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Film formation apparatus

Abstract

A film formation apparatus includes: a chamber which an interior thereof can be made vacuum; a rotary table provided inside the chamber, holding a workpiece, and circulating and transporting the workpiece in a circular trajectory; a film formation unit including a target formed of film formation material and a plasma generator which turns sputtering gas introduced between the target and the rotary table into plasma, the film formation unit depositing by sputtering film formation material on the workpiece; a film processing unit processing the film deposited by the film formation unit on the workpiece; holding regions each holding the workpiece and provided in a circular film formation region facing the film formation unit and the film processing unit that is a region other than the rotation axis in the rotary table; and a heater provided in the holding regions.

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USPC: None

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application is based upon and claims the benefit of priority from Japan Patent Application No. 2022-099203, filed on Jun. 20, 2022, and Japan Patent Application No. 2023-080995, filed on May 16, 2023, the entire contents of which are incorporated herein by reference.

FIELD OF INVENTION

(2) The present disclosure relates to a film formation apparatus.

BACKGROUND

(3) Compound semiconductors of nitrided gallium are getting attention as next-generation device material. For example, devices using gallium nitride (GaN) include light emitting devices, power devices, and high-frequency communication devices. Such devices are fabricated by forming compound film of nitrided gallium (GaN film) on silicon (Si) wafers, silicon carbide (SiC) wafers,

sapphire substrates, and glass substrates.
(4) Conventionally, the GaN film has been formed by MO-CVD (Metal Organic Chemical Vapor Deposition) method. In the MO-CVD method, since large amount of NH.sub.3 gas used in the process is required to suppress evaporation of gallium (Ga) that is liquid under normal temperature and normal pressure and to react Ga with nitrogen (N), the usage efficiency of the material is low. Furthermore, since it is difficult to handle the material gas and it is difficult to keep the condition of the device stable, the yield is low. In addition, since hydrogen (H) contained in the processing gas is captured in the formed GaN film at the time of processing, extra dehydrogenation process is required.
(5) Accordingly, a film formation apparatus is proposed in which sputtering gas and processing gas flow inside a vacuum chamber and target material is deposited and nitrided on a workpiece held in the chamber by sputtering to improve the usage efficiency of the material. In such a film formation apparatus, since reaction gas containing hydrogen (H) is not used, extra processes such as dehydrogenation is not necessary. Furthermore, since only easy-to-handle noble gas is introduced into the chamber, it is easy to maintain the condition of the apparatus stable, which results in excellent yields.
SUMMARY OF INVENTION
Problems to be Solved by Invention
(6) In the film formation apparatus which forms compound film of nitrided gallium (Ga) by sputtering, the film formation needs to be performed while heating to about several hundred degrees to improve the crystallinity of the film during the film formation. For example, the heat source may be fixed and arranged distantly from a rotary table on which a substrate is placed, like Patent Document 1.
(7) However, when heating from a position distant from the rotary table, the workpiece is only mainly heated by radiant heat because the chamber is vacuum. Accordingly, even when said position is close as about 30 mm from the rotary table, the heat must be more than it is originally required. For example, when the workpiece is required to be heated to 600 degrees, the heat must be 1000 degrees, which requires high power heating device and high cost. Therefore, a film formation apparatus with a heat source that can heat the workpiece efficiently when forming film is demanded.
(8) The present disclosure is proposed to address the above-described problem, and the objective is to provide a film formation apparatus which can form film while efficiently heating the workpiece.
Means to Solve the Problem
(9) To achieve the above objective, a film formation apparatus of the present embodiment include: a chamber which an interior thereof can be made vacuum; a rotary table provided inside the chamber, holding a workpiece, and circulating and transporting the workpiece in a circular trajectory; a film formation unit including a target formed of film formation material containing and a plasma generator which turns sputtering gas introduced between the target and the rotary table into plasma, wherein the film formation unit deposits by sputtering particles of the film formation material on the workpiece circulated and transported by the rotary table; a film processing unit processing the film deposited on the workpiece in the film formation unit circulated and transported by the rotary table in the film formation unit; a plurality of holding regions which holds each workpiece and which is provided in a film formation region that is an annular region in the rotary table other than a rotary shaft facing the film formation unit and the film processing unit; and a heater arranged in the plurality of the holding regions.
Effect of Invention
(10) According to the present disclosure, a film formation apparatus that can form film while efficiently heating the workpiece is provided.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a transparent plan view schematically illustrating the configuration of the film formation apparatus according to the embodiment.
(2) FIG. **2** is an A-B cross sectional diagram of FIG. **1** and is a detailed view of an inner structure of the film formation apparatus viewed from the side.
(3) FIG. **3** is an A-C cross sectional diagram of FIG. **1** and is a detailed view of an inner structure of the film formation apparatus viewed from the side.
(4) FIG. **4** is a flowchart of processes of the film formation apparatus according to the embodiment.
(5) FIG. **5**(A) is a cross sectional diagram illustrating an example of a LED layer structure, and FIG. **5**(B) is an enlarged view of a buffer layer.
(6) FIG. **6** is a transparent plan view schematically illustrating a modified example of the embodiment.
EMBODIMENTS
(7) Embodiments of the film formation apparatus are described in detail with the reference to the figures. Note that the figures schematically illustrate each component and each configuration and do not precisely illustrate their dimension and distance.
Summary
(8) A film formation apparatus **1** illustrated in FIGS. **1** to **3** is an apparatus for forming GaN (Gallium Nitride) film or AlN (Aluminum Nitride) on a workpiece **10** that is a film formation target by sputtering.
(9) For example, the workpiece **10** that is the film formation target is silicon (Si) wafers, silicon carbide (SiC) wafers, sapphire substrates, and glass substrates.
(10) The film formation apparatus **1** includes a chamber **20**, a transporting unit **30**, a film formation unit **40**, a film processing unit **50**, a surface processing unit **60**, a transfer chamber **70**, a cooling chamber **80**, and a controller **90**. These are described below.
(11) The film formation apparatus **1** performs each process in the chamber **20** which an interior thereof can be made vacuum can be by the film formation unit **40** to perform film formation process on the workpiece **10**, the film processing unit **50** to perform chemical reaction processing on the film formed by the film formation unit **40**, and the surface processing unit **60** to process a surface of the workpiece **10** before or after the film formation. Furthermore, the film formation apparatus **1** includes a transfer chamber **70** to carry the workpiece **10** into and out of the chamber **20** and the cooling chamber **80** to cool the workpiece **10** that has been carried out of the chamber **20**. These units are controlled by the controller **90**.
(12) [Chamber]
(13) As illustrated in FIG. **2**, the chamber **20** is a container which can make an interior thereof vacuum. The chamber **20** has a cylindrical-shape and is formed by a disk ceiling **20***a*, a disk bottom **20***b*, and an annular inner surface **20***c*. The interior of the chamber **20** is divided into a plurality of sections by a divider **22**. The divider **22** is a square wall plate arranged radially from a center of the cylinder, and extends from the ceiling **20***a* toward the bottom **20***b* but does not reach the bottom **20***b*. That is, a cylindrical space of the chamber **20** is ensured at the bottom-**20***b* side of the chamber **20**.
(14) A rotary table **31** to transport the workpiece **10** is arranged in this cylindrical space. A lower end of the divider **22** faces a placement surface for the workpiece **10** in the rotary table **31** with a gap for the workpiece **10** placed on the rotary table **31** to pass through. A processing space **41** for processing the workpiece **10** by the film formation unit **40** is divided by the divider **22**. That is, the film formation unit **40** has the processing space **41** that is smaller than the chamber **20**. The divider **22** can suppress sputtering gas G**1** used in the film formation unit **40** from diffusing in the chamber

20. In the film formation unit **40**, since only the pressure in the processing space **41** that is divided and smaller than the chamber **20** needs to be adjusted, pressure adjustment can be easily performed, and plasma discharge can be stabilized.
(15) Note that an exhaustion port **21** is provided in the chamber **20**. An exhaustion unit **23** is connected to the exhaustion port **21**. The exhaustion unit **23** has piping and unillustrated pumps and valves, and others. The chamber **20** can be depressurized and made vacuum by exhaustion using the exhaustion unit **23** via the exhaustion port **21**. In order to suppress the oxygen concentration low, the exhaustion unit **23** exhausts the chamber **20** until degree of vacuum becomes, for example, 10.sup.−4 Pa.
(16) [Transporting Unit]
(17) The transporting unit **30** includes the rotary table **31**, a motor **32**, a heat insulator **33**, a heater **34**, a rotary connection **35**, and a heat shield **36**. The transporting unit **30** is provided inside the chamber **20**, holds a plurality of the workpieces **10**, and circulates and transports the workpiece **10** along a transporting path L that has the trajectory of a circle. Furthermore, the transporting unit **30** heats the workpiece **10** by the heater **34**.
(18) The rotary table **31** is a disk-shape member arranged inside the chamber **20** and expands to a size that does not contact with an inner surface **20***c*. The rotary table **31** is supported by a cylindrical rotary shaft **311** which is coaxial with an insertion hole **31***a* provided at the center of the rotary table **31** and which is inserted into the insertion hole **31***a* via a fastening member **31***b*. The interior of the rotary shaft **311** is a hollow atmospheric space, and a central hole **311***a* that is an opened end is covered with a circular plate **311***b*. Furthermore, the rotary shaft **311** penetrates a through hole **20***d* provided in the bottom **20***b* of the chamber **20** to protrudes outside and is fastened to the bottom **20***b* by a fastening member **20***e* to make it airtight.
(19) The motor **32** is arranged outside the chamber **20** and continuously rotates the rotary table **31** at the predetermined rotation speed by rotating the rotary shaft **311** via an unillustrated coupling member. For example, the rotary table **31** rotates at speed of 1 to 150 rpm.
(20) The workpiece **10** is placed on a tray **11** and is transported by the rotary table **31**. The tray **11** is a plate held by the rotary table **31**. The workpiece **10** is placed on the tray **11** via an absorption member **12**.
(21) The absorption member **12** is a plate with a depression on an upper surface to place the workpiece **10**. The absorption member **12** is fit in the tray **11** so that the upper and lower surface thereof are exposed. The absorption member **12** is a member that absorbs the heat from the heater **34** and improves the heating efficiency of the workpiece **10** by emitting electromagnetic wave with the heat-absorbing wavelength of the workpiece **10**. For example, when the workpiece **10** is the sapphire substrate, the absorption member **12** is a member emitting the wavelength between mid-infrared and far-infrared of about 2 μm to 4 μm that is the heat-absorbing wavelength of the sapphire substrate. This value of the heat absorbing wavelength is a value when the workpiece **10** is a sapphire substrate, and when other material is used, the absorption member **12** with the wavelength suitable for said material is employed. The absorption member **12** is a black plate member. For example, the absorption member **12** may be carbon graphite and glassy carbon. The absorption member **12** may be a hard heat-resistant member in which a surface is coated black. Note that the color is not limited to black. That is, coating with the wavelength including the heat-absorbing wavelength of the workpiece **10** may be applied, or the member and coating may have partially different absorbing wavelength to have broader range of heat-absorbing wavelength.
(22) Furthermore, in the present embodiment, since the workpiece that is the heating target is the sapphire substrate which is difficult to heat, the absorption member **12** is used. The absorption member **12** may not be installed if the material of the workpiece **10** itself easily absorbs heat. That is, the absorption member **12** is not necessary if the workpiece **10** can be heated to the desired temperature only by using the heater **34**.
(23) As illustrated in FIG. **1**, a film formation region FA to form film on a plurality of the

workpieces **10** is provided in the rotary table **31**. As illustrated in the double-dotted line in FIG. **1**, the film formation region FA is a region in the rotary table **31** other than the rotary shaft **311** and is an annular region facing the film formation unit **40** and the film processing unit **50**. A holding region HA to hold each workpiece **10** is provided in the film formation region FA at equal intervals in the circumferential direction.

(24) A holder such as grooves, holes, protrusions, fits, or holders is provided in the holding region HA, and holds the tray **11**, on which the workpiece **10** is placed, by mechanical chucks or adhesive chucks. For example, a plurality of the workpieces **10** is arranged on the tray **11**, and six holding regions HA are arranged on the rotary table **31** at 60 degrees interval. That is, the film formation apparatus **1** can form film on a plurality of the workpieces held on a plurality of the holding regions HA at once, resulting in high productivity. Note that the tray **11** may be omitted and the workpiece **10** may be directly held in the holding region HA of the rotary table **31**.

(25) As illustrated in FIG. **2**, the heat insulator **33** is a plate formed of heat insulating material and is fit and fixed to the holding region HA. For example, the heat insulator **33** is ceramics. The heater **34** is a heater that generates heat when electricity is conducted. The heater may generate heat by resistance heating or by electromagnetic induction heating. The heater **34** is a circular plate and is fit on the heat insulator **33**. By this, the heater **34** is arranged between the rotary table **31** and the workpiece **10** in the holding region HA, and the heat insulator **33** is arranged between the heater **34** and the rotary table **31**. The heater **34** should at least have a size in which the workpiece **10** can be arranged on the absorption member **12** or on the tray **11**. Therefore, the heater **34** may not necessarily have a size that includes the entire tray **11**. The heat insulator **33** and the heater **34** as described above are each arranged in the holding region HA.

(26) An upper surface of the heater **34** is arranged to correspond to the lower part of the absorption member **12** when the workpiece **10** is placed on the holding region HA of the rotary table **31**. That is, as illustrated in FIG. **2**, the heat insulator **33**, the heater **34**, the absorption member **12**, and the workpiece **10** are arranged to be stacked in this order from the lower side of the rotary table **31**.

(27) The heat insulator **33** makes the heat generated from the heater **34** to escape to the rotary table **31** so that damages (such as deformation) to the rotary table **31** can be suppressed. Furthermore, the heat is suppressed from being discharged from lower part of the rotary table **31**. Note that the heater **34** heats the workpiece **10** via the absorption member **12** of the tray **11**. However, as described above, the absorption member **12** may be omitted, and the workpiece **10** may contact the heater **34**. The heater **34** may contact and directly heat the workpiece **10** or may indirectly heat the workpiece **10** via other members.

(28) The rotary connector **35** is a connector for electrically connecting the heater **34** circulated and transported in the trajectory of circle together with the workpiece **10**, and a power supply. The rotary connector **35** of the present embodiment is a slip ring having a rotary electrode **351** and a static electrode **352**. Note that the rotary connector **35** may be a rotary connector.

(29) In more detail, in the rotary connector **351**, a plurality of conductive ring electrodes **351***a* are arranged coaxially on the rotary shaft **311** outside the chamber **20**. Each ring electrode **351***a* is connected to the heater **34** by a cable **351***b* (positive wire, negative wire) passing through a hole provided in the rotary shaft **311** and passing through a center of a plate **311***b* from inside the rotary shaft **311**, and rotates together with the rotary shaft **311**.

(30) The static electrode **352** is a configuration in which a plurality of conductive brush electrodes **352***a* are fixed separately from the rotary shaft **311** at a position in contact with each ring electrode **351***a*. A brush electrode **352***a* is connected to a controller **353** via a cable **352***b* and is powered and controlled via the controller **353**.

(31) The controller **353** includes a temperature sensor, a temperature adjuster, and an operator. The temperature sensor detects the temperature of the heater **34** and transmits a signal of the detected temperature to the temperature adjuster. The temperature adjuster compares the detected temperature and the predetermined temperature, and transmits an operation signal to the operator.

The operator applies or stops applying power to the ring electrode **351***a* via the brush electrode **352***a* based on the operation signal to raise or lower the temperature of the heater **34**. Accordingly, the controller **353** can control the temperature of the heater **34** by performing feedback control. For example, the temperature sensor may be a thermocouple which is in contact with the heater **34** and which can detect temperature. For example, the operator may be a voltage adjuster such as SCR (Silicon Controlled Rectifier).
(32) Since a part of the brush electrode **352***a* is pressed to an outer circumference of the ring electrode **351***a*, a sliding contact is formed. By this, the rotary electrode **351** and the static electrode **352** are conducted, so that the ring electrode **351***a* and the brush electrode **352***a* are always maintained in contact to transmit power to the heater **34** even when the rotary electrode **351** rotates together with the rotary shaft **311**.
(33) The rotary connection **35** that is the slip ring is provided outside the chamber **20** to avoid vacuum discharge at the sliding contact between the brush electrode **352***a* and the ring electrode **351***a*. Furthermore, although omitted in FIG. **2**, a pair of the cables **351***a* and **352***b* connected to the ring electrode **351***a* and the brush electrode **352***a* are provided to each of the heaters **34**, so that the temperature of each of the heaters **34** can be controlled individually.
(34) The heat shield **36** is arranged along the film formation region FA distantly from the rotary table **31** at a side opposite the film formation region FA which is facing each processing unit of the rotary table **31**. That is, the heat shield **36** is arranged to distantly cover the lower surface of the rotary table **31**. The heat shield **36** includes a plurality of heat shielding plates **36***a*. The heat shielding plate **36***a* is a metal component with L-shaped cross-section formed by a flat plate that is a horizontal ring-shaped plate and a cylindrical side plate standing straight from an outer edge of the flat plate. Note that a transport port is formed in the cylindrical side plate by cutting out a part thereof corresponding to a load lock **71** to carry in the workpiece **10** to the rotary table **31**. The plurality of the heat shielding plates **36***a* is arranged as stacked layers which are spaced vertically and is supported and fixed to the bottom **20***b* of the chamber **20** by a support leg **36***b*. The rotary shaft **311** is inserted with space into the opening at the center of the heat shielding plate **36***a*.
(35) In such a way, by stacking the plurality of heat shielding plate **36***a* from a position close to the rotary table **31** toward a direction away from the rotary table **31**, the radiant heat from the heater **34** is reduce by stages so that the heat discharge to the bottom **20***b* of the chamber **20** can be suppressed in a vacuum. Since the heat discharge to the bottom **20***b* of the chamber **20** is suppressed, damages to the inner wall of the bottom **20***b* and side surface **20***c* of the chamber **20**, a bearing of the rotary shaft **311**, and the like can be prevented. Note that, to suppress the damage due to heat, reflection plates other than the heat shielding plate **36***a* may be provided to prevent light produced from the heater **34** from hitting the bottom **20***b* of the chamber **20**. To achieve the similar light reflection effect, a surface of the heat shielding plate **36***a* may be plated with gold.
(36) [Film Formation Unit]
(37) The film formation unit **40** generates plasma and exposes a target **42** formed of film formation material to the plasma. By this, the film formation unit **40** bombards ions contained in the plasma to the target **42** and deposits beaten-out particles (hereinafter, referred to as sputtering particles) forming the target **42** on the workpiece **10** to form the film. The film formation unit **40** includes a plasma generator to turn sputtering gas G**1** introduced between the target **42** formed of the film formation material and the rotary table **31** into plasma.
(38) As illustrated in FIG. **2**, the plasma generator includes the target **42**, a sputtering source formed by a backing plate **43** and an electrode **44**, a power supply **46**, and a sputtering gas introducer **49**.
(39) The target **42** is a tabular component formed of the film formation material that will be the film deposited on the workpiece **10**. The target **42** is provided distantly from the transporting path L of the workpiece **10** placed on the rotary table **31**. A surface of the target **42** is held on a ceiling **20***a* of the chamber **20** to face the workpiece **10** placed on the rotary table **31**. For example, three targets

42 are installed. Three targets **42** are provided in at positions that are apexes of a triangle in a plan view.
(40) The backing plate **43** is a supporting component to hold the target **42**. The backing plates **43** hold each target **42** separately. The electrode **44** is a conductive component for separately applying electric power to each target **42** from outside the chamber **20** and is electrically connected to the target **42**. The electrical power applied to each target **42** may be separately modified. If necessary, magnets, cooling mechanism, and the like may be provided to the sputtering source as appropriate.
(41) The power supply **46** is, for example, DC power supply that applies high voltage and is electrically connected to the electrode **44**. The power supply **46** applies electric power to the target **42** via the electrode **44**. Note that the rotary table **31** is at the same potential as the grounded chamber **20**, and the potential difference is produced by applying high voltage to the target-**42** side.
(42) As illustrated in FIG. **2**, the sputtering gas introducer **49** introduces sputtering gas G**1** into the chamber **20**. The sputtering gas introducer **49** includes an unillustrated source for the sputtering gas G**1** such as a cylinder, piping **48**, and a gas inlet **47**. The piping **48** is connected to the source for the sputtering gas G**1**, air-tightly penetrates the chamber **20**, and extends into an interior of the chamber **20**, and an end thereof opens as the gas inlet **47**. The sputtering gas introducer **49** of the present embodiment introduces the sputtering gas G**1** into the processing space **41** so that pressure in the processing space **41** becomes 0.3 Pa to 1.0 Pa.
(43) The gas inlet **47** opens between the rotary table **31** and the target **42** and introduces the sputtering gas G**1** for film formation into the processing space **41** formed between the rotary table **31** and the target **42**. Noble gas is employed for the sputtering gas G**1**, and argon gas and the like are suitable. The sputtering gas G**1** is gas not containing nitrogen (N) and may be single gas of Argon (Ar).
(44) In the film formation processing unit **40**, when the sputtering gas G**1** is introduced from the sputtering gas introducer **49** and high voltage is applied to the target **42** by the power supply **46** via the electrode **44**, the sputtering gas G**1** introduced in the processing space **41** formed between the rotary table **31** and the target **42** becomes plasma, and active species such as ions is produced. The ions in the plasma bombards the target **42** and beat out sputtering particles.
(45) Furthermore, the workpiece **10** circulated and transported by the rotary table **31** passes through the processing space **41**. The beaten-out sputtering particles are deposited on the workpiece **10** when the workpiece **10** passes through the processing space **41**, and film formed of the sputtering particles is formed on the workpiece **10**. The workpiece **10** is circulated and transported by the rotary table **31** and repeatedly passes through the processing space **41**, to perform the film formation process. The thickness of the film deposited when the workpiece passes through film formation unit **40** once depends on the processing rate of the film processing unit **50**, and is, for example, may be thin as about 1 to 2 atomic level (5 nm or less). By circulating and transporting the workpiece for multiple times, the film thickens and the film with the predetermined thickness is formed on the workpiece **10**.
(46) In the present embodiment, the film formation apparatus **1** includes a plurality of the film formation units **40** (herein, two film formation unit **40**), and in the chamber **20**, the film formation unit **40** is divided into two sections by the divider **22**. The plurality of the film formation units **40** selectively deposits the film formation material to form film formed of layers of a plurality of the film formation material. In particular, the present embodiment includes the sputtering source corresponding to different types of film formation material, and the plurality of the film formation units **40** selectively deposits the film formation material to form film formed of layers of multiple types of the film formation material. Including the sputtering source corresponding to different types of film formation material may include a case in which all film formation units **40** utilize different film formation material, and a case in which some film formation units **40** utilize the same film formation material while other film formation units **40** utilize the different film formation material. Selectively depositing the film formation material of one type means that when any one

type of the film formation material is deposited by the film formation unit **40**, other film formation material is not deposited by the film formation unit **40**.
(47) In the present embodiment, the film formation material forming the target **42** in one film formation unit **40** is material containing Ga and GaN, and the target **42** is a source for the sputtering gas containing Ga atoms to be deposited on the workpiece **10**. The target **42** contains GaN and deficient GaN that lacks nitrogen, that is, Ga atom that lacks bonding with N (nitrogen).
(48) The film formation material forming the target **42** in the other film formation processing unit **40** is material containing Al, and the target **42** is a source for the sputtering gas containing Al atoms to be deposited on the workpiece **10**. Note that the target **42** for sputtering may contain atoms other than Ga, Al, and N (nitrogen) if it can supply sputtering particles containing Ga atoms and sputtering particles containing Al atoms.
(49) To distinguish the two film formation units **40**, the film formation unit **40** having the target **42** formed of the material containing Ga and GaN is referred to as the film formation unit **40**A (GaN film formation unit), and the film formation unit **40** having the target **42** formed of the material containing Al is referred to as the film formation unit **40**B (Al film formation unit).
(50) [Film Processing Unit]
(51) The film processing unit **50** generates inductively coupled plasma inside a processing space **59** into which processing gas G**2** was introduced, and chemically reacts chemical species in said plasma and the film deposited on the workpiece **10** by the film formation unit **40**, to produce compound film. The film processing unit **50** is arranged in sections other than the sections in which the film formation processing unit **40** is arranged inside the chamber **20**.
(52) For example, the introduced processing gas G**2** includes oxygen or nitrogen. The processing gas G**2** may include inert gas such as argon gas, other than oxygen gas and nitrogen gas. The processing gas G**2** in the present embodiment is gas containing nitrogen. In the present embodiment, the film processing unit **50** is a nitriding processing unit that generates inductively coupled plasma inside the processing space **59** into which the processing gas G**2** containing nitrogen gas was introduced, and chemically reacts chemical species in said plasma and the film deposited on the workpiece **10** by the film formation unit **40**, to produce nitride film.
(53) As illustrated in FIG. **2**, the film processing unit **50** includes a cylinder body **51**, a window **52**, an antenna **53**, a RF power supply **54**, a matching box **55**, and a plasma generator formed by a processing gas introducer **58**.
(54) The cylinder body **51** is a component that covers the surrounding of the processing space **59**. As illustrated in FIGS. **1** and **2**, the cylinder body **51** is a cylinder with rectangular horizontal cross-section and rounded corners, and has an opening. The cylinder body **51** is fit in the ceiling **20***a* of the chamber **20** so that the opening thereof faces the rotary-table-**31** side with distance, and protrudes into the interior space of the chamber **20**. The cylinder body **51** is formed of material as same as the rotary table **31**.
(55) The cylinder body **51** divides the processing space **59** where the nitriding process is performed by the film processing unity **50**, so that the diffusion of the processing gas G**2** inside the chamber **20** is suppressed. That is, the film processing unit **50** has the processing space **59** that is smaller than the chamber **20** and is apart from the processing space **41**. Since only the pressure in the processing space **59** that is divided and smaller than the chamber **20** needs to be adjusted, pressure adjustment can be easily performed, and plasma discharge can be stabilized.
(56) The window **52** is a flat plate of dielectric material such as quartz with a shape that is substantially the same as the horizontal cross-section of the cylinder body **51**. The window **52** is provided to block the opening of the cylinder body **51** and divides the processing space **59** in the chamber **20** into which the processing gas G**2** containing nitrogen gas is introduced and the interior of the cylinder body **51**. Note that the window **52** may be dielectric such as alumina or semiconductors such as silicon.
(57) The processing space **59** is formed between the rotary table **31** and the interior of the cylinder

body **51** in the film processing unit **50**. The workpiece **10** is circulated and transported by the rotary table **31** and repeatedly passes through the processing space **59** to perform the nitriding process.
(58) The antenna **53** is a conductor wound in a coil-shape, is arranged in the interior space of the cylinder body **51** which is separated from the processing space **59** in the chamber **20** by the window **52**, and generates electric field when AC current is applied. To efficiently introduce the electric field generated from the antenna **53** to the processing space **59** via the window **52**, it is desirable to arrange the antenna **53** near the window **52**. The RF power supply **54** to apply high-frequency voltage is connected to the antenna **53**. The matching box **55** that is a matching circuit is connected in series to the output side of the RF power supply **54**. The matching box **55** stabilizes plasma discharge by matching impedance at the input side and the output side.
(59) As illustrated in FIG. **2**, the processing gas introducer **58** introduces the processing gas G**2** into the processing space **59**. The processing gas introducer **58** includes an unillustrated source for the processing gas G**2** such as a cylinder, piping **57**, and a gas inlet **56**. The piping **57** is connected to the source for the processing gas G**2**, air-tightly seals and penetrates the chamber **20**, and extends into the interior of the chamber **20**, and an end thereof opens as the gas inlet **56**.
(60) The gas inlet **56** opens at the processing space **59** between the window **52** and the rotary table **31**, and introduces the processing gas G**2**.
(61) In the film processing unit **50**, high-frequency voltage is applied to the antenna **53** from the RF power supply **54**. By this, high-frequency current flows in the antenna **53** and electric field by electromagnetic induction is generated. The electric field is generated at the processing space **59** via the window **52**, and inductively coupled plasma is generated in the processing gas G**2**. At this time, chemical species of nitrogen containing nitrogen atoms is produced, and the species bombards the film on the workpiece **10** and bonds with atoms forming the film. As a result, the film on the workpiece **10** is nitrided, and nitride film is formed as the compound film.
(62) Note that the reason for further providing the film processing unit **50** for nitriding while using the material containing GaN as the target **42** in the film formation unit **40**A is as follows. That is, since the melting point of Ga is low and Ga is in liquid state under normal temperature and normal pressure, nitrogen (N) may be contained to make the solid target **42**. Accordingly, it is considered to simply increase the nitrogen content of the target **42** and form the film only by the sputtering of the target **42**.
(63) Here, DC discharge sputtering is preferred than RF discharge sputtering to improve the film formation rate. However, when a large amount of nitrogen is contained in the target **42**, a surface thereof becomes insulated. DC discharge may not be produced in the target **42** with such an insulated surface.
(64) That is, there is a limit for the nitrogen content in the GaN target **42**, making the nitriding of Ga in the target **42** insufficient. That is, Ga atoms which do not bond with N (nitrogen) atoms are contained in the target **42** containing GaN.
(65) If the nitrogen content in the formed GaN film is low and there is nitrogen defect, the crystallinity and flatness of the film become worse, and therefore lacking nitrogen needs to be supplemented. Therefore, it is considered to add nitrogen gas to the sputtering gas G**1** introduced into the film formation unit **40** and perform sputtering, however, there is a concern that the surface of the target **42** may be nitrided and insulated. Therefore, nitrogen gas cannot be added to the sputtering gas G**1** in sufficient amount in the GaN film formation unit **40**A to supplement lacking nitrogen.
(66) Therefore, to supplement the lack of nitrogen, the nitriding is further performed on the GaN film formed in the film processing unit **50** after the film formation in the film formation unit **40**A. As a result of such nitriding process at the time of the film formation, the nitrogen content of the film on the workpiece **10** is increased, and GaN film without nitrogen deficiency can be obtained.
(67) [Surface Processing Unit]
(68) The surface processing unit **60** processes the surface of the workpiece **10** and the film

deposited by the film formation unit **40** circulated and transported by the rotary table **31**. The processing performed by the surface processing unit **60** is removal of oxide film on the surface of the workpiece **10** before the film is deposited by the film formation unit **40**, or flattening of the surface of the film during the formation on the workpiece **10**.
(69) The film during the formation on the workpiece **10** is film formed on the workpiece **10** before it becomes the desired thickness, and in detail, is compound film on the workpiece **10** to which the processing by the film processing unit **50** was performed or is film on the workpiece **10** formed by the film formation unit **40**. In other words, the transporting unit **30** circulates and transports the workpiece **10** to pass through the film formation unit **40**, the film processing unit **50**, and the surface processing unit **60**. By this, the surface processing unit **60** irradiates ions on the compound film on the workpiece **10** to which the processing by the film processing unit **50** was performed. Otherwise, when the film formation unit **40**, the surface processing unit **60**, and the film processing unit **50** are arranged in this order in the transporting direction of the transporting unit **30**, the transporting unit **30** circulates and transports the workpiece **10** to pass through the film formation unit **40**, the surface processing unit **60**, and the film processing unit **50** so that the surface processing unit **60** can irradiates ions on the film in the workpiece **10** formed by the film formation unit **40**.
(70) The surface processing unit **60** is arranged in sections other than the sections in which the film formation unit **40** and the film processing unit **50** are arranged inside the chamber **20**. The surface processing unit **60** includes a cylindrical electrode **61**, a shield **62**, and a plasma generator formed by a processing gas introducer **65** and a RF power supply **66**.
(71) As illustrated in FIGS. **1** and **3**, the surface processing unit **60** includes the box-shaped cylindrical electrode **61** provide across the upper portion to the interior of the chamber **20**. Although the shape of the cylindrical electrode **61** is not limited, in the present embodiment, the cylindrical electrode **61** is substantially arc-shaped in plan view. The cylindrical electrode **61** has an opening **61***a* in the bottom. An outer edge of the opening **61***a*, that is, a lower end of the cylindrical electrode **61** faces the upper surface of the workpiece **10** on the rotary table **31** via a slight gap therebetween.
(72) The cylindrical electrode **61** has a square cylinder in which one end has the opening **61***a* and the other end is blocked. The cylindrical electrode **61** is attached to the opening **21***a* provided in the ceiling of the chamber via an insulation member **61***c* so that the one end with the opening **61***a* faces the rotary table **31**. A side wall of the cylindrical electrode **61** extends inside the chamber **20**.
(73) In the cylindrical electrode **61**, a flange **61***b* extending outward is provided at the other side of the opening **61***a*. The insulation member **61***c* is fixed between the flange **61***b* and the circumferential edge of the opening **21***a* of the chamber **20** to keep the interior of the chamber **20** airtight. The material of the insulation member **61***c* is not limited if the material is insulative, and for example, may be formed of material such as PTFE (polytetrafluoroethylene).
(74) The opening **61***a* of the cylindrical electrode **61** is arranged at a position facing the transporting path L of the rotary table **31**. The rotary table **31** transports the tray **11** on which the workpiece **10** is loaded to pass through the position facing the opening **61***a* as the transporting unit **30**. Note that the opening **61***a* of the cylindrical electrode **61** is larger than the size of the tray **11** in the radial direction of the rotary table **31**.
(75) As described above, the cylindrical electrode **61** penetrates the opening **21***a* of the chamber **20** and a part of the cylindrical electrode **61** is exposed outside the chamber **20**. As illustrated in FIG. **3**, the portion of the cylindrical electrode **61** exposed outside the chamber **20** is covered by a housing **61***d*. The inner space of the chamber **20** is maintained airtight by the housing **61***d*. A portion of the cylindrical electrode **61** located inside the chamber **20**, that is, around the side wall is covered by the shield **62**.
(76) The shield **62** is a fan-shaped square cylinder coaxial with the cylindrical electrode **61** and is larger than the cylindrical electrode **61**. The shield **62** is connected to the chamber **20**. In detail, the

shield **62** stands upward from the edge of the opening **21***a* of the chamber **20**, and an end of the shield **62** extending inside the chamber **20** is positioned at the same height as the opening **61***a* of the cylindrical electrode **61**. The shield **62** is preferably formed by conductive metal component with low electrical resistance because the shield **62** acts as a cathode like the chamber **20**. The shield **62** and the chamber **20** may be integrally formed, or the shield **62** may be attached to the chamber **20** using fixtures and the like.

(77) The shield **62** is provided to stably generate plasma inside the cylindrical electrode **61**. Each wall of the shield **62** is provided to extend substantially in parallel with each wall of the cylindrical electrode **62** via a slight gap. It is preferable that the gap is as small as possible, because when the gap is too large, the capacitance may become small or the plasma generated inside the cylindrical electrode **61** may enter the gap. However, if the gap is too small, the capacitance between the cylindrical electrode **61** and the shield **62** becomes large, which is not preferred. The size of the gap may be set as appropriate in accordance with the capacitance required to generate plasma. Note that, although two side walls extending in the radial direction of the shield **62** and the cylindrical electrode **61** are illustrated, the gap with the same size as the gap for the side walls in the radial direction is also provided between two side walls extending in the circumferential direction of the shield **62** and the cylindrical electrode **61**.

(78) Furthermore, the processing gas introducer **65** is connected to the cylindrical electrode **61**. The processing gas introducer **65** includes an unillustrated source for the processing gas G**3**, a pump, and a valve, other than piping. The processing gas introducer **65** introduces the processing gas G**3** into the cylindrical electrode **61**. The processing gas G**3** may be changed depending on the purpose of the processing as appropriate. For example, the processing gas G**3** may include inert gas such as argon gas, oxygen gas or nitrogen gas, or oxygen gas or nitrogen gas in addition to argon gas.

(79) The RF power supply **66** to apply high-frequency voltage is connected to the cylindrical electrode **61**. The matching box **67** that is a matching circuit is connected in series to the output side of the RF power supply **66**. The RF power supply **66** is also connected to the chamber **20**. When voltage is applied from the RF power supply **66**, the cylindrical electrode **61** acts as an anode, and the chamber **20**, the shield **62**, the rotary table **31**, and the tray **11** act as a cathode. That is, they act as electrodes for reverse-sputtering. Therefore, as described above, the rotary table **31** and the tray **11** are conductive and contact with each other to be electrically connected.

(80) The matching box **67** stabilizes plasma discharge by matching impedance at the input side and the output side. Note that the chamber **20** and the rotary table **31** are grounded. The shield **62** connected to the chamber **20** is also grounded. The RF power supply **66** and the processing gas introducer **65** are both connected to the cylindrical electrode **61** via a through hole provided in the housing **61***d.*

(81) When the processing gas G**3** that is argon gas is introduced into the cylindrical electrode **61** from the processing gas introducer **65** and high-frequency voltage is applied to the cylindrical electrode **61** from the RF power supply **66**, capacitively coupled plasma is generated and argon gas is made into plasma, generating electrons, ions, radicals, and the like. The ions in the generated plasma is irradiated to the film on the workpiece **10** during formation.

(82) That is, the surface processing unit **60** includes the cylindrical electrode **61** in which the opening **61***a* is provided in one end and to which the processing gas G**3** is introduced the inside, and the RF power supply **66** to apply high-frequency voltage to the cylindrical electrode **61**, in which the transporting unit **30** transports the workpiece **10** to pass through right below the opening **61***a*, and the ions are drawn on the film formed on the workpiece and the ion irradiation is performed. In the surface processing unit **60**, to draw the ions on the film formed on the workpiece **10**, negative bias voltage is applied to the tray **11** on which the workpiece **10** is placed and the rotary table **31**.

(83) By using the cylindrical electrode **61** like in the surface processing unit **60**, the desired negative bias voltage can be applied to the tray **11** on which the workpiece **10** is placed and the

rotary table **31** while keeping said components at earth potential without applying high-frequency voltage on the tray **11** and the rotary table **13**, to draw the ions on the formed film. By this, there is no need to add structures for applying high-frequency voltage on the tray **11** and the rotary table **31** or to consider the ratio between the surface area of the electrode that is the anode and the surface area of other components surrounding the electrode that is the cathode for obtaining desired bias voltage, facilitating the apparatus design.

(84) Therefore, to flatten the film on the workpiece during formation, it is possible to draw the ions on the film formed on the workpiece **10** by simple structures even when the film formation and the ion irradiation are repeatedly performed while moving the workpiece **10**.

(85) The processing space **64** for surface processing by the surface processing unit **60** is divided by the cylindrical electrode **61** in the chamber **20**. The cylindrical electrode **61** can suppress the processing gas G**3** from diffusing in the chamber **20**. That is, the surface processing unit **60** has the processing space **64** that is smaller than the chamber **20** and is apart from the processing spaces **41** and **59**. Since only the pressure in the processing space **64** that is divided and smaller than the chamber **20** needs to be adjusted, pressure adjustment can be easily performed, and plasma discharge can be stabilized. Note that the number and order of the above film formation unit **40**, the film processing unit **50**, and the surface processing unit **60** are not particularly limited. Said number and order are not limited if desired process can be performed on the circulated and transported workpiece **10**.

(86) In this way, the film processing unit **50** turns nitrogen gas into plasma to produce the chemical species containing nitrogen atoms and chemically reacts the chemical species and the film formed on the workpiece **10** to produce the compound film. The film processing unit **50** can utilize inductively coupled plasma with high plasma density to chemically react the chemical species in said plasma and the film deposited on the workpiece **10** by the film formation unit **40**, to produce the compound film.

(87) The surface processing unit **60** applies negative bias voltage on the tray **11** on which the workpiece **10** is placed and the rotary table **31** and draws the ions on the film formed on the workpiece **10**, to flatten the film. The surface processing unit **60** can utilize the cylindrical electrode **61** to easily draw the ions on the film formed on the workpiece **10** to flatten the film.

(88) [Transfer Chamber]

(89) The transfer chamber **70** is a container for carrying the workpiece **10** in and out the chamber **20** via gate valves GV**1** and GV**2**. As illustrated in FIG. **1**, the transfer chamber **70** includes an interior space to house the workpiece **10** before it is carried into the chamber **20**. The transfer chamber **70** is connected to the chamber **20** via the gate valve GV**1**. Although not illustrated, transporting means to carry a tray **11** on which the workpiece **10** is loaded in and out the chamber **20** is provided in the interior space of the transfer chamber **70**. The transfer chamber **70** is depressurized by an unillustrated exhaustion mean such as a vacuum pump, and carries in the tray **11** on which the unprocessed workpiece **10** is loaded into the chamber **20** and carries out the tray **11** on which the processed workpiece **10** is loaded from the chamber **20** by the transporting means while keeping the vacuum condition in the chamber **20**.

(90) The transfer chamber **70** is connected to a load lock **71** via the gate valve GV**2**. The load lock **71** is a device to carry in the tray **11** on which unprocessed workpiece **10** is loaded into the chamber **20** from outside and carries out the tray **11** on which processed workpiece **10** is loaded from the transfer chamber **70** by the unillustrated transporting mean while keeping a vacuum condition in the transfer chamber **70**. Note that, in the load lock **71**, the vacuum condition which is depressurized by the unillustrated exhaustion mean such as a vacuum pump and the air-open condition in which vacuum is broken are switched.

(91) [Cooling Chamber]

(92) The cooling chamber **80** cools the workpiece **10** carried out from the chamber **20**. The cooling chamber **80** includes a container connected to the transfer chamber **70** and a cooling mean to cool

the workpiece **10** loaded on the tray **11** carried out from the transfer chamber **70**. For example, the cooling mean may be a spray to spray cooling gas. For example, the cooling gas may be Ar gas from the source of the sputtering gas G**1**. If the workpiece **10** of high temperature is carried out to the atmosphere, oxide film is formed on the workpiece **10**. Since this oxide film is unnecessary, if this oxide film is formed, it has to be removed. To avoid increasing this process, the cooling chamber **80** is provided to lower the temperature of the workpiece **10** to temperature which the oxide film will not be formed on the surface of the workpiece **10** in the atmosphere. It is preferable that cooling temperature may be temperature in which the oxide film will not be formed, such as 100 degrees or less, and preferably 80 degrees or less. Note that the tray **11** loading the processed workpiece **10** in the transfer chamber **70** is carried into the cooling chamber **80** by an unillustrated transporting mean.
(93) [Controller]
(94) The controller **90** controls various components of the film formation apparatus **1**, such as the exhaustion unit **23**, the sputtering gas introducer **49**, the processing gas introducers **58** and **65**, the power supply **46**, the RF power supplies **54** and **66**, the motor **32**, the controller **353**, the transfer chamber **70**, the load lock **71**, and the cooling chamber **80**. The controller **90** is a processing device including PLC (Programmable Logic Controller) and CPU (Central Processing Unit) and stores programs describing control contents.
(95) Detailed control contents may be initial exhaustion pressure of the film formation apparatus **1**, power applied to the target **42**, the antenna **53**, and the cylindrical electrode **61**, flow amount of the sputtering gas G**1** and the processing gas G**2** and G**3**, introduction time and exhaustion time, film formation time, surface processing time, heating temperature and time of the heater **34**, rotation speed of the motor **32**, cooling temperature, and cooling time. By this, the controller **90** can perform wide variety of film formation specification.
(96) Note that the controller **90** controls the heating temperature of the heater **34** via the controller **353**. The heating temperature of the heater **34** is controlled so that the temperature of the workpiece **10** rises by stages to the target temperature. That is, the heater **34** can control the temperature so that the temperature of the workpiece **10** rises by stages. “By stages” means “gradually”, “gently”, and “not rapidly”, and means that the time for the temperature to rise to the target temperature from the start of heating is time that can prevent the workpiece **10** from damaging. Furthermore, the controller **90** can control the heating temperature of the heater **34** depending on the types of the workpiece **10**. The heating temperature of a plurality of the heaters **34** can be controlled separately. By this, different types of workpieces **10**, such as sapphire substrates and silicon wafers, can be placed on the rotary table **31** and can be processed simultaneously.
(97) [Action]
(98) Next, action of the film formation apparatus **1** controlled by the controller **90** will be described. Note that, as described below, the film formation method to form film by the film formation apparatus **1** is also an aspect of the present disclosure. FIG. **4** is a flowchart of film formation processes by the film formation apparatus **1** according to the present embodiment. The film formation process is a process to alternately form layers of AlN film and GaN film, and to further form GaN layer. Since silicon wafers and sapphire substrates have crystal lattice different from GaN, there is a problem that if GaN film is directly formed, the crystallinity of GaN decreases. To address this mismatch of crystal lattice, layers of AlN film and GaN film are alternately deposited to form a buffer layer, and the GaN layer is formed on the buffer layer. For example, in the manufacturing of lateral MOSFET or LED, the film formation apparatus **1** can be used to form the buffer layer and the GaN layer on the silicon wafer.
(99) For example, FIG. **5**(A) illustrates a layer structure of LED, and a buffer layer **10***a*, a GaN layer **10***b* containing n-channel, the buffer layer **10***a*, the GaN layer containing p-channel, a light emitting layer **10***d*, and transparent conductive film **10***e* are layered on the silicon workpiece **10**. The transparent conductive film **10***e* is ITO (Indium Tin Oxide) film. Note that the electrode is not

illustrated in the figure. In addition, FIG. **5**(B) illustrates the buffer layer **10***a*.

(100) Firstly, pressure inside the chamber **20** is always reduced to predetermined pressure by exhaustion by the exhaustion unit **23** from the exhaustion port **21**. Furthermore, the heater **34** starts heating together with the exhaustion. At the same time, the rotary table **31** starts rotating. The interior of the chamber **20** is heated by radiation from the rotating heater **34** (Step S**01**). Heating while exhaustion facilitates desorption of residual gas in the chamber **20**, such as water molecules and oxygen molecules. By this, the residual gas less contaminates as impurities at the time of the film formation, and the crystallinity of the film is improved. After detecting that the oxygen concentration inside the chamber **20** became equal to or less than the predetermined value by a gas analysis apparatus such as Q-Mass, the rotary table **31** stops rotating.

(101) The tray **11** loading the workpiece **10** is sequentially carried into the chamber **20** via the load lock **71**, the gate valve GV**2**, the transfer chamber **70**, and the gate valve GV**1** by the transfer mean (Step S**02**). In Step S**02**, the rotary table **31** moves the empty holding region HA to transporting position from the transfer chamber **70**. The holding regions HA each hold the tray **11** that was carried in by the transporting mean. Accordingly, the trays **11** on which the workpiece **10** is placed are placed on all holding regions HA in the rotary table **31**.

(102) When the rotary table **31** starts rotating again, the heater **34** heats the workpiece **10**, and the oxide film on the surface of the workpiece **10** is removed by the surface processing unit **60** (Step S**03**). At this time, the absorption member **12** is heated by the heater **34**, so that the absorption member emits electromagnetic wave with wavelength which can be easily absorbed by the workpiece **10**, facilitating the heating of the workpiece **10** on the tray **11**.

(103) Furthermore, the workpiece **10** repeatedly passes through under the surface processing unit **60** by the rotation of the rotary table **31**. The surface processing unit **60** introduces the processing gas G**3** into the cylindrical electrode **61** from the processing gas introducer **65** and applies high-frequency voltage to the cylindrical electrode **61** from the RF power supply **66**. The processing gas G**3** is made into plasma by the application of high-frequency voltage, and the ions in the plasma hits the surface of the workpiece **10** passed through under the opening **61***a*, so that the oxide film is removed from the surface of the workpiece **10**.

(104) After the processing by the surface processing unit **60** is performed for the predetermined length of time for the oxide film is removed which is determined by experiments or the like, the buffer layer is formed by repeatedly and alternately performing the formation of the AlN film by the film formation unit **40**B and the film processing unit **50** and the formation of the GaN film by the film formation unit **40**A and the film processing unit **50**. As described above, the target **42** formed of the material containing Ga and GaN is attached to the film formation unit **40**A, and the target **42** formed of the material containing Al is attached to the film formation unit **40**B.

(105) Firstly, the Al film formation unit **40**B and the film processing unit **50** form the AlN film on the workpiece **10** (Step S**04**). That is, the sputtering gas introducer **49** supplies the sputtering gas G**1** into the processing space **41** of the film formation unit **40**B through the gas inlet **47**. The sputtering gas G**1** is supplied around the target **42** formed of Al. The power supply **46** applies voltage to the target **42** of the film formation unit **40**B. Accordingly, the sputtering gas G**1** becomes plasma. The ions produced by the plasma bombards the target **42** and beats out sputtering particles containing Al.

(106) Thin film which is the deposited sputtering particles containing Al atoms is formed on a surface of the unprocessed workpiece **10** when the workpiece **10** passes through the film formation unit **40**B. In the present embodiment, the film is deposited at thickness that can include one or two Al atoms in the thickness direction each time the workpiece **10** passes through the film formation unit **40**B.

(107) The workpiece **10** that has passed through the film formation unit **40**B by the rotation of the rotary table **31** passes through the film processing unit **50**, and Al atoms of the thin film is nitrided in said process. That is, the processing gas introducer **58** supplies the sputtering gas G**2** containing

nitrogen gas through the gas inlet **56**. The processing gas G**2** containing nitrogen gas is supplied to the processing space **59** between the window **52** and the rotary table **31**. The RF power supply **54** applies high-frequency voltage to the antenna **53**.

(108) The electric field generated by the antenna **53** through which high-frequency current has flown by the application of high-frequency voltage is generated in the processing space **59** via the window **52**. Then, the electric field excites the processing gas G**2** containing nitrogen gas supplied to the processing space **59** and produces plasma. The chemical species of nitrogen produced by the plasma bombards the Al thin film on the workpiece **10** and bonds with Al atoms, so that the AlN film that is sufficiently nitrided is formed.

(109) The workpiece **10** on which the AlN film is formed passes through the film processing unit **50** by the rotation of the rotary table **31**, goes to the surface processing unit **60**, and the ions are irradiated on the AlN film in the surface processing unit **60** (Step S**05**). That is, the processing gas introducer **65** supplies the sputtering gas G**3** containing argon gas through the piping. The processing gas G**3** is supplied to the space in the cylindrical electrode **61** surrounded by the cylindrical electrode **61** and the rotary table **31**. When voltage is applied from the RF power supply **66** to the cylindrical electrode **61**, the cylindrical electrode **61** acts as an anode, and the chamber **20**, the shield **62**, the rotary table **31**, and the tray **11** act as a cathode, exciting the processing gas G**3** supplied in the space in the cylindrical electrode **61** and generating plasma. Furthermore, argon ions produced by plasma bombards the AlN film formed on the workpiece **10** and moves the particles to sparse area in the film to flatten the surface of the film.

(110) In such a way, in the Steps S**04** and S**05**, the film formation is performed by passing the workpiece **10** through the processing space **41** of the operating film formation unit **40**B, and the nitriding process is performed by passing the workpiece **10** through the processing space **59** of the operating film processing unit **50**. Furthermore, the workpiece **10** passes through the space in the cylindrical electrode **61** of the operating surface processing unit **60** to flatten the AlN film formed on the workpiece **10**. Note that “operating” means that plasma generation operation to generate plasma is performed in respective processing spaces of the units **40**, **50**, and **60**.

(111) The rotary table **31** continues to rotate until the AlN film with predetermined thickness is formed on the workpiece **10**, that is, until the predetermined time obtained in advance by, for example, simulation and experiment has elapsed. In other word, the workpiece **10** continues to circulate through the film formation unit **40** and the film processing unit **50** until the AlN film with predetermined thickness is formed. Note that it is preferable to determine the film formation speed, the nitriding speed, and the rotation speed (speed to pass through each unit) of the rotary table **31** so that the film formation and the nitriding are balanced, because it is preferable to perform nitriding each time Al is deposited at atomic thickness. For example, the rotary table **31** rotates at speed of 50 to 60 rpm.

(112) After the predetermined time has elapsed (Step S**06**, Yes), firstly, the operation of the film formation unit **40**B is stopped. In detail, the power supply **46** stops applying voltage to the target **42**.

(113) Next, the film formation unit **40**A and the film processing unit **50** form the GaN film on the workpiece **10** (Step S**07**). Then, the GaN film is flattened (Step S**08**). That is, the sputtering gas G**1** is supplied around the target **42** of the film formation unit **40**A by the sputtering gas introducer **49** and voltage is applied to the target **42** of the film formation unit **40** by the power supply **46**, to make plasma sputtering gas G**1** supplied inside the processing space **41** of the film formation unit **40**A into plasma. The ions produced by the plasma bombards the target **42** and beat out sputtering particles containing Ga atoms.

(114) The workpiece **10** that has passed through the film formation unit **40***a* by the rotation of the rotary table **31** passes through the film processing unit **50**, and Ga atoms of the thin film is nitrided in said process. That is, the processing gas introducer **58** supplies the processing gas G**2** containing nitrogen gas through the gas inlet **56**. The processing gas G**2** containing nitrogen gas is supplied to

the processing space **59** between the window **52** and the rotary table **31**. The RF power supply **54** applies high-frequency voltage to the antenna **53**.
(115) The electric field generated by the antenna **53** through which high-frequency current has flown by the application of high-frequency voltage is generated in the processing space **59** via the window **52**. Then, the electric field excites the processing gas G**2** containing nitrogen gas supplied to the processing space **59** and produces plasma. The chemical species of nitrogen produced by the plasma bombards the GaN thin film on the workpiece **10** and bonds with Ga atoms, so that the GaN film that is sufficiently nitrided is formed.
(116) The workpiece **10** on which the GaN film is formed passes through the film processing unit **50** by the rotation of the rotary table **31**, goes to the surface processing unit **60**, and the ions are irradiated on the GaN film in the surface processing unit **60** (Step S**08**). Ions produced by plasma bombards the GaN film formed on the workpiece **10** and moves the particles to sparse area in the film to flatten the surface of the film.
(117) By this, thin film which is the deposited sputtering particles containing Ga atoms is formed on a surface of the AlN film. In the present embodiment, the film is deposited at thickness that can include one or two Ga atoms in the thickness direction each time the workpiece passes through the film formation unit **40**.
(118) In such a way, in the Steps S**06** and S**07**, the film formation to form film containing Ga is performed by passing the workpiece **10** through the processing space **41** of the operating film formation unit **40**A, and the nitriding process to form the GaN film is performed by passing the workpiece **10** through the processing space **59** of the operating film processing unit **50**. Furthermore, the workpiece **10** passes through the space in the cylindrical electrode **61** of the operating surface processing unit **60** to flatten the GaN film formed on the workpiece **10**.
(119) When time for the GaN film with predetermined thickness to be formed on the work piece **10**, which is the time determined by simulation and experiment, has elapsed, firstly, the rotary table **31** stops the operation of the film formation unit **40**. That is, after the predetermined time has elapsed (Step S**09**, Yes), the operation of the film formation unit **40**A is stopped. In detail, the power supply **46** stops to apply voltage to the target **42**. Note that it is preferable to determine the film formation speed, the nitriding speed, and the rotation speed (speed to pass through each unit) of the rotary table **31** so that the film formation and the nitriding are balanced, because it is preferable to perform nitriding each time Ga is deposited at atomic thickness. For example, the rotary table **31** rotates at speed of 50 to 60 rpm.
(120) The formation of the AlN film and the GaN film as described above is repeated until predetermined number of layers of the film are formed (Step S**10**, No). When predetermined number of layers of the film is formed (Step S**10**, Yes), the formation of the buffer layer is completed.
(121) Furthermore, GaN layer is formed on the buffer layer (Step S**11**). This GaN layer is formed in the same way as the GaN layer in the above buffer layer. However, the film is formed for the time required to form GaN layer with predetermined thickness.
(122) After the formation of the buffer layer and the GaN layer as described above, the operation of the film formation processing unit **40**A is stopped, and then the operation of the film processing unit **50** is stopped, as described above (Step S**12**). In detail, the RF power supply **54** stops supplying high-frequency electric power to the antenna **53**. Then, the rotation of the rotary table **31** is stopped, and the tray **11** on which the film-formed workpiece **10** is placed is carried into the cooling unit **80** via the transfer chamber **70** by the transporting mean, and is carried out from the load lock **71** after the workpiece **10** is cooled to the predetermined temperature (Step S**13**).
(123) Note that, in the above description, the film processing unit **60** and the surface processing unit **60** continues to operate while forming the buffer layer (Steps S**04** to S**11**), however, the film processing unit **50** and the surface processing unit **60** may be stopped every time each of the steps S**04** to S**11** is stopped. In this case, the operation of the film processing unit **50** is stopped after the

operation of film formation unit **40**B and the film formation unit **40**A is stopped. As a result, the surface of the film formed on the workpiece **10** can be sufficiently nitrided, and GaN film and AlN film without nitrogen deficiency can be obtained.
(124) [Effect]
(125) (1) The film formation apparatus **1** of the present embodiment includes: the chamber **20** which an interior thereof can be made vacuum; the rotary table **31** provided inside the chamber, holding the plurality of the workpieces **10**, and circulating and transporting the workpiece **10** in a circular trajectory; the film formation unit **40** including the target **42** formed of film formation material and the plasma generator which turns sputtering gas introduced between the target and the rotary table **31** into plasma, the film formation unit **40** depositing by sputtering the film formation material on the workpiece **10** circulated and transported by the rotary table **31**; the film processing unit **50** processing the film deposited by the film formation unit **40** on the workpiece **10** circulated and transported by the rotary table **31**; the plurality of the holding regions HA each holding the workpiece **10** and provided in the circular film formation region FA facing the film formation unit **40** and the film processing unit **50** that is a region other than the rotation axis **311** in the rotary table **31**, and the heater **34** provided in the plurality of the holding regions HA.
(126) Conventionally, when the heat source is fixed and arranged distantly from the rotary table, the temperature of the workpiece that is heated is not stable, because time to heat the workpiece that is rotated is limited. By this, it is difficult to heat to and keep the desired temperature. However, since the present embodiment includes the heater **34** in each holding region HA in the rotary table **31**, the heater **34** can rotate together with the workpiece **10** and heat the workpiece **10** that is rotated. By this, the temperature of the workpiece **10** will not decrease, and the workpiece **10** can be heated and kept at the desired temperature.
(127) Furthermore, since the heater **34** provided in each holding region HA in the rotary table **31** heats the workpiece **10** held by the holding region HA, the heating temperature of the heater **34** need not be excessively high compared with the case in which the workpiece **10** is heated only by radiation heat from the distant rotary table **31**, so that efficient heading is achieved.
(128) (2) The heat insulator **33** is provided between the heater **34** and the rotary table **31**. Therefore, since the transmission of heat from the heater **34** to the rotary table **31** is suppressed, the thermal deformation which harms the flatness of the rotary table **31** can be prevented.
(129) For example, since the rotary table **31** moves the workpiece **10** to pass through under the film formation unit **40**, the film processing unit **50**, and the surface processing unit **60**, the rotary table **31** has a disc-shape with large diameter and is made of metal to achieve strength and heat resistance by relatively low cost. Then, when the rotary table **31** is heated, the rotary table **31** may be thermally deformed, losing its flatness. In particular, if drastic change in temperature, such as from normal temperature to about 600 degrees, occur, the rotary table **31** plastically deforms and will not return the original state and loses its flatness even after cooling. If the flatness is lost, size of the gap between the workpiece **10** on the rotary table **31** and the divider **22** provided in the film formation unit **40**, the film processing unit **50**, and the surface processing unit **60** changes, and the pressure in the film formation unit **40**, the film processing unit **50**, and the surface processing unit **60** cannot be kept constant, which makes the plasma discharge in each processing space unstable. Furthermore, in the film formation unit **40**, since the positional relationship between the target **42** and the workpiece **10** on the rotary table **31** changes from the predetermined distance, the desired film formation rate may not be achieved or the film thickness may be non-uniform. In addition, since the height position and horizontal position of the holding region HA change because the flatness of the rotary table **31** is lost, the workpiece **10** may be displaced relative to or may hit the rotary table **31** when transferring the workpiece **10** from the transfer chamber **70** to the holding region HA by the transporting mean even if the workpiece **10** is transferred at the predetermined position.
(130) On the other hand, it is not realistic to form all of the rotary table **31** by heat insulator such as

ceramics in view of cost. Therefore, the heat insulator **33** is provided between the rotary table **31** and the heater **34** to insulate heat from the rotary table **31**, suppressing cost and the heating of the rotary table **31** other than the holding region HA.

(131) (3) The rotary connection **35** to enable power supply to the heater **34** rotating and moving by the rotary table **31** is provided in the rotary shaft **311**. Therefore, electrical power can be supplied to each heater **34** moving in a trajectory of circle using simple structures.

(132) (4) The heater **34** can control the temperature so that the temperature of the workpiece **10** rises by stages to the target temperature. By this, the workpiece **10** is prevented from being damaged due to the rapid increase in temperature. For example, after all the workpieces **10** is set on the rotary table **31**, the temperature is gradually increased, that is, the heater **34** is controlled to gradually increase the temperature, so that the workpiece **10** is prevented from being damaged due to the rapid increase in temperature. Furthermore, since the polarity of the Ga changed depending on the temperature, crystal phase of the film (Ga) formed on the workpiece **10** can be changed by adjusting the temperature of the heater **34**. Note that a plurality of the heater **34** is provided corresponding to each region holding the workpiece **10** in the plurality of the holding regions HA, and the temperature of the plurality of the heaters **34** can be individually adjusted. Therefore, the workpiece **10** that is the processing target can be heated by appropriate temperature according to the types, size, and the like.

(133) (5) The heat shield **36** is arranged along the film formation region FA distantly from the rotary table **31** at a side opposite the film formation region FA which is facing each processing unit of the rotary table **31**. Therefore, the heating of the chamber **20** by radiation from the heater **34** is suppressed. Since the heat absorption of the inner wall of the chamber **20** is suppressed, deformation of the wall surface of the chamber **20**, and damages to the bearing of the rotary shaft **311** and the sealing member caused by heating can be prevented.

(134) (6) The workpiece **10** is held by the rotary table **31** via the tray **11**, and the absorption member **12** which absorbs the heat from the heater **34** and generates electromagnetic wave is provided between the tray **11** and the workpiece **10**. Therefore, the workpiece **10** can be efficiently heated by the electromagnetic wave generated from the absorption member **12**. For example, the workpiece **10** can be efficiently heated even when the workpiece **10** is sapphire substrates or glass substrates, because the absorption member **12** generates electromagnetic wave that can be absorbed.

(135) (7) The film formation apparatus **1** includes the surface processing unit **60** processing at least one of the surface of the workpiece and the surface of the film circulated and transported by the rotary table **31**. Therefore, the adhesion of the surface of the workpiece **10** and the surface of the film is improved. For example, if oxide film is on the workpiece **10**, the film deposited on the oxide film easily peel off. If the surface of the film is uneven, the adhesion of the film deposited thereon is reduced. Therefore, the adhesion of the film can be improved by removing the oxide film on the surface of the workpiece **10** by the surface processing unit **60** and flattening the surface of the film. Since the surface of the workpieces **10** can be processed in the chamber **20** at once in advance, the throughput is improved than the case in which the surface is processed separately outside the chamber **20**. Furthermore, since the heating by the heater **34** and the surface processing can be performed at the same time, the overall processing time can be reduced.

Modified Example

(136) Note that the present disclosure is not limited to the following examples. Modified examples such as in below can be implemented with the similar basic configuration as the above embodiment.

(137) (1) Although the surface processing unit **60** is provided inside the chamber **20** in the above aspect, as illustrated in FIG. **5**, a surface processing unit **60**S may be arranged outside the chamber **20**. The surface processing unit **60**S includes the cylindrical electrode **61**, the RF power supply **66**, and the processing gas introducer **65**, like the surface processing unit **60**, and performs oxide film

removing process in the static condition on the transported workpiece **10**. In this aspect, the oxide film removing process can be performed on the workpiece **10** waiting outside the chamber during the film formation process on the workpiece **10** inside the chamber **20**, so that the processing time in the chamber **20** can be reduced.

(138) (2) The shape and number of the heat shielding plate **36***a* are not limited to the above embodiment. Although the heat shield **36** is arranged to distantly cover the lower surface of the rotary table **31**, the annular heat shielding plate **36***a* with U-shaped cross-section may be layered to cover a position in the lower surface of the eotary table **31** corresponding to the holding region HA. Furthermore, although the example heat shielding plate **36***a* has the shape formed by a side plate and a flat plate, the heat shielding effect can be achieved even when the heat shielding plate is formed only by a flat plate.

(139) (3) In the above embodiment, a plurality of the heaters **34** is arranged, and respective ring electrodes **351***a* are connected to the heaters **34** via the cables **351***b*. One or a plurality of the heaters **34** may be connected to one ring electrode **351***a*. For example, when connecting the plurality of the heaters **34** to one ring electrode **351***a*, the heaters **34** are electrically connected with each other, and the representative one heater **34** is connected to the ring electrode **351***a* via the cable **351***b*. By this, the number of the ring electrodes **351** can be less than the number of the heaters **34**, and the length of the rotary electrode **351** can be shorter. As a result, the rotary shaft **311** in which the rotary electrode **351** is arranged can be shorter, and the installation space for the apparatus can be reduced, and the rotation of the rotary table **31** can be stabilized.

(140) (4) The types and numbers of the film formation processing unit **40** and the types and numbers of the film processing unit **50** and the surface processing unit **60** provided in the chamber **20** are not limited to the above aspects. The number of the film formation unit **40** may be one or more than three. A plurality of the film processing unit **50** and the surface processing unit **60** may be provided. For example, the film formation unit **40** may only include the film formation unit **40**A to form the film formation apparatus **1** forming GaN film. Furthermore, in addition to the above film formation unit **40**, the film formation unit **40** with different target material may be provided, the film formation unit **40** with the same material target may be provided, and the film processing unit **50** may be provided.

(141) Furthermore, for example, as illustrated in FIG. **6**, the film formation unit **40**C including a target **42** containing indium oxide and tin oxide that is the film formation material of ITO may be added to form ITO film in the chamber **20**. In this case, in the film processing unit **50**, oxygen gas may be introduced instead of nitrogen gas to supplement the oxidation of the ITO film. In addition, for example, the film formation unit **40**A, the film formation unit **40**B, and the film processing unit **50** may be operated at the same time to form AlGaN (Aluminum Gallium Nitride) film that contains Ga, Al, and N. As illustrated in FIG. **5**(A), the AlGaN film acts as a light emitting layer **10***d* of LED. That is, the light emitting layer **10***d* may be formed in the chamber **20**.

(142) (5) The film formation unit **40** may include a film formation unit depositing film formation particles containing gallium oxide (Ga.sub.2O.sub.3), and the film processing unit **50** may include a oxidation processing unit to oxidize the film formation particles deposited in the film formation unit. That is, the film formation unit using material containing Ga atoms and oxygen (O) as the target may be provided instead of or in addition to the above film formation unit **40**A, and the oxidation processing unit using gas containing oxygen as the processing gas G**2** may be provided instead of or in addition to the nitriding processing unit.

(143) (6) In addition to the above aspects, a film formation unit including a target **42** formed of film formation material containing InN may be provided as the film formation processing unit **40**. Since indium (In) alone has low melting point, in practice, an InN target to which nitrogen is added is used as the solid target **42**. Similarly to the above, the InN target contains In atoms lacking bonds with nitrogen.

(144) (7) In addition to the above aspect, an impurity addition processing unit to add n-type or p-

type impurities (dopant) to the formed GaN film may be provided. In this case, the film formation unit, the nitriding processing unit, and the impurity addition processing unit are arranged in line in this order along the circulation and transportation path. The impurity addition processing unit includes the same configuration as the film formation unit **40**.

(145) In such aspects, a layer containing a p-channel (p-type semiconductor) to which Mg ions are added to the GaN layer can be formed by operating the impurity addition processing unit together with the film formation unit **40**A and the film processing unit **50** during the formation of the GaN film. Furthermore, a layer containing a n-channel (p-type semiconductor) to which Si ions are added to the GaN layer can be formed by operating the impurity addition processing unit together with the film formation unit **40**A and the film processing unit **50** during the formation of the GaN film.

(146) The n-type impurity and the p-type impurity added in the impurity addition processing unit are not limited to the above embodiments. For example, the n-type impurity may be Ge or Sn. In this case, the film formation material forming the target provided in the impurity addition processing unit may be film formation material containing Ge and Sn instead of Si.

Other Embodiment

(147) Although the modified examples of the embodiments and portions according to the present disclosure are described, these modified examples of the embodiments and portions are only presented as examples and are not intended to limit the scope of the claims. These new embodiments described above can be implemented in other various forms, and various omission, replacement, modification, and changes may be made without departing from the abstract of the invention. These embodiments and modification thereof are included in the scope and abstract of the invention, and are included in the invention described in the scope of the claims.

REFERENCE SIGN

(148) **1**: film formation apparatus **10**: workpiece **10***a*: buffer layer **10***b*, **10***c*: GaN layer **10***d*: light emitting layer **10***e*: transparent conductive film **11**: tray **12**: absorption member **20**: chamber **20***a*: ceiling **20***b*: bottom **20***c*: side surface **20***d*: through hole **20***e*: fastening member **21**: exhaustion port **21***a*: opening **22**: divider **23**: exhaustion unit **30**: transporting unit **31**: rotary table **31***a*: through hole **31***b*: fastening member **32**: motor **33**: heat insulator **34**: heater **35**: rotary connection **36**: heat shield **36***a*: heat shielding plate **36***b*: support leg **40**, **40**A, **40**B, **40**C: film formation unit **41**: processing space **42**: target **43**: backing plate **44**: electrode **46**: power supply **47**: gas inlet **48**: piping **49**: sputtering gas introducer **50**: film processing unit **51**: cylinder body **52**: window **53**: antenna **54**: RF power supply **55**: matching box **56**: gas inlet **57**: piping **58**: processing gas introducer **59**: processing space **60**, **60**S: surface processing unit **61**: cylindrical electrode **61***a*: opening **61***b*: flange **61***c*: insulation member **61***d*: housing **62**: shield **64**: processing space **65**: processing gas introducer **66**: RF power supply **67**: matching box **70**: transfer chamber **71**: load lock **80**: cooling chamber **90**: controller **311**: rotary shaft **311***a*: central hole **311***b*: plate **351**: rotary electrode **351***a*: ring electrode **351***b*: cable **352**: static electrode **352***a*: brush electrode **352***b*: cable **353**: controller

Claims

1. A film formation apparatus comprising: a chamber which an interior thereof can be made vacuum; a rotary table provided inside the chamber, holding a workpiece, and circulating and transporting the workpiece in a circular trajectory; a film formation unit including a target formed of film formation material containing and a plasma generator which turns sputtering gas introduced between the target and the rotary table into plasma, wherein the film formation unit deposits by sputtering particles of the film formation material on the workpiece circulated and transported by the rotary table; and a film processing unit processing the film deposited on the workpiece in the film formation unit circulated and transported by the rotary table in the film formation unit, wherein the rotary table comprises a plurality of holding regions which holds each workpiece and

which is provided in a film formation region that is an annular region in the rotary table other than a rotary shaft facing the film formation unit and the film processing unit, a heater arranged between the rotary table and the workpiece in each of the plurality of the holding regions to heat the workpiece on each of the plurality of the holding regions, and a heat insulator arranged between the rotary table and the heater in at least one of the plurality of holding regions.

2. The film formation apparatus according to claim 1, wherein the heater can control temperature so that temperature of the workpiece rises by stages to target temperature.

3. The film formation apparatus according to claim 1, further comprising a heat shield arranged along the film formation region distantly from the rotary table at a side opposite the film formation region facing each processing unit of the rotary table, wherein the heat shield comprises a plurality of heat shielding plates being a flat ring-shaped plate and arranged as stacked layers with vertical spaces, and a support leg supporting and fixing the plurality of the heat shielding plates to a bottom of the chamber.

4. The film formation apparatus according to claim 1, wherein the workpiece is held by the rotary table via a tray, the film formation apparatus further comprising an absorption member which absorbs heat from the heater and generates electromagnetic wave is provided between the tray and the workpiece.

5. The film formation apparatus according to claim 1, wherein the film processing unit performs chemical reaction processing on the film formed by the film formation unit, wherein the film formation apparatus further comprises a surface processing unit drawing and irradiating ion on at least one of the surface of the workpiece and the surface of the film circulated and transported by the rotary table.

6. The film formation apparatus according to claim 1, wherein: the film formation unit includes a GaN film formation unit depositing particles of the film formation material containing GaN, and the film processing unit includes a nitriding processing unit nitriding the particles of the film formation material deposited in the GaN film formation processing unit.

7. The film formation apparatus according to claim 5, wherein the film processing unit further comprises: a cylinder body fit in a ceiling of the chamber so that a first opening thereof faces the rotary-table side with distance, and protruded into an interior space of the chamber, a window provided to block the first opening of the cylinder body, an antenna being a conductor wound in a coil-shape, arranged in an interior space of the cylinder body being separated from a processing space in the chamber by the window, and generating electric field when AC current is applied, and a first processing gas introducer introducing a first processing gas into the processing space, wherein the surface processing unit further comprises: a cylindrical electrode having a square cylinder wherein one end has a second opening, the other blocked end of the cylindrical electrode is attached to the third opening provided in the ceiling of the chamber via an insulation member so that the one end with the second opening faces the rotary table, a shield covering a side wall of the cylindrical electrode located inside the chamber, a second processing gas introducer introducing a second processing gas into the cylindrical electrode, and an RF power supply applying high-frequency voltage to the cylindrical electrode, wherein the RF power supply applies the high-frequency voltage to the cylindrical electrode, so that a desired negative bias voltage is applied to the rotary table, and ions are drawn to the workpiece.

8. The film formation apparatus according to claim 7, wherein: the film formation unit includes a GaN film formation unit depositing particles of the film formation material containing GaN, and the film processing unit includes a nitriding processing unit nitriding the particles of the film formation material deposited in the GaN film formation processing unit.

9. The film formation apparatus according to claim 8, wherein the film processing unit, the nitriding processing unit, and the surface processing unit are arranged in this order on a path for circulating and transporting the workpiece.

10. The film formation apparatus according to claim 1, further comprising a rotary connector

electrically connecting the heater and a power supply, wherein the rotary connector comprises a plurality of conductive ring electrodes arranged coaxially on the rotary shaft outside the chamber and rotating with the rotary shaft, and a static electrode comprising a plurality of conductive brush electrodes fixed separately from the rotary shaft at a position in contact with the ring electrode.

11. The film formation apparatus according to claim 10, wherein the rotary shaft is cylindrical, wherein the rotary shaft further comprises: a circular plate airtightly covering a central hole that is an opened end of the rotary shaft, and a cable passing through a hole provided outside the chamber in the rotary shaft and airtightly passing through a center of the circular plate from inside the rotary shaft, wherein the cable passes through a hole provided in the rotary table and is connected to the heating unit from a rear side of the rotary table.

12. The film formation apparatus according to claim 3, wherein the heat shield is a metal component with L-shaped cross-section comprising a cylindrical side plate standing straight from an outer edge of a flat plate, and a transport port is formed in the cylindrical side plate by cutting out a part thereof corresponding to a load lock to carry in the workpiece to the rotary table.
