ATOMIC LAYER ETCHING DEVICE AND ATOMIC LAYER ETCHING METHOD USING SAME

TECHNICAL FIELD

The present invention relates to the field of etching, and particularly to an atomic layer etching device and an atomic layer etching method using the same.

BACKGROUND

Currently, atomic layer deposition (ALD) technology, as a mainstream process for fabricating a high-K gate dielectric layer of a field-effect transistor, has been widely applied in semiconductor industry. A subtraction process corresponding thereto, atomic layer etching (ALE) technology, has also been developed with the need of application. The earliest solution to achieve GaAs atomic layer etching is to alternately perform two processes of Cl_2 adsorption and electron beam etching. The atomic layer etching technology in the related art has many disadvantages such as long etching cycle, low etching efficiency, complex equipment, and so on.

SUMMARY

The present invention aims to solving one of the technical problems in the related art to a certain extent at least. To this end, an object of the present invention is to propose an atomic layer etching device, which can significantly improve the etching rate and shorten the etching cycle, and has a simple structure.

Another object of the present invention is to propose an atomic layer etching method using the atomic layer etching device provided in the present invention, which can also significantly improve the etching rate, shorten the etching cycle, and reduce the complexity of the device used.

The atomic layer etching device according to embodiments of the present invention comprises: a reaction cavity, which is provided therein with a reaction chamber; a baffle assembly, which is provided in the reaction chamber and divides the reaction chamber into an upper chamber and a lower chamber, wherein, the baffle

assembly comprises at least one baffle, through-holes penetrating through the baffle in a thickness direction of the baffle are provided in the baffle, and the baffle is grounded or connected to a direct current (DC) bias power supply to prevent charged particles in the upper chamber from entering the lower chamber and allow active neutral particles to enter the lower chamber; the upper chamber is provided with a gas inlet for supplying gas into the reaction chamber; the lower chamber is provided with a support component for holding a wafer and a gas outlet for exhausting gas from the reaction chamber; a first plasma generation device, which is used for exciting gas entering the upper chamber into plasma; and a second plasma generation device, which is used for exciting gas entering the lower chamber into plasma.

Optionally, the at least one baffle comprises a plurality of baffles, which are arranged at a certain interval in a vertical direction, and a baffle at the top among the plurality of baffles is grounded.

Optionally, a distance between a baffle at the bottom among the plurality of baffles and the support component is in a range of 5 cm to 50 cm.

Optionally, a distance between adjacent baffles is in a range of 0.1 mm to 10 mm.

Optionally, the baffle has a thickness ranging from 0.5 mm to 20 mm.

Optionally, the through-hole has a radial dimension ranging from 10 μm to 10 mm.

Optionally, the baffle is a metal member, a graphite member or a metal member with a coating.

Optionally, the first plasma generation device comprises a coil provided on a dielectric window at the top of the reaction chamber and a first radio frequency (RF) power supply; the second plasma generation device comprises a second RF power supply connected with the support component.

Optionally, a first gas inlet is provided at the top of the upper chamber and used for introducing reaction gas into the reaction chamber; a second gas inlet is provided on the side of the upper chamber and used for introducing purge gas into the reaction chamber.

In the atomic layer etching device provided in the present invention, by

providing the baffle assembly grounded or connected to the DC bias power supply in the reaction chamber, it can be achieved that the active neutral particles are separated from the charged particles in the plasma, and the active neutral particles are allowed to pass through the baffle assembly and adsorb on the surface of the wafer in the lower chamber, thereby achieving replacement of the traditional reaction gas adsorption with chemical adsorption using active particles. The adsorption particles in the present invention are active particles, and thus can not only significantly improve etching rate and shorten etching cycle, but also greatly reduce the amount of reaction gas used for etching in the chemical adsorption phase and lower process cost due to strong adsorption capacity of the active particles. In addition, desorption using plasma ion of purge gas is adopted in the present invention, which can reduce complexity of the device to obtain the atomic layer etching device having a simple and reliable structure, and thereby facilitate mass production, as compared with a device where desorption using ion beam / neutral particle beam is adopted.

As another aspect, the present invention further provides an atomic layer etching method using the atomic layer etching device provided in the present invention, comprising steps of: S1, placing a wafer for reaction on the support component; S2, introducing reaction gas into the reaction chamber, and starting the first plasma generation device to excite the reaction gas entering the upper chamber into plasma, wherein, active neutral particles in the plasma are allowed to pass through the baffle assembly, go into the lower chamber from the upper chamber and adsorb on a surface of the wafer, and charged particles in the plasma are prevented by the baffle assembly from going into the lower chamber from the upper chamber; S3, stopping introduction of the reaction gas, and turning off the first plasma generation device; S4, introducing purge gas into the reaction chamber, and exhausting reaction residual from the reaction chamber via the gas outlet; S5, stopping introduction of the purge gas; S6, introducing reaction gas into the reaction chamber and starting the second plasma generation device to excite the reaction gas entering the lower chamber into plasma, so as to irradiate the surface of the wafer having the active neutral particles adsorbed thereon; S7, stopping introduction of the reaction gas, and turning off the second

plasma generation device; S8, introducing purge gas into the reaction chamber, and exhausting reaction residual from the reaction chamber via the gas outlet; S9, stopping introduction of the purge gas; and repeating the above steps of S2 to S8 until an etching depth reaches a preset value.

Optionally, the first plasma generation device comprises a coil provided on a dielectric window at the top of the reaction chamber and a first radio frequency (RF) power supply connected to the coil, starting the first plasma generation device in step S2 includes setting an output power of the first RF power supply within a range of 100 W to 1000 W, and turning off the first plasma generation device in step S3 includes setting the output power of the first RF power supply as 0.

Optionally, the second plasma generation device comprises a second RF power supply connected with the support component, starting the second plasma generation device in step S5 includes setting an output power of the second RF power supply within a range of 30 W to 100 W, and turning off the second plasma generation device in step S7 includes setting the output power of the second RF power supply as 0.

Optionally, the reaction gas in step S2 is at least one of CF_4, CHF_3, CH_2F_2, CH_3F, Cl_2, HF, HCl, HBr, SF_6, NF_3, Br_2, BCl_3, $SiCl_4$, O_2 and SiO_2.

Optionally, the reaction gas in step S2 is Cl_2, and has a flow rate ranging from 5 sccm to 200 sccm.

Optionally, the reaction gas in step S6 is an inert gas.

Optionally, the inert gas in step S6 is at least one of He, Ni, Ar, Kr, and Xe.

Optionally, the reaction gas in step S6 is He, and has a flow rate ranging from 10 sccm to 200 sccm.

Optionally, a first gas inlet is provided at the top of the upper chamber, and the reaction gas enters the reaction chamber via the first gas inlet; a second gas inlet is provided on the side of the upper chamber, and the purge gas enters the reaction chamber via the second gas inlet.

Optionally, the baffle assembly comprises three baffles, which are arranged at a certain interval in a vertical direction, and baffles at the top and at the bottom among the three baffles are grounded, and a baffle in the middle among the three baffles is

connected to a direct current (DC) bias power supply.

Optionally, output voltage of the DC bias power supply is in a range of 5 V to 100 V. Preferably, the output voltage of the DC bias power supply is in a range of 10 V to 50 V.

In the atomic layer etching method provided in the present invention, since separation of the active neutral particles from the charged particles in the plasma can be achieved, and the active neutral particles can adsorb onto the surface of the wafer, replacement of the traditional reaction gas adsorption with chemical adsorption using active particles is achieved. The adsorption particles in the present invention are active particles, and thus can not only significantly improve etching rate and shorten etching cycle, but also greatly reduce the amount of reaction gas used for etching in the chemical adsorption phase and lower process costs due to strong adsorption capacity of the active particles. In addition, desorption using plasma ion of purge gas is adopted in the present invention, which can not only reduce complexity of the atomic layer etching device used, but also facilitate mass production, as compared with a manner in which desorption using ion beam / neutral particle beam is adopted.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a schematic diagram of an atomic layer etching device according to an embodiment of the present invention;

Fig. 2 is a schematic diagram of a baffle assembly according to an embodiment of the present invention;

Fig. 3 is a schematic diagram of an etching process using an atomic layer etching device provided by an embodiment of the present invention; and

Fig. 4 is a flow chart of an etching method according to an embodiment of the present invention.

Reference Numerals:

atomic layer etching device 100,

reaction cavity 1, reaction chamber 10, upper chamber 213, lower chamber 214,

intake nozzle 204, first gas inlet 216, second gas inlet 215, gas outlet 217,

baffle assembly 203, baffle 303, through-hole 302, first baffle 303a, second baffle 303b, third baffle 303c,

coil 205, dielectric window 206, first RF power supply 209, first adapter 208,

purging assembly 207, extraction device 212, support component 202, second RF power supply 211, second adapter 210, wafer 201, plasma 402, active neutral particle 403, plasma 404, ion 405, etching by-product 406.

DETAILED DESCRIPTION

Embodiments of the present invention will be described in detail below, and examples of the embodiments are shown in the accompanying drawings, in which identical or like reference numerals refer to identical or like elements or elements with same or similar functions throughout. The following embodiments described with reference to the drawings are exemplary and intended to explain the present invention, and should not be construed as limiting the present invention.

In the description of the present invention, it should be understood that, an orientation or position relation denoted by a term such as ‘thickness’, ‘above’, ‘below’, ‘top’, ‘bottom’, ‘inner’, ‘outer’, ‘radial’ or the like is an orientation or position relation as shown in the drawings, merely for the purpose of facilitating and simplifying the description of the present invention, does not indicate or suggest that the device or element involved must have a particular orientation or be configured and operated at a particular orientation, and thus should not be construed as limiting the present invention.

In addition, terms such as ‘first’, ‘second’, etc. are used merely for the purpose of description, and should not be construed as indicating or suggesting relative importance or implicitly indicating the number of technical features involved. Therefore, a feature defined by ‘first’, ‘second’, etc. may include, explicitly or implicitly, one or more said features. In the description of the present invention, the expression ‘a plurality of’ means two or more, unless otherwise specifically defined.

The essence of the present invention is to provide an atomic layer etching device

and an etching method using the same. In a reaction chamber of the atomic layer etching device, there is provided a baffle assembly which can divide the reaction chamber into an upper chamber and a lower chamber. The baffle assembly includes at least one baffle, in each of which through-holes penetrating through the baffle in its thickness direction are provided. Each baffle is electrically connected to the ground (hereinafter simply referred to as 'grounded') or connected to a DC bias power supply, and can prevent charged particles in the upper chamber from entering the lower chamber and allow active neutral particles to enter the lower chamber. Further, the atomic layer etching device is also provided with a first plasma generation device used for exciting the gas entering the upper chamber into plasma, and a second plasma generation device used for exciting the gas entering the lower chamber into plasma. Based on the atomic layer etching device and the atomic layer etching method, replacing the traditional reaction gas adsorption with chemical adsorption using active particles is achieved. Moreover, the adsorption particle in the present invention is active particle, which can not only significantly improve etching rate and shorten etching cycle, but also greatly reduce the amount of reaction gas for etching used in a chemical adsorption phase and lower process costs. In addition, desorption using plasma ion of purge gas is adopted in the present invention, which can not only reduce complexity of the atomic layer etching device used, but also facilitate mass production, as compared with desorption using ion beam / neutral particle beam.

The structure of the atomic layer etching device 100 according to a specific embodiment of the present invention will be described below in detail with reference to Figs. 1 and 2. Here, the atomic layer etching device 100 provided in the present embodiment is used for etching a wafer 201, which may be a wafer material member of a single element such as Si, Ge, C, or the like, and may also be a wafer material member of a compound such as GaAs, GaN, or the like.

The atomic layer etching device 100 provided in the present embodiment includes a reaction cavity 1, a baffle assembly 203, a first plasma generation device, a purging assembly 207, an extraction device 212, a support component 202 and a second plasma generation device.

Here, the reaction cavity 1 defines and forms the reaction chamber 10, and the baffle assembly 203 is provided within the reaction chamber 10 to divide the reaction chamber 10 into an upper chamber 213 and a lower chamber 214. A gas outlet 217 is provided on a bottom wall of the lower chamber 214, and the extraction device 212, which may be a vacuum pump set, is directly connected to the gas outlet 217. A first gas inlet 216, in which an intake nozzle 204 for introducing reaction gas into the reaction chamber 10 is provided, is provided at the top of the upper chamber 213 (i.e., in a top wall of the upper chamber 213); a second gas inlet 215 connected with the purging assembly 207 and used for supplying purge gas into the reaction chamber 10 is provided on the side of the upper chamber 213 (i.e., in a side wall of the upper chamber 213). It can be understood that, in practical applications, the second gas inlet 215 may also be provided in a side wall of the lower chamber 214. By separating the first gas inlet 216 from the second gas inlet 215, emptying effect of reaction gas remaining at each corner in the reaction chamber 10 can be improved, and detrimental effect on the desorption process in a next cycle can be avoided.

The baffle assembly 203 includes three baffles 303, i.e., a first baffle 303a, a second baffle 303b and a third baffle 303c, which are arranged at a certain interval in a vertical direction. A distance between adjacent baffles 303 is in a range of 0.1 mm to 10 mm, and among the three baffles 303, the baffle 303 directly contacting plasma 402 in the upper chamber 213 (i.e., the first baffle 303a at the top in Fig. 2) is grounded, the second baffle 303b in the middle is connected to a DC bias power supply, and the third baffle 303c at the bottom is grounded. Each baffle 303 has a thickness ranging from 0.5 mm to 20 mm, and is provided therein with through-holes 302 penetrating through the baffle 303 in a thickness direction of the baffle 303. The through-holes 302 in each baffle 303 are evenly distributed and have a same size, the through-holes 302 may be in the shape of a circle, or a rectangle, or in other shape, and each through-hole 302 has a radial dimension ranging from 10 μm to 10 mm. Each baffle 303 is a metal member (e.g., aluminum, stainless steel, or the like), a graphite member or a metal member with a coating. For example, the baffle 303 may be anodized aluminum oxide, an aluminum member containing a coating of Y_2O_3,

TIN, Si, or the like. Preferably, graphite is chosen as the material of the baffle 303.

In the present invention, the main function of the baffle assembly 203 is to repel and capture charged particles, so as to prevent the charged particles in the upper chamber 213 from entering the lower chamber 214 and allow active neutral particles 403 to pass through the through-holes 302 to arrive at a surface of the wafer 201 within the lower chamber 214. In short, the baffle assembly 203 is configured to prevent the charged particles in the upper chamber 213 from entering the lower chamber 214 and yet allow the active neutral particles to enter the lower chamber 214. It can be understood that, in practical applications, the number of the baffles 303 is not limited to three in the present embodiment, but may also be one, two, or more than three. Regardless of the number of the baffles 303, each baffle 303 may be configured to be grounded for the purpose of capturing charged particles, or connected to a DC bias power supply for the purpose of repelling charged particles. In the case where there are a plurality of baffles 303 in the baffle assembly 203, the plurality of baffles 303 are arranged at a certain interval in the vertical direction, and a distance between the baffle 303 at the bottom and the support component 202 is preferably in a range of 5 cm to 50 cm. In addition, in practical applications, the number and shape of the baffles 303 may not be particularly limited, as long as it is ensured that the baffle assembly 203 can play a role of preventing the charged particles from passing and yet allowing the active neutral particles to pass.

In the present embodiment, the first plasma generation device includes a coil 205, a first adapter 208 and a first RF power supply 209, and is used for exciting the reaction gas entering the upper chamber 213 into plasma 402, which is high-density plasma. Thus, the upper chamber 213 may also be referred to as high-density plasma generation chamber. Specifically, the coil 205 is arranged above a dielectric window 206 at the top of the reaction chamber 10, and is connected to the first RF power supply 209 via the first adapter 208. Here, the dielectric window 206 plays a role of energy coupling, and may be made of dielectric such as ceramic, quartz, or the like. When the coil 205 is an inductive coil, the first RF power supply 209 supplies RF power to the coil 205, and under the cooperation of the coil 205 and the dielectric

window 206, RF energy in the coil 205 is coupled and applied to the reaction gas in the reaction chamber 10 in an inductive coupling manner, so as to generate plasma 402 including charged particles and active neutral particles 403. That is to say, when the coil 205 is an inductive coil, the plasma generated in the reaction chamber 10 is inductive coupling plasma. It can be understood that, the structure of the first plasma generation device is not limited thereto, as long as it is ensured that the reaction gas entering the upper chamber 213 can be excited into plasma 402 under the action of the first plasma generation device. Besides, the plasma generated by the first plasma generation device is not necessarily limited to inductive coupling plasma, but may be plasma of other type, for example, capacitive coupling plasma, microwave plasma, continuous plasma, pulsed plasma, etc.

In the present embodiment, the second plasma generation device includes a second RF power supply 211, a second adapter 210 and the support component 202, and is used for exciting reaction gas entering the lower chamber 214 into plasma. Specifically, the second RF power supply 211 is connected to the support component 202 via the second adapter 210 to supply RF power to the support component 202, and by means of the second adapter 210, it is ensured that the RF power provided by the second RF power supply 211 can meet various demands of use. By controlling the second plasma generation device, it can be ensured that the energy of ions 405 in the plasma is controlled such that the ions only react with surface atoms having active neutral particles 403 adsorbed thereon, i.e., the energy can only break bonding of the surface atoms of the wafer 201, but is not strong enough to result in significant physical sputtering with atoms under a layer of the surface atoms. In other words, the plasma generated by exciting the reaction gas in the lower chamber 214 is low-energy plasma. Similar to the first plasma generation device, the second plasma generation device may also have any appropriate structure.

A process of etching the wafer 201 by using the atomic layer etching device 100 as shown in Figs. 1 and 2 will be described below in detail in conjunction with Fig. 3. The process specifically includes the following steps.

At step S11, the wafer 201 which is to be reacted and has clean surface is placed

on the support component 202.

At step S12, i.e., in a chemical adsorption phase, reaction gas is introduced into the reaction chamber 10 via the intake nozzle 204. In the present embodiment, Cl_2 is used as the etching reaction gas, the flow rate thereof is in a range of 5 sccm to 200 sccm, and gas pressure in the reaction chamber 10 is controlled within a range of 0.5 mT to 100 mT. Because the power of the first RF power supply is in a range of 100 W to 1000 W, and the power applied onto the support component 202 from the second RF power supply is 0 W, high-density plasma 402 can be formed from the reaction gas in the upper chamber (i.e., high-density plasma generation chamber) 213, that is, Cl_2 is ionized and decomposed as being excited by the RF energy, and the resulting particles mainly include Cl ions, Cl atoms, Cl_2 molecules and electrons, etc. In this case, the first baffle 303a and the third baffle 303c are grounded to capture most of charged particles, and the second baffle 303b is connected to a DC bias power supply and have a voltage ranging from 5 V to 100 V (preferably, 10 V to 50 V) so that charged particles such as Cl ions with relatively high energy are repelled and thus limited in the upper chamber 213. As a result, the resulting active neutral particles 403 with low energy (Cl_2 molecules and Cl atoms in excited state) are driven by the airflow to pass through the baffle assembly 203, enter the lower chamber 214 and quickly adsorb onto the surface of the wafer 201. Since the particles are active, adsorption rate thereof is far larger than that of reaction gas in a traditional etching process.

At step S13, i.e., in residual reaction gas purging phase, introduction of the reaction gas is stopped, and the first plasma generation device is turned off; purge gas is allowed to enter the reaction chamber 10 via the purging assembly 207 so as to purge the residual reaction gas in the reaction chamber 10; by means of the extraction device 212, the residual reaction gas and the purge gas in the reaction chamber 10 are finally evacuated via the gas outlet 217. Herein, the purge gas may be an inert gas.

At step S14, i.e., in a desorption etching phase, reaction gas is introduced into the reaction chamber 10 via the intake nozzle 204, and the second plasma generation device is activated to excite the reaction gas entering the lower chamber 214 into

plasma, so as to irradiate the surface of the wafer 201 having the active neutral particles adsorbed thereon. Specifically, in the present embodiment, inert gas He is used as the reaction gas, the flow rate thereof is in a range of 10 sccm to 200 sccm, and gas pressure in the reaction chamber 10 is controlled within a range of 200 mT to 4 Torr. Because the power of the first RF power supply is 0 W, and the power applied to the support component 202 from the second RF power supply is in a range of 30 W to 100 W, low-energy (<100eV) plasma 404 can be formed from the reaction gas in the lower chamber (i.e., low-energy plasma generation chamber) 214, thereby irradiating the surface of the wafer 201. By controlling the power of the second RF power supply, the energy of ions 405 in the plasma 404 is controlled such that the ions only react with surface atoms having the active neutral particles adsorbed thereon, and the energy breaks bonding of the surface atoms of the wafer 201, but is not strong enough to result in significant physical sputtering with atoms under a layer of the surface atoms.

At step S15, the purge gas is allowed to enter the reaction chamber 10 via the purge assembly 207, and by means of the extraction device 212, the residual reaction gas and the purge gas in the reaction chamber 10 are finally exhausted via the gas outlet 217 so that etching by-products 406 in the reaction chamber are exhausted.

After going through steps S11 to S15, a layer of surface atoms of the wafer 201 is etched. In order to achieve etching of different depths, steps S12 to S15 are repeated so that atoms on the surface of the wafer 201 are etched layer by layer until etching depth reaches a preset value. In other words, the etching method provided in the embodiment of the present invention can achieve an etching accuracy on an atomic layer scale. The so-called atomic layer scale means that atoms can be etched layer by layer when the surface of the wafer 201 is subjected to etching.

In the atomic layer etching device 100 according to the embodiments of the present invention, by providing the baffle assembly 203 grounded or connected to a DC bias power supply, it can be achieved that the active neutral particles in the plasma are separated from the charged particles in the plasma, and the active neutral particles are allowed to pass through the baffle assembly 203 and adsorb on the

surface of the wafer 201 in the lower chamber 214, thereby achieving replacement of the traditional reaction gas adsorption with chemical adsorption using active particles. The adsorption particles in the embodiment of the present invention are active particles, and thus can not only significantly improve etching rate and shorten etching cycle, but also greatly reduce the amount of reaction gas used for etching in the chemical adsorption phase and lower process costs due to strong adsorption capacity of the active particles. In addition, desorption using plasma ion of purge gas is adopted in the embodiment of the present invention, which can reduce complexity of the device to obtain the atomic layer etching device 100 having a simple and reliable structure, and further facilitate mass production, as compared with a device where desorption using ion beam / neutral particle beam is adopted.

As another technical solution, the present invention further provides an atomic layer etching method. An atomic layer etching method provided in a specific embodiment of the present invention will be described below in detail with reference to Fig. 4. The method is implemented by means of the atomic layer etching device provided in the foregoing embodiments of the present invention, and specifically includes the following steps.

At step S1, a wafer for reaction is placed on the support component in the reaction chamber.

At step S2, reaction gas is introduced into the reaction chamber, output power of the first RF power supply is set within a range of 100 W to 1000 W, i.e., the first plasma generation device is activated to excite the reaction gas entering the upper chamber into high-density plasma, and active neutral particles in the plasma are allowed to pass through the baffle assembly, go into the lower chamber from the upper chamber, and adsorb on the surface of the wafer, while the charged particles in the plasma are blocked by the baffle assembly so that the charged particles are prevented from going from the upper chamber into the lower chamber. That is to say, the reaction chamber in the present embodiment is divided by the baffle assembly into the upper chamber and the lower chamber, and the baffle assembly has a function of preventing the charged particles in the upper chamber from entering the lower

chamber and yet allowing the active neutral particles in the upper chamber to enter the lower chamber.

In a specific example of the present invention, the baffle assembly may include three baffles, which are arranged at intervals in the vertical direction. The baffle at the top and the baffle at the bottom are grounded, and the baffle in the middle is connected to a DC bias power supply. The output voltage of the DC bias power supply is in a range of 5 V to 100 V, preferably, 10 V to 50 V.

In step S2, the reaction gas goes into the upper chamber via the intake nozzle in the first gas inlet provided at the top of the upper chamber, and the reaction gas may be at least one of CF_4, CHF_3, CH_2F_2, CH_3F, Cl_2, HF, HCl, HBr, SF_6, NF_3, Br_2, BCl_3, $SiCl_4$, O_2 and SiO_2. Preferably, the reaction gas in step S2 is Cl_2, and has a flow rate ranging from 5 sccm to 200 sccm.

At step S3, introduction of the reaction gas is stopped, and the first plasma generation device is turned off, that is, the output power of the first RF power supply is set to 0.

At step S4, purge gas is introduced into the reaction chamber to exhaust the reaction gas remaining in the reaction chamber via the gas outlet. Specifically, the purge gas may be introduced into the reaction chamber by the purging assembly, e.g., via the second gas inlet provided on the side of the upper chamber, and reaction residues are finally extracted by the extraction device.

At step S5, introduction of the purge gas is stopped.

At step S6, reaction gas is introduced into the reaction chamber, and the output power of the second RF power supply is set within a range of 30 W to 100 W, that is, the second plasma generation device is activated to excite the reaction gas entering the lower chamber into low-energy plasma, so as to irradiate the surface of the wafer having the active neutral particles adsorbed thereon.

The reaction gas in step S6 is an inert gas, and for example, may be at least one of He, Ni, Ar, Kr, and Xe. Preferably, the reaction gas may be He, and has a flow rate ranging from 10 sccm to 200 sccm.

At step S7, introduction of the reaction gas is stopped, and the second plasma

generation device is turned off, i.e., the output power of the second RF power supply is set to 0.

At step S8, purge gas is introduced into the reaction chamber to exhaust the reaction gas remaining in the reaction chamber via the gas outlet.

At step S9, introduction of the purge gas is stopped.

The above steps of S2 to S9 are repeated until the etching depth reaches a preset value.

In the atomic layer etching method provided in the embodiment of the present invention, since separation of the active neutral particles from the charged particles in the plasma can be achieved, and the active neutral particles can adsorb onto the surface of the wafer, replacement of the traditional reaction gas adsorption with chemical adsorption using active particles is achieved. The adsorption particles in the embodiment of the present invention are active particles, which thus can not only significantly improve etching rate and shorten etching cycle, but also greatly reduce the amount of reaction gas used for etching in the chemical adsorption phase and lower process costs due to strong adsorption capacity of the active particles. In addition, desorption using plasma ion of purge gas is adopted in the embodiment of the present invention, which can not only reduce complexity of the atomic layer etching device used, but also facilitate mass production, as compared with a manner in which desorption using ion beam / neutral particle beam is adopted.

In the description of the present specification, description with reference to terms such as ‘one embodiment’, ‘some embodiments’, ‘an example’, ‘an specific example’, ‘some examples’, or the like means that a specific feature, structure, material or characteristic described in conjunction with the embodiment(s) or example(s) is contained in at least one embodiment or example of the present invention. In the present specification, illustrative description with the above terms is not necessarily for a same embodiment or example. Further, a specific feature, structure, material or characteristic described may be combined in an appropriate way in any one or more embodiments or examples. In addition, in the absence of contradictory circumstances, a person skilled in the art can incorporate and combine

different embodiments or examples, and features in different embodiments or examples described in the present specification.

Although the embodiments of the present invention have been illustrated and described above, it can be understood that, the above embodiments are illustrative, and cannot be construed as limiting the present invention. A person of ordinary skill in the art can make various variations, modifications, replacements and transformations to the above embodiments within the scope of the present invention.

CLAIMS:

1. An atomic layer etching device, comprising:

a reaction cavity, which is provided therein with a reaction chamber;

a baffle assembly, which is provided in the reaction chamber and divides the reaction chamber into an upper chamber and a lower chamber, wherein, the baffle assembly comprises at least one baffle, through-holes penetrating through the baffle in a thickness direction of the baffle are provided in the baffle, and the baffle is grounded or connected to a direct current (DC) bias power supply to prevent charged particles in the upper chamber from entering the lower chamber and allow active neutral particles to enter the lower chamber; the upper chamber is provided with a gas inlet for supplying gas into the reaction chamber; the lower chamber is provided with a support component for holding a wafer and a gas outlet for exhausting gas from the reaction chamber;

a first plasma generation device, which is used for exciting gas entering the upper chamber into plasma; and

a second plasma generation device, which is used for exciting gas entering the lower chamber into plasma.

2. The atomic layer etching device according to claim 1, wherein, the at least one baffle comprises a plurality of baffles, which are arranged at a certain interval in a vertical direction, and a baffle at the top among the plurality of baffles is grounded.

3. The atomic layer etching device according to claim 2, wherein, a distance between a baffle at the bottom among the plurality of baffles and the support component is in a range of 5 cm to 50 cm.

4. The atomic layer etching device according to claim 2, wherein, a distance between adjacent baffles is in a range of 0.1 mm to 10 mm.

5. The atomic layer etching device according to claim 1, wherein, the baffle has a thickness ranging from 0.5 mm to 20 mm.

6. The atomic layer etching device according to claim 1, wherein, the through-hole has a radial dimension ranging from 10 μm to 10 mm.

7. The atomic layer etching device according to claim 1, wherein, the baffle is a metal member, a graphite member or a metal member with a coating.

8. The atomic layer etching device according to claim 1, wherein, the first plasma generation device comprises a coil provided on a dielectric window at the top of the reaction chamber and a first radio frequency (RF) power supply; the second plasma generation device comprises a second RF power supply connected with the support component.

9. The atomic layer etching device according to claim 1, wherein, a first gas inlet is provided at the top of the upper chamber and used for introducing reaction gas into the reaction chamber; a second gas inlet is provided on the side of the upper chamber and used for introducing purge gas into the reaction chamber.

10. An atomic layer etching method using the atomic layer etching device according to claim 1, comprising steps of:

S1, placing a wafer for reaction on the support component;

S2, introducing reaction gas into the reaction chamber, and starting the first plasma generation device to excite the reaction gas entering the upper chamber into plasma, wherein, active neutral particles in the plasma are allowed to pass through the baffle assembly, go into the lower chamber from the upper chamber and adsorb on a surface of the wafer, and charged particles in the plasma are prevented by the baffle assembly from going into the lower chamber from the upper chamber;

S3, stopping introduction of the reaction gas, and turning off the first plasma

generation device;

S4, introducing purge gas into the reaction chamber, and exhausting reaction residual from the reaction chamber via the gas outlet;

S5, stopping introduction of the purge gas;

S6, introducing reaction gas into the reaction chamber and starting the second plasma generation device to excite the reaction gas entering the lower chamber into plasma, so as to irradiate the surface of the wafer having the active neutral particles adsorbed thereon;

S7, stopping introduction of the reaction gas, and turning off the second plasma generation device;

S8, introducing purge gas into the reaction chamber, and exhausting reaction residual from the reaction chamber via the gas outlet;

S9, stopping introduction of the purge gas; and

repeating the above steps of S2 to S8 until an etching depth reaches a preset value.

11. The atomic layer etching method according to claim 10, wherein, the first plasma generation device comprises a coil provided on a dielectric window at the top of the reaction chamber and a first radio frequency (RF) power supply connected to the coil, starting the first plasma generation device in step S2 comprises setting an output power of the first RF power supply within a range of 100 W to 1000 W, and turning off the first plasma generation device in step S3 comprises setting the output power of the first RF power supply as 0.

12. The atomic layer etching method according to claim 10, wherein, the second plasma generation device comprises a second RF power supply connected with the support component, starting the second plasma generation device in step S5 comprises setting an output power of the second RF power supply within a range of 30 W to 100 W, and turning off the second plasma generation device in step S7 comprises setting the output power of the second RF power supply as 0.

13. The atomic layer etching method according to claim 10, wherein, the reaction gas in step S2 is at least one of CF_4, CHF_3, CH_2F_2, CH_3F, Cl_2, HF, HCl, HBr, SF_6, NF_3, Br_2, BCl_3, $SiCl_4$, O_2, and SiO_2.

14. The atomic layer etching method according to claim 13, wherein, the reaction gas in step S2 is Cl_2, and has a flow rate ranging from 5 sccm to 200 sccm.

15. The atomic layer etching method according to claim 10, wherein, the reaction gas in step S6 is an inert gas.

16. The atomic layer etching method according to claim 15, wherein, the inert gas in step S6 is at least one of He, Ni, Ar, Kr, and Xe.

17. The atomic layer etching method according to claim 16, wherein, the reaction gas in step S6 is He, and has a flow rate ranging from 10 sccm to 200 sccm.

18. The atomic layer etching method according to claim 10, wherein, a first gas inlet is provided at the top of the upper chamber, and the reaction gas enters the reaction chamber via the first gas inlet; a second gas inlet is provided on the side of the upper chamber, and the purge gas enters the reaction chamber via the second gas inlet.

19. The atomic layer etching method according to claim 10, wherein, the baffle assembly comprises three baffles, which are arranged at a certain interval in a vertical direction, and baffles at the top and at the bottom among the three baffles are grounded, and a baffle in the middle among the three baffles is connected to a direct current (DC) bias power supply.

20. The atomic layer etching method according to any one of claims 10 to 19,

wherein, an output voltage of the DC bias power supply is in a range of 5 V to 100 V.

21. The atomic layer etching method according to claim 20, wherein, the output voltage of the DC bias power supply is in a range of 10 V to 50 V.