

## DESCRIPTION

TITLE OF THE INVENTION: METHOD FOR REMOVING CHLORINE TRIFLUORIDE CLEANING RESIDUES IN SiC EPITAXIAL GROWTH FURNACE SYSTEM

TECHNICAL FIELD

[0001]

The present invention relates to a method for removing, after a SiC epitaxial growth furnace system including an epitaxial growth furnace for epitaxially growing a SiC film by chemical vapor deposition (hereinafter referred to as "CVD") and an exhaust pipe of the furnace is cleaned with chlorine trifluoride gas, a chlorine trifluoride cleaning residue adhering and remaining in the exhaust pipe.

BACKGROUND ART

[0002]

Silicon carbide (SiC) has recently attracted attention as a material for semiconductor power devices because it is superior to silicon (Si) in terms of physical properties such as band gap width, breakdown field strength and thermal conductivity. SiC epitaxial wafers to be used for such semiconductor elements are usually produced by epitaxially growing a SiC film on a SiC bulk single crystal substrate by CVD.

[0003]

Specifically, a susceptor holding a substrate to be processed is placed in an epitaxial growth furnace. Then, a silane-based gas such as monosilane ( $\text{SiH}_4$ ) or trichlorosilane ( $\text{SiHCl}_3$ ) as a raw material gas for supplying Si and a hydrocarbon-based gas such as propane ( $\text{C}_3\text{H}_8$ ) as a raw material gas for supplying C are respectively introduced into a growth furnace, and concurrently the temperature of the substrate is raised to a growth temperature required for epitaxial growth, so that a SiC film is

epitaxially grown on the substrate. The processed gas used in the film formation process is discharged to the outside of the system through an exhaust pipe provided to the growth furnace.

[0004]

In this process, the SiC produced by CVD adheres and deposits not only on the substrate surface but also on the inner surface of the epitaxial growth furnace, the surface of the susceptor, and the inner surface of the exhaust pipe. For this reason, it is necessary to periodically clean the epitaxial growth furnace system including the epitaxial growth furnace and the exhaust pipe when the film formation process has been completed, and remove the deposits.

#### PRIOR ART DOCUMENTS

#### PATENT DOCUMENTS

[0005]

Patent Document 1: Japanese Patent Examined Application Laid-open No. H03-48268

Patent Document 2: Japanese Patent Examined Application Laid-open No. H06-63097

Patent Document 3: Japanese Patent No. 4662034

#### SUMMARY OF THE INVENTION

#### PROBLEMS TO BE SOLVED BY THE INVENTION

[0006]

There are various methods for the above cleaning, but the present inventors have investigated to clean a SiC epitaxial growth furnace system by using, as non-plasma cleaning without using plasma, chlorine trifluoride (ClF<sub>3</sub>) gas having high cleaning power.

[0007]

However, cleaning the SiC epitaxial growth furnace system with chlorine trifluoride gas has caused the problem that a residue after cleaning (herein referred to as “chlorine trifluoride cleaning residue”) adheres and remains in the exhaust pipe though the interior of the epitaxial growth furnace is thoroughly cleaned. As a result of the present inventors’ investigations, it has been found that the above problem is mainly due to the difference between the materials of the furnace and the pipe. Specifically, the reason is that a member whose surface or gas-contacting surface is coated with SiC is often used for an epitaxial growth furnace that is required to have heat resistance, whereas for example stainless steel is often used for an exhaust pipe that is not required to have such heat resistance as in epitaxial growth furnace, and stainless steel has the property of easily adsorbing chlorine trifluoride cleaning residues.

[0008]

As a method for removing such chlorine trifluoride cleaning residues, the applicant has previously proposed Patent Documents 1 and 2. The method disclosed in Patent Document 1 is a method in which hydrogen being in a molecular state as a whole is flown in a processing operation system after completion of cleaning and chlorine trifluoride cleaning residues are removed with the hydrogen molecules. The method disclosed in Patent Document 2 is a method in which a gas containing a hydrogen-containing compound such as silane, phosphine or arsine is flown in a processing operation system after completion of cleaning and chlorine trifluoride cleaning residues are removed with the hydrogen-containing compound.

[0009]

However, in both the conventional technologies of Patent Documents 1 and 2,  $H_2$ ,  $SiH_4$  or the like is flown as a second cleaning gas after completion of cleaning with

chlorine trifluoride gas and substantially cleaning is carried out twice, so that the technologies have caused the problem that it takes time to perform the cleaning process, leading to decrease in the efficiency of wafer production. Therefore, the conventional technologies of Patent Documents 1 and 2 still have room for improvement.

[0010]

The present invention has been made to solve such problems, and an object thereof is to provide a method for efficiently removing chlorine trifluoride cleaning residues adhering and remaining in an exhaust pipe when a SiC epitaxial growth furnace system is cleaned with chlorine trifluoride gas.

#### SOLUTION TO THE PROBLEMS

[0011]

The present inventors have found that when a SiC film is formed by introducing hydrogen chloride (HCl) gas together with a raw material gas into an epitaxial growth furnace in a SiC film formation process, chlorine trifluoride cleaning residues in an exhaust pipe can be removed by hydrogen-based substances such as hydrogen molecules and hydrogen radicals generated in the process.

[0012]

The present invention has been devised based on such findings, and is characterized by adopting the following method.

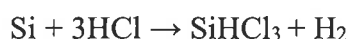
[0013]

That is, the present invention is a method for removing, after a SiC epitaxial growth furnace system including an epitaxial growth furnace for forming a SiC film and an exhaust pipe of the furnace is cleaned with chlorine trifluoride gas, a chlorine trifluoride cleaning residue in the exhaust pipe, the method including the steps of: forming a SiC film by introducing hydrogen chloride gas together with a raw material

gas into the epitaxial growth furnace in a SiC film formation process after completion of the cleaning with the chlorine trifluoride gas; and removing the chlorine trifluoride cleaning residue in the exhaust pipe by discharging a processed gas used in the SiC film formation through the exhaust pipe.

[0014]

It is known that hydrogen chloride is difficult to be thermally decomposed, and hydrogen chloride is decomposed only about 0.22% at 1800°C. However, when hydrogen chloride is allowed to be present together with Si, conversion of hydrogen chloride to SiHCl<sub>3</sub> or the like proceeds and H<sub>2</sub> is generated. Specifically, when a SiC film is formed by introducing hydrogen chloride gas together with a raw material gas into an epitaxial growth furnace in a SiC film formation process, H<sub>2</sub> is secondarily generated together with SiHCl<sub>3</sub> through the following reaction.



[0015]

Among them, SiHCl<sub>3</sub> is a substance indispensable for epitaxial growth of a SiC film, but H<sub>2</sub> itself does not directly participate in the film formation. However, as disclosed in Patent Document 1, H<sub>2</sub> molecules can remove fluorine-based contaminants, so that chlorine trifluoride cleaning residues can be removed in the same process by the H<sub>2</sub> molecules.

[0016]

Although the above reaction formula shows only the generation of H<sub>2</sub>, active species such as hydrogen radicals and hydrogen ions are also considered to be generated in the course of SiC film formation. Patent Document 1 has disclosed in the Prior Art section (column 2, line 5 to the last line) that fluorine-based contaminants can be removed even by such active species. Therefore, the removal of chlorine trifluoride

cleaning residues in the present invention is not necessarily limited to the case of H<sub>2</sub> molecules.

[0017]

Accordingly, in the present invention, when a SiC film is formed by introducing hydrogen chloride gas together with a raw material gas into an epitaxial growth furnace in a SiC film formation process, hydrogen-based substances such as hydrogen molecules and hydrogen radicals are generated, so that chlorine trifluoride cleaning residues in the exhaust pipe can be removed. In other words, it is unnecessary to, after cleaning the SiC epitaxial growth furnace system by chlorine trifluoride gas, remove chlorine trifluoride cleaning residues by another cleaning gas, so that it is possible to shorten the time required for the cleaning process and improve the efficiency of wafer production.

[0018]

In addition to the above, the present invention also has an advantage that the epitaxial growth itself of a SiC film can also be promoted. This is because film growth is promoted by mixing HCl into the raw material gas for SiC epitaxial growth as described in paragraph [0045] of Patent Document 3. Therefore, the present invention can also enhance the productivity of wafers in this respect.

#### EFFECTS OF THE INVENTION

[0019]

As described above, the present invention can remove chlorine trifluoride cleaning residues adhering and remaining in an exhaust pipe by a simple method of introducing hydrogen chloride gas together with a raw material gas into an epitaxial growth furnace in a SiC film formation process to form a SiC film, so that it is advantageously possible to shorten a cleaning time and promote the epitaxial growth

itself of SiC film.

As a result, the productivity of wafers can be enhanced.

## EMBODIMENTS OF THE INVENTION

[0020]

Hereafter, embodiments of the present invention will be described.

[0021]

In the present invention, after completion of cleaning with chlorine trifluoride gas, hydrogen chloride gas is introduced into an epitaxial growth furnace together with a raw material gas necessary for SiC film formation in a SiC film formation process.

[0022]

A CVD device to be used in the present invention mainly has a raw material gas supply pipe system configured to supply a raw material gas, an epitaxial growth furnace in which a film is formed, and an exhaust pipe system through which a processed gas after completion of film formation is discharged.

[0023]

A susceptor for holding a substrate to be processed is disposed in the interior of the epitaxial growth furnace, and is configured to be heated by a heating means such as a heating coil, a halogen lamp or an infrared lamp to a temperature required for film formation.

[0024]

A material for the epitaxial growth furnace is not particularly limited, and one example thereof may include a member coated with SiC on a surface or gas-contacting surface thereof. A material for the exhaust pipe may be made of stainless steel, but other materials may also be used. As a material other than stainless steel, for example, a Ni alloy, fluororesin-coated stainless steel or carbon-coated stainless steel may be

used in the present invention.

[0025]

While the raw material gas is not particularly limited as long as it is capable of epitaxially growing a SiC film, examples thereof may preferably include silane-based gases such as monosilane ( $\text{SiH}_4$ ) and trichlorosilane ( $\text{SiHCl}_3$ ) as a raw material gas for supplying Si. Examples of the raw material gas for supplying C may include hydrocarbon-based gases such as methane ( $\text{CH}_4$ ), ethane ( $\text{C}_2\text{H}_6$ ), propane ( $\text{C}_3\text{H}_8$ ), and neopentane ( $\text{C}_5\text{H}_{12}$ ). Among them, monosilane gas is preferable as the raw material gas for supplying Si, and propane gas is preferable as the raw material gas for supplying C. In the present invention, a doping gas may be supplied to further add a dopant.

[0026]

In the present invention, hydrogen chloride gas is introduced into the epitaxial growth furnace together with the raw material gas in the SiC film formation process. The method for introducing hydrogen chloride gas into the epitaxial growth furnace is not particularly limited. Both of them may be mixed beforehand in the upstream of the growth furnace and then supplied into the growth furnace, or both of them may be supplied to the growth furnace through separate paths and then mixed in the growth furnace.

[0027]

A SiC film is formed on the substrate by using the CVD device as described above. To form a SiC film, a substrate is mounted on the susceptor, and then a raw material gas is supplied through a raw material supply pipe and concurrently the substrate is heated to a growth temperature (one example is 1400 to 1800°C, and 1500 to 1800°C is more preferred from the viewpoint of promoting SiC film formation) by a heating means. Further, other film formation conditions such as furnace pressure and

gas flow rate are appropriately adjusted, as necessary. By bringing the raw material gas into contact with the substrate surface in this way, a SiC film can be epitaxially grown on the substrate surface. The processed gas after the film formation process or the exhaust gas is discharged through the exhaust pipe.

[0028]

When the SiC film formation process is completed, the SiC produced by CVD adheres and deposits not only on the substrate surface but also on the inner surface of the epitaxial growth furnace, the surface of the susceptor, and the inner surface of the exhaust pipe. Therefore, when the film formation process is completed, the epitaxial growth furnace system including the epitaxial growth furnace and the exhaust pipe is cleaned at an appropriate timing. In the present invention, such deposits are cleaned with chlorine trifluoride gas.

[0029]

In cleaning with the chlorine trifluoride gas, the cleaning is performed by supplying the chlorine trifluoride gas into the growth furnace after removing the substrate (wafer) on which film formation has been completed. The chlorine trifluoride gas may be used after being diluted with an inert gas such as Ar. One example of the temperature applied during the cleaning with chlorine trifluoride is 400°C or less. However, the temperature is not limited to this.

[0030]

As described above, by using the chlorine trifluoride gas as a cleaning gas and flowing the gas in the epitaxial growth furnace and the exhaust pipe, deposits in the epitaxial growth furnace are removed. On the other hand, however, chlorine trifluoride cleaning residues resulting from the cleaning with the chlorine trifluoride gas adhere to the interior of the exhaust pipe. Especially when the exhaust pipe is made of

stainless steel, chlorine trifluoride cleaning residues tend to adhere.

[0031]

However, in the present invention, such chlorine trifluoride cleaning residues are to be removed in the subsequent SiC film formation process. Therefore, in the present invention, after a cleaning gas is flown for a necessary time, the next production of a wafer (formation of a SiC epitaxial film) is started. That is, a new substrate is placed in the growth furnace to prepare for the next film formation, and after all preparations are made, hydrogen chloride gas is introduced into the epitaxial growth furnace together with a raw material gas again to form a SiC epitaxial film on the substrate. Then, the processed gas after the film formation process or the exhaust gas is discharged to the outside of the furnace through the exhaust pipe.

[0032]

In the present invention, hydrogen-based substances such as hydrogen molecules and hydrogen radicals are secondarily generated in the SiC film formation process. By flowing the hydrogen-based substances together with the processed gas into the exhaust pipe, the chlorine trifluoride cleaning residues in the exhaust pipe are removed. The removed chlorine trifluoride cleaning residues are detoxified in a detoxification device provided in the downstream of the exhaust pipe and then discharged to the outside of the system.

[0033]

As described above, in the present invention, by a simple method that involves epitaxially growing a SiC film with supplying hydrogen chloride gas together with a raw material gas into an epitaxial growth furnace and concurrently flowing the processed gas used in the film formation process or the exhaust gas directly through an exhaust pipe, chlorine trifluoride cleaning residues adhering and remaining in the

exhaust pipe during the prior cleaning can be removed.

## CLAIM

1. A method for removing, after a SiC epitaxial growth furnace system including an epitaxial growth furnace for forming a SiC film and an exhaust pipe of the furnace is cleaned with chlorine trifluoride gas, a chlorine trifluoride cleaning residue in the exhaust pipe, the exhaust pipe being made of stainless steel and having the stainless steel exposed on a gas-contacting surface thereof, the method comprising the steps of:
  - forming a SiC film by introducing hydrogen chloride gas together with a raw material gas into the epitaxial growth furnace in a SiC film formation process after completion of the cleaning with the chlorine trifluoride gas; and
  - removing the chlorine trifluoride cleaning residue in the exhaust pipe by discharging a processed gas used in the SiC film formation through the exhaust pipe.