SUBSTRATE DRYING

FIELD OF INVENTION

The present invention relates to a method and apparatus for generating polar organic compound vapor which are used for drying integrated circuit components. More particularly, the present invention relates to the method and apparatus for generating isopropyl alcohol and nitrogen vapor mixture for drying semiconductor wafer.

BACKGROUND ART

Commonly, during fabrication of semiconductor devices, many processes such as lithography, a deposition and etching are repeatedly performed on a semiconductor substrate. Thus, during these processes, contaminants such as particles, metals, natural oxides and organic layers may be left on the substrate. Therefore, it is an important task to reduce metallic, particle and organic contamination of semiconductor substrate, more particularly integrated circuit wafers for further assembly of a semiconductor device. A wafer is typically cleaned by a wet cleaning process using a cleaning solution. After that, there is a need for drying the cleaned wafer without affecting surface of the cleaned wafer. If the cleaned wafer is exposed to water for a long time, then the cleaned wafer maybe denaturalized. The denaturalization might cause substantial problems for large scaled semiconductor devices.

Prior methods and apparatus for drying semiconductor substrates or wafers include introducing a drying alcohol such as isopropyl alcohol (IPA) into a process chamber in a vapor form. The apparatus used for drying the semiconductor substrates is an IPA dryer. The IPA dryer needs large quantity of solvent such as isopropyl alcohol and other volatile organic liquids for drying of the semiconductor substrate. Generally, the IPA dryer generates a superheated or saturated drying vapor as a drying fluid. A disadvantage of this dryer is that the use of the large quantity of solvent which is hot, highly flammable and extremely hazardous to health and environment. Another limitation of this apparatus is cost of the dryer and solvent which is expensive.

Another drying method of the IPA dryer is by using bubbling method wherein the IPA dryer supplies organic liquid vapor which is restrictively supplied by a pressurized bubbling gas source through bubbling gas supply pipe to a drying chamber. There are two limitations using this drying method. The first limitation relates to particles that may increase in number and reattach to the semiconductor wafer. This occurs when the bubbling gas pressure is high. When the bubbling gas pressure is high, it leads to large volumetric supply rate of the supplied vapor. Concentration of organic liquid on the surface of DI (de-ionized) water may become high as a result of organic liquid vapor supplied in a second step. Thus, particles may increase in number. The second limitation relates to long process

time, erosion and denaturalization of a metal layer. This occurs when the bubbling gas pressure is low. When the bubbling gas pressure is low, time taken to supply sufficient organic liquid to raise concentration of the organic liquid on the surface of the DI water becomes long and lead to the second limitations as mentioned above.

Another prior art, US 6,722,056 patent document teaches a system of introducing IPA in liquid form and evaporating the IPA vapor through a tube within a process chamber, wherein concentration of the IPA vapor depends on IPA feeding rate and gas flow rate. Both the feeding rate and gas flow rate are difficult to be controlled unless by introducing an expensive setup such as mass flow controller. Besides that, it is a tedious work to change the IPA concentration in IPA/N_2 vapor mixture or time interval of IPA/N_2 vapor mixture to the chamber.

Accordingly, there is a need for a method and apparatus for drying semiconductor substrates which does not result in flammable mists, expensive equipments, contamination problems, flexibility and also consistency as mentioned above. It is an object of the present invention to provide a method and apparatus that solves the problems of fire hazards, low concentration of IPA due to bubbling method and mechanical diffusion that leads to inconsistence of IPA concentration.

SUMMARY OF THE INVENTION

The present invention relates to an assembly of apparatus for drying electronic substrate comprising a chamber for cleaning and drying the substrates, means for generating a polar organic compound vapor and mixing the vapor with an inert gas, an inert gas supplier and a drainage system at the chamber. The means for generating a polar organic compound vapor and mixing the vapor with an inert gas includes at least one inlet for receiving the polar organic compound in liquid form continuously from a polar organic compound liquid supply, a means for generating ultrasonic energy which converts polar organic compound liquid into particles attached to the means for generating polar organic compound vapor, oscillator that generates power to the means for generating ultrasonic energy, at least one inlet for receiving an inert gas wherein the inert gas is mixed with the polar organic compound particles, at least one outlet for transporting and introducing the mixed polar organic compound vapor with inert gas to the chamber for drying process of the electronic substrates. The means for generating polar organic compound vapor and mixing the vapor with inert gas is spaced apart from the chamber and the introducing of the polar organic compound mixed with the inert gas to the chamber is controlled by a control device to ensure a consistence concentration of the mixed polar organic compound and the inert gas. There is also a sensor for monitoring and controlling polar organic compound liquid level connected to the means for generating polar organic compound vapor.

The polar organic compound is isopropyl alcohol (IPA) and the inert gas is nitrogen (N_2). The electronic substrate is a semiconductor wafer. The oscillator operates at the megasonic frequency of 1.6 to 2.4MHz.

The present invention also relates to a preferred embodiment of a method of drying electronic substrate comprising submerging the electronic substrate in a cleaning solution in a chamber, introducing a polar organic compound in liquid form into means of generating a polar organic compound vapor and mixing the vapor with an inert gas, generating a polar organic compound vapor mixed with the inert gas, introducing the vapor mixed with inert gas into the chamber to form an organic liquid layer on a surface of the cleaning solution, extracting the substrate from the cleaning solution, draining the cleaning solution and drying the substrate. The method for generating a polar organic compound vapor mixed with inert gas includes generating polar organic compound vapor at 1.5 – 2.0 % v/v by using means of generating ultrasonic energy which converts the liquid to vapor in the means of generating polar organic compound vapor, introducing the inert gas at a volumetric supply rate into the means of generating a polar organic vapor to form a inert polar organic compound vapor and maintaining a constant volume of organic compound liquid or inert polar organic compound vapor in the means of generating a polar organic vapor. The means of generating ultrasonic energy is powered by an oscillator that operates at 4.6 to 2.4 MHz; and concentration of the polar organic compound vapor is controlled between 1.5 – 2.0 % v/v. The draining

of the cleaning solution is conducted within a range of 0.001m/s to 0.0025m/s. The polar organic compound is isopropyl alcohol (IPA). The inert gas is nitrogen (N_2). The electronic substrate is semiconductor wafer.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be fully understood from the detailed description given herein below and the accompanying preferred drawings which are given by way of illustration only, and thus are not limitative of the present invention, wherein:

Figure 1 shows a schematic diagram of the IPA supply system to the drying chamber for drying the semiconductor substrate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A detailed description of preferred embodiments of the invention is disclosed herein. It should be understood, however, that the disclosed preferred embodiments are merely exemplary of the invention, which may be embodied in various forms. Therefore, the details disclosed herein are not to be interpreted as limiting, but merely as the basis for the claims and for teaching one skilled in the art of the invention.

The present invention relates to a preferred embodiment of an assembly of apparatus for effective drying of semiconductors substrate, i.e. semiconductor wafer used in fabricating of integrated circuits. Figure 1 shows a schematic diagram of the IPA supply system to the drying chamber for drying the semiconductor substrate. The assembly of apparatus includes isopropyl alcohol (IPA) vapor generator (10), feeding system to the IPA vapor generator, process tank (18) where the drying process occurs, inlets to the process tank (18) and outlets from the process tank (18). The IPA vapor generator (10) includes two feeding systems which are nitrogen supply (14) and IPA supply (12). The two feeding systems are fed to the IPA generator (10) via supply lines, preferably of PFA (Perfluoroalkoxy) material. The IPA vapor generator (10) comprises a vessel which is to continuously receive IPA from an IPA supply (12) line. Amount of IPA in the vessel is maintained at a fixed quantity by continuous liquid level feedback control. An ultrasonic nebulizer (11) is installed at bottom of the IPA vapor generator (10) and it is powered by an external oscillator that generates ultrasonic oscillations. A PFA tube transports the IPA vapor from the vapor generator (10) to the process tank (18) through a cover (20) of the tank (18) and the IPA vapor defuse into the tank (18) through multiple nozzles (22). N_2 filters (16) are fitted along the N_2 supply line to ensure purity of N_2.

The process tank (18) comprises of a tank with four sided over flow compartment (31). The semiconductor substrate is placed in a carrier and seated at a base of the tank. A cover (20) is installed on top of the tank. The cover includes nozzles for spraying N_2 (23) and nozzles for spraying IPA and nitrogen vapor mixture (22). There are three connections at the bottom of the tank. The first connection is for de-ionized (DI) water inlet and is connected to an air operated valve (27) which turns on and off DI water supply (21) to the tank (18). The second connection is to a quick dump valve (24) which is air operated and allows quick discharge of DI water from tank (18). The third connection is connected to a set of air operated valve (26) and manual multi-turn valve (28) which has a function of draining the DI water in the tank (18) at a slow, controlled rate. There is another inlet to the process tank (18) from the nitrogen supply (14) which is connected to nitrogen spraying nozzles (23). The nitrogen is transported from a nitrogen supply (14) via nitrogen supply line and pneumatically operated valve (34) to the nitrogen nozzles (23) which are built into the cover (20) of the tank. Along the nitrogen supply line there is a nitrogen heater (36) which is used to raise the temperature of the nitrogen which accelerates drying of the semiconductor substrate. N_2 filters (16) are fitted along the N_2 supply line to ensure purity of N_2.

Another preferred embodiment of the present invention is the method of generating the IPA and nitrogen vapor mixture and drying the semiconductor

substrate using the IPA and nitrogen vapor mixture. Firstly, the semiconductor substrates, i.e. wafers that need to be dried are placed onto a carrier in the empty process tank (18), the cover (20) is then closed and nitrogen is purged into the tank through the nitrogen spraying nozzles (23) to remove all types of airborne contaminants. Thereafter, the process tank (18) is filled from bottom with DI water from the DI water supply (21) through air operated valve (27) until it overflows into the overflow compartments (31). As the tank (18) is continuously filled with fresh, clean DI water from the tank bottom, dirtier water is removed from upper portion of the process tank (18) to the overflow compartments (31) and discharged through an over-flow drain valve (25), this process goes on for a preprogrammed time before valve (27) closes to stop the DI water supply. The overflow time can be carried out for a time period of at least 30 seconds and preferably for approximately 1 minute 30 seconds.

At this point, the IPA and nitrogen vapor mixture is introduced into the tank (18), the over-flow drain valve (25) closes to prevent escape of the IPA and nitrogen vapor mixture. Valve (26) opens to allow DI water to slowly drain through valves (26) and (28) and discharge to waste drain (35). Pressure within the tank (18) is continuously equalized through a PFA tube (32) connected to exhaust. The IPA and nitrogen vapor mixture diffuses into water surface and causes a surface tension gradient into a wetting film of the wafer. This gradient effectively removes the dirtier water together with any contaminants from the wafer surface. The IPA

and nitrogen vapor mixture is generated in the IPA vapor generator (10). The IPA vapor generator (10) continuously receives IPA from an IPA supply (12) line which is one of the feeding systems. The amount of the IPA in the IPA vapor vessel is maintained at a fixed quantity by continuous liquid level feedback control. There is an optical sensor (30) that monitors and controls the IPA liquid level by turning on /off the IPA supply valve (13) connected to the vapor generator. An ultrasonic nebulizer (11) is installed at the bottom of the IPA vapor generator (10) and it is powered by an external oscillator that generates ultrasonic oscillations. The ultrasonic nebulizer (11) generates energy that converts IPA into fine like particles. As the energy waves move through the IPA, the fine like particles will be pushed above IPA liquid level and it appear like fog. At this point, nitrogen supply valve (15) is opened and nitrogen is introduced into the IPA vapor generator (10) wherein the nitrogen is directed to the IPA liquid surface and carries the IPA fine particles away to form an IPA and nitrogen vapor mixture. The oscillator operates in megasonic frequency of 1.6 to 2.4 MHz range. However, the frequency of the oscillator can be controlled as needed. The IPA and nitrogen vapor mixture is transported to the process tank (18) via PFA tube at ambient temperature and diffuses into the water surface as mentioned at the beginning of this paragraph.

It is important to control concentration of the IPA in the IPA and nitrogen vapor mixture in a proper range (1.5 to 2.0 % v/v). When the concentration is too low, effective drying is not obtained. But when the concentration is too high,

excessive IPA in the IPA and nitrogen vapor mixture will condense on the wafer surface resulting in poor cleaning. Concentration of the IPA has to be controlled at a concentration of less than 2% v/v (volumetric ratio of IPA/mixture of IPA and N_2) which is the lower explosion limit of IPA. The concentration of IPA in the IPA and nitrogen vapor mixture from the IPA vapor generator (10) is kept constant by effectively controlling the amount of IPA in the generator (10), both power and frequency of the generator (10) and nitrogen flow rate.

The draining rate of the DI water in the tank is a very important factor, it determines the efficiency of drying process. When drain speed is too fast, the surface tension gradient effect will not be effective and that directly affect the drying and cleaning effect. On other hand, if the drain speed is slow, then the drying process efficiency is affected. The draining of DI water is also depended on the process prior to cleaning process which affects surface property of the semiconductor substrate surface. Therefore, the drain speed is fixed at a different drain speed according to the surface property of the substrate surface but should be within a range of 0.001m/s to 0.0025m/sec measured by rate of falling water level in the process tank (18).

When water level of cleaning solution is drained below the semiconductor substrate, i.e. wafer, supply of the N_2 to the IPA generator (10) stop, quick dump valve (24) opens to drain the remaining water in the process tank (18). Nitrogen is

purged to remove the remaining IPA and nitrogen vapor mixture residue in the process tank (18). Subsequently, nitrogen heater will be turned on to raise the temperature of nitrogen (approximately 80–90^{o}C), the heated nitrogen gas removes all residue condensation of IPA and water vapor from the wafers, cassettes and vessel walls by evaporation. This drying step is preferably carried out for approximately 5 to 10 minutes. At the end of this step, the cover (20) is opened and the fully dried wafers and cassette are removed form the process tank (18).

Therefore the present invention has the advantages of not having flammable mists, expensive equipments, contamination problems and inconsistent concentration of IPA introduced into the process tank for drying process of the semiconductor substrate.

CLAIMS

1. An assembly of apparatus for drying electronic substrate comprising a chamber (18) for cleaning and drying the substrates, means (10) for generating a polar organic compound vapor and mixing the vapor with an inert gas, an inert gas supplier and a drainage system at the chamber characterized in that wherein the means (10) for generating a polar organic compound vapor and mixing the vapor with an inert gas includes:

   i) at least one inlet (12) for receiving the polar organic compound in liquid form continuously from a polar organic compound liquid supply;

   ii) a means for generating ultrasonic energy (11) which converts polar organic compound liquid into particles attached to the means for generating polar organic compound vapor;

   iii) oscillator that generates power to the means for generating ultrasonic energy (11);

   iv) at least one inlet (14) for receiving an inert gas wherein the inert gas is mixed with the polar organic compound particles;

   v) at least one outlet for transporting and introducing the mixed polar organic compound vapor with inert gas to the chamber for drying process of the electronic substrates; and

   wherein the means (10) for generating polar organic compound vapor and mixing the vapor with inert gas is spaced apart from the chamber (18); and

wherein the introducing of the polar organic compound mixed with the inert gas to the chamber (18) is controlled by a control device to ensure a consistence concentration of the mixed polar organic compound and the inert gas; and

wherein a sensor (30) for monitoring and controlling polar organic compound liquid level is connected to the means (10) for generating polar organic compound vapor.

2. An assembly of apparatus as claimed in claim 1 wherein the polar organic compound is isopropyl alcohol (IPA).

3. An assembly of apparatus as claimed in claim 1 wherein the inert gas is nitrogen (N_2).

4. An assembly of apparatus as claimed in claim 1 wherein the electronic substrate is a semiconductor wafer.

5. An assembly of apparatus as claimed in claim 1 wherein the oscillator operates at the megasonic frequency of 1.6 to 2.4MHz.

6. A method of drying electronic substrate comprising submerging the electronic substrate in a cleaning solution in a chamber (18), introducing a polar organic compound in liquid form into means (10) of generating a polar

organic compound vapor and mixing the vapor with an inert gas, generating a polar organic compound vapor mixed with the inert gas, introducing the vapor mixed with inert gas into the chamber (18) to form an organic liquid layer on a surface of the cleaning solution, extracting the substrate from the cleaning solution, draining the cleaning solution and drying the substrate characterized in that wherein the method for generating a polar organic compound vapor mixed with inert gas includes:

i) generating polar organic compound vapor at 1.5 – 2.0 % v/v by using means of generating ultrasonic energy (11) which converts the liquid to vapor in the means (10) for generating polar organic compound vapor;

ii) introducing the inert gas at a volumetric supply rate into the means (10) of generating a polar organic vapor to form a inert polar organic compound vapor;

iii) maintaining a constant volume of organic compound liquid or inert polar organic compound vapor in the means of generating a polar organic vapor; and

wherein the means of generating ultrasonic energy (11) is powered by an oscillator that operates at 4.6 to 2.4 MHz; and

wherein concentration of the polar organic compound vapor is controlled between 1.5 – 2.0 % v/v; and

wherein the draining solution is conducted within a range of 0.001m/s to 0.0025m/s.

7. A method of drying electronic substrates as claimed in claim 6 wherein the polar organic compound is isopropyl alcohol (IPA).

8. A method of drying electronic substrates as claimed in claim 6 wherein the inert gas is nitrogen (N_2).

9. A method of drying electronic substrates as claimed in claim 6 wherein the electronic substrate is semiconductor wafer.