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METHOD FOR FORMING PLATINUM CATALYST LAYER IN REACTION FURNACE FOR GENERATING WATER GAS

Field of the Invention

5 The present invention is primarily concerned with improvements in the method of manufacturing a moisture-generating reactor used in semiconductor manufacturing facilities and chemical manufacturing facilities. More particularly, the present invention is concerned with the process of forming a barrier film which constitutes a platinum catalyst layer formed on the inner wall surface of a
10 reaction space inside the reactor.

Background of the Invention

For example, for affixing a silicon oxide film by means of a water oxidation method in semiconductor manufacturing, continuous supply of ultra-high purity
15 water is required. Consequently, the inventors of the present invention have developed a moisture-generating reactor as shown in Figure 3 and disclosed it (see TOKU-KAI No. 2000-169109 and others).

The moisture-generating reactor is made by welding together reactor body parts 22, 23 which are placed opposite to each other so that a reactor body
20 having a reaction space P inside is formed. The reactor body is provided with a material gas inlet 24, a moisture gas outlet 25, an inlet side reflector 26, an outlet side reflector 27 and others, and has a platinum coating catalyst layer 28 on the inner wall surface of the reactor body part 23 on the side opposite to the material gas inlet 24.



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More specifically, the afore-mentioned platinum coating catalyst layer 28 is formed on the whole area of the inner surface of the reactor body part 23 made of SUS316L on the side of the moisture gas outlet 25. After a TiN-made barrier film 28a has been formed on the inner surface of the reaction body part 23, a platinum film 28b is formed thereon.

The thickness of the afore-mentioned barrier film 28a is most preferably $0.1\ \mu\text{m}$ to $5\ \mu\text{m}$. In the figure, the TiN barrier film 28a with a thickness of about $5\ \mu\text{m}$ is formed with an ion plating method.

Furthermore, a thickness of the afore-mentioned platinum film 28b is preferably $0.1\ \mu\text{m}$ to $3\ \mu\text{m}$, and in the figure, the platinum film 28b of about $3\ \mu\text{m}$ thick is formed by the vacuum vapor deposition method.

As methods to form the barrier film 28a, in addition to the afore-mentioned ion plating method, it is possible to employ an ion sputtering method, a PVD method such a vacuum vapor deposition method and the like, a chemical vapor deposition method (CVD method), a hot press method, a flame spray method and the like. As methods to form the platinum film 28b, in addition to the afore-mentioned vacuum vapor deposition method, it is possible to employ an ion plating method, an ion sputtering method, a chemical vapor deposition method, a hot press method and the like. In addition, if the barrier film 28a is made of an electrically conductive material such as TiN and the like, a plating method may be employed too.

The afore-mentioned barrier film 28a is formed to prevent the lowering of the reaction rate of the platinum film 28b occurring with the passage of time.

Namely, as the temperature of a stainless steel base material rises due to

the reaction heat at the time of generating moisture, Ni and Fe diffuse from the metal base material to the inside of the platinum film 28b. Ni and Fe as diffused are oxidized on the platinum film 28b in an oxidation atmosphere, thus making the platinum film 28b lose its catalytic activity.

5 To prevent Fe and Ni from diffusing from the metal base material into the platinum film 28b, the afore-mentioned barrier film 28a is formed on the surface of the stainless steel (base material).

For the afore-mentioned barrier film 28a, materials not containing the elements such as Ni and Fe, and not producing oxides in the platinum coating
10 film are most preferred. It has been found that in addition to the afore-mentioned TiN, not only TiAlN, TiC, TiCN and Al₂O₃ but also oxides and nitrides such as Cr₂O₃, SiO₂, SrN and the like may be used for the barrier film 28a.

Referring to Figure 3, hydrogen and oxygen supplied through the material
15 gas inlet 24 into the reactor body are diffused by a diffusing member comprising an inlet side reflector 26 and an outlet side reflector 27, and brought into contact with the platinum coating catalyst layer 28. When hydrogen and oxygen are brought into contact with the platinum coating catalyst layer 28, reactivity of hydrogen and oxygen is raised due to the catalytic action of the platinum such
20 that hydrogen and oxygen are brought in a so-called radicalized state. The radicalized hydrogen and oxygen instantly react at the temperature (about 300°C ~400°C) lower than the combustion temperature of a hydrogen mixture gas such that moisture is produced without the high temperature combustion.

Generated moisture (moisture gas) is guided outside through the moisture

gas outlet 25 and supplied to a semiconductor manufacturing chamber and the like (not illustrated).

Description of the Prior Art

5 A moisture-generating reactor having a construction as illustrated in the afore-mentioned Figure 3 is permitted to make O₂ and H₂ react safely with a reaction rate of almost 100% and without high temperature combustion, and continuously produce a required amount of moisture gas of ultra-high purity, thus achieving excellent, practical effects.

10 However, there remain some problems to solve in the above mentioned moisture-generating reactor. One of the problems is concerned with the formation of the barrier film 28a which constitutes a part of the afore-mentioned platinum coating catalyst layer 28.

That is, with the conventional moisture-generating reactor, the barrier film
15 28a with thickness of 1~5 μ m is formed by means of an ion plating method, an ion sputtering method, a vacuum deposition method and the like. But, it is difficult to form the barrier film 28a of uniform thickness such that the barrier film 28a tends to have patches of a different thickness. In addition, there may be another problem such as pin holes formed on the barrier film 28a.

20 It will become more difficult to form a barrier film 28a with a uniform thickness on the inner wall surface of the reactor body part 23 especially when an outlet side reflector 27 provided on the inner wall surface of the reactor body part 23 is complicated in form.

Furthermore, it is quite costly to form the barrier film 28a, thereby making it

difficult to reduce the manufacturing cost of the water-generating reactor.

In addition, since adherence between the barrier film 28a and the reactor body part 23 tends to be somewhat poor, there occurs so-called floating (i.e. separation) of the barrier film 28a when a heat cycle is applied.

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Object of the Invention

The present invention is aimed to solve the afore-mentioned problems of the conventional moisture generating reactor – that is (1) it is difficult to form the barrier film with a uniform thickness and with no pin holes on the inner wall surface in the reaction space; (2) it is difficult to reduce the cost for forming the barrier film; and (3) adherence of the barrier film to the base material is somewhat poor. The present invention provides a method to form a platinum coating catalyst layer in the moisture-generating reactor wherein a stainless steel alloy containing Al is heat-treated for a prescribed time and at the prescribed temperature in an inert gas with the prescribed ratio of hydrogen and water (H_2/H_2O), thereby making it possible to manufacture, using a so-called selective oxidation characteristic of the stainless alloy, the barrier film comprising an almost 100% Al_2O_3 layer and a principally Al_2O_3 composed layer (i.e. a layer composed of principally Al_2O_3) on the outer surface of the stainless steel alloy containing Al at an extremely low cost.

Disclosure of the Invention

The present invention as claimed in Claim 1 has a basic construction in which a moisture-generating reactor having a platinum coating catalyst layer on

the inner wall surface in the reaction space is formed, hydrogen and oxygen supplied into the reaction space are brought into contact with the platinum coating catalyst layer and radicalized thereby, and the radicalized hydrogen and oxygen are reacted to generate moisture without the high temperature combustion wherein the moisture-generating reactor is made of an alloy containing aluminum, a principally aluminum oxide (Al_2O_3)-composed barrier film is formed by applying an aluminum selective oxidation treatment on the inner wall surface of the moisture-generating reactor, and thereafter a platinum layer is stacked on and affixed to the barrier film so that a platinum coating catalyst layer is formed.

Claim 2 relates to a process of forming a platinum coating catalyst layer as claimed in Claim 1 wherein a stainless steel alloy containing aluminum is employed for an alloy containing aluminum.

Claim 3 relates to a process of forming a platinum catalyst layer as claimed in Claim 1 wherein the aluminum selective oxidation treatment is effected on the alloy containing aluminum by heating for a prescribed time under the conditions where the hydrogen-to-water ($\text{H}_2/\text{H}_2\text{O}$) ratio in a treatment atmosphere is $10^4 / 1 \sim 10^9 / 1$ and the heating temperature is $300^\circ\text{C} \sim 1500^\circ\text{C}$.

Claim 4 relates to a process of forming a platinum coating catalyst layer as claimed in Claim 1 wherein the platinum coating catalyst layer is formed on the inner wall surface of only a reactor body part on the moisture gas outlet side of the moisture generating reactor.

Claim 5 relates to a process of forming a platinum coating catalyst layer as claimed in Claim 1 wherein the barrier film which forms part of the platinum

coating catalyst layer comprises an almost 100% aluminum oxide (Al_2O_3) layer on the inner wall surface of the base material and a principally aluminum oxide (Al_2O_3)-composed layer on the outside thereof.

5 Claim 6 relates to a process of forming a platinum coating catalyst layer as claimed in Claim 2 wherein an austenitic alloy containing aluminum having chemical components of Cr 17.7wt%, Ni 25.5wt%, Mo 0.01wt%, Mn not more than 0.01wt%, Al 3~4wt%, C not more than 0.01wt%, S not more than 0.01wt%, P not more than 0.01wt% and Fe the remainder is employed for the alloy containing aluminum.

10 Claim 7 relates to a process of forming a platinum coating catalyst layer as claimed in Claim 3 wherein the heating treatment is effected at the temperature of 800°C for 3 hours in the treatment atmosphere of an argon gas containing 10VOL% hydrogen and 10ppm water.

15 Brief Description of the Drawings

Figure 1 is a diagram (the Ellingham diagram) showing the relation between the temperature and atmosphere ($\text{H}_2/\text{H}_2\text{O}$) at the oxidation of major elements in the stainless alloy containing aluminum.

20 Figure 2 is an atom composition graph of the Al_2O_3 film formed by applying the Al selective oxidation treatment on the surface of the stainless steel alloy containing aluminum (FR31).

Figure 3 is a sectional schematic illustration of the conventional moisture generating reactor (TOKU-KAI No.2000-169109).

List of Reference Characters and Numerals

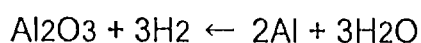
P designates a reaction space, 22 a reactor body part, 23 a reactor body part, 24 a material gas inlet, 25 a moisture gas outlet, 26 an inlet side reflector, 27 an outlet side reflector, 28 a platinum coating catalyst layer, 28a a barrier film, 28b a platinum film and 29 a filter.

Mode of Carrying Out the Invention

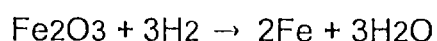
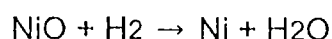
Figure 1 is the Ellingham diagram showing the relation between H₂/H₂O and the temperature in the oxidation of each of the elements (Ni, Fe, Cr and Al) contained in the stainless steel alloy containing Al to be employed in the present invention. A curve A shows the oxidation of Ni, B the oxidation of Fe, C the oxidation of Cr and D the oxidation of Al.

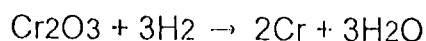
As apparent from Figure 1, it is possible to selectively oxidize only Al out of the elements Ni, Fe, Cr and Al by setting the value of H₂/H₂O (Vol ratio) in the oxidizing atmosphere and the temperature in the proper ranges. For example, only aluminum can be selectively oxidized in the temperature range of 300°C ~1500°C when the H₂/H₂O ratio (vol ratio) is 10⁴ /1~10⁹ /1.

For example, when only Al out of Ni, Fe, Cr and Al is to be selectively oxidized by setting the H₂/H₂O ratio value and temperature in the proper ranges, the oxidation of Al is expressed as below:



Also, Ni, Fe, and Cr oxides (NiO, Fe₂O₃, Cr₂O₃) are reduced as below:





The present invention relates to the forming of the barrier film L comprising a 100% Al₂O₃ layer and a principally Al₂O₃ composed layer on the inner surface of the reactor body parts 22, 23 where the Al selective oxidation characteristic is utilized to oxidize Al alone on the inner surface of the reactor body parts 22, 23 made of a stainless alloy containing Al.

Embodiment

A stainless steel alloy containing Al (HR31) having a chemical composition (wt%) listed at the upper section in Table 1 given below was used to produce the reactor body parts 22, 23 with an outside diameter of 110mm in a shape as shown in Figures 2 and 3. The lower section in Table 1 is for the conventional stainless steel (SUS316L).

Table 1

Chemical Composition (wt%)									
	Fe	Cr	Ni	Mo	Mn	Al	C	S	P
Austenitic	remainder	17.7	25.5	0.01	<0.01	3~4	<0.01	<0.01	<0.01
<u>HR31</u>									
Austenitic	remainder	17.2	15.1	2.76	<0.01	<0.01	<0.01	<0.01	<0.01
<u>SUS316L</u>									

The pre-treatment step such as cleaning was applied on the inner surface

of the reactor body part 23 made of the afore-mentioned Stainless steel alloy containing Al. After the inner surface was cleaned, the reactor body part 23 was placed in the heat treatment furnace and heat-treated under the undermentioned conditions.

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Conditions of Al Selective Oxidation

Ar gas containing 10% of H₂ and 10ppm of H₂O is flowed into the heat treatment furnace (the inner volume of about 1 litre) at the flow rate of 1 litre/min, and the heat treatment was applied in the heat treatment furnace for about 3
10 hours while maintaining the temperature of the heat treatment furnace at about 800°C.

Figure 2 is a depth profile (the result of the depth direction analysis) using the ESCA. The figure shows the element composition inside the Al₂O₃ film formed on the inner surface of the reactor body part 23 by means of the
15 afore-mentioned Al selective oxidation treatment. Referring to Figure 2, the curve E shows the atom number ratio (%) of Oxygen O, F the atom number (%) of Al, G the atom number (%) of Fe, H the atom number (%) of Ni, and I the atom number (%) of Cr. As apparent from Figure 2, the so-called Al-rich layer is formed in the range L within about 180nm (0.18 μ m) from the inner side surface
20 (adjacent the base material) of the Al₂O₃ film, and entirely Al₂O₃ composed layer is formed in the range L' within about 50nm (0.05 μ m) from the inner side surface.

According to embodiments of the present invention, the reactor body parts 22, 23 are made of A stainless steel alloy containing Al. The afore-mentioned

Al selective oxidation treatment is applied on the inner wall surfaces of the reactor body parts to form the barrier film L which is composed of principally Al_2O_3 . Then, a platinum film 28b is stacked on and affixed to the afore-mentioned barrier film L on the inner wall surface of the reactor body part 23 on the moisture gas outlet side such that the moisture generating reactor is formed by placing the afore-mentioned reactor body part 23 and the reactor body part 22 on the material gas inlet 24 side opposite to each other, and welding together their opposing outer peripheral surfaces where they contact.

According to the moisture generating test conducted using the moisture-generating reactor formed in accordance with this embodiment, it has been confirmed that in regard to the change of reactivity with the passage of time, adhesiveness (mechanical strength) of the platinum coating catalyst layer 28 and the likes, the moisture-generating reactor according to the present embodiment is never inferior to the conventional moisture generating reactor having a TiN barrier film 28a formed by the iron plating method.

According to the afore-mentioned embodiment, the reactor body parts 22, 23 are made of stainless steel alloy containing Al (austenite HR 31). However, it will be understood that any kind of material can be used as long as it is an alloy containing Al.

Furthermore, according to this embodiment, about $0.18\ \mu\text{m}$ thick layer L composed of principally Al_2O_3 , which is provided with a $0.05\ \mu\text{m}$ thick 100% (entirely) Al_2O_3 layer L', is formed on the outer surface of the stainless steel alloy containing Al (the base material S) to serve as the barrier film L. However, the thickness of the said Al_2O_3 layer L' and the principally Al_2O_3 composed layer

L can be appropriately chosen by changing the conditions of the oxidation treatment in the Al selective oxidation.

In addition, according to this embodiment, the barrier film L is formed on both the reactor body parts 22, 23. However, the barrier film L can be formed
5 on the inner wall surface of only the reactor body part 23 on the side of the moisture gas outlet 25.

Effects of the Invention

According to embodiments of the present invention, reactor body parts of
10 the moisture-generating reactor are made of an alloy containing Al, and a principally Al_2O_3 -composed barrier film is formed on the inner wall surface of the reactor body parts by applying an Al selective oxidation treatment thereon. Further, a platinum film is stacked on and affixed to the barrier film to form a platinum coating catalyst layer.

15 As a result, in comparison with the case where the barrier film is formed by the conventional ion plating method or ion sputtering method and the like, the principally Al_2O_3 -composed barrier film with uniform thickness can be formed at ease and at a low cost, thus making it possible to substantially reduce the manufacturing cost of the moisture-generating reactor.

20 The principally Al_2O_3 -composed barrier film formed by the afore-mentioned Al selective oxidation is provided with excellent mechanical strength such as strong adhesiveness to the base material, and, at the same time, it functions superbly to block the invasion of atoms constituting the base material into the platinum film, thus ensuring a remarkably long service life of the

platinum coating catalyst layer.

Thus, embodiments of the present invention achieve excellent, practical effects.

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CLAIMS

1. A process of forming a platinum coating catalyst layer in a
5 moisture-generating reactor where a moisture-generating reactor having a
platinum coating catalyst layer on the inner wall surface in the reaction space is
formed and hydrogen and oxygen supplied into the reaction space are both
brought into contact with the platinum coating catalyst layer and radicalized
thereby so that the radicalized hydrogen and oxygen are reacted to generate
10 moisture without high temperature combustion wherein the moisture-generating
reactor is made of an alloy containing aluminum, a principally aluminum oxide
(Al₂O₃)-composed barrier film is formed by applying an aluminum selective
oxidation treatment on the inner wall surface of the moisture generating reactor,
and thereafter a platinum layer is stacked on and affixed to the barrier film such
15 that a platinum coating catalyst layer is formed.
2. A process of forming a platinum coating catalyst layer in a
moisture-generating reactor as claimed in Claim 1 wherein a stainless steel alloy
containing aluminum is employed for the alloy containing aluminum.
3. A process of forming a platinum coating catalyst layer in a
20 moisture-generating reactor as claimed in Claim 1 wherein the aluminum
selective oxidation treatment of the alloy containing aluminum is effected by
heating for a prescribed time under the conditions where the ratio of the
hydrogen-to-moisture (H₂/H₂O) in the treatment atmosphere is $10^4 / 1 \sim 10^9 / 1$
and the heating temperature is 300°C~1500°C.

4. A process of forming a platinum coating catalyst layer in the moisture-generating reactor as claimed in Claim 1 wherein the platinum coating catalyst layer is formed on the inner wall surface of only the reactor body part on the
5 moisture gas outlet side of the moisture-generating reactor.

5. A process of forming a platinum coating catalyst layer in the moisture-generating reactor as claimed in Claim 1 wherein the barrier film which forms part of the platinum coating catalyst layer comprises an almost 100% aluminum oxide (Al_2O_3) layer on the base material of the inner wall surface of the reactor
10 body part and a principally aluminum oxide (Al_2O_3)-composed layer on the outside thereof.

6. A process of forming a platinum coating catalyst layer in the moisture-generating reactor as claimed in Claim 2 wherein the alloy containing aluminum is an austenitic alloy containing aluminum having chemical
15 composition of 17.7wt% of Cr, 25.5wt% of Ni, 0.01wt% of Mo, not more than 0.01wt% of Mn, 3 to 4wt% of Al, not more than 0.01wt% of C, not more than 0.01wt% of S, not more than 0.01wt% of P and the remaining % of Fe is employed for an aluminum containing alloy.

7. A process of forming a platinum coating catalyst layer in the moisture-generating reactor as claimed in Claim 3 wherein the heating treatment is
20 effected at the temperature of 800°C for 3 hours in the treatment atmosphere of an argon gas containing 10VOL% hydrogen and 10ppm water.