

Method and Device for Plasma Treatment of Substrates

Specification

This invention relates to a device for bombarding a substrate with a plasma as well as a corresponding method.

Many semiconductor production processes contain one or more plasma treatment steps. The plasma can be used, e.g., for coating a substrate, for depositing semiconductor layers, for etching a substrate, for plasma activation, or for creating an ion reservoir. In this case, gases such as, e.g., silane (SiH_4), helium (He), argon (Ar), hydrogen (H_2) and/or nitrogen trifluoride (NF_3) are directed into the plasma chamber. SiH_4 or H_2 are used, e.g., in the deposition of semiconductor layers, and NF_3 is used in the plasma etching of semiconductor layers. If a mixture made of noble gas and a reactive gas is used, the layer composition can be controlled by the adjustment of the gas mixture ratios. Thus, not only metals, but also oxides, nitrides and carbides can be deposited. Working gas and/or selection of gas mixture, gas flow and pressure has/have an influence on the plasma that is produced. Atmospheric-pressure plasma, low-pressure plasma or high-pressure plasma are practical examples. In contrast to low-pressure plasma or high-pressure plasma, atmospheric-pressure plasmas do not require any reaction vessel, which ensures the maintenance of a pressure level that is other than atmospheric pressure or deviating gas atmospheres. Plasma chambers can be operated in a pulsed manner or continuously, for example with plasma processes based on high-frequency discharge, microwave discharge, d.c. discharge, as well as d.c. magnetron sputtering and/or high-frequency magnetron sputtering.

For the production of plasmas, there are very different methods that differ considerably with respect to the type of energy coupling. A d.c. discharge can be produced by application of a d.c. voltage. Capacitively-coupled MHz discharges (CCP: capacitively-coupled plasma) are used for plasma etching and plasma coating. Conductive and also insulating substrates can be treated

with CCP plasmas. Ion flows and plasma density can be controlled separately from one another by the use of several frequencies. In the case of an inductively-coupled discharge (ICP: inductively-coupled plasma), the plasma density is still further increased, since the plasma acts as a secondary winding of a transformer. The coupling is done via a dielectric electrode, which has the disadvantage that a metal coating of this electrode can further impede the coupling.

The substrate is fastened to a holding device in the reaction chamber, preferably a plasma chamber. In this case, a high-frequency voltage is applied to the holding device of the (semiconductor) substrate in order to direct the reactive ions from the plasma to the surface to be treated. The high-frequency voltage is applied to the substrate itself by means of the holding device.

Mechanical clamping devices such as, for example, 3-point mountings, are used, but cause sagging substrates, abrasion, and poor heat contact. The substrate is raised using pins located in the sample holder so that a robotic gripper (paddle), designed in particular as a robotic arm, can run below or laterally to the wafer and will remove the latter with a forward movement of the pins. A disadvantage is that thin wafers bend greatly, and thus an inaccurate positioning of the substrate on the pins also results. The electrostatic holding is a good alternative. The substrate can be secured by an electrical voltage between the sample-holder electrodes. Electrostatic wafer-holding devices are part of the plasma chamber and are used as lower electrodes to generate plasma. In this case, the electrode is electrically insulated by the chamber wall. In embodiments where an inner round electrode and several outer ring electrodes are used, the individual ring electrodes are mutually insulated from one another. Electrostatic wafer-holding devices are shown in, for example, US 2002/0159216 A1 as well as EP 0473930 A1.

Wafer-holding devices have to pick up and put down a wafer on the holding device or lift away a wafer that has been put down from the holding device in the holding device of a lifting mechanism with loading pins. A lifting mechanism is integrated in a part of the second electrode

in WO 03/038891 A1 or is integrated in the substrate holder in US 2012/0003836 A1 and can be operated by means of a control network.

Structures with loading pins as sample pickup devices have the following problem: because of the loading pin, there is inhomogeneity of the plasma field, which leads to voltage peaks during the process at the necessary recesses.

Embodiments of this invention provide a method and a device that ensure the generation of homogeneous plasma with a uniform profile, in particular over the entire substrate surface.

According to a first aspect of the present invention, there is provided a device for bombarding at least one substrate with a plasma with a first electrode and a second electrode that can be arranged opposite thereto, which electrodes are formed together producing the plasma between the electrodes, characterized in that at least one of the electrodes is formed from at least an inner and an outer electrode unit, wherein the inner and the outer electrode units are on the same potential, wherein the inner electrode unit can be driven upwards and a robot arm can place the substrate on the inner electrode unit, wherein the inner electrode unit and the outer electrode unit can be arranged to form a common support plane.

According to a second aspect of the present invention, there is provided a method for bombarding at least one substrate with a plasma produced by a first electrode and a second electrode arranged opposite to the first electrode, wherein at least one of the electrodes has at least an inner and an outer electrode unit, wherein the inner electrode unit is driven upwards and a robot arm places the substrate on the inner electrode unit, wherein inner electrode unit and the outer electrode unit are arranged for bombardment with the plasma in a common support plane.

All combinations of at least two features indicated in the specification, the claims and/or the figures also fall within the scope of the invention. In the indicated ranges of values, values that lie within the

CLAIMS

1. A device for bombarding at least one substrate (7) with a plasma with a first electrode (1) and a second electrode (12) that can be arranged opposite thereto, which electrodes are formed together producing the plasma between the electrodes (1, 12), characterized in that at least one of the electrodes (1, 12) is formed from at least an inner and an outer electrode unit (2, 3), wherein the inner and the outer electrode units (2, 3) are on the same potential, wherein the inner electrode unit (3) can be driven upwards and a robot arm (8, 8', 8'') can place the substrate (7) on the inner electrode unit (3), wherein the inner electrode unit (3) and the outer electrode unit (2) can be arranged to form a common support plane (E).
2. The device according to Claim 1, whereby the two electrode units (2, 3) can be controlled separately.
3. The device according to one of the preceding claims, whereby the at least two electrode units (2, 3) have an inner electrode unit (3) and an outer electrode unit (2) that pick up and/or surround, in particular enclose, in particular the inner electrode unit (3).
4. The device according to one of the preceding claims, whereby at least one of the electrode units (2, 3), in particular the inner electrode unit (3), can be moved in a Z-direction, in particular relative to another of the electrode units (2, 3), preferably the outer electrode unit (2).
5. The device according to Claim 1, whereby the common support plane can be applied as a closed and/or contact-providing surface, in particular with a uniform potential.
6. The device according to one of the preceding claims, whereby at least one of the electrode units (2, 3), in particular the inner electrode unit, is designed as a sample holder for receiving and/or attaching the substrate or the substrates.
7. A method for bombarding at least one substrate with a plasma produced by a first electrode (1) and a second electrode (12) arranged opposite to the first electrode (1), wherein at least one of the electrodes (1, 12) has at least an inner and an outer electrode unit (2, 3),

wherein the inner electrode unit (3) is driven upwards and a robot arm (8, 8', 8'') places the substrate (7) on the inner electrode unit (3), wherein inner electrode unit (3) and the outer electrode unit (2) are arranged for bombardment with the plasma in a common support plane (E).

8. The method according to Claim 7, whereby the two electrode units (2, 3) are controlled separately.

9. The method according to one of Claims 7 or 8, whereby at least one of the electrode units (2, 3), in particular the inner electrode unit (3), is moved to receive and/or attach the substrate or the substrates in a Z-direction, in particular relative to the outer electrode unit (2).

10. The method according to Claim 7, whereby the common support plane (E) is applied as a closed and/or contact-providing surface, in particular with a uniform potential.