Method and Apparatus for Measuring and Dispensing a Wafer Etchant

Field of the Invention

This invention relates generally to the manufacture of circuit devices on a semiconductor wafer and more specifically to a method and apparatus for dispensing a specified amount of an acid component of an etchant bath.

Background of the Invention

In one familiar step in manufacturing a semiconductor wafer, a silicon dioxide layer on the wafer is etch with an etchant, commonly hydrofluoric acid. The etch rate varies with the concentration of the acid, and the acid is diluted with deionized water to a concentration that is appropriate for a particular etching operation.

Therefore, it is a common goal in this art to produce a solution of hydrofluoric acid and deionized water having a predefined concentration.

In a specific manufacturing technique that this invention is intended for, the wafers are placed in a bath formed by a solution of hydrofluoric acid and deionized water. This bath is held in a tank. This familiar environment will be used for illustrating the invention. The acid and the deionized water are mixed in the bath. In one practice, a specified amount of deionized water is first added to the bath and then a specified volume of acid is added.

A bath is used for a number of wafers and is then replaced. Thus, the preparation of this acid solution is a continuing task in wafer manufacture.

In the preferred manufacturing environment, the solution has 50 parts of deionized water to one part hydrofluoric acid. As a more specific example, the volume of the bath (both acid and deionized water) is 26.5 liters and the volume of hydrofluoric acid is 0.540 liters. The intended accuracy of the acid volume is +/- 5 milliliters (0.005 liter).

With this high ratio of water to acid, the desired amount of water can be measured easily with any convenient means of reasonable accuracy, but the acid volume must be established very precisely. Thus, one recognized goal in this art is to supply a precise volume of acid to the bath.

The Prior Art

In concept, the acid could be measured by hand, using familiar laboratory measuring apparatus. However, a more automated technique is needed for a manufacturing environment.

The prior art has suggested using metering valves to supply precise amounts of deionized water and hydrofluoric acid to the tank that holds the bath. However, these valves are inaccurate if the pressure is not kept constant, and they require frequent replacement at a significant expense.

Summary of the Invention

According to this invention, a tank is adapted to hold the acid and is provided with a adjustable overflow pipe. The overflow level is set to provide a volume that is slightly larger than the volume of acid that is to be supplied to the bath. The tank also has a vertically adjustable volume occupying element that reduces the volume of acid that can be held below the overflow level. The preferred volume occupying element is a rod that is threadably supported in the tank. Turning the rod raises

or lowers it and thereby changes the volume at a rate that permits simple adjustments.

The tank is small and is easily located in a manufacturing line over the tank holding the acid bath.

Other objects and features of the invention will appear in the description of the preferred embodiment of the invention.

The Drawing

Fig. 1 is a schematic diagram of the apparatus of this invention.

The Preferred Embodiment

The Apparatus of Fig. 1 — Introduction

A tank **12** holds a bath **14** of hydrofluoric acid diluted with deionized water. The tank and bath are conventional and are shown schematically in Fig. 1. Apparatus that is conventional and not shown in the drawing carries a wafer to the bath and immerses the wafer for a sufficient time to perform a selected etch operation on silicon dioxide exposed at the surface of the wafer. As already explained, the amount of etching is a function of both the time the wafer is subjected to the etchant and the concentration of the etchant.

A suitable supply of deionized water is provided, and a selected amount is placed in tank **12** before the apparatus of this invention is used to dispense the acid.

The Measuring and Dispensing Tank

My novel measuring and dispensing apparatus includes a tank **15** that is constructed to hold a selected volume of hydrofluoric acid and to permit an easy adjustment to this volume. Tank **15** and other components that contact the acid are made of acid

resistant materials or are coated with acid resistant materials, as will be readily understood.

The preferred tank has a square bottom wall **17** that is 6 centimeters on a side and rectangular side walls **18** that are 19 centimeters high. The preferred tank also has a top **19**. These dimensions provide a volume of 686 cubic centimeters (0.686 liters). These values illustrate the requirement that the volume of the tank is greater than the volume of acid (0.540 liters in the related earlier example).

From a more general standpoint, the volume of acid will be selected in relation to the volume of the bath **14** and the desired concentration. The invention can be understood most easily from the more limited approximation that the preferred volume of acid tank in **15** is on the order of one half liter and the total tank volume is on the order of one liter.

The Acid Filling and Dispensing Apparatus

In concept, the acid can be poured into tank **15** from a bottle containing the acid, but preferably the acid is supplied through a pipe **16** that is connected to any convenient supply of the acid. Pipe **16** may be supported by a conventional attachment to the top **19** of tank **15**, represented schematically.

The acid is dispensed from tank **15** through a pipe **20** and a drain valve **21**. Pipe **20** has an upper section **20a** that is attached to the bottom **17** of the tank **15** by means of a fitting **22**, and it has a lower section **20b** that extends from the outlet side of valve **21** to a convenient position above the tank **12** that holds the etching bath **14**. A control system for drain valve **21** will be described later.

The volume of tank **15** includes the volume of upper pipe section **20a**.

The Acid Level Control System

An overflow pipe **23** allows excess acid to flow out of the tank and it thereby defines the level of acid in the tank. This level is shown by a dashed line **24**. Pipe **23** is attached to the bottom of tank **15** by a fitting **25** that is releasable to allow pipe **23** to be raised or lowered to set overflow line **24** to a desired level. The position of line **24** defines a maximum volume of acid in the tank (including the acid in upper pipe section **20a**), as will be explained later. Other volumes that are slightly different will also be explained later.

As Fig. 1 shows, the upper rim **26** of overflow pipe **23** is preferably slanted so that acid flows into the pipe until level **24** falls to the lowest point along the rim. This construction provides a more precise definition of level **24**.

Ordinarily, the excess acid that overflows pipe **23** will be collected and reused, and a section **23a** of overflow pipe **23** extends below fitting **25**. The schematic break in the drawing of this pipe represents that the collection apparatus is independent of tank **15** and the associated the apparatus.

The volume of acid defined by the overflow line **24** is a precise value, and at least in concept the vertical position of overflow pipe **23** can be adjusted to locate the line **24** at a level for a desired volume of acid. However, it is sometimes necessary to make small increases or decreases in the percentage of acid when the bath is replaced, and these changes may be difficult to make by positioning the overflow pipe because access to pipe **23** and fitting **25** may be blocked by nearby components of the wafer manufacturing line. If the pipe and fitting are accessible, it may be time consuming to change the volume by adjusting pipe **23**.

The Volume Adjusting Apparatus

A volume adjustment mechanism **27** is located to occupy a selected volume below the overflow line **24**, and it permits the tank volume to be adjusted to a specified value.

As Fig. 1 shows, the volume adjusting apparatus comprises a threaded rod **28** that is held in a suitable support, such as the top **19** of tank **15**, having complementary threads. The rod extends both above and below overflow line **24**. As the rod is turned (preferably by hand), it extends farther below overflow line **24** or it is raised from this position, and a small volume is displaced from the tank or added to the tank volume.

The volume adjusting mechanism **27** is adapted to provide a suitable range of variation in the volume of tank **15**. Giving the threaded rod a greater diameter provides more displacement for each turn. The displacement for one turn can be calculated from the diameter of the rod and the pitch of the threads. The apparatus will operate easily with a wide range in the diameter and length of rod **28**, and the drawing shows these components to an approximate scale for the preferred apparatus.

Giving the rod a greater threaded length also increases the range of displacement. If it is expected that the position of overflow level line **24** will be changed significantly, the threaded part of the rod is extended or the rod is otherwise adapted to extend across any expected overflow level.

The Valve Control System

Preferably, drain valve **21** is a conventional pneumatically operated valve, actuated by compressed air in a line **30**. The compressed air in line **30** is controlled by a solenoid valve **32** that is controlled by relay having contacts **33** that are actuated by a coil **34**. These components are conventional and are shown schematically in Fig. 1.

A proximity sensor **35** is located to sense the flow of acid in overflow pipe section **23a**. These sensors are well known and a detailed description is not required; commonly they include capacitor electrodes that respond to the difference in dielectric constant between the acid and the air that otherwise occupies pipe section **23a**.

When the tank has been filled with acid to line **24** and acid begins to flow in pipe section **23a**, proximity sensor **35** produces a signal on a line **36** to start a timer **37**. Timer **37** produces a signal to energize the relay coil **34** and open solenoid valve **32** and pneumatic valve **21** for a time that is sufficient to drain tank **15**. At then end of this time period, coil **34** is de-energized and valve **21** is closed.

Setting up Tank 14

A person initially setting up the tank to hold a preselected volume of acid can select the appropriate position for level **24** in any suitable way. (The volume corresponding to this level is only required to be somewhat larger than the desired volume of acid, within the range of volume change that can be produced by rod **25**.) For example, the position can be calculated from the dimensions of tank **15**, or a known volume of water can be put in the tank.

The fitting **25** for overflow pipe **23** is then released, overflow pipe **23** is positioned with the lowest point of its rim **26** at the selected position for line **24**, and fitting **25** is tightened to seal the overflow pipe to the bottom of the tank and to lock it in the selected position. This technique can be used to establish the position of line **24** for a selected volume, or the tank can be marked to show several volumes from a succession of these measurements.

The volume occupying rod **28** is then adjusted to give the tank a selected volume. One way to make this adjustment is to raise rod **28** to a high position, place the desired volume of water in the tank, and then lower the rod until the level rises to the overflow point.

Ordinarily, the volume occupying rod **28** will be given a vertical range that will cover expected changes in the concentration of the acid bath **14**, and the initial setting of the overflow position will remain fixed unless a greater change in the acid concentration is required. The position of rod **28** can be easily repositioned to adjust the concentration within this range.

Other Embodiments

Specific examples have been used to make the description of the invention easier to understand, and those skilled in the art will recognize appropriate modifications for a particular application, within the spirit of the invention and the scope of the claims.

The Claims

1. Apparatus for supplying a first predetermined volume of an acid to a second predetermined volume of deionized water to form a bath of a preselected concentration for etching a semiconductor wafer comprising,

a tank adapted to hold the acid and having a second predetermined volume larger than the first predetermined volume of the acid to be supplied to the bath, and a first pipe and a first valve for controlling the flow of acid from the tank to the bath,

an overflow pipe for returning acid from the tank when the acid supplied to the tank reaches the overflow level of the overflow pipe, the volume of the tank below the overflow level being larger than the first predetermined volume of acid to be supplied to the bath,

and a volume occupying element located in the tank and extending above and below the overflow level, the volume occupying element being adjustable with respect to the overflow level for adjusting the volume of acid contained below the overflow level to said first predetermined volume.

2. The apparatus of claim 1 including a second pipe for supplying acid to the tank.

3. The apparatus of claim 2 including means mounting the second pipe on the tank for support.

4. The apparatus of claim 1 wherein the overflow pipe is adjustable vertically for adjusting the position of the overflow level.

5. The apparatus of claim 4 wherein the overflow pipe extends through the bottom of the tank and is sealed to the bottom of the tank with a releasable fitting that permits the overflow position to be adjusted.

6. The apparatus of claim 1 wherein the volume occupying element is a rod.

7. Apparatus for supplying a selected volume of an acid to a predetermined volume of deionized water to form a bath of a preselected concentration for etching a semiconductor wafer comprising,

a tank adapted to hold the acid and having a volume larger than the volume of the acid to be supplied to the bath, and a first pipe and a first valve for controlling the flow of acid from the tank to the bath,

an overflow pipe for returning acid from the tank when the acid supplied to the tank reaches the overflow level of the overflow pipe, the volume of the tank below the overflow level being larger than the volume of acid to be supplied to the bath,

and a rod shaped volume occupying element located in the tank and extending above and below the overflow level, the volume occupying element being adjustable with respect to the overflow level for adjusting the volume of acid contained below the overflow level to said first predetermined volume.

8. The apparatus of claim 7 including means for releasably mounting the overflow pipe in the tank to permit adjusting the overflow level.

9. The apparatus of claim 8 wherein the rim of the overflow pipe is slanted with respect to the acid level so that acid overflows the pipe at a small circumference of the rim.

10. The apparatus of claim 9 wherein the first valve is controllable and the apparatus includes a sensor located to sense the flow of acid in the overflow pipe when the acid has reached overflow level and means for thereafter opening the drain valve for a predetermined time sufficient to drain the acid in the tank.

11. A method for forming an acid bath for etching a semiconductor wafer, comprising the following steps,

providing a tank for holding the acid component of the bath,

providing an overflow pipe for the tank, the level of the overflow defining a first predetermined volume inside the tank, the first predetermined volume being larger than the volume of acid to be supplied to the bath,

locating a volume occupying element inside the tank at a position where the overflow volume extends above and below the overflow level,

and adjusting the position of the volume occupying element with respect to the overflow level to provide a preselected volume of acid when the tank is filled to the overflow level,

and emptying the tank into a bath containing a predetermined amount of water.

12. The method of claim 11 wherein the method includes adjusting the position of the overflow pipe to establish a selected value for the overflow volume.

13. The method of claim 12 wherein the method of adjusting the overflow pipe comprises releasing a fitting connecting the pipe to the bottom of the tank, moving the pipe to a selected position, and refastening the fitting.

14. The method of claim 13 wherein the tank has a pipe and a valve for controlling the flow of acid from the tank to the bath and wherein the step of emptying the tank comprises detecting the flow of acid in the overflow pipe when the tank has been filled to the overflow level, opening the valve for a fixed time sufficient to empty the tank, and then closing the valve.