

[54] **APPARATUS FOR AUTOMATIC CHEMICAL PROCESSING OF WORKPIECES, ESPECIALLY SEMI-CONDUCTORS**

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[58] Field of Search **134/57 R, 73, 74, 76, 77, 134/83, 58 R, 125, 126, 108; 156/345**

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[57] **ABSTRACT**

Apparatus for automatically and continuously treating workpieces, especially semi-conductor devices, with liquids, provides for a plurality of liquid treatment operations including at least one dipping step and one spraying step. Metering pumps are provided for maintaining the composition of a liquid mixture in at least one dipping step within predetermined limits and a controlled heater is employed for controlling the temperature of the liquid mixture therein. A conveyor automatically transfers workpieces from one treatment chamber to another according to a predetermined time cycle. The apparatus is useful for a number of liquid treating operations including various cleaning, stripping, etching, rinsing and drying operations such as are frequently used in the manufacture of semiconductor devices.

11 Claims, 7 Drawing Figures

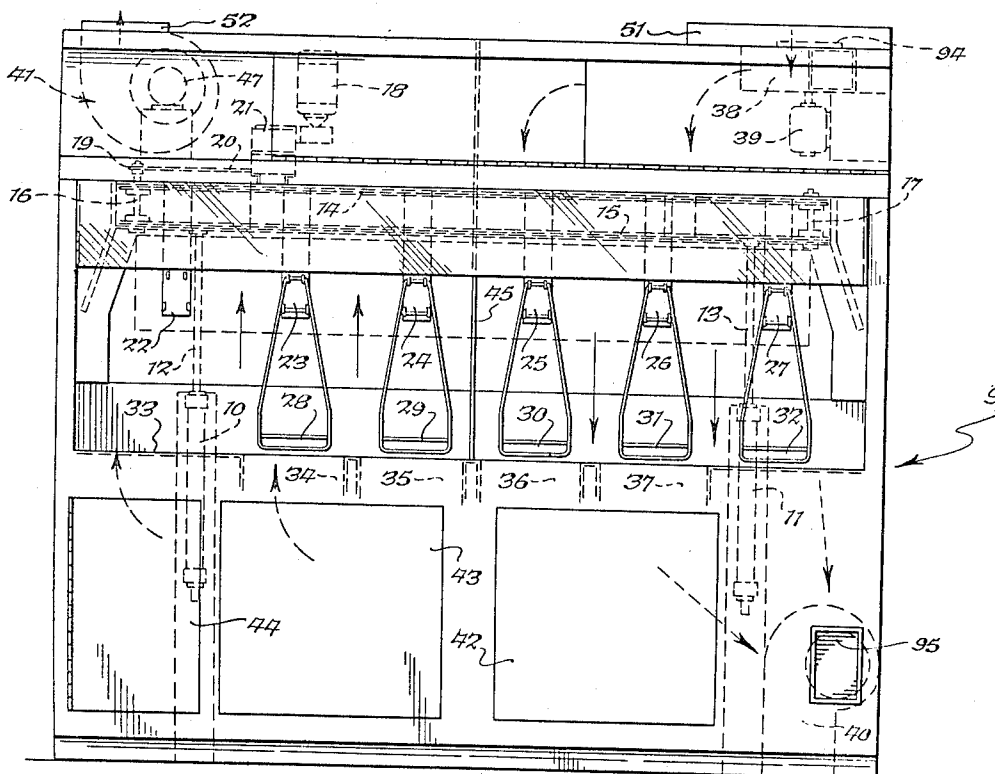
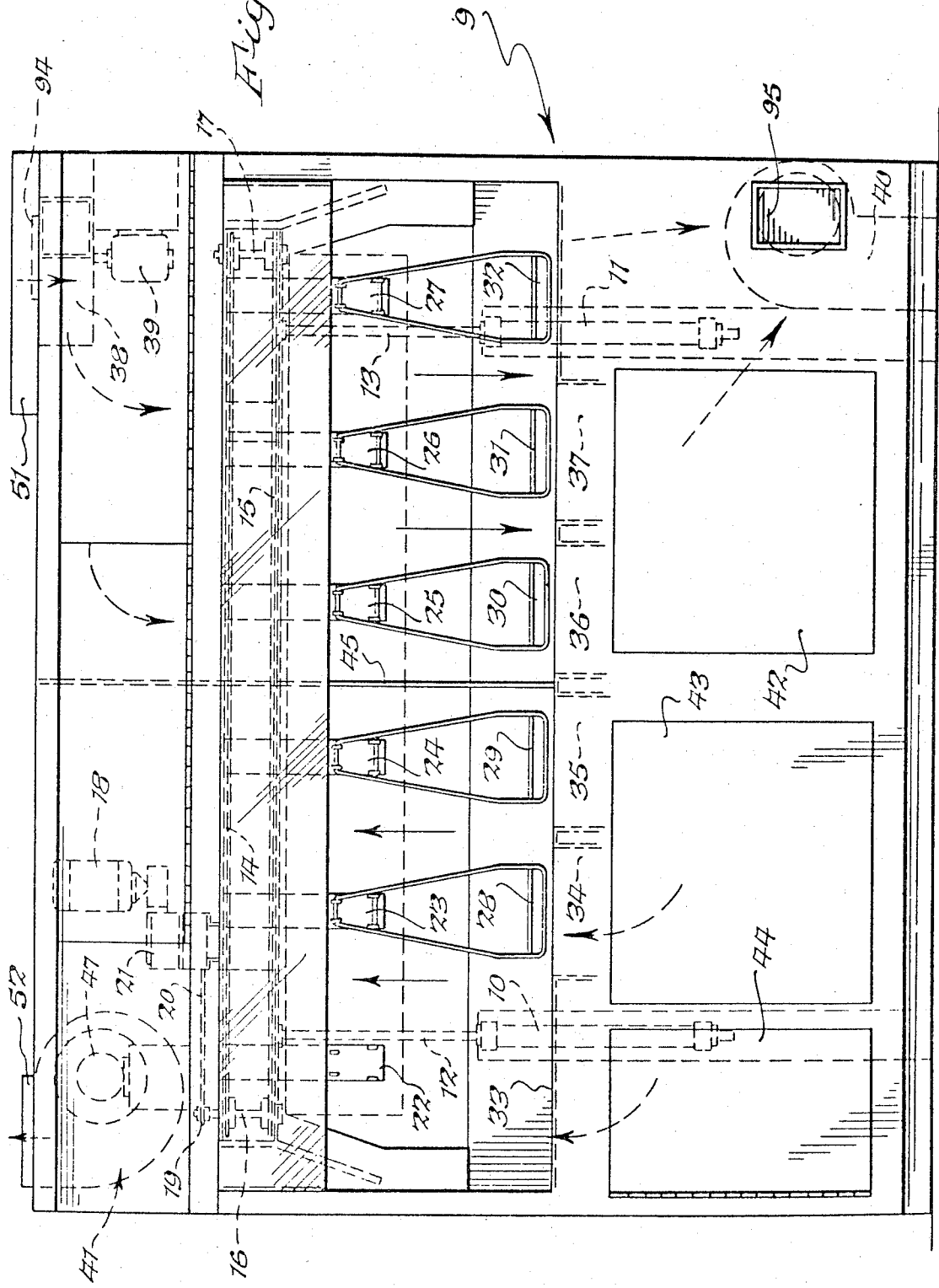
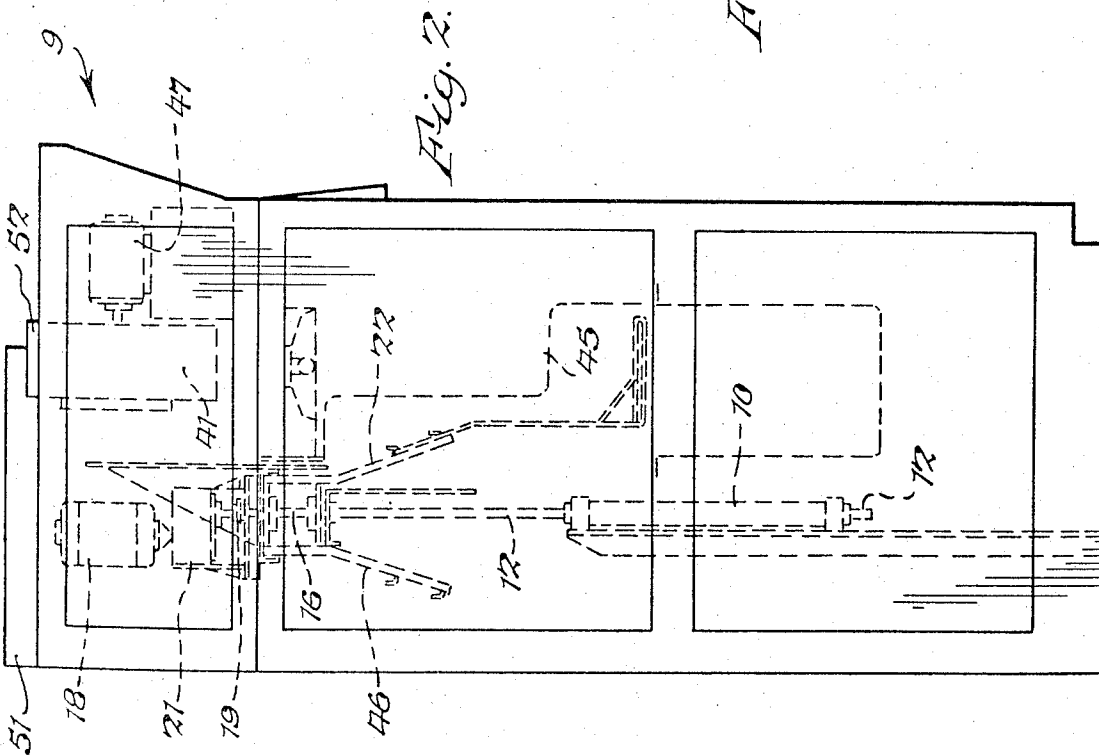
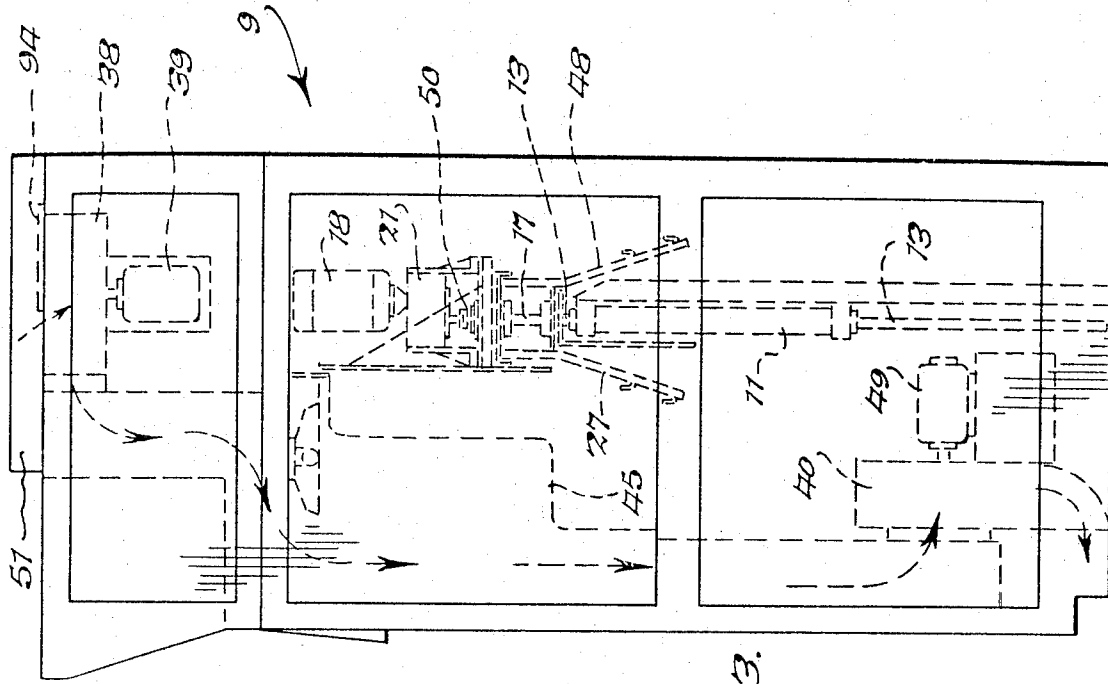


Fig. 1.





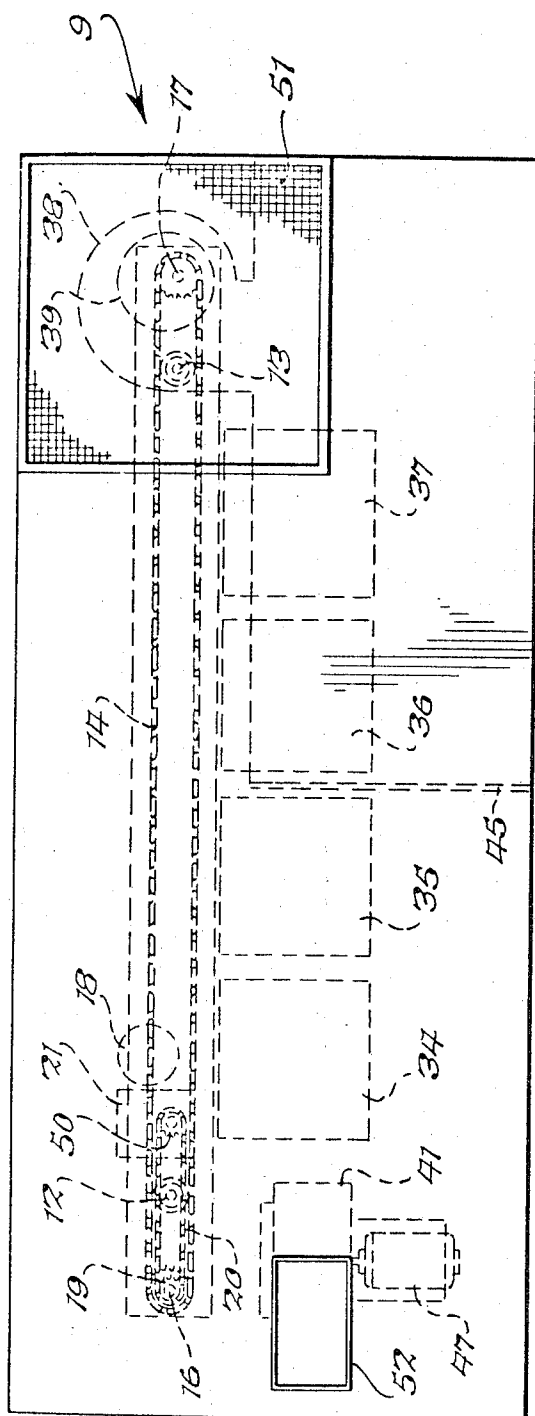


Fig. 4.

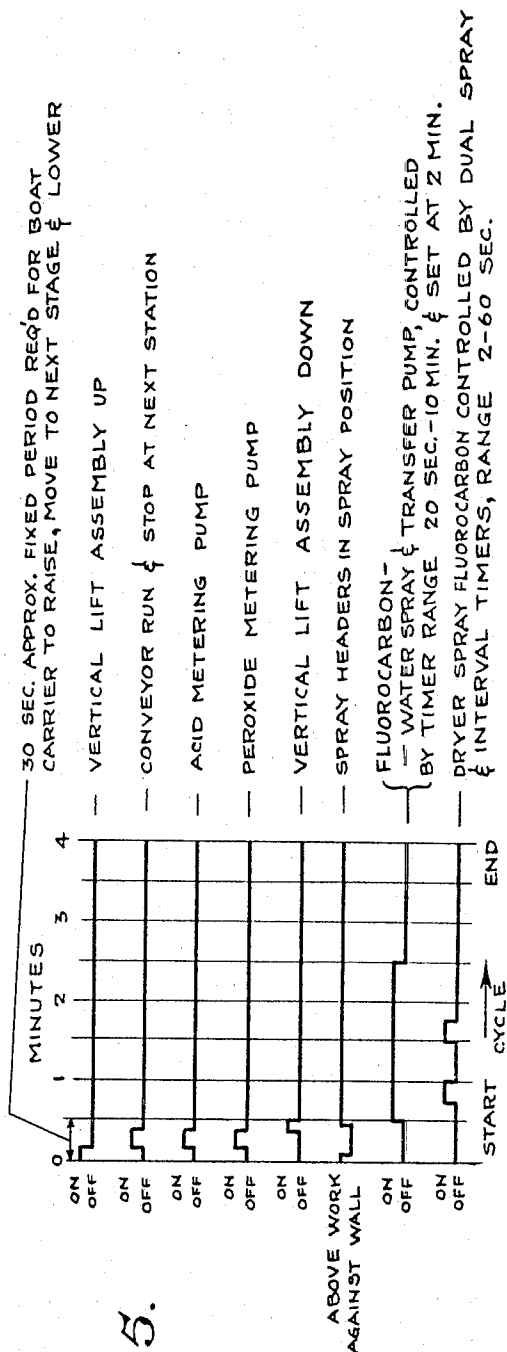


Fig. 5.

Fig. 6A.

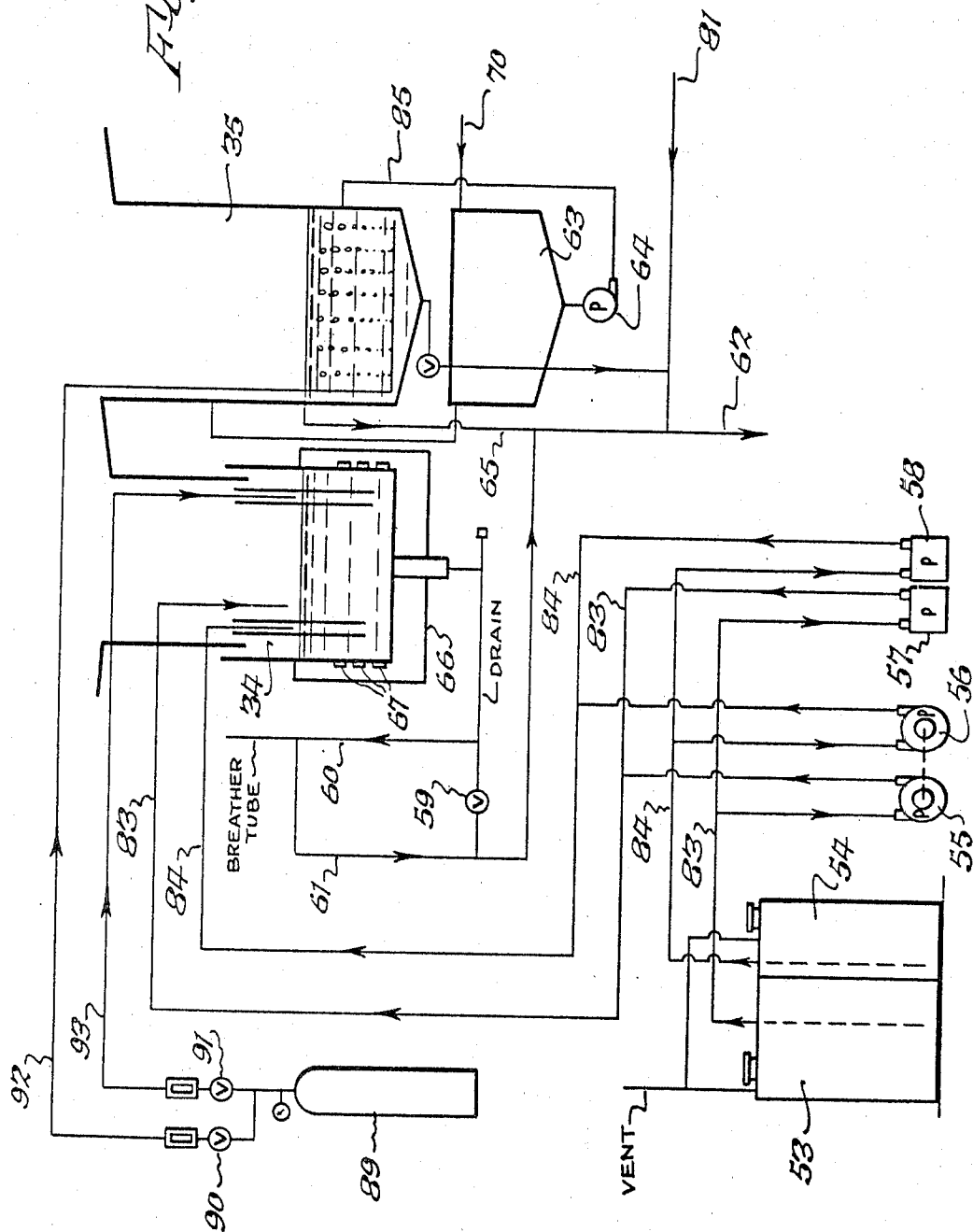
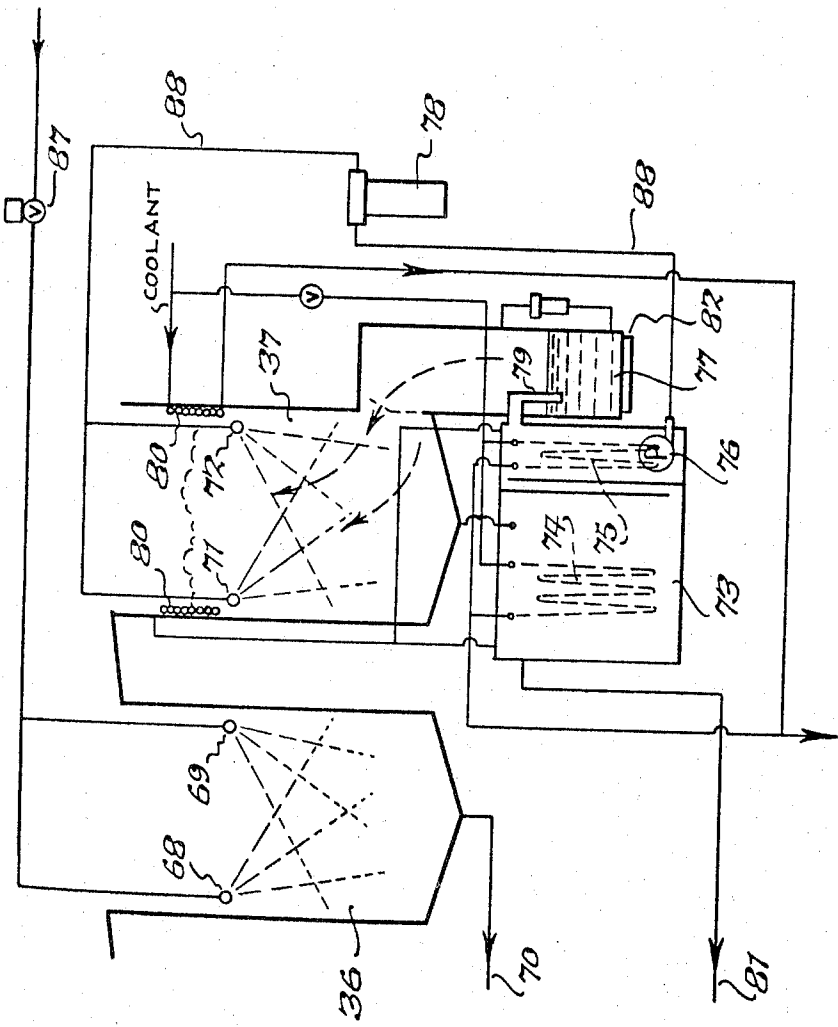


Fig. 6B.



APPARATUS FOR AUTOMATIC CHEMICAL PROCESSING OF WORKPIECES, ESPECIALLY SEMI-CONDUCTORS

BACKGROUND OF THE INVENTION

Many of the distant steps involved in the manufacture of electronic semi-conductor devices involve the use of liquid chemicals. Prior art workers have attempted to provide continuous type machines for conducting the various steps involved in the manufacture of electronic semiconductor devices, for example, U.S. Pat. No. 3,219,509, U.S. Pat. No. 3,388,023, U.S. Pat. No. 3,630,804, U.S. Pat. No. 3,657,049, U.S. Pat. No. 3,663,724 and U.S. Pat. No. 3,727,620.

Apparently, for reasons of complexity, economics, reliability, lack of uniform results, or other reasons, these devices have not met with wide acceptance in the semiconductor manufacturing industry since the practice of conducting these liquid chemical treatment steps by means of small individual batches is still widespread in the industry. These batch-wise processes are conducted in small vessels, usually less than five gallons of liquid and typically about one gallon. The workpieces are transported manually through the individual process steps. Semi-skilled operators are employed to conduct these processes according to techniques based on successful past experience. Operator variables such as over- or under-processing, contamination, incorrect bath compositions and the like are becoming economically unacceptable. Results obtained are not as uniform as would be desired. Furthermore, effluent pollution from these liquid chemical batch processes are becoming an increasing burden on semi-conductor manufacturers.

It is an object of this invention to provide a novel apparatus for the continuous and automatic treatment of workpieces with liquids which is simple and yet capable of mass handling and treatment of articles with uniform results.

It is another object of the invention to provide an apparatus of the type described which is particularly suited to the continuous automatic manufacture of electronic semi-conductor devices.

Other objects and advantages of the invention will become apparent from the following description.

SUMMARY OF THE INVENTION

The objects and advantages of the invention are achieved by apparatus for continuously treating workpieces comprising: a plurality of treatment chambers, at least one of which is a dip chamber adapted to contain a liquid and at least one of which is a spray chamber equipped with means to spray liquid on workpieces suspended within said chamber, means for controlling the temperature of the treating liquid in at least one dip chamber, means for maintaining the composition of the liquid mixture in at least one dip chamber within predetermined limits, and conveyor means for automatically transferring the workpieces from treatment chamber to treatment chamber and lowering the workpieces through the top of the treatment chambers according to a predetermined timed cycle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevation of the apparatus showing the major operating components of the equipment, including the vertical lift and transverse drive assemblies,

the transport brackets and wafer boat carriers, and location of the treatment chambers, the chemical reservoirs and the air distribution blowers. This Figure shows the conveyor in the up position.

FIG. 2 is an end view of the left side of FIG. 1.

FIG. 3 is an end view of the right side of FIG. 1. In this Figure the conveyor is shown in the down position.

FIG. 4 is a top plan view of FIG. 1 showing further details of the transverse drive assembly and also the location of the treatment chambers.

FIG. 5 is a graphical representation of the timing sequence of various operations which occur during a typical processing cycle.

FIGS. 6A and 6B are a piping schematic of a typical processing system.

DETAILED DESCRIPTION OF THE INVENTION AND OF THE PREFERRED EMBODIMENTS

The apparatus comprises a cabinet 9 which contains a plurality of treatment chambers at least one of which is a dip chamber adapted to contain a liquid and at least one of which is a spray chamber equipped with means to spray liquid on the workpieces suspended within said chamber. At least two and any greater number of treatment chambers, in any order, may be provided depending upon the requirements of the particular liquid treating operations contemplated.

In the embodiment shown in FIG. 1, four treatment chambers 34, 35, 36 and 37 are provided which are recessed below a countertop 33. Treatment chamber 34 is a dip chamber and is equipped with controlled heater 67 to control the temperature of the treating liquid in this chamber as can best be seen in FIG. 6A. A constant volume of liquid in process tank 34 is maintained by closing valve 59 and allowing liquid to flow up stand-pipe 60 through pipe 61 to drain 62. Treatment chamber 34 is fed with liquid chemicals from reservoirs 53 and 54 through pipes 83 and 84, respectively, using filling pumps 55 and 56. As these chemicals are used in treatment chamber 34, fresh make-up chemicals may be added using metering pumps 57 and 58. Through judicious use of these metering pumps the composition of a liquid mixture in treatment chamber 34 can be maintained between predetermined limits. Nitrogen bubbling system comprised of nitrogen tank 89, valves 90 and 91 and pipes 92 and 93 provides both agitation as well as means of solution height measurement in dip tank 34 and also dip tank 35. In the embodiment shown treatment chamber 34 would be used as a chemical treatment chamber.

Referring to FIGS. 1 and 6A, treatment chamber 35 is another dip chamber, and would be used in the illustrated embodiment as a rinse chamber. In such capacity chamber 35 would be filled, for example with deionized water from deionized reservoir 63 and pipe 85 by means of pump 64. A constant volume of water is maintained in process chamber 35 by means of overflow pipe 65 which also flows to drain 62.

As can be seen in FIGS. 1 and 6B, treatment chamber 36 is a spray chamber which, in the embodiment shown, also serves as a rinse chamber. A rinse liquid, such as deionized water may be sprayed from spray heads 68 and 69. Spray heads 68 and 69 are fed from pumping through pipe 86 controlled by valve 87. Waste liquid from treatment chamber 36 flows through pipe 70 to reservoir tank 63 (See FIGS. 6A and 6B).

Treatment chamber 37 (FIG. 6B) is also a spray chamber which, in the embodiment shown, may be used as a drying chamber. Drying is accomplished by spraying the article with a fluorocarbon containing solvent, such as trichlorotrifluoroethane, or an azeotropic mixture of trichlorotrifluoroethane and isopropanol. Workpieces held in this chamber are sprayed with liquid through spray heads 71 and 72. The sprayed liquid is circulated from separating tank 73 by means of pump 76 through pipe 88 and filter 78. When pump 76 is not in operation, workpieces held in treatment chamber 37 are heated by condensation of fluorocarbon containing solvent vapors generated from boiling sump 77. (Vapor flow shown by the arrows from the top of sump 77.) Vapors not condensed on the workpieces are condensed by condenser coils 80 before they escape from the treatment chamber. Sprayed fluorocarbon containing solvent and condensed fluorocarbon containing solvent, both contaminated by water from the processed workpieces, are drained from treatment chamber 37 to separation tank 73. There the vapors are cooled by cooling coils 74 and 75. Water contained in the contaminated solvent is phase separated in tank 73 and is drained through pipe 81 to drain 62 (FIG. 6A). Water purified fluorocarbon containing solvent from separation tank 73 flows through drain 79 to boiling sump 77. This sump is equipped with heater 82 to generate solvent vapors.

In a preferred embodiment, the treatment chambers are provided as removable modules which can be interchanged with one another or added or subtracted to a given designed train of treatment chambers in order to provide flexibility of operation.

Preferably, the apparatus includes at least two dip chambers such as chambers 34 and 35 shown in the drawings. A desirable variation not shown is the inclusion of means for recirculating the treating liquid in at least one dip chamber.

Each dip chamber, that is to say each chamber in which a body of liquid is maintained for the purpose of dipping workpieces therein, may be provided with means to automatically maintain the volume of liquid within the chamber within predetermined limits.

In a typical photoresist stripping operation, the first and second chambers in the sequence are preferably dip chambers and the third chamber is a spray chamber. This corresponds to chambers 34, 35 and 36 as shown in FIGS. 6A and 6B.

An essential part of the apparatus is a conveyor means for automatically transferring the workpieces from treatment chamber to treatment chamber and lowering the workpieces through the top of the treatment chambers according to a predetermined timed cycle.

An illustrative conveyor means is shown in detail in FIGS. 1-4 and comprises a vertical lift assembly composed of left member 10 and right member 11. The vertical lift members 10 and 11 are connected by lift rods 12 and 13 to a transverse drive assembly. The transverse drive assembly is composed of upper and lower transverse chains 14 and 15 which pass around left chain sprocket 16 and right chain sprocket 17, respectively. The left chain sprocket is connected to the transverse drive motor 18 through the driven sprocket 19, driving chain 20 and the transverse drive 21. Connected to the transverse chains are transport brackets 22, 23, 24, 25, 26 and 27. Supported on the transport

brackets are wafer boat carriers 28, 29, 30, 31 and 32. These wafer boat carriers, which are basket-like members, facilitate handling of wafers which are carried in trays or holders, commonly known as wafer boats. The baskets comprise a series of slots and webbs forming an open grill type construction. The baskets are fabricated from a material which is not subject to attack by the treating liquid, such as fluoropolymer coated stainless steel. The carriers should allow ready contact of the liquids with the wafers within the baskets and ready draining of the liquids therefrom.

As shown in FIG. 1, the carriers are elevated slightly above countertop 33. Treatment chambers 34, 35, 36 and 37 are recessed below the countertop. The load and unload stations for the apparatus are comprised of the countertop area located below transport brackets 22 and 27 respectively.

In a preferred embodiment means are included to provide an atmosphere of clean filtered air in the vicinity where the workpieces are unloaded from the apparatus, i.e., the unload station. In the embodiment shown in the drawings and particularly FIGS. 1 and 3 thereof, this is accomplished by a system of blowers and baffles. Intake blower 38 is driven by motor 39 and blows clean air from a filter (not shown) in laminar flow into the right air distribution zone of the apparatus which is the area on the right hand side of baffle 45 as one looks at FIG. 1. The function of this flow of air is not only to provide a clean air atmosphere at the unload station, but to sweep up solvent vapors from treatment chamber 37 for eventual exhaust through desired channels. Air distribution blower 40 sucks air from the right air distribution zone and creates circulation which distributes air upwardly through the left air distribution zone, as defined by baffle 45, towards exhaust blower 41 which then exhausts the air from the system. Dampers 94 and 95 on blowers 38 and 40, respectively, afford a control over the balance of air distribution in the system. In the drawings particularly FIGS. 1 and 3, the arrows show the direction of the air circulation system.

In the lower front portion of the apparatus are located removable panels 42 and 43, which facilitate servicing of the apparatus and access door 44 behind which are located the chemical reservoir tanks, chemical loading pumps and chemical metering pumps (not shown). FIG. 2 shows more clearly the location of exhaust blower motor 47 and rear facing transport bracket 46 which is connected to the transport drive assembly in a position opposite to forward-facing bracket 22. In this Figure is also shown the back edge profile of the central air baffle 45. The rear cutouts of this baffle allow for passage of transport brackets and wafer boat carriers from one treating chamber of the apparatus to another.

The location of the air distribution motor 49 can clearly be seen in FIG. 3. Also visible in this Figure is another transport bracket 48 which is also connected to the transport drive assembly and is located behind transport bracket 27.

In FIG. 4, further details of the transverse drive assembly can be seen. In particular, driving sprocket 50, which is part of the transport drive 21, is seen to be connected to the driven sprocket 19 by drive chain 20. The central location of treatment chambers 34, 35, 36 and 37, as well as the air intake filter 51 and exhaust blower duct 52, are best shown in this Figure.

The apparatus of the invention may be used in any application for which it is desired to continuously treat workpieces with liquids. It is particularly suited for liquid chemical processes which are employed in the manufacture of electronic semi-conductor devices. These may be carried out by incorporation in a system of the type described in any number and order.

The liquid chemical processes involved in the manufacture of electronic semi-conductor devices are generally those which involve the removal of some material from the semi-conductor substrate. Material being removed may be either liquid or solid, may have been either a contaminate, a protective layer or substrate layer. The material may be removed by the liquid chemical either by physical or chemical means. The nature of the material being removed may be organic, inorganic, or semi-conductor. Specific examples of the kind of liquid chemical processes contemplated are removal of particular material via washing processes, the removal of water by either dissolution or liquid displacement methods, the removal of organic photoresist polymeric materials by chemical oxidation and dissolution of residues, and the selective removal of silicon dioxide from silicon substrates by appropriate choice of aqueous solutions. These processes are often grouped into categories such as cleaning, polishing, etching, stripping and drying.

CLEANING

Cleaning usually involves the removal of superficial dirt, oily films or natural oxide layers. A variety of substrates may be involved. Semi-conductor substrates include wafers of Group IV materials, such as silicon and germanium, Group III-V materials, such as gallium arsenide, gallium phosphide, gallium arsenide phosphide, indium aluminum phosphide and others. Dielectric substrates include alumina squares, sapphire wafers, garnet alloy wafers or dielectric outer layers of silicon dioxide or silicon nitride on silicon wafers. Glass plates used for masks with or without photoemulsion or metallic coatings are included.

The cleaning liquids may be selected from a wide range of materials and are essentially dependent on the contaminant to be removed and the compatibility of the cleaning liquid with the substrate. Common solvents are organic solvents such as methyl and isopropyl alcohols, acetone, tri- and tetrachloroethylene and trichlorotrifluoroethane. Aqueous cleaning usually involves sulfuric, nitric, chromic, phosphoric, hydrochloric, hydrofluoric acids, and combinations thereof. Common acid blends are nitric with sulfuric, chromic with sulfuric and hydrogen peroxide in combination with either sulfuric or hydrochloric acids or with ammonium hydroxide. Dilute aqueous hydrofluoric acid is used for the removal of trace oxides. The cleaning conditions may vary widely, such as from room temperature to 100°C and may involve use of dilute cleaning agents or concentrated agents.

POLISHING

Chemical polishing is that method which smoothes a substrate surface by selective dissolution of surface high spots or irregularities. The peaks are more readily dissolved than level areas and minimal attack occurs in depressed areas. Polishing is usually accomplished by a rapid rate of attack as compared to an etching pro-

cess. Substrate peaks are chemically attacked and dissolved by the polishing agent.

Examples of polishing operations are the polishing of silicon substrate with either chromic acid plus hydrofluoric acid, or nitric and acetic acids mixed with hydrofluoric acid. The chromic or nitric acids are believed to oxidize the silicon which then dissolves in the hydrofluoric acid. The acetic acid where used is an non-aqueous diluent with further polishing effects. The amount of hydrofluoric acid is a polishing formulation is relatively low; the amount of oxidizer is high. This type of process is moderately exothermic and is generally conducted anywhere from room temperature up to about 60°-80°C. Other examples of polishing are the action of hydrogen peroxide-hydrofluoric acid on germanium and the action of sodium hypochlorite on gallium arsenide.

ETCHING

Etching generally refers to methods of rapid, complete, sharply defined removal of selected exposed areas of metallic or dielectric films via oxidation and/or dissolution. Many etching steps are used in semiconductor manufacture. Often, it is desired to selectively etch one layer without affecting an adjacent protective layer or the substrate layer. The most common example is the etching of "windows" through a silicon dioxide (SiO₂) layer down to metallic silicon substrate. The SiO₂ layer is formed by oxidizing the silicon surface. Organic photoresist coatings are applied on top of the oxide. Patterns are developed which cover portions of the oxide, leaving bare oxide areas exposed to attack by the etchant bath. A common SiO₂ etchant is a solution containing hydrofluoric acid buffered with ammonium fluoride. This material, sometimes referred to as buffered oxide etchant, attacks and dissolves the exposed SiO₂ down to but not including the silicon substrate. The etchant attacks SiO₂ but not silicon or the remaining photoresist areas.

Etchant compositions in common use contain 3 to 10 percent by weight hydrofluoric acid, 15 to 40 weight percent ammonium fluoride and the remainder water. Temperatures used are usually near ambient, 18°-30°C and rarely up to as high as 50°C. Etch rates of 500 to 1,500 Angstroms of oxide per minute are common.

The buffered oxide etch process is one of the most common and crucial liquid chemical processes for semiconductor manufacture. A single integrated circuit may pass through such a process ten to twelve times as various "window" patterns are required.

Other etchant processes within the scope of the invention include dilute hydrofluoric acid (0.5 to 5 percent by weight) for removal of oxide films; hydrogen peroxide plus sulfuric acid solutions for etching nickel films or gallium arsenide substrates; hydrogen peroxide plus hydrofluoric acid for etching of germanium; mixtures of nitric, hydrofluoric and acetic acids for gross etching of silicon. Refluxing phosphoric acid is used for etching of silicon nitride dielectric layers and for selective etching of silicon with little attack on adjacent SiO₂. Some etchants are selected for particular crystal faces and are called anisotropic etchants. An example is KOH in isopropyl alcohol at reflux conditions of about 80°C. This etchant is selective for one face of silicon and is useful for isolation of circuits from each other. Pattern masks used during exposure of light to the photoresist coatings are often prepared by applying

a thin metallic film to a glass plate substrate. The film, either chromium metal or transparent iron oxide, may be etched with acid solutions such as hydrochloric acid.

PHOTORESIST STRIPPING

Another common repeated process during semiconductor manufacture is stripping of photoresist residues. The exposed photoresist is used to define the areas to be etched. After etching, the photoresist is stripped in an oxidizing medium. The photoresist must be completely removed as the typical subsequent process is diffusion of controlled amounts of inorganic impurities through the oxide windows at 1,100°–1,300°C. Photoresists must be resistant to etching acids, hence they are difficult to remove in "stripping" acids. Most liquid chemical media for photoresist stripping are mixtures containing sulfuric acid. Hot concentrated sulfuric acid is capable of stripping, although it is more common to incorporate one to 5 weight percent of oxidizing agent such as chromic acid or hydrogen peroxide. Sulfuric acid-hydrogen peroxide mixtures may be used with or without water. Such mixtures have been used at 60–99.95 weight %, preferably 70–98 weight % and still preferably 80–94.5 weight % sulfuric acid (100% basis); 0.05–25 weight %, preferably 0.2–10 weight % and still preferably 0.5–5 weight % hydrogen peroxide (100% basis) and 0–39.95 weight %, preferably 1.8–29.8 weight % and still preferably 5–19.5 weight % water. Typical stripping temperatures are 80°–140°C and more usually 80°–100°C.

Hot sulfuric acid solutions are compatible with most substrates e.g., silicon and silicon dioxide, but not where metallizations for circuit interconnection is present. A class of organic strippers based on chlorinated solvents, e.g., tetrachloroethylene and *o*-dichlorobenzene, and also phenol, toluene sulfonic acids and surfactants, strip photoresist at 100°–140°C with minimal harmful attack on the aluminum metallization layer. The presence of some moisture, less than 1% H₂O, is required in this type of formulation which suggests that concentrated acid from the toluene sulfonic acids and surfactants may be the functional component.

An acid formulation which does not require high temperature for rapid attack of the polymeric photoresist is concentrated sulfuric acid containing 1 to 2 weight % chromic acid plus 1 to 5 weight % nitric acid.

Common to all of the above strippers is a sequence of steps, namely, stripping, rinsing and drying. Common problems are disposal of the stripping solution and the rinse effluent. Chromium contaminated rinse water cannot be disposed of without treatment. Phenol and solvent contaminated rinse water should not be sewered. Methods for avoiding these problems may be advantageously incorporated into automated processing equipment of the type described. Optimum use of chemicals, proper rinsing cycles and collection of harmful effluents are advantages which such equipment offers.

The photoresist polymeric materials involved in these stripping operations are organic materials containing light-activated catalysts for either cross-linking (negative working photoresists) or for polymer degradation (positive working photoresists). Commercial examples are Kodak's KPL and KPR products (polyvinyl alcohol partially esterified with cinnamic acid).

RINSING

Rinsing is a liquid chemical process used after the above-described processes are completed. The purpose of rinsing is to dilute and remove residues from prior steps. It is common to rinse with high purity water to dissolve and remove aqueous soluble residues and organic solvents, such as fluorocarbon containing solvents, to remove non-aqueous soluble residues. It is also intended in some instances to utilize liquid displacement rinsing, i.e., immiscible solvents to flush away aqueous residues where biphasic separation minimizes effluent volume.

Specific examples of rinsing processes as they apply to resist stripping sequences are water rinsing after H₂SO₄ - H₂O₂ stripping, trichlorotrifluoroethane-isopropyl alcohol (preferably in the form of its azeotrope) solvent rinsing of organic stripper residues, and biphasic trichlorotrifluoroethane solvent rinsing of acidic stripping residues (e.g., H₂SO₄ - CrO₃). Solvent rinsing processes are of special interest where normal aqueous rinse effluents cannot be suitably treated by simple acid neutralization. Solvent rinsing allows the collection of an effluent concentrate as opposed to large volumes of contaminated rinse water. The effluent concentrate may be collected, treated, reconstituted or disposed of in the same manner as the spent stripping solution.

Separation of residues from the solvent rinse agent may be relatively simple. Low boiling rinsing solvent may be recovered from high boiling organic stripper by simple distillation. Or, the aqueous acidic residues may be separated from the immiscible rinsing solvent by gravity and the solvent reused. In both instances, stripper residues are accumulated in a concentrate form. The separation techniques are not as useful when water is used as the rinsing agent.

DRYING

The final step in many process sequences is drying. Drying implies the removal of all liquids whether organic or aqueous. Essentially, however, by drying is usually intended water removal. Heat or heated air is one technique or drying but the results may be non-uniform and require excess time or heat.

Liquid chemical drying processes may be accomplished by either dissolving or displacing the undesirable liquid by a more volatile, faster drying liquid. For example, water or a high boiling organic liquid may be dissolved and diluted by a suitable low boiling solvent such as acetone or methyl alcohol. The remaining acetone or alcohol solution readily evaporates in air and the resulting parts then are essentially dry and free of liquids.

The drying liquid gradually becomes contaminated with the original liquid and, as a result, poor drying results. Conventional vapor degreaser techniques improve these results. A vapor degreaser is a tank in which a boiling liquid is kept under total reflux. The liquid wet parts must be cooler than the boiling liquid. Condensation of vapors occurs on the cool parts placed in the vapor zone. Condensation continues until the parts are at the vapor temperature. If the process has been properly chosen, the parts have no more liquid on them and dry parts may be removed from the vapor zone. Acetone or alcohol could be the boiling liquid, except that these materials have the disadvantage of

being flammable. Compatible non-flammable solvents which may be employed are the fluorocarbons, such as trichlorotrifluoroethane, and fluorocarbon containing solvents. A common sequence for drying of semiconductor wafers is to dip water-wet wafers in acetone or alcohol followed by vapor rinsing in trichlorotrifluoroethane. Such a drying process would require two stages or treatment chambers within the system described herein.

An alternate drying process which is compatible with the systems described would be a single-stage liquid displacement technique in which a refluxing solvent is used to physically displace the immiscible higher boiling liquid. The undesired liquid is rejected through a biphasic gravity separator. Only one stage (treatment chamber) is required for this embodiment. Liquid spray followed by vapor rinse has been found most advantageous in this embodiment.

THE PREFERRED EMBODIMENT

An illustrative embodiment, as described by the piping diagram of FIGS. 6A and 6B, is designed for the stripping of photoresists using a mixture of hydrogen peroxide and sulfuric acid.

At specified times, an operator places a boat of coated wafers in a wafer boat carrier at the load station and removes a similar boat of completely stripped residue-free, dry wafers from another carrier at the unload station. The automatic transfer station, comprised of the vertical lift and transverse drive assemblies, takes the wafer boats sequentially from the load station and through treatment chambers 34, 35, 36 and 37 and places the finished wafer boat at the unload station. The sequence of events which occurs during this typical cycle (four minutes) is shown in FIG. 5. At the beginning of the cycle the vertical lift assembly raises the transverse drive assembly and connected transport brackets and wafer boat carriers in an upward direction. During this lifting motion the transport bracket (22 — See FIG. 1) in back of the load station, picks up a wafer boat carrier with wafer boat at the load station. When the upper motion of the vertical lift mechanism has been stopped, the transverse drive assembly moves the transport brackets and wafer boat carriers in a left to right direction. This transverse motion is stopped when the wafer boat carrier has been moved from one process station to the next. At this point, the wafer boat carrier which had been placed at the load station is located directly above treatment chamber 34. The wafer boat carrier which had been in treatment chamber 34 is now located directly above treatment chamber 35 (and so on). During the time it takes the transverse drive assembly to complete its motion, metering pumps 57 and 58 are supplying small amounts of fresh hydrogen peroxide and sulfuric acid to process tank 34 to maintain a predetermined concentration of hydrogen peroxide and sulfuric acid therein.

After the transverse drive assembly has stopped its left to right motion, the vertical lift assembly lowers the wafer boat carriers into the various treatment chambers. During the downward motion, the wafer boat carrier which had previously been in treatment chamber 37 is detached from its transport bracket and is set at the unload station. At the end of the downward motion or the vertical lift assembly, the liquid spray heads in process tanks 36 and 37 are actuated to spray liquids on the articles.

The remaining time in the cycle is devoted to the other processing steps. In treatment chamber 34 coated wafers are stripped of their photoresist by the chemical action of the hydrogen peroxide-sulfuric acid mixture. In treatment chamber 35 the sulfuric acid solution is washed from the wafers by contaminated water from reservoir 63. In treatment chamber 36, the wafers are further cleaned of residual sulfuric acid solution by a spray of fresh deionized water. In treatment chamber 37 the water-wet wafers are dried by a fluorocarbon-containing solvent comprising an azeotrope of trichlorotrifluoroethane and isopropanol.

At the end of the cycle, the vertical lift assembly begins its upward motion and a new cycle is started.

Electrical wiring of systems of the type described in order to accomplish the timed cycles and objectives is within the skill of persons skilled in the electrical arts and is not a part of this invention. The apparatus may be modified from that described as will be apparent and may include panel timers, dials and indicator lights which provide the operator with an instant readout on process and cycle status. Additionally, alarms and warning lights may be provided to indicate need for corrective action by the operator such as to refill chemical or solvent supply tanks or to remove finished wafers from the unload station. Safety interlocks may be provided to prevent damage to either the workpieces or to the equipment.

The invention is to be limited only by a reasonable interpretation of the following claims.

We claim:

1. Apparatus for continuously treating workpieces with liquids comprising:

- a. a plurality of treatment chambers
- b. at least one of which is a dip chamber adapted to contain a liquid and
- c. at least one of which is a spray chamber equipped with means to spray liquid on workpieces suspended within said chamber,
- d. means for controlling the temperature of the treating liquid in at least one dip chamber,
- e. means for maintaining the composition of a liquid mixture in at least one dip chamber within predetermined limits, and
- f. conveyor means for automatically transferring the workpieces from treatment chamber to treatment chamber and lowering the workpieces through the top of the treatment chambers according to a predetermined timed cycle.

2. Apparatus according to claim 1 in which the conveyor means is adapted to transport the workpieces in wafer boat carriers.

3. Apparatus according to claim 2 in which the first and second treatment chambers are dip chambers and a third chamber is a spray chamber.

4. Apparatus according to claim 3 in which at least one spray chamber is equipped with means for recirculating the treating liquid sprayed in that chamber.

5. Apparatus according to claim 3 which includes means to provide an atmosphere of clean filtered air in the vicinity where the workpieces are unloaded from the apparatus.

6. Apparatus according to claim 1 in which the treatment chambers are removable modules which can be interchanged with one another.

7. Apparatus according to claim 1 which includes at least two dip chambers.

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8. Apparatus according to claim 1 which includes means to automatically maintain the volume of liquid within the dip chamber or chambers within predetermined limits.

9. Apparatus according to claim 1 which includes means to provide an atmosphere of clean filtered air in the vicinity where the workpieces are unloaded from

the apparatus.

10. Apparatus according to claim 1 in which the first treatment chamber is a dip chamber.

11. Apparatus according to claim 1 in which the first and second treatment chambers are dip chambers and a third chamber is a spray chamber.

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