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APPARATUS AND METHODS FOR EFFECTING A BURN-IN PROCEDURE ON SEMICONDUCTOR DEVICES

This invention relates generally to apparatus and methods for thermally accelerating temperature-related failure mechanisms in semiconductor electronic devices or components, such as discrete transistors and integrated circuits, and particularly to such apparatus and methods in which the semiconductor devices are carried on circuit boards and are immersed in a liquid, heat

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exchanging medium for obtaining desired thermal conditions.

Semiconductor devices, such as discrete transistors and integrated circuits have time and temperature dependant failure mechanisms that occur at a high percentage rate during the first year of regular service. Thereafter, the surviving devices exhibit a low and relatively constant failure rate over the remainder of their useful lives of many years.

This high percentage failure rate is referred to as "infant mortality", since it occurs mainly during the first year of the life of a semiconductor device. Those devices that will fail during the first year can be substantially eliminated from commercially available products by subjecting the devices to precise elevated thermal conditions under electrical operating conditions. This procedure, or testing, called "burn-in", effectively accelerates the devices through one year of normal operation in approximately 168 hours, or one week.

Recently the burn-in procedure has been effected in a liquid, heat exchange or transfer medium. The semiconductor devices are loaded onto circuit cards and the cards are immersed in a bath of the liquid medium elevated to the desired temperature. The devices then are electrically operated for a period determined by a mathematical equation

relating the operating parameters, including temperature, to accelerated life of the devices. The heat exchange medium, thus, serves to increase the ambient operating temperature of the devices and to dissipate received excess operating heat produced by the operating devices to maintain the devices at a precise, elevated ambient temperature.

The heat exchange medium typically is that known under the trademark Fluorinert liquid FC-40 manufactured by 3M Commercial Chemicals Division and is well known to be non-reactive and electrically insulating in such an environment. This medium has a specific gravity greater than water, a specific heat greater than air and is selected to have a boiling point greater than the elevated temperature at which the burn-in procedure is effected. Other silicone based liquid mediums also can be used.

Use of a liquid medium improves upon the use of gas mediums, such as air and nitrogen, in burn-in procedures and apparatus in that, among other things, the selected liquid medium has a greater specific heat or increased capacity to hold heat produced by the devices, can provide improved temperature control of the bath environment, especially with a high density of energy dissipation, and can absorb increased quantities of heat when vaporized by a localized "hot spot", such as a failed device, to prevent thermal runaway of

that failed device. This last feature provides for continuance of the burn-in procedure without having to stop for removal of a single, failed device. A Fluorinert medium has some qualities, however, that must be specially cared for.

First, Fluorinert medium, which is unusually expensive, has a low evaporation rate at room temperature, but at the elevated temperatures of a burn-in procedure, has an evaporation rate that is significant. A burn-in effecting apparatus must thus provide for recovery of the evaporated liquid medium vapors to be cost efficient. The recovery must be performed carefully, however, because the Fluorinert medium vapors readily combine chemically with any included moisture to form hydrofluoric acid, which can erode the stainless steel and plastic components of the burn-in effecting unit. Thus, condensed water vapor must be separated from the condensed Fluorinert heat exchange medium vapor prior to return of the Fluorinert medium liquid to the bath.

Second, the Fluorinert medium must be controlled in temperature by a heater to raise the medium to the desired elevated temperature for effecting the burn-in procedure and by a cooler, such as a mechanical refrigeration unit, to remove excess heat produced by the operating devices from the bath medium during the burn-in procedure to maintain the elevated

temperature and possibly to cool the medium at the end of the procedure. Third, filtration must be provided to remove particulate and chemical contaminants, such as solder flux, debris and acids, introduced into or produced in the bath medium.

Such a burn-in apparatus should have a bath tank large enough to facilitate burn-in procedures of production quantities of semiconductor devices and be self contained upon connection to an electrical power supply. The apparatus should also provide easy circuit card handling.

A burn-in unit has a liquid medium receiving tank enclosing a burn-in chamber that is normally open to the top to facilitate installing and removing circuit cards therefrom carrying semiconductor devices for burn-in testing. The top of the burn-in chamber is closed with a cover during the burn-in testing or procedure. The apparatus includes a vapor recovery system, a main liquid medium heating and cooling system and a filter system. These three systems cooperate to effect the burn-in procedure for semiconductor devices installed in the tank chamber.

Further, movable racks in the tank chamber serve to lower and raise the circuit

cards into and out of the liquid medium. This structure in combination provides a burn-in apparatus or unit that is efficient in conserving the expensive liquid Fluorinert medium, and that is self contained upon connection to an electrical power source. Lastly, each of the described systems have structure particularly suited to achieve the beneficial results of the burn-in apparatus with the liquid medium.

In particular, a rectangular box-like heat exchanger tank forms a burn-in chamber sufficiently deep to contain circuit cards at two levels: one level at the bottom of the chamber in which the circuit cards are completely immersed in the medium, and a second level at the top of the chamber in which the circuit cards are spaced above the medium. The cover for the tank is segmented to provide individual access to any one of the five racks of circuit card connectors in its raised position and reduce the quantity of ambient moisture vapors entering the burn-in chamber.

The main liquid medium heating and cooling system includes mechanical refrigeration cooling coils contained in a pipe under the tank. A pump assembly moves the medium from one side of the chamber to one end of the pipe for the medium to flow closely across the coils and from the other end of the pipe back to the bottom of the chamber through a larger counterflow tube enclosing the pipe

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and riser tubes vertically extending to the tank bottom. The pump, thus, removes medium from one location of the chamber and the riser tubes return the medium at a plurality of other locations to result in a good turbulence or mixing of medium that maintains the temperature of the medium in the chamber substantially constant. The flow of medium from and to the chamber also results in a flow of medium across the cards and semiconductor devices.

A cartridge or coil electrical heater extends into the counterflow tube to raise the medium temperature to the desired elevated temperature. The pump assembly includes a lead screw/nut arrangement to obtain a variable speed impeller rotation with a fixed speed electric motor to accommodate changes in medium viscosity at various medium temperatures.

The vapour recovery system includes an exhaust manifold and feed manifold on opposite ends of the tank and in fluid communication with the air, water vapour and medium vapour in the chamber above the liquid medium at the second, raised level of the circuit cards. A fan moves the air and vapors from the exhaust manifold, across expansion coils of a vapour condensor and back to the exhaust manifold. The fan also maintains a fluid flow of returned air across the length of the chamber to aid in evaporating the medium from cards and devices at the raised level. The exhaust manifold includes acid absorbing material to neutralize

any hydrofluoric acid that may have formed by combination of the water and medium vapors.

A liquid water separator has a container that receives the mixture of liquid condensed water vapour and medium vapour from the condensor and allows the mixture to rest to separate the liquid water from the liquid medium; thereafter, the liquid medium is returned to the chamber and the liquid water is discarded. The liquid medium has a density greater than the liquid water so the liquid water tends to rise and float above the medium. An electric circuit includes a pair of opposed electrodes mounted on the wall of the container to ascertain the presence therebetween of liquid water, which is alkaline from the acid absorbing material of the exhaust manifold and thereby conductive. The circuit then indicates the presence of the liquid water and signals the operator that it is to be removed.

The invention includes methods of achieving the results obtained with the described structure.

According to a first aspect of the invention, there is provided an apparatus for thermally stressing a plurality of semiconductor devices at an elevated temperature in a bath of an inert, substantially electrically insulating liquid heat exchange medium, the medium having a specific heat capacity greater than air and a boiling point greater than the elevated temperature, and the semiconductor devices being electrically operated to produce excess heat while being thermally stressed, the apparatus comprising a tank having a burn-in chamber adapted to receive therein the semiconductor devices and further adapated to receive therein a quantity of the liquid medium sufficient to cover the semiconductor devices while they are being electrically operated, the tank having sufficient size for the chamber to include an upper free space containing ambient gases, in which water vapour can be present, above the medium and of sufficient size for the semiconductor devices to be positioned in the free space and be clear of the medium; cooling means exterior of the chamber in liquid communication with the chamber and adapted to remove the excess heat from the liquid medium to maintain the liquid medium substantially at the said elevated temperature; pump means adapted, in use, to move the liquid medium from the tank to the cooling means and back to the tank with the liquid medium entering the chamber at plural locations to produce agitation of the liquid medium therein, so that the apparatus maintains a substantially uniform temperature throughout the medium in the tank chamber; and vapour recovery means for removing vapours of at least the medium from the upper free space in a closed loop from and to the upper

free space, the vapours being condensed to liquid medium and liquid water and the condensed liquid medium being returned to the liquid medium in the chamber substantially free of any liquid water vapour simultaneously condensed.

According to a second aspect of the invention, there is provided a method of thermally stressing a plurality of semiconductor devices at an elevated temperature comprising first installing the semiconductor devices in operative relationship in a bath of a liquid heat exchange medium that is inert, is substantially electrically insulating, has a specific heat capacity greater than air and has a boiling point greater than the elevated temperature to subject the devices to the said elevated temperature and dissipate excess operating heat of the devices in the medium, and then; removing heat from the medium by a cooling device separated from the bath to maintain the medium substantially at the said elevated temperature; and agitating the medium by moving the medium from and back into the bath to maintain a substantially uniform temperature throughout the medium in the bath.

The invention may be carried into practice in various ways and one specific apparatus, and method, will now be described, by way of example, with reference to the drawings, in which

Figure 1 is a perspective view of a burn-in unit;

Figure 2 is a block diagram of several systems of the apparatus;

Figure 3 is an idealized rear elevation view of the systems illustrated in **Figure 2**;

Figure 4 is a plan view of a pump motor mounting structure of the invention;

Figure 5 is a fragmentary side elevation view of the pump motor mounting structure, taken partly in section along the line 5-5 of **Figure 4** and in the direction indicated by the arrows;

Figure 6 is a rear elevation view of a heat exchanger tank;

Figure 7 is an end elevation view of the heat exchanger tank;

Figure 8 is a fragmentary view of the top of the heat exchanger tank illustrating feed and exhaust manifolds of the invention;

Figure 9 is a sectional view of the exhaust manifold taken along the line 9-9 of **Figure 8** and in the direction indicated by the arrows;

Figure 10 is a sectional view of the exhaust manifold taken along the line 10-10 of **Figure 9** and in the direction indicated by the arrows;

Figure 11 is a perspective view of the exhaust fan impeller used in the exhaust manifold; and

Figure 12 is a front elevation view, partly in broken away section, of a water separator assembly.

A large, self-contained burn-in bath unit incorporating the invention hereof is indicated generally by the reference character 20. The unit comprises a generally rectangular box-like cabinet 22 mounted on casters 24 for ease of movement of the unit in such as a laboratory. Electrical connection of the unit 20 is by cord 26 to a suitable electrical power supply connection.

Cabinet 22 comprises sheet metal walls mounted on an internal frame. A ventilating screen 28 is mounted on the cabinet front wall 29 to facilitate ventilation of the mechanical refrigeration unit contained in the cabinet. An upper housing 30 encloses control circuits and mounts indicators of the status and condition of the unit. Input knobs and switches also can be mounted on upper housing 30. A top wall 32 of the cabinet comprises a segmented cover 34 and a surround portion 36 peripheral of the cover 34 in its closed position.

In the interior of cabinet 22, a heat exchange tank 38 defines a rectangular burn-in chamber 40 that is generally open to the top and that can be closed by cover 34. Tank 38 contains a quantity of liquid heat exchange medium 42 and a plurality of circuit card carrying racks with one rack 44 carrying of plurality of circuit cards 46 being shown. A side wall 48 of the tank 38 includes a plurality of openings 50 for ventilation of the chamber space 52 above the medium 42.

Thus arranged, a technician can approach the unit from the front, raise the cover 34 and install or remove circuit cards 46 from therack 44 in the burn-in bath chamber 40. Controls and indicators of the burn-in procedure are available on the front of the control housing 30 and the unit can be moved on the casters 24 to suitable locations in a laboratory or testing facility. Once connected to a source of electrical power by cord 26, the unit 20 is self-contained.

In the interior of cabinet 22 are additional systems that operated to effect a desired burn-in procedure. In **Figure 2**, tank 38 is connected to a main liquid medium heating and cooling system 54 by conduits 56 and 58. The main liquid medium heating and cooling system provides three functions. First, this system raises the temperature of the liquid medium to the desired elevated temperature at which the burn-in procedure is to be effected, this being

accomplished by a heating element contained therein. Second, this system removes additional heat dissipated into the heat exchange medium by the operating semiconductor devices during the burn-in procedure, and third, serves to cool the liquid medium to ambient temperature at the termination of a burn-in procedure. This system thus serves as a temperature controller of the unit.

A portion of the liquid medium returning to the tank 38 in conduit 58 is carried by conduit 60 to a filter 62 and back to tank 38 through a conduit 64. Filter 62 serves to clean the liquid heat exchange medium by removing particulate and chemical contaminants introduced into the chamber or produced therein during the burn-in procedure.

A vapor recovery system 66 comprises a vapor recovery condensor 68 and a liquid water separator 70. Gases including air, water vapor and medium vapor are exhausted from the tank 38 to the condensor 68 through duct 72. These gases, less the condensed water and medium vapors, are fed back to the tank in duct 74. The object of this recovery system 66 is conserving the supply of the expensive heat exchange medium.

The liquid condensed water vapor and liquid condensed medium vapor are intermixed when condensed in the condensor 68 and are fed through duct 76 to liquid water separator 70.

There the intermixed liquids are allowed to rest for the liquid water to separate from and rise above the liquid medium as a result of the liquid medium having a greater specific gravity than water and the water being insoluble in the medium. The liquid water then is removed through schematically illustrated duct 78 while the expensive and recovered liquid medium is returned to the tank by duct 80.

In **Figure 3**, there is shown a structure, somewhat idealized, embodying the systems illustrated in block form in **Figure 2**. Referring also to **Figures 6** and **7**, tank 38 has a rear wall 90, two side walls 48 and 94, a bottom wall 96 and a front wall 98. Tank 38 thus defines the burn-in chamber 40 that is closed on five sides by tank walls and is open to the top to be closed by cover 34. Cover 34 has five segments 34A through 34E that individually can be raised and lowered over the chamber 40 hinged at the rear wall 90 of the tank. The cover segments are arranged to be aligned with the racks and circuit cards carried by the racks for access to individual racks by raising individual cover segments. Thus cover segment 34C is aligned directly above rack 42C carrying cards 46C while cover segment 34D is arranged aligned above rack 42D carrying cards 46D.

Burn-in chamber 40 contains in subtantially its bottom half, the liquid heat exchange medium 42 previously generally

described to be the Fluorinert perfluorinated hydrocarbons manufactured by the 3M Corporation. In particular, the heat exchange medium has a specific heat greater than air, a specific gravity greater than liquid water and a boiling point or temperature greater than the elevated temperature at which the burn-in procedure is to be effected.

The upper half or space 52 of chamber 40 is filled with ambient gases that can include water vapor and especially during a burn-in procedure can include Fluorinert medium vapor. The Fluorinert medium has a low evaporation rate at room temperature that increases markedly at the elevated temperature of a burn-in procedure. During a burn-in procedure, the racks 44 are in the lowered position to place their circuit cards 46 and the carried semiconductor devices in the medium 42 in the bottom half 100 of the chamber 40. Before and after testing, the racks 44 hold the cards 46 in the top half space 52 of the chamber. The movements of the racks 44 are by means such as a hydraulic or pneumatic cylinder 101 connected with shaft 102 which in turn carries the racks 44. Shaft 102 then is vertically movable into and out of the pneumatic or hydraulic cylinder 101.

The main liquid heating and cooling system 54 comprises a structure arranged adjacent the tank side wall 94 and bottom wall 96. In particular, the heating and cooling

system 54 comprises a pump assembly 110 and a heating and cooling tube assembly 112.

In operation, the pump assembly 110 moves the liquid medium from the lower half 100 of burn-in chamber 40 through horizontally extending conduit 56, vertically extending conduit 114, horizontally arranged tube 116 of tube assembly 112 and then in a reverse direction therethrough and lastly through vertical riser pipes 58A through 58D back into the lower half 100 of chamber 40, the flow being indicated by the arrows in the described conduits, tubes and pipes.

Referring also to **Figures 4** and **5**, pump assembly 110 includes an impeller 120 carried at one end of a driven shaft 122 extending downward into substantially the length of conduit 114 with the impeller arranged adjacent tube 116. A bearing and baffle 124 are mounted inside the conduit 114 to stabilize the driven shaft 122 and to prevent up flow of liquid medium into the top half of conduit 114. The other end of driven shaft 122 extends above the top end of conduit 114 and carries thereon a driven pulley 126. A fixed length belt 128 connects the driven pulley 126 to a drive pulley 130 that is carried at the end of a drive shaft 132 of an electric motor 134.

The medium 42 changes its viscosity with a change in its temperature and,

therefore, the impeller 120 needs to be driven at a particular desired speed when the medium is at room ambient temperature and at a different speed when the medium is at the elevated temperature for effecting the burn-in procedure. To attain this result with the constant speed electric motor 134, the pump assembly 110 includes a structure for varying the effective diameter of the drive pulley 130 while using a fixed length pulley belt 128. The function is effected through use of a lever arm and lead screw and nut arrangement varying the distance between the drive shaft 132 and the driven shaft 122 and using a spring actuated mechanism to vary the effective diameter of the pulley 130 that engages the fixed length belt 128.

In particular, electric motor 134 is mounted on a mounting plate that is in turn mounted on a rotatable pivot shaft 138. Pivot shaft 138 is mounted on a horizontal support plate 140 by means of a sleeve bearing 142. Plate 140 is clamped on the vertically extending tube 114 by a clamp portion 144 and clamp bolts 146.

The pivot shaft 138 passes downwardly through plate 140 and below plate 140 is connected to one end 148 of a lever arm 150. The other end 152 of lever arm 150 is connected to a lead nut 154 threaded onto a lead screw 156 mounted below the plate 140 by a pair of brackets 158. Lead screw 156 is mounted by

brackets 158 for rotation around its longitudinal axis and is driven in such rotation by a stepping motor 160 mounted on support plate 140 by suitable bracket means 162.

In operation, stepping motor 160 rotates the lead screw 156 to move the lead nut 154 and lever arm end 152 to a selected position. This rotates or pivots the pivot shaft 138 to move the motor and its drive shaft 132 to a selected position on an arc around the pivot shaft 138, selecting a particular distance between the center of the drive shaft 132 and the center of the driven shaft 122. A spring mechanism 164 mounted on the drive pulley 130 varies the effective diameter of drive pulley 130 engaging belt 128 to accommodate the fixed length belt 128 operating with different distances between the drive and driven shafts. In **Figure 4**, the solid lines indicate the position of the lever arm 150, and motor 134 in one position while the dashed or broken lines indicate the positions of these same structures at another selected position.

Thus, by incrementally stepping the stepping motor 160, variable speed rotation of the impeller driven shaft 122 can be obtained from a constant speed electric motor 134. This accommodates the varying pump requirements for the variable viscosity medium 42 without resorting to a variable speed drive motor and control device.

Referring now to **Figures 3, 6, and 7,** tube assembly 112 provides the desired heating and cooling of the liquid heat exchange medium to raise the temperature of the medium to the elevated temperature, remove energy dissipated into the medium by the operating semiconductor devices and cool the medium to ambient temperature. Assembly 112 comprises the earlier mentioned outer, horizontal tube 116 that is connected in fluid communication with the bottom end of vertically extending conduit 114. Outer tube 116 contains wholly therein an inner pipe 170 and a baffle 172. Pipe 170 rests on the bottom of the interior surface of outer tube 116 and can be held in position thereat, at least in part, by said baffle 172. Baffle 172 closes the space between the interior surfaces of horizontal tube 116 and pipe 170 so that liquid medium entering horizontal tube 116 can pass only into the interior of inner pipe 170.

The tube assembly 112 further comprises a cooling coil 174 that extends into one end of the tube 116 and into substantially the entire length of inner pipe 170. The cooling coil in the preferred embodiment is the evaporator coil of a mechanical refrigeration unit and is intended to remove energy from the liquid medium as the liquid medium passes thereacross. While only one loop of the cooling coil 174 is shown for clarity of the drawing, plural coils can be inserted therein. In any event, the inner pipe 170 is arranged

relative to the cooling coil 174 to contain the liquid medium in close contact with the cooling coil to obtain a maximum heat transfer. In this arrangement the medium 40 passes over and across coil 174 in inner pipe 170 in a first direction.

The liquid medium that exits the inner pipe 170 empties into a space 176 interior of the outer tube 116 and reverses its flow to a second direction opposite the first direction within outer tube 116 to flow to the riser conduits 58. Therefrom the medium flows back into the burn-in chamber 40.

The flow and counterflow of medium in one direction in inner pipe 170 and a second direction in outer tube 116 contributes to reduction in cabinet space required to effect the desired cooling and return of the medium to the tank at a plurality of locations. Baffle 172 prevents the return of cooled medium back into the entrance to inner pipe 170. Outer tube 116 is closed at both ends 178 and 180 to contain the liquid medium therein with the cooling coil 174 entering the outer tube 116 through the end 178.

A portion of the liquid medium discharged into space 176 interior of horizontal tube 116 passes into conduit 60 and therefrom flows through filter 62 and conduit 64 back to chamber 40. The flow through conduit 60 in the preferred embodiment is

approximately 10% of the liquid medium discharging into space 176 so that there is a constant filtering of the medium from the tank 38. The filter 62 is intended to remove particulate foreign matter such as scale, solder particles, dirt and all types of foreign substances that are carried by the medium, aids in removing moisture from the liquid medium, and also removes acids, sludge and varnish from the medium. This is important for long term operation of the unit 20 for maximum efficiency.

Tube assembly 112 further comprises a heater element 182, shown in **Figure 3**, that extends into space 176. Heater element 182 is any electrical heating device desired, such as a cartridge or coil heater, and functions to raise the temperature of the liquid medium 42 passing thereover to the desired elevated temperature for the burn-in procedure. Thereafter the heating element 82 is not used because the semiconductor devices under test are sufficient to maintain the medium at the elevated temperature, with removal of excess energy by the cooling coil 174.

The arrows in **Figures 3** and **6** indicate the flow of liquid medium from chamber 40 through conduit 56, through vertically extending conduit 114 passed impeller 120 into outer tube 116 and contained pipe 170, therein across cooling coil 174, into space 176 and therefrom by counterflow in outer tube 116 to

the vertical riser pipes 58 and back into chamber 40. The return of medium to the main burn-in chamber at a plurality of locations effects an agitation or turbulence of the medium therein that is beneficial in mixing the medium in the chamber to achieve a homogenous temperature throughout the bath medium. This achieves precise control of the elevated temperature at which the burn-in procedure is effected for closely following the calculated burn-in time requirements. The agitation of the bath medium also is aided by the return of cooled medium to the bottom of the chamber and the removal of medium for cooling from the side of the burn-in chamber. This causes a flow of the medium across the cards carrying the semiconductor devices, also maintaining the semiconductor devices at the desired elevated temperature.

Thus, the function of the main liquid medium heating and cooling system is to elevate the temperature of the heat exchange medium to the desired temperature at which the burn-in procedure is to be effected, and to maintain the medium at that desired temperature through removal of the heat energy produced by the semiconductor devices into the cooling coil arrangement. At the end of the test, the cooling coil arrangement can be used to reduce the temperature of the liquid medium to ambient or room temperature.

Referring now specifically to **Figures 3, 8** and **9**, the vapor recovery system 66 provides recovery of the vapors of the expensive heat exchange medium. Without this or a like recovery system, all of the medium would be lost in a short time through evaporation. System 66 comprises the vapor recovery condensor 68 located below the tank 38, the liquid water separator 70 located to one side of the tank 38 and an exhaust manifold 190 and a feed manifold 192 located at the top side margins of tank 38. Exhaust ducts 194 provide for movement of gases from the upper space 52 of burn-in chamber 40 into the exhaust manifold 190 and feed ducts 196 provide for movement of gases from feed manifold 192 into the upper space 52 of chamber 40.

In operation, the gases in the upper space 52 of chamber 40, which gases include water vapor and vapors of the liquid medium, are pulled by a fan assembly 198, shown in **Figures 8** and **9**, through the exhaust ducts 194 and into the exhaust manifold 190. There, any of the medium vapors that have joined with the water vapor to form hydrofluoric acid are removed and any remaining water vapor is made alkaline. Therefrom the gases are pushed by the fan assembly down through duct 72 into the vapor recovery condensor 68.

Vapor recovery condensor 68 comprises a box-like outer container 200 completely enclosing expansion coil 202 of a mechanical

refrigeration device. The gases and vapors from duct 72 pass over the expansion coil 202 and included water vapors and medium vapors are condensed thereon. The condensed water and medium vapors, now in intermixed liquid stage, drip off the bottom of the expansion coil into the bottom of the container 200 to form a pool 204 of intermixed liquid water and liquid medium.

The remaining stripped gases exit from the vapor recovery condensor 68 through return duct 74 into feed manifold 192 wherefrom they are fed into the upper space 52 of chamber 40 through the feed ducts 196 opening through wall 48 at openings 50. Thereafter the stripped gases pass through the length of the chamber 40 between walls 48 and 94 back to the exhaust ducts 194 picking up vapors to complete one cycle.

Gases passing from the feed ducts to the exhaust ducts are used to advantage to remove liquid medium from semiconductor devices 47 carried on cards 46 that are raised to the upper position by the rack 44. While most of the liquid medium drips off of the cards while they are held in the upper space 52, the gases that pass across the semiconductor devices and cards aid in evaporating residual quantities of medium to "dry" the cards.

This can be helpful in draining and "drying" a rack of cards before removal of the

cards and devices from burn-in chamber 40 while the other racks of card carried semiconductor devices remain submerged in the liquid medium undergoing the burn-in procedure. In such a situation, after the cards are "dry" of medium, only one segment of the cover need be raised to gain access to the cards.

Referring specifically to **Figures 8** and **9**, the exhaust manifold 190 comprises an outer cylindrical housing 210 closed at one end by a plate 212 and at the other end by the fan assembly 198. The exhaust ducts 194 extend horizontally from the side wall 94 of tank 38 and are bent at a 90° angle to meet the cylindrical housing 210 vertically. The exhaust ducts 194 thus place the interior 214 of the cylindrical housing in gaseous fluid communication with the burn-in chamber 40 interior tank 38.

Mounted in the interior of cylindrical housing 210 by the plate 212 and an internal baffle 216, are means 218 for removing acids from the gases exhausted from the chamber 40 into the interior 214 of exhaust manifold 190. These means 218 comprise a pair of cylindrical members 220 and 222 concentrically mounted one within the other to form annular space 224 that is filled with an acid absorbing material 226. This material 226 can be such as SODA-SORB or other acid absorbing materials. A drain pipe 228 extends downwardly from the bottom of cylindrical housing 210 to carry any liquids

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that have condensed in the exhaust manifold such as liquid water and liquid medium to the duct 72 earlier described.

A space 230 interior of cylindrical member 222 is in gaseous fluid communication through an opening 232 in baffle 216 with impeller 236 of the fan assembly 198. The impeller 236 is driven by a motor 238 through a belt 240 and a driven shaft 242. The impeller 236 is mounted in a space 244 opening to the duct 72 earlier described.

In operation the impeller 236 of the fan assembly 198 withdraws gases from the opening 232 into space 244 and forces them into duct 72. This in turn draws gases including water vapor and medium vapor from the upper space 52 of chamber 40 through the exhaust duct 194 to the interior 214 of the cylindrical housing 210. Therefrom the gases pass through fine openings (not shown) in the cylindrical member 220 into close contact with the acid absorbing material 226 in the annular space 224. This removes hydrofluoric acid vapors and makes the water vapor alkaline. The remaining gases and vapors pass through additional fine openings (not shown) in the inner cylindrical member 222 and into the space 230 interior of the cylindrical member 222. Therefrom these gases pass into the opening 232, and are moved by the impeller 236 into the duct 72.

Also referring to **Figure 11**, impeller 236 comprises a circular disc of solid material that has a plurality of radially extending openings 246 machined or drilled therein. When rotated by motor 238, impeller 236 centrifically moves gases and vapors radially outwardly from its center into space 244. This provides an inexpensive piece part impeller that can be replaced easily upon excessive wear caused by any unabsorbed hydrofluoric acid that may pass through the acid absorbing means.

The feed manifold 192 comprises a cylindrical housing 250 closed at both ends with the interior thereof in gaseous fluid communication with the chamber 40 through the feed ducts 196. The feed manifold 192 performs the function of roughly equalizing the flow of gases from duct 74 into the several feed ducts 196 to chamber 40.

Turning now to **Figures 3** and **12**, the liquid water separator 70 receives intermixed liquid water and liquid medium from conduit 76 by way of pump 260 from pool 204 in the vapor recovery condensor 68. The liquid water separator 70 feeds separated liquid medium back to chamber 40 through conduit 80 by way of pump 262. Conduit 80 returns the liquid medium to the tank 38 and chamber 40 well above the top surface of the liquid medium 42 to prevent a siphoning of the liquid medium back into the liquid water separator 70.

The purpose of separator 70 is to separate the liquid medium from the liquid water so that the expensive liquid medium can be reused in the burn-in chamber 40. It is desired to remove the liquid water to prevent formation in the bath of hydrofluoric acid that can corrode the tank, racks, cards and semiconductor devices.

Liquid water separator 70 comprises an upstanding cylindrical housing 254 closed at its top by a cover 266 and at its bottom by a base 268 and having a pair of depending cylindrical tubes 270 and 272, which are closed at their bottom ends by bases 274 and 276. Housing 264 defines a substantially cylindrical separator chamber 278 that is in fluid communication with a well 271 interior of depending tube 270 and a well 280 interior of the depending tube 272. A diffuser material 282 such as a rolled web of stainless steel mesh is installed in the well 280 of the tube 272 for a purpose to be dscribed presently.

Liquid water separator 70 further comprises a pair of electrodes 283 and 284 each connected to a bridge circuit 286 by conductor leads 288 and 290. The electrodes 282 and 284 extend radially through the wall of the housing 264 at a certain level so that their tips 292 and 294 are in fluid communication with any

liquids or gases in the separator chamber 278 interior of the housing 264.

In operation, and initially, the interior of the housing and the two depending tubes are filled only with gases and are void of any liquid such as the intermixed liquid medium or liquid water. When the burn-in procedure commences, quantities of liquid intermixed water and medium will be pumped up from pool 204 through conduit 76 into well 280 and therefrom into chamber 278. The liquid entering chamber 278 from the well 280 of tube 272 will do so in a substantially planar flow, because the mesh material 282 has greatly diffused the stream of flow resulting from the liquid entering from conduit 76. This prevents any turbulence or agitation of the intermixed liquids in chamber 278 so that the liquid water can rest and separate from the liquid medium and rise to float above the liquid medium at the top of chamber 278. Suitable controls (not shown) are provided so that chamber 278 remains substantially filled with liquid.

During the course of the burn-in procedure, the liquid water separating from the intermixed liquids in the bottom of chamber 278 will increase in volume from the top of chamber 278 downwardly. When the interface 296 between the liquid water 298 and the liquid medium 42 touches both of the tips 292 and 294 of the

electrodes 283 and 284, an electrical signal can be conducted through the liquid water because it is alkaline, the alkalinity resulting from the water vapors passing through the acid absorbing material 226 in the exhaust manifold 190. No electrical signal passes between the electrodes 282 and 284 while they are submerged in only the liquid medium because the liquid medium is non-conductive.

The electrical signal flowing between the two electrodes causes a change in the balance of a bridge circuit 286 and an indicator is activated so that the operator may manually removed the liquid water from the liquid water separator 70 with such as a syringe. This is performed by lifting the cover 266 from the housing 264 for manual removal of the liquid water 298. Alternatively, the liquid water can be removed automatically through the conduit 78 schematically illustrated in **Figure 2.**

The flow of intermixed liquid into the liquid water separator 70 is minimal and provides for the liquid substantially to rest in chamber 278 for the lighter specific density liquid water to rise and float above the heavier specific density heat exchange medium. This separation of the liquid water from the liquid medium aids in reducing the quantity of hydrofluoric acid formed in the tank 38, increasing the life of the tank and related pipes, ducts and conduits.

While the well 280 serves to contain the diffuser means 282, the well 271 serves another, equally important purpose. There is a substantial distance between the outlet port 300 in the bottom of well 271 through base 274 and the level of the two electrode tips 292 and 294 indicated by the water/medium interface 296. This distance in separator chamber 278 and well 271 forms a long stable column of mainly liquid medium that, due to the differences in specific gravities, strongly urges any intermixed liquid water to separate, rise above and float on the medium. This urging is greatest at the bottom of well 271 adjacent outlet port 300 and results in medium containing the least amount or concentration of intermixed liquid water first being removed from the bottom of well 271 and separator 70. This effect also occurs adjacent inlet port 302 in the base 276 of well 280 but the separated liquid heat exchange medium has to rise into separator chamber 278 before it can be removed through outlet port 300.

The burn-in procedure effecting unit 20 thus provides a structure that aids an operator in placing semiconductor devices in the tank burn-in chamber for the procedure and removing the devices after completion of the procedure. The unit includes special provisions for maintaining the heat exchange bath medium at the desired, elevated temperture for effecting the procedure precisely and for re-cycling evaporated medium into the bath.

Moisture, in the form of liquid water and water vapor, is removed substantially to protect the unit components from the attack of hydrofluoric acid that can form from interaction of the moisture and heat exchange medium. An included filter removes from the liquid medium particulate matter, chemical contaminants and moisture.

All of this is provided in a unit that is self-contained after connection to an electrical power source and that has a burn-in chamber capable of effecting the procedure on production quantities of semiconductor devices.



CLAIMS

1. An apparatus for thermally stressing a plurality of semiconductor devices at an elevated temperature in a bath of an inert, substantially electrically insulating liquid heat exchange medium, the medium having a specific heat capacity greater than air and a boiling point greater than the elevated temperature, and the semiconductor devices being electrically operated to produce excess heat while being thermally stressed, the apparatus comprising a tank having a burn-in chamber adapted to receive therein the semiconductor devices and further adapated to receive therein a quantity of the liquid medium sufficient to cover the semiconductor devices while they are being electrically operated, the tank having sufficient size for the chamber to include an upper free space containing ambient gases, in which water vapour can be present, above the medium and of sufficient size for the semiconductor devices to be positioned in the free space and be clear of the medium; cooling means exterior of the chamber in liquid communication with the chamber and adapted to remove the excess heat from the liquid medium to maintain the liquid medium substantially at the said elevated temperature; pump means adapted, in use, to move the liquid medium from the tank to the cooling means and back to the tank with the liquid medium entering the chamber at plural locations to produce agitation of the liquid medium therein, so that the apparatus maintains a substantially uniform temperature throughout the medium in the tank chamber; and vapour recovery means for removing vapours of at least the medium from the upper free space in a closed loop from and to the upper

free space, the vapours being condensed to liquid medium and liquid water and the condensed liquid medium being returned to the liquid medium in the chamber substantially free of any liquid water vapour simultaneously condensed.

2. The apparatus of claim 1 in which said apparatus is self-contained upon connection to an electrical power source.

3. The apparatus of claim 1 or claim 2 in which the tank has four side walls and a bottom wall in a rectangular configuration open to the top, the walls defining the chamber interior of the tank and the chamber having an upper, free space above the liquid medium, and the medium, in use, being arranged to be contained in a lower space of the chamber.

4. The apparatus of claim 1 or claim 2 or claim 3 including conduit means connected to the walls of the tank for carrying the medium between the chamber and cooling means.

5. The apparatus of any one of the preceding claims in which the cooling means include an inner pipe surrounding at least one cooling coil with the pipe containing a flow of the medium in one direction from the chamber around the cooling coil.

6. The apparatus of claim 5 in wich the cooling means include an outer tube containing the inner pipe and arranged to contain a flow of the medium exiting the inner pipe in a second direction opposite the said one

direction, and a baffle extending between the interior of the tube and the inner pipe.

7. The apparatus of claim 6 including conduit means having a plurality of riser conduits extending from the outer tube to the tank to return the medium to the chamber.

8. The apparatus of claim 5 or claim 6 or claim 7 including conduit means having a conduit extending from the tank to the pump means and inner pipe to remove the medium from the chamber to the cooling means.

9. The apparatus of any one of the preceding claims in which the cooling means are integral with the tank.

10. The apparatus of claim 5 or claim 6 or claim 7 or claim 8 in which the cooling coil is an expansion coil of a mechanical refrigeration unit.

11. The apparatus of any one of the preceding claims in which the cooling means includes heater means for increasing the temperature of the medium to the elevated temperature.

12. The apparatus of any one of claims 6 to 8 including filter means for filtering approximately 10 percent of the liquid medium exiting the inner tube and returning the filtered medium to the tank.

13. The apparatus of any one of the preceding claims including at least one rack located in the chamber and adapted to carry the semiconductor devices thereon, the

rack being movable between a raised position spaced above the medium, in which position the rack is adapted to receive the semiconductor devices and a home position in which any carried semiconductor devices are immersed in the medium; and means for moving the rack between the raised and the home positions.

14. The apparatus of claim 14 in which the rack includes a plurality of circuit card connectors adapted to receive and operate circuit cards carrying the semiconductor devices.

15. The apparatus of claim 13 or claim 14 in which means for moving the rack includes a pneumatic cylinder to raise and lower a shaft on which the rack is carried.

16. The apparatus of claim 13 or claim 14 or claim 15 in which there are a plurality of racks that are each capable of being raised and lowered independently of the other racks.

17. The apparatus of any one of claims 13 to 16 including a cover arranged to close the open top of the chamber, the cover having a plurality of segmented portions each aligned with a rack in the chamber, so that each rack can be accessed through one segmented portion of the cover without having to raise the entire cover.

18. The apparatus of any one of the preceding claims in which the liquid medium has a relative density greater than liquid water so that liquid water tends to

rise above and float on the liquid medium while at rest.

19. The apparatus of any one of the preceding claims in which the vapour recovery means includes acid absorbing means adapted for absorbing any acid vapours removed from the free space, and adapted for making alkaline any water vapour removed from the free space; feed manifold means adapted to return any uncondensed vapours to the free space; and the means for returning the condensed liquid medium including separator means adapted to separate from the liquid medium prior to the liquid medium being returned to the chamber, any liquid water condensed from water vapour, the liquid water being alkaline and electrically conductive as a result of action of the acid absorbing means, and the separator means including electrical circuit means adapted to detect the presence of liquid water separated from the liquid medium.

20. The apparatus of claim 19 in which the vapour recovery means includes an exhaust manifold external of the chamber, the manifold containing the acid absorbing means and receiving the vapours from the free space at a plurality of locations.

21. The apparatus of claim 20 including fan means for moving the vapours from and to the free space.

22. The apparatus of claim 20 or claim 21 including a drain for conducting condensed liquids in the exhaust manifold to the separator means.

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23. The apparatus of claim 21 in which the fan means are mounted on the vapour recovery means and are arranged to draw the vapours from the chamber through the acid absorbing means.

24. The apparatus of claim 23 in which the acid absorbing means are concentrically mounted in the exhaust manifold and the fan means are mounted at one end of the acid absorbing means.

25. The apparatus of any one of claims 21 to 24 including an impeller that is a disc having radial passages drilled therein.

26. The apparatus of any one of claims 19 to 25 in which the means for condensing the vapours includes the expansion coil of a mechanical refrigeration unit over which the medium and water vapours are arranged to be passed and the condensed liquids intermixed.

27. The apparatus of any one of claims 19 to 26 in which the feed manifold means returns the uncondensed vapours to the chamber at a pluarlity of locations opposite the vapour recovery means.

28. The apparatus of any one of claims 19 to 27 in which the means for returning the condensed liquid medium are arranged to receive intermixed liquid medium and water, and the separator means includes a separator chamber adapted to bring the intermixed liquid medium and water to rest so that the liquid water can separate from the liquid medium and rise above it and float thereon, and the electrical circuit means includes

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electrodes extending into the chamber at a certain level and adapted to effect an electrical signal through the liquid water when the liquid water attains the said certain level.

29. The apparatus of claim 28 in which the separator includes a first and second wells depending from the separator chamber, an inlet port for receiving the intermixed liquid medium and water at the bottom of the first well, and an outlet port for removing separated liquid medium at the bottom of the second well.

30. The apparatus of claim 29 in which the separator means includes diffuser means in the first well adapted to provide a substantially laminar flow of liquid into the separator chamber from the first well.

31. The apparatus of claim 30 in which the diffuser means comprises stainless steel wire mesh.

32. The apparatus of any one of claims 28 to 31 in which the electrical circuit means includes a bridge circuit connected to the electrodes to indicate the presence of an electrical signal passing through the electrodes.

33. The apparatus of any one of claims 28 to 32 including conduit means arranged to carry intermixed liquid medium and water to the separator chamber.

34. The apparatus of any one of claims 28 to 33 in which the means for returning the condensed liquid medium includes pump means adapted to move the

intermixed liquid to the separator chamber, and pump means adapted to move liquid medium to above the level of the liquid medium to be in the burn-in chamber.

35. The apparatus of any one of claims 19 to 34 in which the separator includes a removable cover for removal of liquid water from the separator chamber.

36. The apparatus of any one of the preceding claims including a variable speed pump assembly comprising driven impeller means adapted for moving the medium, including a rotatable driven pulley, a driven shaft fixed to the pulley and an impeller fixed to the shaft and adapted to be in fluid engagement with the medium, the driven pulley, driven shaft and impeller being substantially fixed in rotatable position; drive motor means for driving the driven impeller means, including a mounting plate, a constant speed motor having a drive shaft and being mounted on the mounting plate, a drive pulley fixed on the drive shaft and a fixed length belt arranged around the drive and driven pulleys; and lead screw means including a lead screw and lead nut connected to the plate, and spring means for varying the effective diameter of the drive pulley in relation to the varying distance between the drive shaft and driven shaft, so that the speed of rotation of the driven shaft can be varied while maintaining constant the speed of rotation of the drive shaft.

37. The apparatus of claim 36 in which the lead screw means includes a lever arm having one end connected to the lead nut and lead screw and an opposite end connected to a pivot shaft, the pivot shaft also being

connected to the mounting plate of the motor so that movement of the lead nut on the lead screw rotates the mounting plate and the pivot shaft.

38. The apparatus of claim 37 in which the driven impeller means includes a mounting tube containing the driven shaft and impeller, and a support plate that is clamped on the mounting tube and that carries bearings supporting the pivot shaft and the lead screw.

39. The apparatus of claim 38 including a stepping motor carried on the supporting plate and rotating the lead screw.

40. The apparatus of claim 38 or claim 39 in which the lever arm is on an opposite side of the support plate from the mounting plate.

41. The apparatus of claim 39 or claim 40 or claim 41 in which the mounting tube includes a baffle therein to contain the liquid medium arranged to be engaged by the impeller.

42. A method of thermally stressing a plurality of semiconductor devices at an elevated temperature comprising first installing the semiconductor devices in operative relationship in a bath of a liquid heat exchange medium that is inert, is substantially electrically insulating, has a specific heat capacity greater than air and has a boiling point greater than the elevated temperature to subject the devices to the said elevated temperature and dissipate excess operating heat of the devices in the medium, and then;

removing heat from the medium by a cooling device separated from the bath to maintain the medium substantially at the said elevated temperature; and agitating the medium by moving the medium from and back into the bath to maintain a substantially uniform temperature throughout the medium in the bath.

43. The method of claim 42 which includes containing the medium in a lower space of a tank burn-in chamber and mounting the devices on racks in a free space of the chamber above the liquid medium.

44. The method of claim 42 or claim 43 including pumping the medium between the bath and the cooling device.

45. The method of claim 42 or claim 43 or claim 44 including containing a flow of liquid medium from the bath in one direction over a cooling coil within an inner pipe.

46. The method of claim 45 including directing the flow of liquid medium leaving the inner pipe in a second direction opposite the said one direction in an outer tube.

47. The method of claim 46 including directing the flow of liquid medium from the outer tube to the bath through a plurality of riser tubes.

48. The method of claim 45 or claim 46 or claim 47 including pumping the liquid medium from the bath to the inner pipe.

49. The method of claim 46 or claim 47 including preventing the liquid medium leaving the inner pipe from re-entering the inner pipe before returning to the chamber.

50. The method of any one of claims 43 to 49 in which the agitating includes removing liquid medium from the bath at one location and returning the cooled liquid medium to the bath at another location.

51. The method of any one of claims 43 to 50 in which the installing includes heating the liquid medium to the elevated temperature with a heater located at the cooling device.

52. The method of claim 45 or any one of claims 46 6o 51 when dependent upon claim 45 including filtering approximately ten percent of the liquid medium leaving the inner pipe and returning it to the bath.

53. The method of any one of claims 42 to 52 including mounting the devices on a rack contained within a chamber holding the bath, lowering the rack into the bath to fully immerse the semiconductor devices therein; and electrically operating the semiconductor devices while they are immersed in the bath.

54. The method of claim 53 including aligning a segmented cover portion of a cover with the rack and raising only that segmented portion to gain access to the rack for mounting the semiconductor devices on the rack.

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55. The method of claim 52 including aligning each of a plurality of segmented portions of the cover with one of a plurality of racks.

56. The method of claim 53 including automatically lowering the rack into the bath.

57. The method of claim 53 including providing a plurality of racks, and lowering each rack independently of the other racks.

58. The method of claim 57, including automatically lowering each rack into the bath.

59. Apparatus for thermally stressing a plurality of semiconductors substantially as specifically described.

60. A method of thermally stressing a plurality of semiconductors substantially as specifically described.