

METHOD AND DEVICE FOR MANUFACTURING HYDROPHILIC SUBSTRATE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims benefit of Chinese Patent Application No. 202110774469.0, filed on July 8, 2021, the contents of which are hereby incorporated by reference in its entirety.

FIELD OF THE TECHNOLOGY

[0002] The disclosure belongs to the technical field of surface treatment, and in particular, to a method and a device for manufacturing a hydrophilic substrate.

BACKGROUND OF THE TECHNOLOGY

[0003] In the related art, the definition of hydrophilicity is that molecules with polar groups have great affinity for water and can attract water molecules or can be dissolved in water. The surface of a solid material formed by such molecules is easily wetted by water. The hydrophilicity of a substance has this characteristic.

[0004] Plasmas contain a large number of active particles such as electrons, ions, excited atoms, molecules, and free radicals. These active particles interact with a substrate of a polymer material to cause various physical and chemical reactions such as oxidation, reduction, cracking, cross-linking, and polymerization on the surface of the substrate, so that the surface performance of the substrate is optimized and the hydrophilicity of the surface of the surface is improved.

[0005] At present, there are inductively coupled plasmas, capacitively coupled plasmas, and Direct Current (DC) glow discharge plasmas commonly used in a plasma surface treatment method. The substrate is in the glow discharge plasmas, and under the action of the plasmas, the surface performance of the substrate is optimized, and the

hydrophilicity of the surface is improved. However, by the abovementioned method, the plasmas are difficult to glow, the effect is unstable, and the defective rate is high.

[0006] In view of this, the disclosure is specially proposed.

SUMMARY

[0007] The technical problems to be solved by the disclosure are to overcome the shortcomings of the related art and provide a method and a device for manufacturing a hydrophilic substrate. By the method, it is easy to glow in the processes of generating first plasmas and second plasmas. After the first plasmas and the second plasmas act on a substrate, the hydrophilic effect of the substrate is stable and the defective rate is low.

[0008] In order to solve the abovementioned technical problems, the basic concept of the technical solution adopted by the disclosure is: a method for manufacturing a hydrophilic substrate. The method may include the following operations.

[0009] A reaction gas is introduced into a vacuum chamber.

[0010] A first voltage is applied to the vacuum chamber, a second voltage is applied to a sample carrier, and an electron source emits an electron beam to bombard the reaction gas to generate first plasmas.

[0011] The first plasmas act on a surface of the substrate.

[0012] A third voltage is applied to the sample carrier, and the electron source stops emitting the electron beam.

[0013] Second plasmas generated by glow discharge act on the surface of the substrate.

[0014] Further, before the reaction gas is introduced into the vacuum chamber, the method may further include that: the electron beam irradiates the surface of the substrate.

[0015] Further, a falling point energy of the electron beam for irradiation may be in the range of 1 KeV to 5 KeV, and the time for irradiation may be in the range of 10 s to 300 s.

- [0016] In some optional implementation modes, a first vacuum degree of the vacuum chamber when the electron beam irradiates the surface of the substrate may be less than 1×10^{-6} Torr.
- [0017] In some optional implementation modes, a second vacuum degree of the vacuum chamber into which the reaction gas is introduced may be in the range of 1×10^{-3} Torr to 1 Torr.
- [0018] In some optional implementation modes, the first voltage may be 0 kV, the second voltage may be in the range of -5 kV to 5 kV, and the third voltage may be in the range of -5 kV to 5 kV.
- [0019] In some optional implementation modes, the second plasmas generated by glow discharge may act on the surface of the substrate for 1 min to 30 min.
- [0020] In some optional implementation modes, the reaction gas may include: oxygen, or air, or nitrogen, or argon.
- [0021] In some optional implementation modes, the substrate may include: a silicon wafer, or a silicon compound, or ceramics, or a metal, or a semiconductor, or carbon fiber cloth, or graphite paper.
- [0022] In addition to the abovementioned method for manufacturing a hydrophilic substrate provided by the disclosure, the disclosure further provides a device for manufacturing a hydrophilic substrate, which may include an electron source and a sample carrier.
- [0023] A vacuum chamber may be connected at a lower end of the electron source. The vacuum chamber may be provided with an openable and closable isolation door body. The vacuum chamber may be provided with a gas inlet and a gas outlet.
- [0024] The sample carrier may be arranged in the vacuum chamber.
- [0025] Due to the adoption of the abovementioned technical solution, the disclosure has the following beneficial effects compared with the related art.
- [0026] The disclosure provides a method and a device for manufacturing a hydrophilic substrate. By the method, it is easy to glow in the processes of generating first plasmas

and second plasmas. After the first plasmas and the second plasmas act on the substrate, the hydrophilic effect of the substrate is stable and the defective rate is low.

[0027] Specific implementation modes of the disclosure will be further described below in detail with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The accompanying drawings, which constitute a part of the disclosure, are used to provide a further understanding of the disclosure, and schematic embodiments of the disclosure and the description thereof are used to explain the disclosure, but do not constitute improper limitations to the disclosure. It is apparent that the accompanying drawings in the following description are only some embodiments, and other accompanying drawings can be obtained by those skilled in the art according to these drawings without any creative work. In the accompanying drawings:

[0029] FIG. 1 illustrates a flowchart of an implementation mode of a method for manufacturing a hydrophilic substrate provided by the disclosure.

[0030] FIG. 2 illustrates a flowchart of another implementation mode of a method for manufacturing a hydrophilic substrate provided by the disclosure.

[0031] FIG. 3 illustrates a schematic structural diagram of a device for manufacturing a hydrophilic substrate provided by the disclosure.

[0032] In the drawings: 1, vacuum chamber; 2, electron source; 201, wiring terminal; 202, filament; 3, isolation door body; 4, sample carrier; 5, substrate; 6, gas inlet; 7, gas outlet; and 8, electron beam.

[0033] It is to be noted that these accompanying drawings and textual descriptions are not intended to limit the conceptual scope of the disclosure in any mode, but to explain the concept of the disclosure to those skilled in the art with reference to specific embodiments.

DESCRIPTION OF EMBODIMENTS

[0034] To make the purposes, technical solutions, and advantages of the embodiments of the disclosure clearer, the technical solutions in the embodiments will be described clearly and completely below with reference to the accompanying drawings in the embodiments of the disclosure. The following embodiments are used to illustrate the disclosure, but are not used to limit the scope of the disclosure.

[0035] In the descriptions of the disclosure, it is to be noted that orientations or positional relationships indicated by the terms "upper", "lower", "front", "back", "left", "right", "vertical", "inner", and "outer" are orientations or positional relationships shown based on the accompanying drawings, and are merely for the convenience of describing the disclosure and simplifying the description, rather than indicating or implying that the devices or elements must have a particular orientation, and be constructed and operated in the particular orientation. Thus, it cannot be construed as a limitation to the disclosure.

[0036] In the description of the disclosure, it should be noted that, unless otherwise specified and defined explicitly, the terms "mounted", "interconnected", and "connected" are to be interpreted broadly, may be, for example, fixedly connected, or detachably connected, or integrally connected; may be mechanically connected, or electrically connected; or may be directly connected, or indirectly connected through an intermediate medium. Those of ordinary skill in the art may understand specific meanings of the abovementioned terms in the disclosure in specific cases.

[0037] As shown in FIG. 1, the disclosure provides a method for manufacturing a hydrophilic substrate 5. The method includes the following steps.

[0038] At S110, a reaction gas is introduced into a vacuum chamber 1.

[0039] At S120, a first voltage is applied to the vacuum chamber 1, a second voltage is applied to a sample carrier 4, and an electron source 2 emits an electron beam 8 to bombard the reaction gas to generate first plasmas.

[0040] At S130, the first plasmas act on a surface of the substrate 5.

[0041] At S140, a third voltage is applied to the sample carrier 4, and the electron source 2 stops emitting the electron beam 8.

- [0042] At S150, second plasmas generated by glow discharge act on the surface of the substrate 5.
- [0043] Specifically, at S110, a reaction gas is introduced into a vacuum chamber 1.
- [0044] In detail, the reaction gas is introduced into the vacuum chamber 1. The reaction gas may be oxygen, or air, or nitrogen, or argon. The disclosure is described by taking the oxygen as the reaction gas as an example, the oxygen is introduced into the vacuum chamber 1. Meanwhile, the vacuum chamber 1 is vacuumized by a vacuum pump, so that a second vacuum degree of the vacuum chamber 1 when the reaction gas is introduced into the vacuum chamber 1 is kept in the range of 1×10^{-3} Torr to 1 Torr.
- [0045] Preferably, the oxygen is introduced into the vacuum chamber 1. Meanwhile, the vacuum chamber 1 is vacuumized by the vacuum pump, so that a second vacuum degree of the vacuum chamber 1 when the reaction gas is introduced into the vacuum chamber 1 is kept at 3.75×10^{-3} Torr.
- [0046] At S120, a first voltage is applied to the vacuum chamber 1, a second voltage is applied to the sample carrier 4, and an electron source 2 emits an electron beam 8 to bombard the reaction gas to generate first plasmas.
- [0047] In detail, the first voltage is applied to the vacuum chamber 1, and the vacuum chamber 1 is grounded, that is, a voltage value of the first voltage is 0 kV. The second voltage is applied to the sample carrier 4, and a voltage value of the second voltage is in the range of -5 kV to 5 kV.
- [0048] The electron source 2 is configured to generate and emit the electron beam 8. The electron source 2 includes a filament 202 and a wiring terminal 201. A power supply is connected to the wiring terminal 201. The wiring terminal 201 is connected to the filament 202. The power supply supplies power for the filament 202 through the wiring terminal 201. The filament 202 will emit the electron beam 8 and thermal radiation when a current is applied to the filament. When the current is applied to the filament 202, the electron beam 8 emitted by the electron source 2 bombards and acts on the oxygen introduced into the vacuum chamber 1. A voltage value of the input voltage of the electron source 2 is in the range of -1 kV to -5 kV. The falling point energy of the electron beam 8 is in the range of 1 KeV to 5 KeV. The electron beam 8 emitted by the electron

source 2 bombards and acts on the oxygen introduced into the vacuum chamber 1 for 0.5 min to 5 min.

[0049] Under the parameters, the electron beam 8 is incident into the vacuum chamber 1 and bombards and acts on the oxygen in the vacuum chamber 1. High-energy electrons collide with oxygen molecules in the vacuum chamber 1. The high-energy electrons lose energy in the manner of inelastic collisions such as collision ionization and excitation. The oxygen is heated and ionized to generate the first plasmas. The first plasmas include oxygen ions, electrons, oxygen free radicals, and oxygen molecules.

[0050] Preferably, the voltage value of the input voltage of the electron source 2 is -1 kV. The second voltage is applied to the sample carrier 4, and the voltage value of the second voltage is 2kV. The falling point energy of the electron beam 8 is 3 KeV. The electron beam 8 is incident into the vacuum chamber 1 and bombards and acts on the oxygen in the vacuum chamber 1. The electron beam 8 bombards and acts on the oxygen in the vacuum chamber 1 for 1 min. The oxygen in the vacuum chamber 1 is heated and ionized to generate the first plasmas. The first plasmas include oxygen ions, electrons, oxygen free radicals, and oxygen molecules.

[0051] At S130, the first plasmas act on a surface of the substrate 5.

[0052] In detail, the substrate 5 may be a silicon wafer, or a silicon compound, or ceramics, or a metal, or a semiconductor, or carbon fiber cloth, or graphite paper. The disclosure is described by taking the silicon wafer as the substrate 5 as an example.

[0053] The silicon wafer is placed on the sample carrier 4. The first plasmas act on the surface of the silicon wafer, so that the surface performance of the silicon wafer is optimized, and the hydrophilicity of the surface is improved.

[0054] At S140, A third voltage is applied to the sample carrier 4, and the electron source 2 stops emitting the electron beam 8.

[0055] In detail, the first voltage is applied to the vacuum chamber 1, and the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. A third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is in the range of -5 kV to 5 kV.

- [0056] The power supply stops supplying power to the filament 202. The filament 202 stops emitting the electron beam 8 and the thermal radiation. The electron source 2 stops emitting the electron beam 8 to bombard and act on the oxygen introduced into the vacuum chamber 1.
- [0057] Since the first voltage is applied to the vacuum chamber 1, the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. The third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is in the range of -5 kV to 5 kV. In an electric field formed between the vacuum chamber 1 and the sample carrier 4, the oxygen introduced into the vacuum chamber 1 and the first plasmas perform glow discharge to generate second plasmas. The second plasmas include oxygen ions, electrons, oxygen free radicals, and oxygen molecules.
- [0058] At S150, second plasmas generated by the glow discharge act on the surface of the substrate 5.
- [0059] The second plasmas act on the surface of the silicon wafer, so that the surface performance of the silicon wafer is optimized, and the hydrophilicity of the surface is improved.
- [0060] Preferably, the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. The third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is -2 kV. When the voltage value of the third voltage is -2 kV, the oxygen ions included in the second plasmas act more on the surface of the silicon wafer.
- [0061] Preferably, the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. The third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is 2 kV. When the voltage value of third voltage is 2 kV, the electrons included in the second plasmas act more on the surface of the silicon wafer.
- [0062] As shown in FIG. 2, in some optional implementation modes, at S110, before the reaction gas is introduced into the vacuum chamber 1, the method further includes that: at S100, the electron beam 8 irradiates the surface of the substrate 5.
- [0063] Specifically, the vacuum chamber 1 is vacuumized, so that a first vacuum

degree of the vacuum chamber 1 is kept less than 1×10^{-6} Torr. The falling point energy of the electron beam 8 for irradiation may be in the range of 1 KeV to 5 KeV, and the time for irradiation is in the range of 10 s to 300 s. The electron source 2 emits the electron beam 8 and thermal radiation to irradiate the surface of the silicon wafer. In the direction perpendicular to the surface of the silicon wafer, a three-dimensional lattice structure of silicon is periodically destroyed, and the electronic potential does not have translational symmetry. The atoms located inside a crystal are in an equilibrium state under the action of symmetric force field of the most adjacent and next-nearest atoms, and the atoms located on the surface form surface dangling bonds due to a residual binding force, pointing to space, in the asymmetric force field. In order to minimize the surface free energy of the silicon wafer, the atoms on the surface are rearranged and adsorb other foreign atoms. So, the surface of the silicon wafer after being irradiated by the electron beam 8 is more beneficial to optimizing the surface performance of the silicon wafer by the plasmas, and improving the hydrophilicity of the surface.

[0064] Preferably, the electron source 2 is configured to generate and emit the electron beam 8. The electron source 2 includes a filament 202 and a wiring terminal 201. A power supply is connected to the wiring terminal 201. The wiring terminal 201 is connected to the filament 202. The power supply supplies power for the filament 202 through the wiring terminal 201. The filament 202 will emit the electron beam 8 and thermal radiation when a current is applied to the filament. The voltage value of the voltage applied to the electron source 2 is -2 kV, the falling point energy of the electron beam 8 is 2 KeV, and the irradiation time is 30 s.

[0065] It is to be noted that the falling point energy of the electron beam 8 refers to the energy of the electron beam 8 acting on the surface of the silicon wafer.

[0066] The silicon wafer is subjected to irradiation pretreatment through the electron beam 8, so that the surface free energy of the silicon wafer is minimum, and the atoms on the surface are rearranged and adsorb other foreign atoms. So, the surface of the silicon wafer after being irradiated by the electron beam 8 is more beneficial to optimizing the surface performance of the silicon wafer by the plasmas, and improving the hydrophilicity of the surface.

[0067] In this disclosure, the electron beam 8 bombards and acts on the reaction gas to

generate first plasmas. In this way, it is easy to glow in a process of generating the first plasmas. The first plasmas act on the surface of the substrate 5.

[0068] In an electric field formed between the vacuum chamber 1 and the sample carrier 4 of the present disclosure, the oxygen in the vacuum chamber 1 and the first plasmas perform glow discharge to generate the second plasmas. The second plasmas act on the surface of the substrate 5.

[0069] By the abovementioned method, it is easy to glow in the processes of generating the first plasmas and the second plasmas. After the first plasmas and the second plasmas act on the substrate 5, the hydrophilic effect of the substrate 5 is stable and the defective rate is low.

[0070] As shown in FIG. 3, the disclosure further provides a device for manufacturing a hydrophilic substrate 5. The device includes an electron source 2 and a sample carrier 4. A vacuum chamber 1 is connected at a lower end of the electron source 2. The vacuum chamber 1 is provided with an openable and closable isolation door body 3. The vacuum chamber 1 is provided with a gas inlet 6 and a gas outlet 7. The sample carrier 4 is arranged in the vacuum chamber 1.

[0071] A specific embodiment is described below.

[0072] The vacuum chamber 1 is connected at the lower end of the electron source 2. The vacuum chamber 1 is provided with the openable and closable isolation door body 3. A telescopic bracket is slidably connected to the isolation door body 3. The telescopic bracket can slide on the isolation door body 3 in an ascending and descending manner, to adjust the height. The sample carrier 4 is arranged on the telescopic bracket. The silicon wafer is arranged on the sample carrier 4. The electron source 2 is configured to generate and emit the electron beam 8. The electron source 2 includes a filament 202 and a wiring terminal 201. A power supply is connected to the wiring terminal 201. The wiring terminal 201 is connected to the filament 202. The power supply supplies power for the filament 202 through the wiring terminal 201. The filament 202 will emit the electron beam 8 and thermal radiation when a current is applied to the filament.

[0073] The vacuum chamber 1 is vacuumized, so that the first vacuum degree of the vacuum chamber 1 is kept less than 1×10^{-6} Torr. The voltage value of the voltage applied

to the electron source 2 is -2 kV, the falling point energy of the electron beam 8 is 2 KeV, and the silicon wafer placed on the sample carrier 4 is irradiated, and the silicon wafer is irradiated by the electron beam 8 for 30 s. So, the surface of the silicon wafer after being irradiated is more beneficial to optimizing the surface performance of the silicon wafer by the plasmas.

[0074] The oxygen is introduced into the vacuum chamber 1 through the gas inlet 6. Meanwhile, the vacuum chamber 1 is vacuumized by a vacuum pump through the gas outlet 7, so that the second vacuum degree of the vacuum chamber 1 when the reaction gas is introduced into the vacuum chamber 1 is kept at 3.75×10^{-3} Torr.

[0075] The voltage value of the input voltage of the electron source 2 is -1 kV. The second voltage is applied to the sample carrier 4, and the voltage value of the second voltage is 2 kV. The falling point energy of the electron beam 8 is 3KeV. The electron beam 8 is incident into the vacuum chamber 1 and bombards and acts on the oxygen in the vacuum chamber 1. The electron beam 8 bombards and acts on the oxygen in the vacuum chamber 1 for 1 min. The oxygen in the vacuum chamber 1 is heated and ionized to generate the first plasmas. The first plasmas include oxygen ions, electrons, oxygen free radicals, and oxygen molecules. The first plasmas act on the surface of the substrate. As such, the surface performance of the silicon wafer is optimized, and the hydrophilicity of the surface is improved.

[0076] The power supply stops supplying power to the filament 202. The filament 202 stops emitting the electron beam 8 and the thermal radiation. The electron source 2 stops emitting the electron beam 8 to bombard and act on the oxygen introduced into the vacuum chamber 1.

[0077] Since the first voltage is applied to the vacuum chamber 1, the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. The third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is in the range of -5 kV to 5 kV. In an electric field formed between the vacuum chamber 1 and the sample carrier 4, the oxygen introduced into the vacuum chamber 1 performs glow discharge to generate second plasmas. The second plasmas include oxygen ions, electrons, oxygen free radicals, and oxygen molecules. The second plasmas act on the surface of the silicon wafer. As such, the surface performance of the silicon wafer is

optimized, and the hydrophilicity of the surface is improved.

[0078] In one optional embodiment, the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. The third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is -2 kV. When the voltage value of third voltage is -2 kV, the oxygen ions included in the second plasmas act more on the surface of the silicon wafer.

[0079] In one optional embodiment, the vacuum chamber 1 is grounded, that is, the voltage value of the first voltage is 0 kV. The third voltage is applied to the sample carrier 4, and the voltage value of the third voltage is 2 kV. When the voltage value of third voltage is 2 kV, the electrons included in the second plasmas act more on the surface of the silicon wafer.

[0080] By the abovementioned method and device for manufacturing a hydrophilic substrate 5, it is easy to glow by the method in the processes of generating first plasmas and second plasmas. After the first plasmas and the second plasmas act on the substrate 5, the hydrophilic effect of the substrate 5 is stable and the defective rate is low.

[0081] The above description is only preferred embodiments of the disclosure, and is not intended to limit the disclosure in any form. Although the above preferred embodiments have disclosed the disclosure, they are not intended to limit the disclosure. The technical contents disclosed above may be changed or modified into equivalent embodiments with equivalent changes by any of those skilled in the art without departing from the scope of the technical solution of the disclosure. Any simple amendments, equivalent changes, and modifications made to the above embodiments in accordance with the technical essence of the disclosure without departing from the contents of the technical solutions of the disclosure still fall within the scope of protection of the technical solutions of the disclosure.

CLAIMS

1. A method for manufacturing a hydrophilic substrate, comprising:

introducing a reaction gas into a vacuum chamber;

applying a first voltage to the vacuum chamber, applying a second voltage to a sample carrier, and emitting, by an electron source, an electron beam to bombard the reaction gas to generate first plasmas;

enabling the first plasmas to act on a surface of the substrate;

applying a third voltage to the sample carrier, and enabling the electron source to stop emitting the electron beam; and

enabling second plasmas generated by glow discharge to act on the surface of the substrate.

2. The method for manufacturing a hydrophilic substrate according to claim 1, before introducing the reaction gas into the vacuum chamber, further comprising: irradiating, by the electron beam, the surface of the substrate.

3. The method for manufacturing a hydrophilic substrate according to claim 2, wherein a falling point energy of the electron beam for irradiation is in the range of 1 KeV to 5 KeV, and the time for irradiation is in the range of 10 s to 300 s.

4. The method for manufacturing a hydrophilic substrate according to claim 2, wherein a first vacuum degree of the vacuum chamber when the electron beam irradiates the surface of the substrate is less than 1×10^{-6} Torr.

5. The method for manufacturing a hydrophilic substrate according to claim 1, wherein a second vacuum degree of the vacuum chamber into which the reaction gas is introduced is in the range of 1×10^{-3} Torr to 1 Torr.
6. The method for manufacturing a hydrophilic substrate according to claim 1, wherein a voltage value of the first voltage is 0 kV, a voltage value of the second voltage is in the range of -5 kV to 5 kV, and a voltage value of the third voltage is in the range of -5 kV to 5 kV.
7. The method for manufacturing a hydrophilic substrate according to claim 1, wherein the second plasmas generated by glow discharge act on the surface of the substrate for 1 min to 30 min.
8. The method for manufacturing a hydrophilic substrate according to claim 1, wherein the reaction gas includes: oxygen, or air, or nitrogen, or argon.
9. The method for manufacturing a hydrophilic substrate according to claim 1, wherein the substrate includes: a silicon wafer, or a silicon compound, or ceramics, or a metal, or a semiconductor, or carbon fiber cloth, or graphite paper.
10. A device for manufacturing a hydrophilic substrate, comprising:
- an electron source, wherein a vacuum chamber is connected at a lower end of the electron source, the vacuum chamber is provided with an openable and closable isolation door body, and the vacuum chamber is provided with a gas inlet and a gas outlet; and
- a sample carrier, arranged in the vacuum chamber.