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Description

Arrangement and a method for reducing contamination with particles on a substrate in a process tool

The present invention relates to an arrangement and a method for reducing contamination with particles on a substrate in a process tool, the substrate having a backside which is to be orientated towards a chuck.

In semiconductor device manufacturing several processing steps have to be performed until a substrate has received the desired structure of an integrated circuit. In many cases the corresponding equipment comprises a process chamber with a chuck inside, upon which the semiconductor device, e.g. a semiconductor wafer, can be laid in order to experience an actual processing step. Despite restrictive cleanroom specification, problems due to particle contamination often arise due to mechanical interactions between semiconductor devices and the chucks during the handling, and due to physical or chemical by-products of the current process. While particles assembling irregularly on the frontside of the semiconductor device can cause defects on the final integrated circuit, also particles accumulating on the backside of the semiconductor device can lead to severe problems in subsequent processing steps. Once particles have accumulated on the device backside the device is warped when placed on the chuck of the next process step having locked the particles between its plane backside and the chuck surface. In particular, the lithographic step then suffers from non-linear warpage of up to 100 nm in lateral direction, and from focus depth variation across the device.

In the case of the semiconductor device being a wafer the process track prior to the lithographic step usually comprises a hot plate, followed by a spin coater and a further hot plate for pre-backing the resist dispensed on the wafer

during the coating step. Of these steps prior to wafer exposure the coating step represents a main contributor of generated particles accumulating on the wafer backside. This is due to resist material being removed from the wafer surface during the spinning movement when the wafer is coated, which then by the airflow may gather as particles on the wafer backside or is deposited on the chuck after the wafer has been removed from the process chamber, i.e. the spinner cup. The following wafer to be processed is then placed on the contaminated chuck and the particles stick to the wafer backside.

In order to hold and fix the wafer during spinning with a rate of up to 5000 rpm vacuum channels are distributed on the chuck surface and are connected to a vacuum port. This further leads to a stronger mechanical interaction between the wafer and the chuck due to the underpressure in the vacuum channels. The particles mainly gather inside these channels beneath the wafer and than eventually stick to the wafer backside in concentrated areas, i.e. a contact area between the wafer backside and the vacuum channels.

Several techniques have been proposed to circumvent the problem of backside particle contamination. One prior art solution is to direct a solvent to the edge of the device for removing the resist where it is not needed and where it could cause the generation of particles in subsequent steps. Since, e.g., 200 mm wafers have a diameter which is slightly larger than the chuck, the edge parts of the backside are often cleaned by the solvent as well. But, because most of the wafer backside is contacting the chuck, few contaminating particles can be removed from the backside using this technique.

Another prior art method for reducing particle contamination is to position those backside areas, which are contaminated on a chuck in a first process step, e.g. coating, onto the position of the vacuum channels on a chuck of subsequent

step, e.g. lithography. While warpage could effectively be reduced, it is not easy to forecast the contaminated areas correctly using, e.g., optical inspection. Additionally, the corresponding chuck designs have to be the same.

In US 5,966,635 the cleaning of chucks between two processing steps of a wafer by applying a solvent liquid to the chuck is proposed to remove particles from the chuck, which then cannot stick to the backside of the next wafer to be processed. Although particles cannot accumulate in the process chamber and on the chuck particles are still able to move to the backside of the wafer within a process step, where most of the particles are generated. Once a particle has entered the vacuum channels it can further be transported beneath the wafer.

A still further technique, which is commonly applied to wafers having a diameter of 300 mm, is to reduce the contact area of the vacuum chuck with the wafer. A typically used chuck-wafer back support area for chucks today is about 50 % of the wafer backside area. Applying a solvent liquid through an edge bead removal nozzle to the backside of the wafer therefore is able to clean about half of the wafer backside area, while the central parts remain contaminated. A main disadvantage of this solution is, that 300 mm-wafers start to vibrate in normal modes at rotation frequencies, that have commonly be used. The resist, which is dispensed onto the wafer during spinning at about 5000 rpm then is not homogeneously distributed on the wafer frontside surface. Rather, it forms wavelike thickness structures due to mechanical interference effects at the outer unsupported surface area, i.e. where the wafer backside does not have contact with the chuck.

For this reason the rotation speed of a spin coater is typically reduced to about 2000 rpm in the 300 mm case. Because of this, it becomes difficult to process a larger thickness

of the resist with a given viscosity resulting in a reduced process quality for the lithographic step.

It is therefore a primary objective of the present invention to reduce particle contamination in semiconductor device manufacturing in order to improve the process conditions for subsequent manufacturing steps.

Specific expressions of the present invention can be found in claims 1 and 6.

The objective is solved by an arrangement for reducing contamination with particles on a substrate in a process tool, the substrate having a backside, which is to be orientated towards a chuck, comprising a process chamber of a process tool for providing a step processing said substrate, said chuck being arranged inside said process chamber for holding the substrate, is said of at least 3 moveable arms having tapered shelves for lifting the substrate from said chuck, a means for controlling the movement of the arms including a drive, at least one rinse nozzle for dispensing a solvent liquid, a means for providing said solvent liquid for supplying the at least one rinse nozzle, and by a method, comprising the steps of providing said substrate, loading said substrate onto the chuck inside the process tool, processing the substrate, lifting said substrate from the chuck using the set of at least 3 arms, dispensing the solvent liquid onto the substrate backside using at least one rinse nozzle, and unload said substrate from said chuck.

According to the present invention a set of arms is provided inside the process chamber of a process tool, which lift a semiconductor device after processing from the chuck in order to be cleaned by applying a solvent liquid through a rinse nozzle onto the backside of the semiconductor device. The invention can advantageously be applied in particlular to a coating track prior to exposure of, e.g., a wafer, the process tool being a spin coater, but any other process tool like CMP, etching, etc. with processing any other suitable semiconductor device or substrate like masks and reticles, flat

panel displays, etc. can be taken to incorporate the arrangement and the method of the present invention.

After having cleaned the semiconductor device backside, the device can either be lifted down again onto the chuck in order to be transferred to the next process step by a robot, or it is directly transferred from the set of arms provided by the arrangement according to the present invention to the robot arms of a track automation system. The arms of the arrangement comprise tapered shelves for providing a smallest possible contact area to the semiconductor device, and can have the form of knife edges. The contact area, i.e. the position where the arms contact and hold the substrate, is preferably located at the substrate edge, because this can be cleaned already by the conventional etch bead removal nozzle. The arms are constructed, such that they lift the device from beneath, the device then being supported by at least 3 arms in order to retrieve a stable position.

The preferable number of supporting arms, or pins, is 3 to 5. The arms have to be moved in at least a vertical direction in order to lift the device. Optional joints enable arms to adjust to different substrate sizes or to clamp the substrate. All arms can have individual drives, which are to be coordinated in their movement by a control unit, or are raised and lowered by one common drive. The arms can be based on a moveable socket either beneath or above the chuck position in the process chamber. In case of such a top-position additional drives and joints are necessary to lead the arms around the substrate from the top for supporting the substrate from its backside, the backside being orientated towards the chuck, i.e. commonly the bottom direction. After the contact has been established the device can be lifted. Preferrably, the substrate is fixed in a stable position lying on the at least three supporting arms being held just by gravity. Additionally, a clamping mechanism for the arms with a force acting on the substrate edges towards the substrate center without

contacting the frontside of the substrate - being covered by the resist in case of the process tool being a spin coater - can be applied as well.

The material used for the arms can be any neutral material like steel or teflon, etc. In a further aspect the at least three movable arms can be rotated around an axis in order to access all parts of the substrate backside homogeneously with the solvent liquid through the rinse nozzle. In a preferred embodiment the rotation axis is the same as that of the chuck. The substrate needs to be clamped by the arms when being rotated in order not to be damaged due to sliding down because of the centrifugal force in connection with a slight off-center position of the substrate. The rotation speed for arm rotation when dispensing the solvent liquid onto the substrate backside should not be in excess of the spin-dry rotation speed, which is typically in the magnitude of 1000 rpm. Preferred rotation speeds are in the range of 50 - 300 rpm.

At least one rinse nozzle is provided to clean the backside of the substrate. The rinse nozzle is connected to a source of solvent liquid, which can be dispensed with a pressure of 3-10 psi through the nozzle onto the backside. For the solvent liquid PGMEA (propylene glycol monomethyl ether acetate), EGMEA (ethylene glycol monoethyl ether acetate), or any other common solvent liquid can be used. If the set of arms is not able to rotate, two rinse nozzles are preferably to be employed to cover the whole substrate backside with the solvent liquid. In a further aspect at least one rinse nozzle can be controlled to move, such that the accessibility of the device backside is advantageously further improved.

The horizontal height level of the at least one rinse nozzle is beneath the lift-up position of the substrate, i.e. the top-most position of the tapered shelves of the arms contacting a substrate. In this position the substrate backside can be accessed by the solvent liquid through the rinse nozzle.

Furthermore, the rinse nozzle has a height above the chuck surface level, and - by means of a drive for changing the nozzle position and/or direction - in a further aspect the rinse nozzle can be directed onto the chuck surface in order to dispense the solvent liquid onto the chuck surface advantageously removing contaminating particles therefrom.

In a further aspect the contamination of the vacuum channels or vacuum ports of the chuck is considered. In order to impede a deposition of particles inside said vacuum channels or ports, gas can be directed out of the vacuum port and through the vacuum channels with a higher pressure than the pressure in the process chamber. For this N_2-gas or any other neutral gas can be utilized, e.g. helium. A switch is used to either apply the vacuum to the vacuum port for sucking the substrate onto the chuck surface via the vacuum channels, or directing the gas out off the vacuum port in order to keep the vacuum channels clean.

Further advantageous features, aspects and details of the invention are evident from the dependent claims.

The invention is now described with reference to an embodiment taken in conjunction with the accompanying drawings, wherein

figure 1 shows a side view of an arrangement inside the process chamber of a spin coater according to an embodiment of the present invention.

figure 2 shows a flow chart of a coating process using a method according to an embodiment of the present invention.

Inside a process chamber 3 of a spin coater 2 a set of four arms 5 is mounted on a rotatable drive and guiding means 6a for vertical arm movement. The rotation axis of a drive and

guiding means 6a is the same as that of a spin coater chuck 4 for holding the semiconductor wafer 1 during processing. As can be seen in figure 1 the drive and guiding means 6a for vertical arm movement is controlled by a means for controlling the movement 6 of the arms 5 in order to lift the semiconductor wafer 1 from the chuck 4, such that the semiconductor wafer backside 1b and the surface of the chuck 4 are freely accessible by a solvent liquid 10 through a rinse nozzle 7. By means of joints for the horizontal arm movement 5b the arms 5 can be adjusted to the size of the semiconductor wafer 1, such that it can be properly clamped into the tapered shelves 5a at the ends of the arms 5. The means for controlling the movement of the arms 6 comprises a control unit, which is connected to the automation system controlling the coating process. In particular the lifting of the arms 5 by the drive and guiding means 6a, the clamping by joints 5b with respective drives, and the rotation of the set of arms 5 by bearings and a drive 6b are put into a time sequence according to a complete coating track process.

In the lift-up position of the set of arms 5 a rinse nozzle can dispense solvent liquid 10 onto the wafer backside 1b, since its height level is beneath the lift-up position of the arms 5 with the tapered shelves 5a holding the wafer 1. Contaminating particles can then be advantageously removed from the wafer backside 1b. Additionally, a means to adjust the direction of the rinse nozzle 8 can switch the direction of the rinse nozzle 7 into a rinse nozzle chuck cleaning position 7a for dispensing the solvent liquid 10 onto the chuck surface. The solvent liquid 10 is supplied by an external means for providing the solvent liquid 11.

The chuck 4 comprises vacuum channels 23 connected to a vacuum port 24 for sucking the semiconductor wafer 1 to the chuck surface when being spun and processed. In the configuration of figure 1 the wafer backside 1b is cleaned with solvent liquid, such that the vacuum channels 23 can be contami-

nated with particles being removed from the wafer backside 1b. Therefore the connection of the vacuum port 24 to a source of vacuum 22 is - by means of a switch 20 - replaced by the connection to a gas vessel 21 containing N_2-gas with a higher pressure than in the process chamber 3, so that the nitrogen gas flows via the vacuum port 24 through the vacuum channels 23 preventing particles from settling down in the vacuum channels 23.

A sequence of steps for reducing contamination with particles on a substrate according to an embodiment of the method of the present invention is shown in figure 2. The arrangement used is the same as explained in the previous embodiment. A robot of the track automation system for coating a wafer provides the wafer 1 to the spin coater 2 and places the wafer 1 on the chuck 4. An organic resist is dispensed on the wafer frontside 1a where the wafer with a diameter of 300 mm is spun at 4000 rpm (revolutions per minute). The chuck 4 has a diameter of 290 mm. After the coating, a conventional backside rinse using a edge bead rinse nozzle is performed on the edge of the wafer 1, which is exposed beyond the chuck while the chuck rotates with 200 rpm. For clarity a resist dispense nozzle, the edge bead rinse nozzle and a spin cup enclosing the process chamber 2 are not shown in the embodiment of figure 1. The backside rinse is an optional step and needs not to be performed according to the present invention.

Thereafter, using the means for controlling the movement of the arms 6 the arms 5 are lifted, contacting the wafer 1 with the tapered shelves 5a and lift the wafer 1 up to a lift-up position. This is followed by 3 processes running in parallel: while the 4 arms rotate the wafer at 100 rpm the rinse nozzle dispenses the solvent liquid with a pressure of 8 psi onto the wafer backside 1b, and switch 20 is opened to release N_2-gas from the vessel 21 via the vacuum port 24 through vacuum channels 23 for removing particles generated in the cleaning process on the wafer backside 1b. Moreover

resist particles that are suspended in the airflow originating from the spinning and coating step, which may move towards the chuck are as well prevented from settling down into the vacuum channels 23.

After the cleaning step the wafer 1 is spun dry while being held on the arms 5 at the rotation speed of 1000 rpm, and is finally handed over to the robot arms, which transfer the wafer 1 to the next process step.

In a similar embodiment the wafer 1 can be placed onto the chuck 4 again (lift-down position) after the cleaning step and spun dry on the chuck followed by the robot transfer step.

In a still further embodiment the wafer backside cleaning step can be followed by a chuck surface cleaning step by switching the rinse nozzle 7 in a chuck cleaning position 7a then dispensing solvent liquid, and continued with the steps of the previous embodiment.

List of reference numerals

1	substrate, semiconductor wafer
1a	frontside of substrate
1b	backside of substrate
2	process tool, spin coater
3	process chamber
4	chuck
5	set of movable arms
5a	tapered shelve of movable arm
5b	joints for horizontal arm movement
6	means for controlling movement of arms
6a	drive and guiding means for vertical arm movement
6b	bearings with drive for rotating arms
7	rinse nozzle
7a	rinse nozzle in chuck cleaning position
8	means to adjust the direction of rinse nozzle
10	solvent liquid
11	means for providing solvent liquid
20	switch: vacuum or N_2-gas
21	source of N_2-gas
22	source of vacuum
23	vacuum channels
24	vacuum port

Claims:

1. Arrangement for reducing contamination with particles on a substrate (1) in a process tool (2), said arrangement comprising: a chuck (4) being arranged inside a process chamber (3) for receiving a backside (1b) of said substrate (1), said process chamber (3) being designed to provide a step of processing said substrate (1), a set of at least three movable arms (5) for lifting the substrate (1) from said chuck (4), a means for controlling the movement (6) of the arms including a drive,
characterized by
- said at least three movable arms (5) each having tapered shelves (5a),
- at least one rinse nozzle (7) for dispensing a solvent liquid (10),
- a means for providing said solvent liquid (12) for supplying the at least one rinse nozzle (7),
- said chuck (4) comprising a vacuum port (24) and vacuum channels (23), which are connected to said vacuum port (24), for fixing the substrate (1),
- at least two sources of gas pressure being connected to said vacuum ports, comprising:
  (a) a first gas pressure (22) being smaller than the gas pressure of the process chamber for providing nearly vacuum conditions, and
  (b) a second gas pressure (21) being larger than the gas pressure of the process chamber for providing a neutral gas to the vacuum channels, and
- a means for switching (20) the source of gas pressure applied to said vacuum ports (24) between said first gas pressure (22) and said second gas pressure (21).

2. Arrangement according to claim 1,
characterised in that
said process tool (3) is a spin coater having a means for dispensing a resist on the frontside (1a) opposite to the

backside (1b) of said substrate (1), and said chuck (4) is designed to rotate around an axis.

3. Arrangement according to claim 2,
c h a r a c t e r i s e d i n t h a t
said set of at least three arms (5) is mounted such that the set can be rotated around said axis.

4. Arrangement according to anyone of claims 2 to 3,
c h a r a c t e r i s e d b y
said substrate (1) being a semiconductor wafer having a diameter of at least 300 millimeters, and said chuck (4) having a contact surface having a diameter of at least 280 millimeters.

5. Arrangement according to claim 4,
c h a r a c t e r i s e d b y
a means to adjust the position and direction of said at least one rinse nozzle (8), such that either the backside (1b) of said wafer (1) lifted by said set of at least three arms (5) or the contact surface or vacuum channels (23) of said chuck (4) can be accessed by the solvent liquid (10) through said at least one rinse nozzle (7).

6. Method for reducing the number of particles on a substrate (1) in a process tool (2), the substrate (1) having a backside (1b) orientated towards a chuck (4), comprising the steps of:
- providing said substrate (1),
- loading said substrate (1) onto the chuck (4) inside a process tool (2),
- processing the substrate (1),
- lifting said substrate (1) from the chuck (4) using a set of at least three arms (5),
- dispensing a solvent liquid (10) onto the substrate (1) backside (1b) using at least one rinse nozzle (7), while

- directing gas out off at least one vacuum port (24), which is formed on said chuck (4) for protecting said at least one vacuum port (24) from being contaminated with particles.
- unloading said substrate (1) from said chuck.

7. Method according to claim 6,
c h a r a c t e r i s e d b y
rotating said set of at least three arms (5) holding the substrate (1) around an axis while dispensing said solvent liquid (10).

8. Method according to claim 7,
c h a r a c t e r i s e d b y
dispensing said solvent liquid (10) onto the chuck (4) after lifting said substrate (1).

9. Method according to anyone of claims 6 to 8,
c h a r a c t e r i s e d b y
rotating said substrate by a rotating means based on an Bernoulli-effect while being held by said set of at least three arms (5) for accessing substrate-arm-contact areas with said solvent liquid (10).