

ALUMINUM NITRIDE SINTERED BODY AND MEMBER FOR
SEMICONDUCTOR MANUFACTURING APPARATUS COMPRISING SAME

Technical Field

5 The present invention relates to an aluminum nitride sintered body and a member, comprising the same, for a semiconductor manufacturing apparatus.

Background Art

10 Of members for semiconductor manufacturing apparatuses, an electrostatic chuck for holding a wafer during semiconductor processing and a semiconductor manufacturing heater for simultaneously holding and heating a wafer in chemical vaporization deposition
15 process employ a ceramic material.

 In particular, aluminum nitride-containing ceramic materials can be applied to ceramic heaters for heating a substrate thanks to the high thermal conductivity thereof. A ceramic heater comprises a ceramic body, a
20 reference potential layer for producing plasma inside the body, and a heating element for generating heat. Hence, an aluminum nitride-containing ceramic material requires excellent electrical insulation and thermal conductivity.

25 Furthermore, the ceramic heater is required to function as an electrostatic chuck utilizing an electrostatic force and thus to have a high volume resistivity value at high temperatures. For example, a ceramic material used as a constituent of the ceramic
30 heater requires a volume resistivity of $1.0 \times 10^7 \Omega \cdot \text{cm}$ or higher at 500°C .

 However, ceramic materials such as aluminum nitrides decrease in volume resistivity with the increase of temperatures. For a ceramic heater using a
35 ceramic material such as aluminum nitride, the volume

resistivity of the ceramic body decreases with the increase of temperatures, which may cause the generation of a leak current between the reference potential layer and the heating layer. Moreover, the ceramic heater may
5 poorly function as an electrostatic chuck.

In order to maintain the volume resistivity value of the ceramic material at high temperatures, a metallic additive such as titanium, magnesium, or silicon, is added to the aluminum nitride accounting for the ceramic
10 body. However, the additives lower the thermal conductivity of the ceramic heater, degrading the temperature uniformity across the ceramic heater. Furthermore, when a ceramic heater composed of an aluminum nitride containing the additive is applied to a
15 semiconductor manufacturing apparatus, the additive may act as a pollution source during the operation of the semiconductor manufacturing apparatus.

Detailed Description of the Invention

20 Technical Problem

An object of the present invention is therefore to provide an aluminum nitride sintered body that simultaneously retains a high volume resistivity value at high temperatures and excellent thermal conductivity
25 and can suppress the generation of impurities.

Another object of the present invention is to provide a member, comprising the aluminum nitride sintered body, for a semiconductor manufacturing
apparatus.

30

Technical Solution

In order to attain the above objects, an aspect of the present invention provides an aluminum nitride sintered body comprising 1 to 5 % by weight of yttrium
35 oxide (Y_2O_3), 10 to 100 ppm by weight of titanium (Ti),

and the balance of aluminum nitride (AlN).

In one embodiment of the present invention, the titanium has a weight ratio of 0.0002-0.0031 to the yttrium oxide.

5 In one embodiment of the present invention, the aluminum nitride sintered body may have a volume resistivity value of 3.0×10^8 to 5.0×10^9 $\Omega \cdot \text{cm}$ at a temperature of 500°C in an electric field of 500 V/mm.

10 In one embodiment of the present invention, the aluminum nitride sintered body may have a thermal conductivity of 100 W/mK or greater.

In one embodiment of the present invention, the aluminum nitride sintered body has an impurity in an amount of 30 ppb or less as measured by an impurity
15 test.

Another aspect of the present invention provides a member for a semiconductor manufacturing apparatus, the member comprising: a heating plate composed of an aluminum nitride sintered body comprising 1 to 5 % by
20 weight of yttrium oxide (Y_2O_3), 10 to 100 ppm by weight of titanium (Ti), and the balance of aluminum nitride (AlN); a conductive member embedded in the heating plate; and a power supply unit connected to the conductive member.

25 In one embodiment of the present invention, the titanium has a weight ratio of 0.0002-0.0031 to the yttrium oxide.

In one embodiment of the present invention, the aluminum nitride sintered body may have a volume
30 resistivity value of 3.0×10^8 to 5.0×10^9 $\Omega \cdot \text{cm}$ at a temperature of 500°C in an electric field of 500 V/mm.

In one embodiment of the present invention, the aluminum nitride sintered body may have a thermal conductivity of 100 W/mK or greater.

35 In one embodiment of the present invention, the

aluminum nitride sintered body has an impurity in an amount of 30 ppb or less as measured by an impurity test.

5 Advantageous Effect

The aluminum nitride sintered body according to the present invention comprises 1 to 5 % by weight of yttrium oxide (Y_2O_3), 10 to 100 ppm by weight of titanium (Ti), and the balance of aluminum nitride (AlN).
10 Therefore, the aluminum nitride sintered body containing a small amount of the titanium element and an optimized amount of yttrium oxide can retain a high volume resistivity value at high temperature while guaranteeing excellent thermal conductivity.

15 Furthermore, when a semiconductor manufacturing member utilizing the aluminum nitride sintered body is employed in a semiconductor manufacturing process, the limited content of titanium, which may act as a pollution source, results in reducing defectives in the
20 manufacturing process.

Brief Description of the Drawings

FIG. 1 is a cross-sectional view illustrating a member for a semiconductor manufacturing apparatus in
25 accordance with an embodiment of the present invention.

Mode for Carrying Out the Invention

Hereinafter, an aluminum nitride sintered body according to an embodiment of the present invention and
30 a member for a semiconductor manufacturing apparatus including the same will be described in detail with reference to the accompanying drawing. The present invention may be applied to various modifications and may have various forms, and specific embodiments are
35 illustrated in the drawing and described in detail in

the text. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed, but includes all modifications, equivalents, and alternatives falling
5 within the spirit and scope of the invention. In the accompanying drawing, the dimensions of the structure are enlarged to illustrate the present invention in order to clarify the present invention.

The terms "first", "second", and the like may be
10 used to describe various components, but the components should not be limited by the terms. The terms are used only for the purpose of distinguishing one component from another. For example, without departing from the scope of the present invention, the first component may
15 be referred to as a second component, and similarly, the second component may also be referred to as a first component.

The terminology used in this application is used only to describe a specific embodiment and is not
20 intended to limit the invention. The singular expressions include plural expressions unless the context clearly dictates otherwise. In this application, the terms "comprises", "having", and the like are used to specify that a feature, a number, a step, an
25 operation, an element, a part or a combination thereof is described in the specification, but do not preclude the presence or addition of one or more other features, integers, steps, operations, components, parts, or combinations thereof.

30 Unless defined otherwise, all terms used herein, including technical or scientific terms, have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Terms such as those defined in commonly used dictionaries are to be
35 interpreted as having a meaning consistent with the

contextual meaning of the related art and are to be interpreted as either ideal or overly formal in the sense of the present application do not.

5 Aluminum nitride sintered body

 An aluminum nitride sintered body according to the present invention comprises yttrium oxide, titanium, and aluminum nitride.

 Aluminum nitride (AlN), which is included in the
10 sintered body of the present invention, is high in thermal conductivity and electrical insulation. Therefore, the aluminum nitride (AlN) acts to allow the aluminum nitride sintered body to exhibit high thermal conductivity and high insulation.

15 As a result, the aluminum nitride sintered body comprising aluminum nitride can be applied to an electrostatic chuck-type heating plate that simultaneously holds and heats a wafer.

 According to an embodiment of the present
20 invention, the aluminum nitride may be in the form of a reductive powder with high purity (99% or higher).

 The aluminum nitride sintered body of the present invention comprises yttrium oxide (Y₂O₃). Percentages by weight of yttrium oxide in the aluminum nitride sintered
25 body are determined on the basis of the quantity of the detected elements as measured by scanning electron microscopy or transmission electron microscopy using an energy dispersive X-ray spectroscope. Percentages by weight of yttrium oxide can be calculated by converting
30 a detected content of yttrium into a content of the oxide thereof.

 The yttrium oxide allows the aluminum nitride sintered body to have thermal conductivity at a certain level or higher. That is, yttrium oxide functions to
35 compensate for the thermal conductivity reduction caused

by titanium addition.

Meanwhile, the yttrium oxide serves to help the sintering between individual ingredients during the fabrication of the aluminum nitride sintered body. For
5 example, when added in an oxide form, yttrium reacts with the oxygen and aluminum contained in the powder for the aluminum nitride sintered body to form an aluminate compound. The aluminate compound has a relatively low sintering temperature. Consequently, the yttrium oxide
10 makes the sintering easy through reaction with other elements for fabrication of a sintered body, acting to lower the sintering temperature during a sintering process. Thus, when used, the yttrium oxide can facilitate the sintering process for the aluminum
15 nitride sintered body of the present invention and can densify the sintered body.

The yttrium oxide may be contained in an amount of 1 to 5 % by weight, based on the total weight of the aluminum nitride sintered body.

20 Less than the suitable amount of yttrium oxide degrades the thermal conductivity of the aluminum nitride sintered body, making it difficult to use the aluminum nitride sintered body as a heater.

On the other hand, when the yttrium oxide is added
25 in an amount exceeding the suitable range, the aluminum nitride sintered body may decrease in mechanical strength. Even an excess of yttrium oxide cannot make a particular contribution to the volume resistivity of the aluminum nitride sintered body. In this case, moreover,
30 there may be the problem that the aluminum nitride sintered body depreciates in appearance such as color brightness or saturation.

The aluminum nitride sintered body of the present invention comprises titanium (Ti). The titanium (Ti) may
35 be contained in an amount of 10 to 100 ppm by weight,

based on the total weight of the aluminum nitride sintered body.

The titanium plays a role in increasing the volume resistivity value of the aluminum nitride sintered body.

5 When the aluminum nitride is formed, together with yttrium oxide and titanium, into a sintered body, the sintered body may range in volume resistivity from 3.0×10^8 to $5.0 \times 10^9 \Omega \cdot \text{cm}$ at 500°C in the electric field of 500 V/mm. Even when increasing in temperature, a ceramic
10 heater having the aluminum nitride sintered body applied thereto maintains a certain range of volume resistivity so that the leak current which might be generated can be suppressed.

When a content of titanium in the sintered body
15 exceeds 100 ppm by weight (0.01 % by weight), the aluminum nitride may discolor and the aluminum nitride sintered body may degrade in physical properties such as hardness and thermal conductivity. Particularly, even an excess of titanium contributes only slightly to
20 increasing the volume resistivity of the aluminum nitride sintered body, without departing from the volume resistivity range of $3 \times 10^9 \Omega \cdot \text{cm}$ to $4.0 \times 10^9 \Omega \cdot \text{cm}$.

Rather, an excess of titanium may force the aluminum nitride sintered body at a high temperature
25 into the state in which titanium nitride (TiN) phases do not exist independently, but are connected to each other, thus rapidly decreasing the volume resistivity value of the aluminum nitride sintered body.

Now, an explanation will be given of the impurity
30 test. According to the impurity test, a product is rubbed for a predetermined period of time while being immersed in a liquid such as isopropyl alcohol (IAP). Then, impurities existing in the liquid are counted. Particularly, the titanium (Ti) element is an impurity
35 in a semiconductor process and thus acts as a processing

pollution source during semiconductor processes.

In this regard, if the number of impurities is determined to exceed 50 ppb as measured by the impurity test, a unit including the sintered body, when applied
5 to a semiconductor manufacturing apparatus, may cause the semiconductor manufacturing apparatus to malfunction due to the serious pollution during process operation.

In addition, if titanium is added in an amount less than 10 ppm by weight (0.001 % by weight), the
10 excessively small amount of titanium oxide decreases the volume resistivity of the aluminum nitride sintered body to too low a value to measure.

Accordingly, the titanium (Ti) is used in an amount of 10 to 100 ppm by weight, based on the total
15 weight of the aluminum nitride sintered body.

Fabrication method for aluminum nitride sintered body

On the basis of the total weight of an aluminum
20 nitride sintered body, yttrium oxide (Y_2O_3) powder, titanium oxide (TiO_2) powder, and excess aluminum nitride (AlN) powder are mixed together to prepare a mixed powder for the aluminum nitride sintered body. In this regard, the aluminum nitride powder may be
25 reductive aluminum nitride powder with high purity. Composition ratios of the yttrium oxide (Y_2O_3) powder, the titanium oxide (TiO_2) powder, and the excess aluminum nitride (AlN) can be controlled.

The powders for the aluminum nitride sintered body
30 may be mixed in a dry or wet manner.

According to one embodiment of the present invention, a wet mixing method is adopted. In this regard, the solvent used may be, for example, absolute ethanol, isopropyl alcohol, etc. The powders for the
35 aluminum nitride sintered body are mixed and subjected

to slurry extraction, followed by drying with a spraying drying method to afford a mixed powder. For example, the mixture is dried at about 60 to about 100°C in a drying chamber.

5 The mixed powder for the aluminum nitride sintered body powder is sieved and then baked into a molded body in a suitable form before sintering. According to one embodiment of the present invention, the sintering is conducted by baking the molded body at about 1,700 to
10 about 2,000°C for 30 min or longer. For example, the powder for the aluminum nitride sintered body powder is loaded into a graphite mold, backed at a sintering temperature of about 1,850°C for about 3 hours under a nitrogen atmosphere in a hot pressing sintering furnace
15 and then cooled to form an aluminum nitride sintered body.

Hereinafter, the aluminum nitride sintered body of the present invention will be described in more detail
20 through various Examples and Comparative Examples.

EXAMPLE 1

Based on the total weight of a powder for an aluminum nitride sintered body, 95% of aluminum nitride
25 powder, 1% of yttrium oxide powder, and the balance of titanium oxide powder were prepared. In this regard, the % by weight of yttrium oxide was calculated as a sum of the added weight of the yttrium oxide powder plus the weight of yttrium oxide converted from the weight of
30 precursors in the form of yttrium-containing hydrate, chloride, and the like.

As the aluminum nitride powder, a reductive aluminum nitride powder with high purity was prepared. The reductive aluminum nitride powder was 99.9 % or
35 higher pure with exclusion of oxygen and had an average

particle size of about 1.3 μm .

The yttrium oxide powder had an average particle size of about 0.8 μm with a purity of 99.9% or higher. The titanium oxide powder had an average particle size of about 1.0 μm with a purity of 99.9% or higher.

These powders were wet mixed for 20 hours using a pot made of nylon and an alumina ball in absolute ethanol as a solvent. Then, the mixture was subjected to slurry extraction, followed by drying at 80°C in a drying chamber. The dried powder mixture was allowed to pass through an 80-mesh sieve. The sieved powder was loaded into a graphite mold with diameter $\Phi 210\text{mm}$ and backed at the sintering temperature of 1,850°C for 3 hours under a press pressure of 15 MPa and a nitrogen gas pressure of 0.1 MPa in a hot pressing sintering furnace and then cooled.

The amounts of yttrium oxide (wt.%) and titanium (ppm) were measured as follows. Amounts of elements in the aluminum nitride sintered body finally obtained were measured by scanning electron microscopy or transmission electron microscopy using an energy dispersive X-ray spectroscope. Percentages by weight of yttrium oxide were calculated by converting a detected content of yttrium into the weight of the oxide thereof. In addition, the titanium element was quantitatively analyzed by ICP MS.

EXAMPLES 2 TO 7 AND COMPARATIVE EXAMPLES 1 TO 9

Aluminum nitride sintered bodies of Examples 2 to 7 and Comparative Examples 1 to 9 were fabricated in the same manner as in Example 1, with the exception that composition ratios of aluminum nitride, yttrium oxide, and titanium were adjusted as given in Table 1, below.

TABLE 1

Example No.	AlN	Y ₂ O ₃	Ti	Ti	Weight Ratio Ti/Y ₂ O ₃
	Wt. %	Wt. %	Wt. ppm	Wt. %	
Example 1	99	1	10	0.0010	0.0010
Example 2	99	1	31	0.0031	0.0031
Example 3	97	3	17	0.0017	0.0006
Example 4	97	3	83	0.0083	0.0028
Example 5	95	5	21	0.0021	0.0004
Example 6	95	5	100	0.0100	0.0020
Example 7	90	10	23	0.0023	0.0002
Comparative Example 1	95	5	1000	0.1000	0.0026
Comparative Example 2	95	5	130	0.0130	0.0020
Comparative Example 3	95	5	0	0	0
Comparative Example 4	100	0	0	0	—
Comparative Example 5	100	0	6	0.0006	—
Comparative Example 6	100	0	19	0.0019	—
Comparative Example 7	100	0	35	0.0035	—
Comparative Example 8	95	5	9	0.0009	0.0002
Comparative Example 9	90	10	9	0.0009	0.0001

Characterization of aluminum nitride sintered body

The aluminum nitride sintered bodies fabricated in Examples 1 to 7 and Comparative Examples 1 to 9 were

evaluated for properties and the results are summarized in Table 2, below.

TABLE 2

Example No.	Volume Resistivity ($\Omega \cdot \text{cm}$) @400°C	Volume Resistivity ($\Omega \cdot \text{cm}$) @500°C	Impurity Test (ppb)	Thermal Conductivity (W/mK)
Example 1	1.0×10^9	3.0×10^8	13	125
Example 2	2.0×10^9	4.0×10^8	20	125
Example 3	4.0×10^{11}	3.0×10^9	18	143
Example 4	5.0×10^{11}	4.0×10^9	24	143
Example 5	1.0×10^{11}	3.0×10^9	16	174
Example 6	5.0×10^{11}	5.0×10^9	26	170
Example 7	2.0×10^{11}	4.0×10^9	13	178
Comparative Example 1	2.0×10^{11}	4.0×10^9	332	152
Comparative Example 2	1.5×10^7	3.0×10^9	56	165
Comparative Example 3	1.0×10^7	x	15	177
Comparative Example 4	x	x	13	86
Comparative Example 5	1.0×10^7	x	17	90
Comparative Example 6	6.0×10^7	x	16	84
Comparative Example 7	7.0×10^7	x	17	89
Comparative Example 8	3.0×10^7	x	15	172
Comparative Example 9	3.0×10^7	x	15	178

Characterization methods

Volume resistivity: Specimens with dimensions width 50 mm x length 50 mm x thickness 1 mm were prepared from the aluminum nitride sintered bodies fabricated in Examples 1 to 7 and Comparative Examples 1 to 9. An applied voltage was set to be 500 V/mm, based on the applied electric field, using an electrode with the main electrode diameter of 26 mm and the protective electrode diameter of 38 mm. After the voltage application was maintained for 60 seconds, volume resistivity values were recorded.

Impurity test method: The sintered body specimen was immersed in a liquid such as IPA and the surface of the specimen was rubbed for 10 minutes. Then, the impurities existing in the liquid were counted.

Thermal conductivity measurement method: The surface of the specimen of the aluminum nitride sintered body was blackened, and then the diffusion coefficient was calculated by a laser flash method. Using the diffusion coefficient, the thermal conductivity was derived from Equation (1):

(Equation 1) Density x Specific Heat x Diffusion Coefficient = Thermal Conductivity (W/mK)

As described above, the aluminum nitride sintered bodies according to Examples 1 to 7 of the present invention exhibited volume resistivity values of 3.0×10^8 to $5.0 \times 10^9 \Omega \text{ cm}$ at a high temperature (500°C), less than 50 ppb of impurities as measured by the impurity test method, and a thermal conductivity of 125 W/mK or more, and thus are identified to be suitable for use as a

heater member.

When yttrium oxide is not added (Comparative Examples 4 to 7), the thermal conductivity is less than 100 W/mK, which is excessively low so that the aluminum
5 nitride sintered bodies are unsuitable for use as a heater member.

On the other hand, in the case of Comparative Examples 3 and 4 in which titanium is not contained, the volume resistivity value at a high temperature (500°C)
10 was reduced to an undetectable degree, whereas an excessively large amount of titanium (Comparative Example 1) makes only a tribute contribution to the increase of the volume resistivity, but causing the problem of sharply increasing impurities, compared to
15 Example 7.

Member for semiconductor manufacturing apparatus

Referring to FIG. 1, a member for a semiconductor manufacturing apparatus according to an embodiment of
20 the present invention includes a heating plate 110, a conductive member 120, and a power supply unit 140.

The heating plate 110 supports a substrate 10 by using an electrostatic force. The heating plate 110 is provided to heat the substrate. The heating plate 110
25 has a disk shape.

The supporting member (not shown) serves to support the heating plate 110 so that the heating plate 110 is not tilted. The support member may also be made of a stainless steel alloy, an aluminum alloy, or a
30 copper alloy.

The heating plate 110 is composed of an aluminum nitride sintered body. The aluminum nitride sintered body includes yttrium oxide, titanium, and aluminum nitride.

35 The aluminum nitride sintered body of the present

invention including aluminum nitride may be used as a heating plate 110 such as a heater for holding and heating a wafer in a semiconductor manufacturing process.

5 The titanium functions to increase the volume resistivity value of the aluminum nitride sintered body.

According to another embodiment of the present invention, a dielectric layer (not shown) may be further formed on the upper surface of the heating plate 110.

10 The conductive member 120 is embedded in the heating plate 110. The conductive member 120 functions as an electrostatic field generating electrode, a high frequency generating electrode, a heating element, or the like.

15 The conductive member 120 is made of metal. For example, the conductive member 120 may be formed of a conductive material such as tungsten (W), titanium (Ti), rhodium (Rh), niobium (Nb), iridium (Ir), rhenium (Re), tantalum (Ta), molybdenum (Mo), or a combination
20 thereof.

A connection cable 125 electrically connected to the conductive member 120 is provided under the conductive member 120. The connection cable 125 is made of a metal having a small contact resistance with the
25 conductive member 120 and having excellent electrical conductivity.

The connection cable 125 is connected to the power supply unit 140 for supplying power to the conductive member 120. The power supplied from the power supply
30 unit 140 to the conductive member 120 can be variously selected. For example, a DC chucking voltage may be applied from the power supply unit 140 to the conductive member 120 to generate an electrostatic field over the plate 110. A plasma may be produced with a high-
35 frequency bias power while a general AC voltage may be

supplied to generate heat from the conductive member 120.

Industrial Applicability

5 The aluminum nitride sintered bodies according to the embodiments of the present invention can be applied to an electrostatic chuck for holding a wafer and to a heater that acts to simultaneously hold and heat a wafer in a chemical vapor deposition (CVD) process and the
10 like.

 While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form
15 and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. In addition, changes may be made without departing from the spirit and scope of the invention.

CLAIMS

1. An aluminum nitride sintered body, comprising:
1 to 5 % by weight of yttrium oxide (Y_2O_3);
5 10 to 100 ppm by weight of titanium (Ti); and
a balance of aluminum nitride (AlN).

2. The aluminum nitride sintered body of claim 1,
wherein the titanium has a weight ratio of 0.0002 to
10 0.0031 to the yttrium oxide.

3. The aluminum nitride sintered body of claim 1,
having a volume resistivity value of 3.0×10^8 to 5.0×10^9
 $\Omega \cdot \text{cm}$ at a temperature of 500°C in an electric field of
15 500 V/mm.

4. The aluminum nitride sintered body of claim 1,
having a thermal conductivity of 100 W/mK or greater.

20 5. The aluminum nitride sintered body of claim 1,
having an impurity in an amount of 30 ppb or less as
measured by an impurity test.

25 6. A member for a semiconductor manufacturing
apparatus, the member comprising:

a plate composed of an aluminum nitride sintered
body comprising 1 to 5 % by weight of yttrium oxide
(Y_2O_3), 10 to 100 ppm by weight of titanium (Ti), and a
balance of aluminum nitride (AlN);

30 a conductive member embedded in the plate; and

a power supply unit connected to the conductive
member.

7. The member of claim 6, wherein the titanium has a weight ratio of 0.0002 to 0.0031 to the yttrium oxide in the aluminum nitride sintered body.

5 8. The member of claim 6, wherein the aluminum nitride sintered body has a volume resistivity value of 3.0×10^8 to $5.0 \times 10^9 \Omega \cdot \text{cm}$ at a temperature of 500°C in an electric field of 500 V/mm.

10 9. The member of claim 6, wherein the aluminum nitride sintered body has a thermal conductivity of 100 W/mK or greater.