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Film forming apparatus and film forming method

Abstract

A film forming apparatus for performing film formation on a substrate comprises a processing chamber, a stage configured to place thereon a substrate disposed in the processing chamber, a film forming part configured to perform film formation on the substrate placed on the stage, a shutter that is movable between a shielding position where the substrate on the stage is shielded and a retracted position retracted from the stage and where the film forming part performs the film formation on the substrate, and a film thickness measuring part. The film thickness measuring part has a film thickness measuring device configured to measure a film thickness of a film formed on the shutter at the shielding position by the film forming part.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This application claims priority to Japanese Patent Application No. 2022-163116, filed on Oct. 11, 2022, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

(2) The present disclosure relates to a film forming apparatus and a film forming method.

BACKGROUND

(3) In manufacturing electronic devices such as semiconductor devices, film formation for forming a film on a substrate is performed. A film forming apparatus disclosed in International Publication

No. WO 2013/179575 is known as an example of a film forming apparatus used for the film formation.

SUMMARY

(4) The present disclosure provides a film forming apparatus capable of preventing abnormal film formation in the case of forming a film on a substrate.

(5) One aspect of the present disclosure provides a film forming apparatus for performing film formation on a substrate, comprising: a processing chamber; a stage configured to place thereon a substrate disposed in the processing chamber; a film forming part configured to perform film formation on the substrate placed on the stage; a shutter that is movable between a shielding position where the substrate on the stage is shielded and a retracted position retracted from the stage and where the film forming part performs the film formation on the substrate; and a film thickness measuring part having a film thickness measuring device configured to measure a film thickness of a film formed on the shutter at the shielding position by the film forming part.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a cross-sectional view showing an example of a film forming apparatus according to one embodiment.

(2) FIG. **2** explains a swiveling operation of a disc shutter in the film forming apparatus of FIG. **1**.

(3) FIG. **3** is a plan view showing a film thickness measuring part disposed at the disc shutter in the film forming apparatus of FIG. **1**.

(4) FIG. **4** is a cross-sectional view showing a state in which the disc shutter is retracted in the film forming apparatus of FIG. **1**.

DETAILED DESCRIPTION

(5) Hereinafter, embodiments will be described in detail with reference to the accompanying drawings.

(6) FIG. **1** is a cross-sectional view showing an example of a film forming apparatus according to one embodiment. FIG. **2** explains a swiveling operation of a disc shutter in the film forming apparatus of FIG. **1**. FIG. **3** is a plan view showing a film thickness measuring part disposed at the disc shutter in the film forming apparatus of FIG. **1**. FIG. **4** is a cross-sectional view showing a state in which the disc shutter is retracted in the film forming apparatus of FIG. **1**.

(7) The film forming apparatus **1** is configured as a sputtering apparatus for forming a film on a substrate W by sputtering (sputtering film formation). The substrate W may be a wafer made of a semiconductor such as Si, glass, ceramic, or the like, but is not limited thereto.

(8) The film forming apparatus **1** includes a processing chamber **10**, a stage **20**, sputtered particle emitting parts **30***a* and **30***b*, a gas supply part **40**, a disc shutter part **50**, a film thickness measuring part **60**, and a controller **70**.

(9) The processing chamber **10** is made of aluminum, for example, and defines a processing space for processing the substrate W. The processing chamber **10** is connected to a ground potential. The processing chamber **10** has a chamber body **10***a* with an upper opening, and a lid **10***b* disposed to close the upper opening of the chamber body **10***a*. The lid **10***b* has a truncated cone shape.

(10) An exhaust port **11** is formed at the bottom portion of the processing chamber **10**, and an exhaust device **12** is connected to the exhaust port **11**. The exhaust device **12** includes a pressure control valve and a vacuum pump, and the processing chamber **10** is evacuated to a predetermined vacuum level by the exhaust device **12**.

(11) A loading/unloading port **13** for loading/unloading the substrate W to/from an adjacent transfer chamber (not shown) is formed in the sidewall of the processing chamber **10**. The loading/unloading port **13** is opened and closed by a gate valve **14**.

(12) The stage **20** has a substantially disc shape, and is disposed near the bottom portion of the processing chamber **10**. The stage **20** is configured to hold the substrate W horizontally. In the present embodiment, the stage **20** has a base portion **21** and an electrostatic chuck **22**. The base portion **21** is made of aluminum, for example. The electrostatic chuck **22** is made of a dielectric material, and has an electrode (not shown) therein. A DC voltage is applied from a DC power supply (not shown) to the electrode, and the substrate W is electrostatically attracted to the surface of the electrostatic chuck **22** by an electrostatic force thus generated. A temperature control mechanism (not shown) having one or both of a heater and a cooling medium channel is disposed in the base portion **21**.
(13) The stage **20** is driven by a driving mechanism **26**. The driving mechanism **26** is disposed below the processing chamber **10**. A support shaft **27** extending upward from the driving mechanism **26** extends while penetrating through the bottom wall of the processing chamber **10**, and the tip end thereof is connected to the center of the bottom surface of the stage **20**. The driving mechanism **26** is configured to rotate and vertically move the stage **20** via the support shaft **27**. A sealing member **28** seals the gap between the support shaft **27** and the bottom wall of the processing chamber **10**. By providing the sealing member **28**, the support shaft **27** can be rotated and vertically moved in a state where the processing chamber **10** is maintained in a vacuum state. The sealing member **28** may be, for example, a magnetic fluid seal.
(14) The sputtered particle emitting parts **30***a* and **30***b* function as processing mechanisms for performing sputtering film formation. The sputtered particle emitting parts **30***a* and **30***b* have target holders (electrodes) **31***a* and **31***b*, targets **32***a* and **32***b*, power supplies **33***a* and **33***b*, and magnets **34***a* and **34***b*, respectively.
(15) The target holders **31***a* and **31***b* are made of a conductive material, and are attached to different positions on the inclined surface of the lid **10***b* of the processing chamber **10** via insulating members **35***a* and **35***b*, respectively. In this example, the target holders **31***a* and **31***b* are disposed at positions facing each other. However, the present disclosure is not limited thereto, and they may be disposed at any other positions.
(16) The targets **32***a* and **32***b* are held by the target holders **31***a* and **31***b*, respectively, and have a rectangular shape. The targets **32***a* and **32***b* are made of a material containing constituent elements of a film to be formed. The targets **32***a* and **32***b* may be made of, but not limited to, a metal such as Mg.
(17) The power supplies **33***a* and **33***b* are DC power supplies, and supply a power to the targets **32***a* and **32***b* via the target holders **31***a* and **31***b*, respectively. The power supplies **33***a* and **33***b* may be AC power supplies (radio frequency power supplies). When the target **32***a* and the target **32***b* are insulators, an AC power supply (radio frequency power supply) is used.
(18) The magnets **34***a* and **34***b* are disposed on the back surfaces of the target holders **31***a* and **31***b*, respectively. The magnets **34***a* and **34***b* apply leakage magnetic fields to the targets **32***a* and **32***b*, respectively, to perform magnetron sputtering. The magnets **34***a* and **34***b* are configured to move along the back surfaces of the target holders **31***a* and **31***b*, respectively, by a magnet driving part (not shown).
(19) Ring-shaped members **36***a* and **36***b* for regulating the direction in which the sputtered particles are emitted are disposed at the outer peripheral portions of the surfaces of the targets **32***a* and **32***b*, respectively. The ring-shaped members **36***a* and **36***b* are grounded.
(20) A voltage may be applied from both power supplies **33***a* and **33***b* to both targets **32***a* and **32***b*, or may be applied to only one of the targets **32***a* and **32***b*. Further, the number of sputtered particle emitting parts is not limited to two.
(21) A target shielding member **81** is disposed below the sputtered particle emitting parts **30***a* and **30***b*. The target shielding member **81** has a truncated cone shape corresponding to the shape of the lid **10***b* of the processing chamber **10**, and has an opening **82** having a size corresponding to the size of the targets **32***a* and **32***b*. The target shielding member **81** is rotated by a rotating mechanism

83. When the opening **82** is made to correspond to at least one of the targets **32***a* and **32***b*, the target corresponding to the opening **82** is opened. On the other hand, the target that does not correspond to the opening(s) **82** is closed. Then, the sputtered particles can be emitted from the target corresponding to the opening **82** to the substrate W. By shielding at least one of the targets **32***a* and **32***b* with the shielding member **81**, the shielded target can be sputter-cleaned.
(22) A shielding member **84** is disposed above the stage **20** to reach from the outer edge of the upper surface of the stage to the vicinity of the lower end of the target shielding member **81**. The shielding member **84** has a function of suppressing sputtered particles from reaching the wall of the processing chamber **10**.
(23) The gas supply part **40** has a gas supply source **41**, a gas supply line **42** extending from the gas supply source **41**, a flow rate controller **43** disposed in the gas supply line **42**, and a gas introducing member **44**. A rare gas such as Ar is supplied, as a sputtering gas to be excited in the processing chamber **10**, from the gas supply source **41** into the processing chamber through the gas supply line **42** and the gas introducing member **44**.
(24) By applying a voltage from the power supply **33***a* and/or **33***b* to the target **32***a* and/or **32***b* via the target holder **31***a* and/or **31***b* in a state where the sputtering gas is supplied from the gas supply part **40** into the processing chamber **10**, the sputtering gas dissociates around the target **32***a* and/or **32***b*. At this time, the leakage magnetic fields of the magnets **34***a* and **34***b* reach the vicinity of the target **32***a* and/or **32***b*, so that magnetron plasma is generated mainly around the target **32***a* and/or **32***b*. In this state, positive ions in the plasma collide with the target **32***a* and/or **32***b*, and sputtered particles are emitted from the target **32***a* and/or **32***b* and deposited on the substrate W.
(25) The disc shutter part **50** is generally included in this type of device, and has a disc shutter **51**, an arm **52**, a rotation shaft **53**, and a rotation mechanism **54**. The disc shutter **51** has a disc shape, has a diameter larger than that of the substrate W. The disc shutter **51** has a function of shielding the substrate W placed on the stage **20**. By shielding the substrate W on the stage **20** with the disc shutter **51**, it is possible to prevent sputtered particles from reaching the substrate W. The disc shutter **51** is originally intended to shield the substrate W during conditioning or the like. However, in the present embodiment, as will be described later, a thickness of a film formed by deposition of the sputtered particles is measured by the film thickness measuring part **60** prior to the film formation on the substrate W.
(26) The arm **52** functions as a swiveling member for supporting and swiveling the disc shutter **51** via a support member **55**.
(27) The rotation shaft **53** is used for swiveling the arm **52**. The rotation shaft **53** is connected to the end of the arm **52**, and extends vertically downward through the bottom wall of the processing chamber **10**. The rotation mechanism **54** is disposed below the processing chamber **10**, and rotates the rotation shaft **53**. When the rotation shaft **53** is rotated by the rotation mechanism **54**, the arm **52** rotates and the disc shutter **51** swivels between a shielding position indicated by a solid line and covering the substrate W and a retracted position indicated by a dashed double-dotted line and retracted from the stage **20** as shown in FIG. **2**. When the disc shutter **51** is located at the retracted position, the sputtered particles from the sputtered particle emitting parts **30***a* and **30***b* reach the substrate W and, thus, sputtering film formation can be performed.
(28) The film thickness measuring part **60** has a function of measuring a film thickness of a film formed on the disc shutter **51** in the case of performing sputtering film formation in a state of FIG. **1** in which the substrate W is shielded by the disc shutter **51**.
(29) In this example, the film thickness measuring part **60** has a plurality of crystal oscillators **61** serving as film thickness measuring devices disposed on the surface of the disc shutter **51**. As shown in FIG. **3**, for example, five crystal oscillators **61** serving as the film thickness measuring devices are disposed on the surface of the disc shutter **51**. In the example of FIG. **3**, one crystal oscillator **61** is disposed at the center of the surface of the disc shutter **51**, and four crystal oscillators are arranged at regular intervals at the outer peripheral portion of the disc shutter **51**.

(30) The crystal oscillator **61** includes a pair of electrodes and a crystal plate embedded between the electrodes. The crystal oscillator **61** vibrates due to piezoelectric properties of crystal by applying an AC voltage to the crystal plate via the electrodes. Since the resonance frequency of the crystal oscillator **61** varies depending on the mass of sputtered particles deposited on the crystal oscillator **61**, the film thickness can be detected from the resonance frequency. Further, the film thickness distribution can be obtained from the film thickness measured by the crystal oscillators **61**.
(31) Therefore, before the film formation on the substrate W, the state of film formation using the target **32***a* or **32***b* can be obtained from the film thickness by performing sputtering film formation on the surface of the disc shutter **51** by applying a voltage from the power supply **33***a* or **33***b* to the target **32***a* or **32***b* through the target holder **31***a* or **31***b* in a state where the substrate W is shielded by the disc shutter **51**, as shown in FIG. **1**.
(32) The controller **70** is a computer, and controls individual components of the film forming apparatus **1**, such as the power supplies **33***a* and **33***b*, the exhaust device **12**, the driving mechanism **26**, the gas supply part **40**, the rotation mechanism **54**, and the like. The controller **70** includes a main controller having a central processing unit (CPU) for controlling the above components, an input device, an output device, a display device, and a storage device. The storage device stores parameters of various processes performed by the film forming apparatus **1**, and has a storage medium that stores a program, i.e., a processing recipe, for controlling the processes performed by the film forming apparatus **1**. The main controller reads out a predetermined processing recipe stored in the storage medium, and causes the film forming apparatus **1** to execute processing based on the processing recipe.
(33) Further, the controller **70** controls power supply to a crystal oscillator power supply (not shown) for supplying a power to the crystal oscillators **61**, and receives the resonance frequency detected by the crystal oscillators **61** at the time of performing sputtering film formation on the surface of the disc shutter **51** to calculate the film thickness of the deposited film.
(34) The following is description of the operation of the film forming apparatus **1** configured as described above. The following operations are performed under the control of the controller **70**.
(35) First, as shown in FIG. **4**, in a state where the disc shutter **50** is retracted, the substrate W is loaded into the processing chamber **10** by a transfer device (not shown) and placed on the stage **20**. Next, the disc shutter **51** is rotated by the rotation mechanism **54** via the rotation shaft **53** and the arm **52**, and the substrate W on the stage **20** is shielded by the disc shutter **51** as shown in FIG. **1**.
(36) Next, the sputtering film formation is performed in the state of FIG. **1**. The film forming conditions at this time are basically the same as those for the film formation on the substrate W in a next step. The film formation at this time is performed separately for the target **32***a* and the target **32***b*.
(37) Then, the film thickness of the film deposited using each target is measured by the crystal oscillators **61** serving as the film thickness measuring devices of the film thickness measuring part **60**. As described above, the film thickness measuring part **60** detects the film thickness of deposited sputtered particles in response to the change in the resonance frequency of the crystal oscillators **61**. Further, the film thickness distribution can be obtained from the film thickness measured by the crystal oscillators **61**.
(38) When the substrate W is shielded by the disc shutter **51**, the disc shutter **51** is positioned close to the substrate W on the stage **20**. Therefore, it is considered that the film thickness obtained by the sputtering film formation on the disc shutter **51** is the same as the film thickness of the film formed on the substrate W. Accordingly, the film thickness obtained by performing the sputtering film formation on the disc shutter **51** is measured by the crystal oscillators **61** serving as the film thickness measuring devices of the film thickness measuring part **60**, and the film formation state can be obtained based on the measurement result.
(39) In other words, abnormal film formation in which a film formation rate or film formation

distribution suddenly changes may occur due to the progress of erosion of the targets, hardware failure of the film deposition apparatus **1**, and the like. If the film formation is performed on the substrate W in that state, product failure may occur. Therefore, prior to the film formation on the substrate W, the sputtering film formation is performed on the disc shutter **51** generally included in a sputtering device and the film thickness is measured by the film thickness measuring part **60** to obtain the film formation state. If it is determined that abnormal film formation such as the change in the film formation rate or the change in the film formation distribution has occurred, it can be appropriately dealt with to prevent abnormal film formation on the substrate W in advance.
(40) Next, the sputtering film formation is performed on the substrate W. The film formation at this time is determined based on the measurement result of the thickness of the film deposited on the disc shutter **51** obtained by the film thickness measuring part **60**.
(41) When it is determined in the film thickness measurement using the crystal oscillators **61** of the film thickness measuring part **60** that abnormal film formation has occurred in the film formation using one of the targets **32***a* and **32***b*, the sputtering film formation on the substrate W is performed using the target without abnormality. If both targets are abnormal, the film formation on the substrate W may be performed after maintenance.
(42) When the change in the film formation rate, i.e., abnormal film formation, is detected based on the film thickness measurement result obtained by the film thickness measuring part **60**, the abnormal film formation on the substrate W may be avoided by adjusting the film formation time during the film formation on a next substrate W.
(43) If it is determined in the measurement result of the thickness of the film on the disc shutter **51** that there is no abnormal film formation, the film formation on the substrate W may be performed. Further, the film formation rate may be calculated from the measurement result of the thickness of the film deposited on the disc shutter **51**, and the calculated film formation rate may be fed back to the film formation on the substrate W in a next step. Accordingly, the film thickness accuracy can be improved during the film formation on the substrate W.
(44) In the sputtering film formation on the substrate W, the disc shutter **51** is retracted from the shielding position A on the substrate W to the retracted position B, resulting in the state shown in FIG. **4**. In this state, an inert gas such as Ar gas is introduced as a sputtering gas from the gas supply part **40** into the processing chamber **10**, and a pressure in the processing chamber **10** is adjusted to a predetermined pressure by the exhaust device **12**. Then, the sputtering film formation is performed while rotating the stage **20** by the driving mechanism **26**.
(45) When the target **32***a* is used for the sputtering film formation on the substrate W, plasma is generated by applying a voltage from the power supply **33***a* to the target **32***a* via the target holder **31***a*, and magnetic field is generated by driving the magnet **34***a*. Accordingly, positive ions in the plasma collide with the target **32***a*, and the target **32***a* emits sputtered particles of a metal forming the target **32***a*. The sputtered particles are deposited on the substrate W, thereby forming a desired film.
(46) When the target **32***b* is used, plasma is generated by applying a voltage to the target **32***b* from the power supply **33***b* via the target holder **31***b*, and magnetic field is generated by driving the magnet **34***b*. Accordingly, a desired film is formed on the substrate W.
(47) Further, when sputtered particles are emitted from both the targets **32***a* and **32***b*, a voltage may be applied from the power supplies **33***a* and **33***b* to the targets **32***a* and **32***b* via the target holders **31***a* and **31***b*.
(48) If there is an unused target between the targets **32***a* and **32***b*, the unused target can be shielded by the target shielding member **81**.
(49) After the sputtering film formation is performed, the power supply to the target **32***a* and/or **32***b* is stopped, and the processing chamber **10** is purged. Then, the substrate W is unloaded from the processing chamber **10**.
(50) The sputtered particle emitting parts **30***a* and **30***b* perform dummy run or conditioning prior to

the sputtering film formation. In this case, the shutter **51** is retracted, so that an undesired film is not adhered to the crystal oscillators **61** of the film thickness measuring part **60**. Accordingly, it is possible to prevent the maintenance cycle of the crystal oscillators **61** from being shortened.

(51) In accordance with the present embodiment, prior to the sputtering film formation on the substrate W, the sputtering film formation on the disc shutter **51** is performed in a state where the substrate is shielded by the disc shutter **51**, and the film thickness is measured by the film thickness measuring part **60**. Since the thickness of the film formed on the disc shutter **51** close to the substrate W is measured prior to the sputtering film formation on the substrate W, the film thickness, which is identical to the film thickness of the film formed on the substrate W during the film formation on the substrate W, can be detected from the film thickness measurement result. Therefore, by measuring the thickness of the film formed on the disc shutter **51** using the film thickness measuring part **60**, the film formation state on the disc shutter **51** can be obtained, and abnormal film formation on the substrate W can be prevented in advanced.

(52) The film formation rate is calculated from the measurement result of the thickness of the film deposited on the disc shutter **51**, and the result is fed back to the controller **70** so that the result can be reflected in the process recipe at the time of performing film formation on the substrate in a next step. Accordingly, the film thickness accuracy can be improved in the film formation on the substrate W.

Other Applications

(53) While the embodiments of the present disclosure have been described, it should be noted that the embodiments of the present disclosure are illustrative in all respects and are not restrictive. The above-described embodiments may be omitted, replaced, or changed in various forms without departing from the scope of the appended claims and the gist thereof.

(54) For example, in the above embodiment, the case where the crystal oscillators are used as the film thickness measuring devices of the film thickness measuring part has been described. However, the present disclosure is not limited thereto, and another film thickness measuring device such as a device using an optical sensor or the like may be used. Further, the number of film thickness measuring devices may be one or more without being limited to that in the above embodiment.

(55) Although the case of using a sputtering apparatus as a film forming apparatus has been described, the present disclosure is not limited thereto, and may be applied to various film forming apparatuses.

Claims

1. A film forming apparatus for performing film formation on a substrate, comprising: a processing chamber; a stage configured to place thereon a substrate disposed in the processing chamber; a first film forming part configured to perform film formation on the substrate placed on the stage; a shutter that is movable between a shielding position where the substrate on the stage is shielded and a retracted position retracted from the stage and where the first film forming part performs the film formation on the substrate; a film thickness measuring part having a film thickness measuring device configured to measure a film thickness of a film formed on the shutter at the shielding position by the first film forming part; and a controller configured to control processing in the film forming apparatus, wherein the controller determines film formation on the substrate based on a film thickness measurement result obtained by the film thickness measuring device, and wherein a second film forming part is provided, and when abnormal film formation is detected from the film thickness measurement result after a film is formed on the shutter by the first film forming part, the controller controls the second film forming part to perform the film formation on the substrate.
2. The film forming apparatus of claim 1, wherein the film thickness measuring part has multiple film thickness measuring devices.

3. The film forming apparatus of claim 1, wherein the film thickness measuring device has a crystal oscillator disposed on a surface of the shutter.

4. The film forming apparatus of claim 1, wherein the first film forming part has a sputtered particle emitting part configured to emit sputtered particles from a target to the substrate placed on the stage, and is configured to perform the film formation by sputtering.

5. The film forming apparatus of claim 1, wherein when a change in a film formation rate is detected from the film thickness measurement result obtained by the film thickness measuring device, the controller adjusts film formation time in the film formation on the substrate.

6. The film forming apparatus of claim 1, wherein the controller calculates a film formation rate from the film thickness of the film on the shutter measured by the film thickness measuring device, and provides feedback on the calculated film formation rate during the film formation on the substrate.

7. A film forming method for performing film formation process on a substrate, by using a film forming apparatus including a processing chamber, a stage configured to place thereon a substrate disposed in the processing chamber, a first film forming part configured to perform film formation on the substrate placed on the stage, a shutter that is movable between a shielding position where the substrate on the stage is shielded and a retracted position retracted from the stage, and a film thickness measuring part having a film thickness measuring device configured to measure a film thickness of a film formed on the shutter at the shielding position by the first film forming part, the film forming method comprising: locating the shutter at a shielding position; forming a film on the shutter using the first film forming part; measuring a thickness of the film on the shutter using the film thickness measuring device of the film thickness measuring part; and locating the shutter at a retracted position and performing film formation on the substrate based on a film thickness measurement result obtained by the film thickness measuring device, wherein the film forming apparatus includes a second film forming part, and when abnormal film formation is detected from the film thickness measurement result after a film is formed on the shutter by the first film forming part, said performing film formation on the substrate is performed by the second film forming part.

8. The film forming method of claim 7, wherein when a change in a film formation rate is detected from the film thickness measurement result obtained in said measuring the thickness of the film, film formation time is adjusted during the film formation on the substrate.

9. The film forming method of claim 7, further comprising: calculating a film formation rate from the film thickness obtained in said measuring the thickness of the film, and providing feedback on the calculated film formation rate during the film formation on the substrate.

10. The film forming method of claim 7, wherein the film thickness measuring part has multiple film thickness measuring devices.

11. The film forming method of claim 7, wherein the film thickness measuring device has a crystal oscillator disposed on a surface of the shutter.

12. The film forming method of claim 7, wherein the first film forming part has a sputtered particle emitting part configured to emit sputtered particles from a target to the substrate placed on the stage, and is configured to perform the film formation by sputtering.