmatic etching gas **64** for isotropic etching is supplied for a certain period of time (for example, five seconds or longer and seven seconds or shorter) to the side of the front surface **11***a* of the workpiece **11**. As a consequence, isotropic plasma etching is applied to the workpiece **11**. It is to be noted that no radio frequency power is applied to the electrode **16** (see FIG. **2**) in the isotropic etching substep S**13**. Isotropic plasma etching is hence applied to the workpiece **11**. As a result, the bottoms of the cut grooves **19** and their vicinities are removed, so that the cut grooves **19** are caused to extend toward the side of the back surface **11***b* of the workpiece **11**.

[0074] Subsequently, the above-described protective film application substep S**11**, the anisotropic etching substep S**12**, and the isotropic etching substep S**13** are repeated until the cut grooves **19** reach the back surface **11***b* of the workpiece **11** ("NO" in the substep S**14**). When the cut grooves **19** reach the back surface **11***b* of the workpiece **11**, and the workpiece **11** is divided along the scribe lines **13** ("YES" in the substep S**14**), the plasma etching step S**3** is completed.

[0075] FIG. **9** is a fragmentary cross-sectional view depicting the workpiece **11** after the plasma etching step S**3**. After the plasma etching step S**3** has been completed, the workpiece **11** has been removed along the scribe lines **13**, and hence divided into a plurality of chips (device chips) **23** individually including the devices **15**. It is to be noted that the description has been made above regarding the example in which the workpiece **11** is divided by the Bosch process, and the details of the plasma etching to be applied to the workpiece **11** can appropriately be changed.

[0076] After the plasma etching step S**3**, the mask **17** is removed (mask removal step S**4**). The mask **17** is removed from the respective chips **23**, for example, by applying an asking treatment to the mask **17**. As a consequence, the front surface **11***a* and devices **15** of the workpiece **11** are exposed.

[0077] In the manufacturing method for chips according to this embodiment, the mask **17** formed on the workpiece **11** is patterned by causing the cutting blade **48** to cut into the mask **17** to remove the mask **17** along the scribe lines **13**, as described above. This enables formation of a mask for plasma etching with an inexpensive cutting apparatus, instead of a costly laser processing apparatus or the like, thereby reducing the costs of plasma etching.

[0078] It is to be noted that the structure, method, and the like according to the above-described embodiment can be practiced with appropriate changes or modifications within the scope not departing from the object of the present invention.

Example

[0079] A description will next be made regarding the results of an evaluation of workpieces processed by the method according to the above-described embodiments. In the evaluation, after a film formed on each workpiece and containing carbon fluoride was divided along scribe lines by cutting it with a cutting blade (mask forming step S**1**, cutting step S**2**), plasma etching was applied to the workpiece (plasma etching step S**3**). By observing the workpiece after the plasma etching, confirmation was made on whether the film with the carbon fluoride contained therein appropriately functioned as a mask for plasma etching.

[0080] As the workpieces, wafers W (see FIGS. **10**A to **11**B) of single crystal silicon were used. In the mask forming step S**1**, a gas mixture with C_4F_8 and Ar contained therein was transformed into a plasma, and the resulting plasmatic gas was supplied to each wafer W, whereby a film with carbon fluoride contained therein (the mask M) was formed on a side of a front surface of the wafer W. It is to be noted that, for the formation of the mask, the plasma processing apparatus (see FIG. **2**) was used, and the plasmatic gas was supplied for 60 seconds to the wafer W with no radio frequency power applied to the electrode **16** (see FIG. **2**). As a result, the mask M was formed to have a thickness of approximately 1 μm on the side of the front surface of the wafer W.

[0081] The mask was next removed along the scribe lines by causing the cutting blade to cut into the mask (cutting step S**2**). The cutting blade (width: 12 μm) used in the cutting of the mask had a rounded tip end portion (see FIG. **5**B). The processing feed rate was set to 10 mm/s, and the rotational speed of the spindle was set to 40,000 rpm. Further, the cut-in depth of the cutting blade was set such that the cutting blade was caused to cut into the wafer W at a depth of approximately 1 μm on the side of the front surface of the wafer W while splitting the mask M. After cutting the mask M, the wafer W was observed by imaging an upper surface and a cross-section thereof.

[0082] FIG. **10**A is a micrograph depicting the side of the upper surface of the wafer W after the formation of the mask and the cut grooves. FIG. **10**B is a micrograph depicting the cross-section of the wafer W after the formation of the mask and cut grooves. By causing the cutting blade to cut into the wafer W and the mask M, a strip-shaped cut groove G was formed along each scribe line, so that the mask M was split and at the same time, the upper surface of the wafer W was exposed inside the cut groove G. It is to be noted that the cutting blade was caused to cut into the mask M so as to allow only the rounded tip end portion thereof to come into contact with the mask M. As depicted in FIG. **10**B, the rounded shape of the cutting blade is therefore reflected in the profile of the cut groove G, and therefore, the cut grooves G was formed including a curved inner surface that is convex toward a side of the wafer W. Further, as depicted in FIG. **10**A, the mask M was split straight along the cut groove G, and no conspicuous peeling of the mask M was observed at opposite edge portions of the cut groove G. This is presumably attributable to a suppression of separation of the mask M owing to the contact of only the (rounded) tip end portion of the cutting blade with the mask M.

[0083] A plurality of gases in a plasma state were next supplied individually and successively to the wafer W through the mask M, and etching was applied to the wafer W. It is to be noted that the above-mentioned Bosch process was used in the etching of the wafer W, and the cut groove G was caused to extend toward a side of a back surface of the wafer W by repeating the protective film application substep S**11**, the anisotropic etching substep S**12**, and the isotropic etching substep S**13** (see FIG. **7**). After the cut groove G has extended to a certain extent, the cross-section of the wafer W was imaged and observed. It is to be noted that the plasma processing apparatus **2** (see FIG. **2**) was used in the etching of the wafer W. Described specifically, in the protective film application substep S**11**, a C_4F_8-containing gas mixture was transformed into a plasma, and with no radio frequency power applied to the electrode **16**, the plasmatic gas was supplied for six to eight seconds to the wafer W. Further, in the anisotropic etching substep S**12**, an SF_6-containing gas mixture was transformed into a plasma, and with radio frequency power (300 W) applied to the electrode **16**, the plasmatic gas was supplied for three seconds to the wafer W. Furthermore, in the isotropic etching substep S**13**, the SF_6-containing gas mixture was transformed into a plasma, and with no radio frequency power applied to the electrode **16**, the plasmatic gas was supplied for five to seven seconds to the wafer W.

[0084] FIG. **11**A is a micrograph depicting a cross-section of the wafer M after the plasma etching. FIG. **11**B is a micrograph depicting on an enlarged scale a cut groove G formed in the wafer W. When plasma etching was applied under the above-described processing conditions for predetermined periods of time, the cut groove G extended straight along a thickness direction of the wafer W, and the cut groove G was formed with a high aspect ratio (width: approximately 10 μm, depth: approximately 200 μm). From this result, it was confirmed that the mask M appropriately functioned as a mask for plasma etching, and the use of the mask M allowed the cut groove G to extend to the side of the back surface of the wafer W with a predetermined width maintained.

[0085] The present invention is not limited to the details of the above-described preferred embodiment. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the equivalence of the scope of the claims are therefore to be embraced by the invention.

What is claimed is:

1. A manufacturing method of a plurality of chips, the method manufacturing the chips by dividing a workpiece that is defined into a plurality of regions by scribe lines, comprising:

a mask forming step of forming a mask by supplying a plasmatic deposition gas to a side of a front surface or a side of a back surface of the workpiece;

a cutting step of forming cut grooves, with the mask being removed along the scribe lines, by causing a cutting blade to cut into the workpiece at a predetermined cut-in depth along the scribe lines on the side of a surface on which the mask has been formed; and

a plasma etching step of removing the workpiece along the scribe lines to divide the workpiece into the chips by applying plasma etching to the workpiece while supplying a plasmatic etching gas to the side of the surface of the workpiece in which the cut grooves have been formed.

2. The manufacturing method according to claim **1**, wherein

the cutting blade has a tip end portion having a width tapering toward a tip end, and

in the cutting step, the cutting blade is caused to cut into the mask such that only the tip end portion comes into contact with the mask.

3. The manufacturing method according to claim **1**, wherein

in the cutting step, the cut-in depth of the cutting blade is set to smaller than 10 μm.

4. The manufacturing method according to claim **1**, wherein

in the plasma etching step, the workpiece is divided into the chips along the scribe lines by repeating:

a protective film application substep of applying a protective film to the cut grooves by supplying a plasmatic deposition gas to the side of the surface of the workpiece in which the cut grooves have been formed;

an anisotropic etching substep of, after the protective film application substep, removing portions of the protective film covering corresponding bottoms of the cut grooves, through anisotropic plasma etching of the protective film by supplying a plasmatic gas for anisotropic etching to the cut grooves; and

an isotropic etching substep of, after the anisotropic etching substep, subjecting the bottoms of the cut grooves to isotropic plasma etching by supplying a plasmatic gas for isotropic etching to the cut grooves.

5. The manufacturing method according to claim **1**, further comprising:

a mask removal step of removing the mask after the plasma etching step.

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