DESCRIPTION

TITLE OF INVENTION: SHUTTER DEVICE AND FILM-FORMATION APPARATUS

TECHNICAL FIELD

[0001]

The present invention relates to a shutter device and a film-formation apparatus.

Priority is claimed on Japanese Patent Application No. 2023-141340 filed on August 31, 2023, the contents of which are incorporated herein by reference.

BACKGROUND ART

[0002]

Conventionally, for example, in a film formation process in manufacture of semiconductor devices, a film-formation apparatus using a sputtering method (hereinafter referred to as a "sputtering apparatus") has been used. In sputtering apparatuses for such an application, with wiring patterns becoming finer in recent years, there is a strong demand for a capability to form a film with a high coverage on fine holes and trenches having a high aspect ratio exceeding 3 in depth-to-width ratio over the entire surface of a substrate to be processed. That is, improvement in coverage is strongly demanded.

[0003]

In a typical sputtering apparatus, as a first step for causing sputtered particles to be emitted from a target, a negative voltage is applied to the target disposed in a vacuum chamber into which argon gas has been introduced (hereinafter referred to as ignition). Therefore, a sputtering gas (for example, argon gas) is ionized and collides with the target, and as a result of this collision, sputtered particles are emitted from a surface of the target. For example, when sputtering is performed using a target formed of a wiring thin film material such as Ta or Cu, Ta atoms or Cu atoms are emitted from the target as

sputtered particles. The emitted atoms adhere to a process-target object and form a thin film. A substrate on which a film is to be formed is disposed to face the target at a predetermined distance in the vacuum chamber.

[0004]

Also, in a DC magnetron-type sputtering apparatus, a magnetic field is formed on a surface of a target by a magnetic-field generation part (for example, a permanent magnet or the like) provided on a rear surface of the target. In this state, when a negative voltage is supplied to the target, sputtering gas ions collide with a surface of the target, and target material atoms and secondary electrons are ejected from the target. As the secondary electrons circulate in the magnetic field formed on the surface of the target, a frequency of ionization collisions between the sputtering gas (inert gas such as argon gas) and the secondary electrons increases, thereby increasing a plasma density and it is possible to form a thin film (see, for example, Patent Document 1).

Citation List

Patent Document

[0005]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2008-47661

SUMMARY OF INVENTION

Technical Problem

[0006]

The inventors have found that, during film formation on fine holes and trenches, a film formation process at a stage in which plasma is not yet stabilized immediately after a negative potential is applied to the target has a significant influence on an occurrence of aggregation of sputtered particles on sidewalls of the fine holes and trenches. A cause

of such aggregation of the sputtered particles is presumably due to a quality of the film at the initial stage formed by the sputtered particles before the plasma is stabilized. Due to the defects in the film quality at the initial stage, film formation after plasma stabilization was affected, resulting in poor film quality. Before wiring patterns became finer, since a thickness of the film to be formed was relatively large, an amount of film formation performed during ignition was relatively small, and did not cause a problem. However, in recent years, as wiring patterns have become finer, a thickness of the film formed at the time of ignition has not been able to be ignored with respect to a required film thickness.

[0007]

Also, conventionally, a technology of inserting a shutter device between a target and a process-target object and thereby suppressing film formation at the stage when plasma is not yet stabilized is known. However, there have been problems in that plasma may leak and contaminate a chamber when a shutter is opened and closed, that an opening of the shutter is narrow, and that enlarging the opening of the shutter requires the chamber to be made larger.

[0008]

Also, in order to improve coverage for fine holes and trenches having a high aspect ratio, it is preferable to parallelize flight directions of sputtered particles. For that purpose, it is necessary to provide a collimator device in the chamber. However, there were cases in which an increase in size of the chamber was unavoidable.

[0009]

In view of the above, an objective of the invention is to provide a shutter device and a film-formation apparatus capable of performing film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in a

substrate, without being affected by sputtered particles deposited at the time of ignition.

Solution to Problem

[0010]

In order to solve the above-described problems, the invention employs the following configuration.

A shutter device according to one aspect of the invention is a shutter device provided in a film-formation apparatus forming a film on a surface of a process-target object by a sputtering method. The shutter device includes a housing having an opening, a plurality of shutter plates disposed inside the opening, each having a base end portion and a distal end portion, and a plurality of drive parts, each connecting the base end portion and the housing, being in one-to-one correspondence with the plurality of shutter plates, and configured to change a posture of each of the plurality of shutter plates. At least a part of a region of the opening serves as a passage region through which sputtered particles emitted from a target pass. The plurality of drive parts are configured to change the plurality of shutter plates to be: a closed state in which the plurality of shutter plates are disposed to close at least the passage region of the sputtered particles; a parallelized state in which a part of the plurality of shutter plates is disposed in the passage region of the sputtered particles such that flight directions of the sputtered particles are parallel to each other; and an open state in which the plurality of shutter plates are retracted from the passage region of the sputtered particles.

In the shutter device according to one aspect of the invention, in a case in which a direction from a center of the opening toward the housing is defined as a radial direction, the drive parts may include a rotary drive shaft having an axial direction oriented in the same direction as the radial direction and configured to rotate each of the shutter plates, and an opening-closing mechanism configured to bring the distal end

portion of the shutter plate closer to or further away from the housing. The rotary drive shaft may be configured to change a posture of the shutter plate between the closed state and the parallelized state. The opening-closing mechanism may be configured to change a posture of the shutter plate between the parallelized state and the open state.

In the shutter device according to one aspect of the invention, the shutter plate may have a pair of long-side portions shaped to approach each other in a direction from the base end portion toward the distal end portion. The shutter plate may have a tapered shape from the base end portion toward the distal end portion.

In the shutter device according to one aspect of the invention, a part of the shutter plate may be a flat portion having a flat plate shape. The flat portion may be a portion overlapping at least the passage region of the sputtered particles in the parallelized state.

In the shutter device according to one aspect of the invention, the long-side portions of the shutter plate may have a flange portion. The flange portion may close a gap between the long-side portion and a long-side portion of another shutter plate adjacent to the shutter plate in the closed state.

A film-formation apparatus according to one aspect of the invention is a film-formation apparatus forming a film on a surface of a process-target object by a sputtering method. The film-formation apparatus includes a chamber housing the process-target object and a target serving as a base material of the film which are disposed to face each other, a vacuuming part reducing a pressure inside the chamber, a magnetic-field generation part generating a magnetic field in front of a sputtering surface of the target, a power supply applying a voltage to the target, a gas-introduction part introducing a sputtering gas into the chamber, and a shutter device disposed between the target and the process-target object. The shutter device is the shutter device according to the aspects

described above.

Advantageous Effects of Invention

[0011]

The shutter device according to one aspect of the invention includes the drive part capable of changing postures of the plurality of shutter plates disposed inside the opening. The drive part is configured to change postures of the shutter plates to the closed state in which the passage region of the sputtered particles is closed, the parallelized state in which flight directions of the sputtered particles are made parallel, or an open state in which the shutter plates are retracted from the passage region of the sputtered particles. In a case of the closed state, sputtered particles do not adhere to the process-target object at the time of ignition. In a case of the parallelized state, the shutter plates function as a collimator for the sputtered particles, it is possible to form a film with a high coverage on holes or trenches having a high aspect ratio. In a case of the open state, the number of sputtered particles passing through the shutter device increases, thereby improving a film formation rate. Therefore, it is possible to perform film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in the process-target object, without being affected by the sputtered particles deposited at the time of ignition.

[0012]

Also, in the shutter device according to the aspect of the invention, the drive parts include the rotary drive shaft and the opening-closing mechanism. Inside the opening, a posture of the shutter plate can be changed between the closed state and the parallelized state by the rotary drive shaft. Also, the posture of the shutter plate can be changed between the parallelized state and the open state by the opening-closing mechanism. Therefore, since it is not necessary to move the shutter plate outside the

opening, the shutter device can be made smaller in size.

[0013]

Also, in the shutter device according to the aspect of the invention, the shutter plate has the pair of long-side portions shaped to approach each other in a direction from the base end portion toward the distal end portion. Furthermore, the shutter plate has a tapered shape in a direction from the base end portion toward the distal end portion. Therefore, inside the opening, the posture can be changed by the drive part connected to the base end portion without causing interference between two shutter plates adjacent to each other.

[0014]

Also, in the shutter device according to the aspect of the invention, at least a part of the shutter plate is a flat portion having a flat plate shape. The flat portion is a portion that overlaps at least the passage region of the sputtered particles in the parallelized state. Therefore, the shutter plate can be caused to function as a collimator. Therefore, it is possible to form a film with even better coverage on fine holes and trenches having a high aspect ratio which are formed in the process-target object.

[0015]

Also, in the shutter device according to the aspect of the invention, the long-side portions of the shutter plate have a flange portion. The flange portion closes a gap between the long-side portion and a long-side portion of another shutter plate adjacent to the shutter plate in the closed state. Therefore, it is possible to reliably prevent deposition of the sputtered particles on the process-target object at the time of ignition without any leakage of the sputtered particles from the gap between the shutter plates.

[0016]

According to the film-formation apparatus of the invention, since the shutter

device according to the aspect of the invention is provided, it is possible to perform film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in the process-target object, without being affected by the sputtered particles deposited at the time of ignition.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

[FIG. 1] A schematic cross-sectional view of a film-formation apparatus according to a first embodiment of the invention when viewed from a side surface thereof.

[FIG. 2] A schematic plan view showing a shutter device according to the first embodiment of the invention.

[FIG. 3A] A view showing an example of a shutter plate provided in the shutter device according to the first embodiment of the invention, and is a schematic perspective view when viewed from a side of a target.

[FIG. 3B] A view showing an example of the shutter plate provided in the shutter device according to the first embodiment of the invention, and is a schematic perspective view when viewed from a side of a process-target object.

[FIG. 4A] A view explaining an operation of a drive part provided in the shutter device according to the first embodiment of the invention, and is a schematic view, from a vertical direction, showing a state in which the shutter plate is open (parallelized state).

[FIG. 4B] A view explaining an operation of the drive part provided in the shutter device according to the first embodiment of the invention, and is a schematic view, from the vertical direction, showing a state in which the shutter plate is closed (closed state).

[FIG. 5A] A view explaining an operation of the drive part provided in the shutter device according to the first embodiment of the invention, and is a schematic view, from the vertical direction, showing a state in which the shutter plate is retracted (parallelized

state).

[FIG. 5B] A view explaining an operation of the drive part provided in the shutter device according to the first embodiment of the invention, and is a schematic view, from the vertical direction, showing a state in which the shutter plate approaches a housing of the shutter device (open state).

[FIG. 6A] A view explaining an operation of the shutter device according to the first embodiment of the invention, and is a schematic plan view showing a closed state.

[FIG. 6B] A view explaining an operation of the shutter device according to the first embodiment of the invention, and is a schematic side view showing the closed state.

[FIG. 7A] A view explaining an operation of the shutter device according to the first embodiment of the invention, and is a schematic plan view showing the parallelized state.

[FIG. 7B] A view explaining an operation of the shutter device according to the first embodiment of the invention, and is a schematic side view showing the parallelized state.

[FIG. 8] A view explaining an operation of the shutter device according to the first embodiment of the invention, and is a schematic plan view showing the open state.

[FIG. 9] A schematic cross-sectional view of a film-formation apparatus according to a second embodiment of the invention when viewed from a side surface thereof.

[FIG. 10] A schematic cross-sectional view of a film-formation apparatus according to a third embodiment of the invention when viewed from a side surface thereof.

[FIG. 11] A schematic cross-sectional view of a film-formation apparatus according to a fourth embodiment of the invention when viewed from a side surface thereof.

DESCRIPTION OF EMBODIMENTS

[0018]

In description of embodiments of the invention, a ceiling portion side of a chamber constituting a film-formation apparatus may be referred to using “upper”,

"upper side", "upward", or the like and a bottom portion side of the chamber may be referred to using "lower", "lower side", "downward", or the like.

Regarding definition of directions, a circumferential direction of a circular housing that constitutes a shutter device may be simply referred to using "circumferential direction". A radial direction of the circular housing may be simply referred to using "radial direction". Also, a direction from a center of an opening of the housing toward the outside of the housing may be simply referred to using "radial direction".

In the drawings for explaining the embodiments of the invention, reference signs X, Y, Z, X1, and Y1 are denoted. Reference sign Z denotes a direction perpendicular to a surface on which the film-formation apparatus is provided (Z direction), and is, for example, a vertical direction. In other words, the vertical direction is a direction from the ceiling portion to the bottom portion of the chamber. Reference sign X denotes a direction parallel to the surface on which the film-formation apparatus is provided (X direction), and is a direction orthogonal to the Z direction. Reference sign Y denotes a direction parallel to the surface on which the film-formation apparatus is provided (Y direction), and is a direction orthogonal to the Z direction. The X direction and the Y direction are orthogonal to each other. The X direction and Y direction correspond to radial directions.

In the description with reference to FIGS. 4A, 4B, 5A, and 5B, reference signs X1 and Y1 are used. Reference sign X1 denotes a direction parallel to the surface on which the film-formation apparatus is provided (X1 direction), and is a direction orthogonal to the Z direction. Reference sign Y1 denotes a direction parallel to the surface on which the film-formation apparatus is provided (Y1 direction), and is a direction orthogonal to the Z direction. The X1 direction and the Y1 direction are orthogonal to each other.

The X1 direction is a direction in which a rotary drive shaft constituting the shutter device extends. The X1 direction is used to describe an operation of the shutter device according to the embodiment, and a relationship between the X1 direction and the X direction is not particularly limited. For example, the X1 direction may be inclined with respect to the X direction, or may be parallel to the X direction. When the X1 direction is inclined with respect to the X direction, an inclination angle between the X1 direction and the X direction is not limited. The X1 direction may or may not coincide with the radial direction.

[0019]

In the following description, ordinal numbers such as “first” and “second” may be used. These ordinal numbers do not indicate the number of members described by the ordinal numbers. Ordinal numbers may be used to indicate that each of a plurality of members is a separate member. For example, among two shutter plates adjacent to each other, one shutter plate 23 may be referred to as a first shutter plate, and the other shutter plate may be referred to as a second shutter plate. Alternatively, each of a plurality of shutter plates disposed in the circumferential direction may be referred to as a “first shutter plate”, a “second shutter plate”, ⋯, an “N-th shutter plate”. In this case, N is a natural number greater than or equal to two. In the embodiment, as an example, the number of the plurality of shutter plates is eight (N=8).

[0020]

The term “facing” is a term indicating a positional relationship between two members. This positional relationship not only means that two members face each other, but also that another member is interposed between the two members. A similar interpretation also applies to the terms “provided”, “disposed”, and “connected”.

[0021]

<First embodiment>

Hereinafter, a film-formation apparatus 1 and a shutter device 21 according to a first embodiment of the invention will be described.

As shown in FIG. 1, the film-formation apparatus 1 is an apparatus for forming a film by a sputtering method. The film-formation apparatus 1 is an apparatus that uses a DC magnetron sputtering method. Also, the film-formation apparatus 1 is a deposition-down type sputtering apparatus. The film-formation apparatus 1 includes a chamber 2. A vacuum atmosphere can be created in an internal space of the chamber 2. The chamber 2 accommodates a substrate W (process-target object) and a target 3. A cathode unit C is attached to a ceiling portion of the chamber 2.

[0022]

The cathode unit C includes the target 3. The target 3 is attached to a holder 5. Furthermore, a magnetic-field generation part that is not shown in the drawings and generates a tunnel-shaped magnetic field in front of a sputtering surface (lower surface) 3a of the target 3 is built in the cathode unit C. The target 3 is a base material of a film to be formed on the substrate W (process-target object). The target 3 is made of a material appropriately selected according to a composition of a thin film to be formed on the substrate W (process-target object) to be processed, such as, for example, Cu, Ti, Al, or Ta. A shape of the target 3 corresponds to a shape of the substrate W to be processed. For example, the target 3 is manufactured by a known method to have a predetermined shape (for example, a circular shape in a plan view) such that an area of the sputtering surface 3a is larger than a surface area of the substrate W. Also, the target 3 is electrically connected to a DC power supply (sputtering power supply) that is not shown in the drawings and has a known structure. Therefore, the target 3 is configured such that a predetermined negative potential (voltage) is applied thereto.

[0023]

The magnetic-field generation part that is not shown in the drawings and is incorporated in the cathode unit C is disposed on a surface (upper surface) of the target 3 opposite to the sputtering surface 3a. The magnetic-field generation part has a yoke that is not shown in the drawings and a plurality of magnets that is not shown in the drawings. The yoke is disposed parallel to the target 3. The plurality of magnets are disposed on a lower surface of the yoke. With respect to a polarity of each of the plurality of magnets, the plurality of magnets are disposed such that magnetic surfaces facing the target 3 have different polarities from each other. Note that, a shape and the number of magnets are appropriately selected according to a magnetic field to be formed in front of the target 3 from the viewpoint of improving stability of discharge and efficiency of use of the target. For example, a flake-shaped or rod-shaped magnet may be used, or a plurality of magnets having such shapes may be appropriately combined and used. Furthermore, the magnetic-field generation part may be configured to perform a reciprocating motion or a rotational motion on a rear side of the target 3.

[0024]

A stage 10 facing the target 3 is disposed at a bottom portion of the chamber 2. The stage 10 is configured to determine a position of the substrate W and to hold the substrate W. Also, a gas pipe (gas-introduction part) that is not shown in the drawings and introduces a sputtering gas such as argon gas is connected to a side wall of the chamber 2. The other end of the gas pipe is connected to a gas source via a mass flow controller that is not shown in the drawings. Furthermore, an exhaust pipe 12a is connected to the chamber 2. The exhaust pipe 12a is connected to a vacuuming part (vacuum discharge unit, vacuum exhaust device) that is not shown in the drawings and is formed of a turbomolecular pump, a rotary pump, or the like. The vacuuming part

reduces a pressure inside the chamber 2.

[0025]

The shutter device 21 is disposed between the substrate W and the target 3. As shown in FIG. 2, the shutter device 21 includes a housing 22, a plurality of shutter plates 23, and a plurality of drive parts 24. In other words, the shutter device 21 may be referred to as a shutter mechanism. The housing 22 has an opening 22a. The plurality of shutter plates 23 are disposed inside the opening 22a. The plurality of drive parts 24 are in one-to-one correspondence with the plurality of shutter plates 23. One of the plurality of drive parts 24 connects the housing 22 and one of the plurality of shutter plates 23. The plurality of drive parts 24 are configured to change postures of the plurality of shutter plates 23 to a closed state, a parallelized state, or an open state. In other words, when one drive part 24 changes a posture of one shutter plate 23, the plurality of drive parts 24 change postures of the plurality of shutter plates 23 as a whole.

Each of the plurality of drive parts 24 is controlled by a control device that is not shown in the drawings. The control device includes, for example, a processing unit, a storage unit, and a communication unit. In the control device, the processing unit may perform information processing in accordance with a program stored in the storage unit, or the processing unit may perform information processing in accordance with information input to the communication unit from an external device of the control device. The control device provides a drive signal corresponding to a result of calculation in the processing unit to each of the plurality of drive parts 24, and the drive parts 24 change the postures of the plurality of shutter plates 23 in accordance with the drive signal.

[0026]

Here, the closed state refers to a state in which the shutter plate 23 is disposed to

close at least a passage region PA of sputtered particles. The closed state is the state shown in FIGS. 2, 6A, and 6B. The parallelized state refers to a state in which a part of the shutter plate 23 is disposed in the passage region PA of the sputtered particles such that flight directions of the sputtered particles are made parallel. The parallelized state is the state shown in FIGS. 7A and 7B. Also, the open state refers to a state in which the shutter plate 23 is retracted from the passage region PA of the sputtered particles. The open state is the state shown in FIG. 8. The passage region PA of the sputtered particles will be described later.

[0027]

As shown in FIGS. 1 and 2, an outer appearance of the housing 22 has an annular shape. The housing 22 has the opening 22a that communicates with a space (first space) in which the target 3 is exposed and a space (second space) in which the substrate W is exposed. In other words, the opening 22a penetrates the housing 22. At least a partial region of the opening 22a serves as the passage region PA through which sputtered particles emitted from the target pass. The passage region PA is the inner region indicated by the one-dot chain line in FIG. 2. Of the sputtered particles emitted from the target 3, those passing through the passage region PA have a relatively higher probability of reaching the substrate W (process-target object) compared to other sputtered particles. Also, the sputtered particles emitted from the target 3 may pass through a region outside the passage region PA. However, the sputtered particles that deviate the passage region PA have a lower probability of reaching the substrate W (process-target object) compared to the sputtered particles that pass through the passage region PA. A range of the passage region PA is determined by a size of the target 3, a size of the substrate W (process-target object), a distance between the target 3 and the substrate W, and the like.

[0028]

Also, a drive mechanism that is not shown in the drawings is incorporated inside the annular housing 22. The drive mechanism has a mechanism in which known mechanical elements are combined, and constitutes the drive part 24.

[0029]

FIGS. 3A and 3B show perspective views of the shutter plate 23. FIG. 3A is a schematic perspective view of the shutter plate 23 from the target 3. FIG. 3B is a schematic perspective view when viewed from the substrate W (process-target object). The shutter plate 23 has a plate shape. The shutter plate 23 has a base end portion 231, a distal end portion 232, and a pair of long-side portions 233. The pair of long-side portions 233 are shaped to approach each other in the direction from the base end portion 231 toward the distal end portion 232. In other words, since the plurality of shutter plates 23 shown in FIG. 2 are disposed in the circumferential direction of the circular housing 22, the pair of long-side portions 233 are formed to approach each other in a radial direction of the housing 22. The pair of long-side portions 233 correspond to two end parts of the shutter plate 23 in the circumferential direction of the housing 22. An overall shape of the shutter plate 23 has a tapered shape from the base end portion 231 toward the distal end portion 232. In other words, in a radial direction from the base end portion 231 to the distal end portion 232, a width of the shutter plate 23 in the circumferential direction of the housing 22 gradually decreases. The base end portion 231 has a substantially arcuate shape in a plan view of the shutter plate 23. The shape of the base end portion 231 corresponds to a shape of the opening 22a of the housing 22. The distal end portion 232 is shaped to form an acute angle. When the shutter plate 23 is in the closed state, the distal end portion 232 is positioned at substantially a center O of the opening 22a.

[0030]

The shutter plate 23 has a curved surface portion 234 and a flat portion 235. The curved surface portion 234 is positioned closer to the base end portion 231 than to the distal end portion 232. The flat portion 235 is positioned closer to the distal end portion 232 than to the base end portion 231. The flat portion 235 has a flat shape. The flat portion 235 is a portion overlapping the passage region PA of the sputtered particles when the posture of the shutter plate 23 is in the parallelized state. A boundary portion is positioned between the curved surface portion 234 and the flat portion 235. A distance between the distal end portion 232 and the boundary portion in the radial direction corresponds to a size of the passage region PA in the radial direction. The boundary portion is a boundary line extending in the circumferential direction to draw an arc. The curved surface portion 234 is formed to be inclined with respect to the flat portion 235 from the boundary line. The curved surface portion 234 may also be referred to as a tapered surface.

As shown in FIG. 3B, a non-through hole that does not penetrate the shutter plate 23 is formed on a surface of the flat portion 235 facing the substrate W. The non-through hole is provided to achieve weight reduction of the shutter plate 23, and may also be referred to as a weight reduction portion. In the example shown in FIG. 3B, the number of the non-through holes is three, but the number of the non-through holes is not limited. When the shutter plate 23 is sufficiently lightweight, or when it is necessary to reduce a processing cost of the shutter plate 23, the non-through hole may not be provided.

[0031]

The long-side portion 233 of the flat portion 235 of the shutter plate 23 has a flange portion 236. The flange portion 236 is provided to close a gap between the long-

side portion 233 of the shutter plate 23 (first shutter plate) and the long-side portion 233 of another adjacent shutter plate 23 (second shutter plate) in the closed state.

[0032]

Also, as shown in FIGS. 3A and 3B, a plate-shaped arm portion 241 is attached to the base end portion 231 of the shutter plate 23. The arm portion 241 constitutes a part of the drive part 24. In FIGS. 3A and 3B, the arm portion 241 is attached to an end part (one end side) of the base end portion 231 in the circumferential direction. A position at which the arm portion 241 is provided is not limited to the structure shown in FIGS. 3A and 3B. The arm portion 241 may also be positioned at a center of the base end portion 231. The arm portion 241 may also be positioned on a side opposite to the position shown in FIGS. 3A and 3B in the base end portion 231.

[0033]

Next, the drive part 24 will be described.

As shown in FIG. 2, the drive part 24 connects the base end portion 231 of each of the shutter plates 23 to the housing 22. The drive part 24 drives the shutter plate 23. The drive part 24 is configured to change a posture of the shutter plate 23. As described above, the drive part 24 is configured to change a posture of the shutter plate 23 to the closed state, the parallelized state, or the open state. The drive part 24 has a drive mechanism that is not shown in the drawings. The drive mechanism includes, for example, a rotation mechanism that rotates the shutter plate 23 around a rotation shaft, and a movement mechanism that moves the rotation shaft. Examples of the rotation mechanism and the movement mechanism include a cylinder linear-motion mechanism, a rack and pinion mechanism, a crank mechanism, a gear mechanism, a spring mechanism, a ball screw, a guide rail, and the like.

[0034]

The drive part 24 has a rotation shaft. The rotation shaft extends in the radial direction. In other words, the rotation shaft extends from the base end portion 231 toward the distal end portion 232 of the shutter plate 23. The drive part 24 is capable of rotating the shutter plate 23 around the rotation shaft by rotating the rotation shaft. Note that, a structure of the drive part 24 is not particularly limited as long as a structure of the drive part 24 has a function that can change the orientation of the shutter plate 23 from the base end portion 231 to the distal end portion 232 with respect to the housing 22.

More specifically, as an example, it is conceivable that the orientation of the shutter plate 23 from the base end portion 231 to the distal end portion 232 substantially coincides with a radial direction from the center O of the opening 22a toward the housing 22. In this case, it is only necessary to have: a function to rotate the shutter plate 23 around the rotation shaft by rotating the rotation shaft; and a function to change the direction from the base end portion 231 toward the distal end portion 232 of the shutter plate 23 from a state facing the center O of the opening 22a to a state extending in the circumferential direction of the housing 22.

Note that, the extending direction of the rotation shaft does not necessarily have to coincide with the radial direction. As long as the operation of the drive part 24 is possible, the extending direction of the rotation shaft is not limited.

[0035]

Next, the drive part 24 will be described with reference to FIGS. 4A, 4B, 5A, and 5B. The drive part 24 preferably includes a rotary drive shaft 242 and an opening-closing mechanism 25.

In FIGS. 4A, 4B, 4A, and 5B, the X1 direction and the Y1 direction are used to describe an example of an operation of the drive part 24, but the X1 direction and the Y1 direction do not limit a posture or position of the shutter plate 23. The dotted line

indicated by the reference sign 22 indicates the housing 22 of the shutter device 21 for convenience. The dotted line is shown so as to facilitate understanding of a relationship between the housing 22 and the drive part 24 in the X1, Y1, and Z directions.

For example, an axial direction of the rotary drive shaft 242 is the same as a radial direction of the opening 22a. That is, the rotary drive shaft 242 extends in the X1 direction. The rotary drive shaft 242 is configured to rotate the shutter plate 23. That is, the rotary drive shaft 242 is configured to rotate the shutter plate 23 around the X1 direction. The opening-closing mechanism 25 is configured to move the distal end portion 232 of the shutter plate 23 toward the housing 22 or away from the housing 22. That is, the opening-closing mechanism 25 is configured to move the shutter plate 23 in a plane parallel to the X1 direction and the Y1 direction. In other words, the opening-closing mechanism 25 is configured to rotate the shutter plate 23 around an axis parallel to the Z direction.

[0036]

The rotary drive shaft 242 protrudes from the housing 22 toward the center of the opening 22a. The rotary drive shaft 242 is rotatable by a drive mechanism that is not shown in the drawings and is incorporated in the housing 22. The rotary drive shaft 242 is attached to the base end portion 231 of the shutter plate 23 via a first joint portion 251 and the arm portion 241. The rotary drive shaft 242 is configured to change a posture of the shutter plate 23 between the closed state and the parallelized state.

[0037]

The opening-closing mechanism 25 includes the arm portion 241, the rotary drive shaft 242, the first joint portion 251, a second joint portion 252, and an opening-closing drive shaft 253. The arm portion 241 is attached to the base end portion 231 of the shutter plate 23. The rotary drive shaft 242 has the configuration described above.

The first joint portion 251 is disposed between the arm portion 241 and the rotary drive shaft 242. The first joint portion 251 is attached between the rotary drive shaft 242 and the arm portion 241. The first joint portion 251 allows a direction in which the arm portion 241 extends to be inclined with respect to a direction in which the rotary drive shaft 242 extends. The first joint portion 251 is, for example, a hinge having an axis parallel to the Z direction.

The second joint portion 252 is attached between the opening-closing drive shaft 253 and the arm portion 241. The second joint portion 252 allows the direction in which the arm portion 241 extends to be inclined with respect to a direction in which the opening-closing drive shaft 253 extends. The second joint portion 252 is, for example, a hinge having an axis parallel to the Z direction.

The opening-closing drive shaft 253 is disposed to be substantially parallel to the rotary drive shaft 242. That is, the opening-closing drive shaft 253 extends in the X1 direction. The opening-closing drive shaft 253 is connected to a drive mechanism that is not shown in the drawings and is incorporated in the housing 22. When the drive mechanism is driven, the opening-closing drive shaft 253 is configured to move forward and backward in a longitudinal direction (X1 direction) of the opening-closing drive shaft 253. The opening-closing drive shaft 253 is configured to move, for example, linearly in a direction parallel to the radial direction. The opening-closing mechanism 25 is configured to change the posture of the shutter plate 23 between the parallelized state and the open state. Examples of the structure of the drive mechanism operating the opening-closing drive shaft 253 include a cylinder linear-motion mechanism, a rack and pinion mechanism, a crank mechanism, a gear mechanism, a spring mechanism, a ball screw, a guide rail, and the like.

In such an opening-closing mechanism 25, as the opening-closing drive shaft

253 moves relative to the rotary drive shaft 242 in the longitudinal direction of the opening-closing drive shaft 253, the arm portion 241 is inclined with respect to the rotary drive shaft 242 in a rotation direction around the first joint portion 251, and the arm portion 241 is inclined with respect to the opening-closing drive shaft 253 in a rotation direction around the second joint portion 252. Therefore, the opening-closing mechanism 25 is configured to move the shutter plate 23 toward or away from the housing 22.

[0038]

An operation of the drive part 24 will be described.

As shown in FIGS. 4A and 4B, when the rotary drive shaft 242 is rotated around the X1 direction, the shutter plate 23 rotates about the rotary drive shaft 242, thereby changing a posture of the shutter plate 23.

[0039]

Also, as shown in FIGS. 5A and 5B, when the opening-closing drive shaft 253 provided in the opening-closing mechanism 25 is moved forward and backward in the X1 direction, an orientation of the arm portion 241 changes with the first joint portion 251 serving as a rotation axis. That is, when the opening-closing drive shaft 253 moves in the X1 direction, the posture of the arm portion 241 changes from a posture oriented in the X1 direction to a posture oriented in the Y1 direction. Accordingly, the posture of the shutter plate 23 also changes from a posture oriented in the X1 direction (FIG. 5A) to a posture oriented in the Y1 direction (FIG. 5B).

Conversely, when the opening-closing drive shaft 253 moves in a direction opposite to the X1 direction, the posture of the arm portion 241 changes from a posture oriented in the Y1 direction to a posture oriented in the X1 direction. Accordingly, the posture of the shutter plate 23 also changes from a posture oriented in the Y1 direction

(FIG. 5B) to a posture oriented in the X1 direction (FIG. 5A).

[0040]

Since the operation of the drive part 24 can be realized as shown in FIGS. 4A, 4B, 5A, and 5B, postures of the plurality of shutter plates 23 can be set to the closed state, the parallelized state, and the open state as shown in FIGS. 6A to 8.

[0041]

That is, in the closed state shown in FIGS. 6A and 6B, the orientation of each shutter plate 23 from the base end portion 231 to the distal end portion 232 faces the center O of the opening 22a. The distal end portion 232 of each shutter plate 23 is positioned at the center O of the opening 22a. Furthermore, the orientations of the plurality of shutter plates 23 are aligned such that each of the plurality of shutter plates 23 closes the opening 22a. With respect to two adjacent shutter plates 23 among the plurality of shutter plates 23, the long-side portion 233 (first long-side portion) of one shutter plate 23 (first shutter plate) is close to the long-side portion 233 (second long-side portion) of the other shutter plate 23 (second shutter plate).

However, in order to prevent generation of particles, the long-side portions 233 of two adjacent shutter plates 23 are disposed with a small gap therebetween without making contact with each other. In this case, in order to prevent sputtered particles from leaking to a side of the process-target object through the gap between the two long-side portions 233, the flange portion 236 provided on the long-side portion 233 is configured to overlap the other long-side portion 233. Therefore, the gap is closed while keeping the long-side portions 233 in a non-contact state.

[0042]

When the rotary drive shaft 242 is operated to rotate the orientation of the shutter plate 23 from such a closed state, the parallelized state as shown in FIGS. 7A and

7B is achieved. In the parallelized state, a part (flat portion 235) of each shutter plate 23 is positioned in the passage region PA of the sputtered particles. At this position, the long-side portion 233 of the shutter plate 23 is oriented to face the target 3 and the process-target object W to be processed. Therefore, the shutter plates 23 function as a collimator, and when sputtered particles pass through the shutter plates 23, flight directions of the sputtered particles are aligned in parallel.

[0043]

Also, when the opening-closing mechanism 25 is operated to incline the distal end portion 232 of the shutter plate 23 to the housing 22 side from the parallelized state, the open state as shown in FIG. 8 is achieved. In the open state, the orientation of the shutter plate 23 from the base end portion 231 to the distal end portion 232 becomes an orientation in the circumferential direction of the opening 22a. Therefore, the distal end portion 232 of the shutter plate 23 is brought into a state in which it is close to the housing 22. Therefore, the shutter plate 23 is retracted from the passage region PA of the opening 22a for sputtered particles.

[0044]

Next, film formation using the film-formation apparatus 1 as described above will be described.

First, the vacuum discharge unit is operated to evacuate the internal space of the chamber 2 until a degree of vacuum in the chamber 2 reaches a predetermined degree of vacuum (for example, a pressure on the order of 10^{-5} Pa). Then, after a pressure in the chamber 2 reaches the predetermined value, the substrate W is set on the stage 10. Furthermore, the shutter plate 23 of the shutter device 21 is brought into a closed state as shown in FIGS. 6A and 6B. A gas or the like (sputtering gas) is introduced into the internal space of the chamber 2 at a predetermined flow rate. In this state, a

predetermined negative potential is applied (power is supplied) from the DC power supply to the target 3 to generate a plasma atmosphere in the chamber 2. In this case, a magnetic field from the magnetic-field generation part captures electrons ionized in front of the sputtering surface 3a and secondary electrons generated by sputtering, thereby generating a high-density plasma in front of the sputtering surface 3a.

[0045]

Argon ions in the plasma collide with the sputtering surface 3a, the sputtering surface 3a is sputtered, and sputtered atoms and sputtered ions (sputtered particles) scatter from the sputtering surface 3a toward the substrate W. At this stage, since the shutter device 21 is in the closed state, the sputtered particles merely adhere to the shutter plate 23 and do not reach the substrate W.

[0046]

At a stage in which the initial stage of sputtering has been completed and the plasma has stabilized, the rotary drive shaft 242 of the drive part 24 is operated to transition from the closed state to the parallelized state. Therefore, the substrate W is exposed to the target 3. Also, the shutter plate 23 functions as a collimator. Therefore, the sputtered particles reach the substrate W and film formation starts. Particularly, when a Cu target is used, a self-sustained discharge is possible. Therefore, it is also possible to start film formation on the substrate W by stopping introduction of the sputtering gas into the internal space of the chamber 2 after ignition by the introduction of the sputtering gas, waiting until the plasma is stably maintained, and then transitioning the shutter device 21 from the closed state to the parallelized state. When film formation is performed in the parallelized state, flight directions of the sputtered particles are parallelized by the flat portion 235 of the shutter plate 23. Therefore, the sputtered particles reach the inside of holes and trenches having a high aspect ratio provided in the

substrate W, thereby increasing a coverage of the film.

[0047]

Also, at a stage in which the initial stage of sputtering has been completed and the plasma has stabilized, the rotary drive shaft 242 of the drive part 24 and the opening-closing mechanism 25 may be operated to transition from the closed state to the open state through the parallelized state. Therefore, the substrate W is exposed to the target 3. Therefore, the sputtered particles reach the substrate W and film formation starts. When the film formation is performed in the open state, although the flight directions of the sputtered particles become random, the sputtered particles are more likely to reach the substrate W, it is possible to increase a film formation rate.

[0048]

As described above, the shutter device 21 according to the first embodiment includes the drive part 24 capable of changing postures of the plurality of shutter plates 23 disposed inside the opening 22a. The drive part 24 is configured to change postures of the shutter plates 23 to: the closed state in which the passage region PA of the sputtered particles is closed; the parallelized state in which flight directions of the sputtered particles are made parallel; or the open state in which they are retracted from the passage region PA of the sputtered particles. In a case of the closed state, the sputtered particles do not adhere to the substrate W at the time of ignition. In a case of the parallelized state, the shutter plates 23 function as a collimator for the sputtered particles, it is possible to form a film with a high coverage on holes or trenches having a high aspect ratio. In a case of the open state, the number of sputtered particles passing through the shutter device 21 increases, thereby improving a film formation rate. Therefore, it is possible to perform film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in the process-target object,

without being affected by the sputtered particles deposited at the time of ignition.

[0049]

Also, in the shutter device 21 according to the first embodiment, the drive part 24 includes the rotary drive shaft 242 and the opening-closing mechanism 25. Inside the opening 22a, a posture of the shutter plate 23 can be changed between the closed state and the parallelized state by the rotary drive shaft 242. Also, the posture of the shutter plate 23 can be changed between the parallelized state and the open state by the opening-closing mechanism 25. Therefore, since it is not necessary to move the shutter plate 23 outside the opening 22a, the shutter device 21 can be made smaller in size.

[0050]

Also, according to the shutter device 21 of the first embodiment, the shutter plate 23 has the base end portion 231, the distal end portion 232, and the pair of long-side portions 233 approaching each other. Furthermore, the shutter plate 23 has a tapered shape in a direction from the base end portion 231 toward the distal end portion 232. Therefore, inside the opening 22a, the posture of the shutter plate 23 can be changed by the drive part 24 connected to the base end portion 231 without causing interference between the two shutter plates 23 adjacent to each other.

[0051]

Also, according to the shutter device 21 of the first embodiment, at least a portion of the shutter plate 23 that overlaps the passage region PA of the sputtered particles in the parallelized state is formed as a flat plate shape. Therefore, the shutter plate 23 can be caused to function as a collimator. Therefore, it is possible to form a film with even better coverage on fine holes and trenches having a high aspect ratio which are formed in the substrate W (process-target object).

[0052]

Also, according to the shutter device 21 of the first embodiment, the long-side portion 233 of the shutter plate 23 includes the flange portion 236 provided to close a gap between itself and another adjacent long-side portion 233 in the closed state. Therefore, it is possible to reliably prevent deposition of the sputtered particles on the substrate W (process-target object) at the time of ignition without any leakage of the sputtered particles from the gap between the shutter plates 23.

[0053]

According to the film-formation apparatus 1 including the shutter device 21 of the first embodiment, it is possible to perform film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in the substrate W, without being affected by the sputtered particles deposited at the time of ignition.

[0054]

<Modified example>

Modified examples regarding a posture and an orientation of the shutter device 21 will be described.

When the shutter device 21 is in the closed state, the shutter device 21 constituted by the plurality of shutter plates 23 has a substantially U shape or cup shape in cross-sectional views shown in FIGS. 1 and 6B.

The posture and orientation of the shutter device 21 are not limited to the examples shown in FIGS. 1 and 6B. As a modified example of the shutter device 21, the posture and orientation of the shutter device 21 may be set to have a substantially inverted U shape or an inverted cup shape in a cross-sectional view. In such a modified example, FIG. 3A is a schematic perspective view of the shutter plate 23 from the substrate W, and FIG. 3B is a schematic perspective view when viewed from the target 3. According to such a modified example of the shutter device 21, it is possible to obtain the

same effects as those described above. Note that, this modified example is also applicable to other embodiments to be described later.

[0055]

<Other embodiments>

In the shutter device 21 according to the first embodiment described above, a state of the shutter plate 23 is changed to the closed state, the parallelized state, or the open state by driving the plurality of drive parts 24. Devices to which the shutter device 21 is applicable are not limited to the above-described film-formation apparatus 1, and it is also applicable to other film-formation apparatus to be described below.

In the following description of FIGS. 9 to 11, members the same as those in the first embodiment described above will be denoted by the same reference signs, and description thereof will be omitted or simplified.

[0056]

<Second embodiment>

The film-formation apparatus 1 described above is a deposition-down type sputtering apparatus, but the shutter device 21 according to the embodiment of the invention is also applicable to deposition-up type sputtering apparatuses.

A film-formation apparatus 1A shown in FIG. 9 is a deposition-up type sputtering apparatus. In the film-formation apparatus 1A, a cathode unit C is provided at a bottom part of a chamber 2. The cathode unit C includes a target 3. The stage 10 is provided in a ceiling portion of the chamber 2. The stage 10 holds a substrate W. The shutter device 21 is disposed between the substrate W and the target 3.

Since the film-formation apparatus 1A with this configuration uses the shutter device 21 as in the first embodiment described above, a state of the shutter plate 23 is changed to a closed state, a parallelized state, or an open state. Therefore, it is possible

to perform film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in a process-target object, without being affected by the sputtered particles deposited at the time of ignition. Therefore, the same effects as those described in the first embodiment described above can be obtained.

[0057]

<Third embodiment>

The film-formation apparatus 1 described above is a device using a DC magnetron sputtering method, but an application of the shutter device 21 according to the embodiment of the invention is not limited to film-formation apparatus using the magnetron sputtering method, and is also applicable to vapor deposition devices.

A film-formation apparatus 1B shown in FIG. 10 is a vapor deposition device. The film-formation apparatus 1B includes a deposition material 50, a crucible 51, and an electron gun 52. The deposition material 50 and the crucible 51 constitute a deposition source. The deposition material 50, the crucible 51, and the electron gun 52 are disposed at a bottom part of a chamber 2. The electron gun 52 is capable of generating an electron beam BM toward the crucible 51 to evaporate the deposition material 50. The shutter device 21 is disposed between a substrate W and the deposition material 50. According to the film-formation apparatus 1B having such a configuration, the evaporated deposition material 50 reaches the substrate W via the shutter device 21. The deposition material 50 is deposited on a surface of the substrate W, and thereby a thin film can be formed on the substrate W.

Since the film-formation apparatus 1B with this configuration uses the shutter device 21 as in the first embodiment described above, a state of the shutter plate 23 is changed to a closed state, a parallelized state, or an open state. Therefore, it is possible to perform film formation with excellent coverage on fine holes and trenches having a

high aspect ratio, which are formed in a process-target object, without being affected by the deposition material 50 deposited on the substrate W at the time of ignition in the vapor deposition device. Therefore, the same effects as those described in the first embodiment described above can be obtained.

[0058]

<Fourth embodiment>

The shutter device 21 according to the embodiment of the invention is also applicable to a chemical vapor deposition (CVD) device.

A film-formation apparatus 1C shown in FIG. 11 is a CVD device. The film-formation apparatus 1C includes a first material supply source 60, a second material supply source 61, a material supply line 62, and a shower head 63. The shower head 63 is disposed at a position close to a ceiling portion of a chamber 2. A stage 10 facing the shower head 63 is disposed at a bottom part of the chamber 2. The first material supply source 60 and the second material supply source 61 supply source gases to the shower head 63 through the material supply line 62. A type of source gas in each of the first material supply source 60 and the second material supply source 61 is selected according to a type of thin film to be formed on a substrate W. The shower head 63 can impart energy to the source gas, causing a chemical reaction in the source gas discharged from the shower head 63. Here, imparting energy to the source gas to cause a chemical reaction means, for example, imparting energy such as heat, plasma, or light to the source gas to cause a chemical reaction. In the present embodiment, plasma is generated between the shower head 63 and the substrate W, and a chemical reaction is caused in the source gas by the plasma. That is, the film-formation apparatus 1C is a plasma CVD device.

The shutter device 21 is disposed between the substrate W and the shower head

63. According to the film-formation apparatus 1C having such a configuration, a chemical reaction occurs in the source gas discharged from the shower head 63, and the source gas reaches the substrate W via the shutter device 21. A reaction product due to the source gas is deposited on a surface of the substrate W, and a thin film can be formed on the substrate W.

Since the film-formation apparatus 1C having this configuration uses the shutter device 21 as in the first embodiment described above, a state of the shutter plate 23 is changed to a closed state, a parallelized state, or an open state. Therefore, it is possible to perform film formation with excellent coverage on fine holes and trenches having a high aspect ratio, which are formed in a process-target object, without being affected by a deposition material 50 deposited on the substrate W at the time of ignition in the CVD device. Therefore, the same effects as those described in the first embodiment described above can be obtained.

In the present embodiment, the plasma CVD device including the shutter device 21 has been described. The shutter device 21 is not limited to a plasma CVD device and may also be applicable to, for example, thermal CVD devices, plasma CVD devices, photo CVD devices, metalorganic chemical vapor deposition (MOCVD) devices, and the like.

In such a CVD device, the shutter device 21 is disposed at a position spaced apart from a film formation surface of the substrate, that is, the shutter device 21 is disposed in a flow path through which the source gas flows toward the film formation surface of the substrate.

[0059]

While preferred embodiments of the invention have been described and shown above, it should be understood that these are exemplary of the invention and are not to be

considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the scope of the invention. Accordingly, the invention is not to be considered as being limited by the foregoing description.

REFERENCE SIGNS LIST

[0060]

1, 1A, 1B, 1C Film-formation apparatus

2 Chamber

3 Target

21 Shutter device

22 Housing

22a Opening

23 Shutter plate

24 Drive part

25 Opening-closing mechanism

50 Deposition material

51 Crucible

52 Electron gun

60 First material supply source

61 Second material supply source

62 Material supply line

63 Shower head

231 Base end portion

232 Distal end portion

233 Long-side portion

235 Flat portion

236 Flange portion

242 Rotary drive shaft

O Center of opening

PA Passage region

5 W Substrate (process-target object)

CLAIMS

[Claim 1] A shutter device provided in a film-formation apparatus forming a film on a surface of a process-target object by a sputtering method, the shutter device comprising:

a housing having an inside surface and an opening, the opening being surrounded by the inside surface;

a plurality of shutter plates disposed inside the opening, each having a base end portion and a distal end portion; and

a plurality of drive parts disposed along the inside surface, each of the plurality of drive parts connecting the base end portion and the housing, being in one-to-one correspondence with the plurality of shutter plates, and configured to change a posture of each of the plurality of shutter plates, wherein

at least a part of a region of the opening serves as a passage region through which sputtered particles emitted from a target pass, and

the plurality of drive parts are configured to change the plurality of shutter plates to be: a closed state in which the plurality of shutter plates are disposed to close at least the passage region of the sputtered particles; a parallelized state in which a part of the plurality of shutter plates is disposed in the passage region of the sputtered particles such that flight directions of the sputtered particles are parallel to each other; and an open state in which the plurality of shutter plates are retracted from the passage region of the sputtered particles, wherein

in a case in which a direction from a center of the opening toward the inside surface of the housing is defined as a radial direction, each of the drive parts includes:

a rotary drive shaft extending in an axial direction oriented in the same direction as the radial direction, the rotary drive shaft being configured to rotate each of the shutter plates around the axial direction; and

an opening-closing mechanism configured to bring the distal end portion of the shutter plate closer to the inside surface of the housing or further away from the inside surface of the housing, and wherein

the rotary drive shaft is configured to change a posture of the shutter plate between the closed state and the parallelized state, and

the opening-closing mechanism is configured to change the posture of the shutter plate between the parallelized state and the open state.

[Claim 2] The shutter device according to claim 1, wherein

the shutter plate has a pair of long-side portions shaped to approach each other in a direction from the base end portion toward the distal end portion, and

the shutter plate has a tapered shape from the base end portion toward the distal end portion.

[Claim 3] The shutter device according to claim 2, wherein

a part of the shutter plate is a flat portion having a flat plate shape, and

the flat portion is a portion overlapping at least the passage region of the sputtered particles in the parallelized state.

[Claim 4] The shutter device according to claim 3, wherein

the long-side portions of the shutter plate have a flange portion, and

the flange portion closes a gap between the long-side portion and a long-side portion of another shutter plate adjacent to the shutter plate in the closed state.

[Claim 5] The shutter device according to claim 1, wherein

each of the plurality of drive parts includes:

an opening-closing drive shaft configured to move forward and backward in a direction in which the rotary drive shaft extends;

an arm portion attached to the base end portion of the shutter plate;

a first joint portion attached between the rotary drive shaft and the arm portion, the first joint portion being configured to allow a direction in which the arm portion extends to be inclined with respect to a direction in which the rotary drive shaft extends; and

a second joint portion attached between the opening-closing drive shaft and the arm portion, the second joint portion being configured to the direction in which the arm portion extends to be inclined with respect to a direction in which the opening-closing drive shaft extends.

[Claim 6] A film-formation apparatus forming a film on a surface of a process-target object by a sputtering method, the film-formation apparatus comprising:

a chamber housing the process-target object and a target serving as a base material of the film which are disposed to face each other;

a vacuuming part reducing a pressure inside the chamber;

a magnetic-field generation part generating a magnetic field in front of a sputtering surface of the target;

a power supply applying a voltage to the target;

a gas-introduction part introducing a sputtering gas into the chamber; and

a shutter device disposed between the target and the process-target object, wherein

the shutter device is the shutter device according to any one of claims 1 to 5.