SYSTEMS AND METHODS OF COOLING TEST SOCKET ASSEMBLIES FOR SEMICONDUCTOR INTEGRATED CIRCUITS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Chinese Patent Application No. 202410323817.6, filed 20 March 2024, entitled SYSTEMS AND METHODS OF COOLING TEST SOCKET ASSEMBLIES FOR SEMICONDUCTOR INTEGRATED CIRCUITS, the entire contents of which are hereby incorporated by reference.

FIELD

[0002] The field of the disclosure relates generally to test sockets for semiconductor integrated circuits (ICs) and, more specifically, to systems and methods of cooling a test socket assembly for testing semiconductor IC chips.

BACKGROUND

[0003] Semiconductor integrated circuit (IC) chips are produced in various packages, or chip configurations, and in relatively large quantities. Production of IC chips generally includes testing of the IC chips in a manner that simulates an end-user's application of the IC chips. One manner of testing IC chips is to connect each IC chip through a test socket assembly to a printed circuit board (PCB), or load board, which exercises various functionalities of the IC chip. The test socket assembly may be re-used to test many IC chips.

[0004] Operation of test socket assemblies may generate a substantial amount of heat. At least some known test socket assemblies have disadvantages when it comes to heat dissipation. Accordingly, improvements for cooling test socket assembles are desirable.

BRIEF DESCRIPTION

[0005] In one aspect, a cooling system of a test socket assembly for testing a semiconductor integrated circuit (IC) chip is provided. The system includes a first level sensor configured to detect that a level of a liquid coolant in a test socket assembly is at or above a first threshold and a second level sensor configured to detect that the level of the liquid coolant is at or above a second threshold. The second threshold is greater than the first threshold. The system also includes a controller configured to adjust flow rates of the liquid coolant based on detection

by the first level sensor and detection by the second level sensor such that the level of the liquid coolant is maintained between the first threshold and the second threshold.

[0006] In another aspect, a method of cooling a test socket assembly for testing a semiconductor IC chip is provided. The method includes positioning a first level sensor, the first level sensor configured to detect that a level of a liquid coolant in a test socket assembly is at or above a first threshold, and positioning a second level sensor, the second level sensor configured to detect that the level of the liquid coolant is at or above a second threshold. The second threshold is greater than the first threshold. The method also includes adjusting flow rates of the liquid coolant based on detection by the first level sensor and detection by the second level sensor such that the level is maintained between the first threshold and the second threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1A is a schematic diagram of an example cooling system for a test socket assembly;

[0008] FIG. 1B shows a portion of the cooling system shown in FIG. 1A coupled with a test socket assembly;

[0009] FIG. 1C shows example probes of the test socket assembly shown in FIG. 1B;

[0010] FIG. 1D shows an example control station of the cooling system with the cover of the control station partially removed;

[0011] FIG. 1E shows an example operation panel of the control station;

[0012] FIG. 2A is a schematic diagram of a test socket assembly coupled with example level sensors;

[0013] FIG. 2B is an enlarged view of a portion of the assembly shown in FIG. 2A, where the section is indicated as 2B in FIG. 2A.

[0014] FIG. 2C is a cross sectional view of the level sensor along a cross-sectional line indicated as 2C-2C in FIG. 2B;

[0015] FIG. 2D is a schematic diagram of level detection by the level sensor;

[0016] FIG. 3A is an enlarged view of a portion of the cooling system in FIG. 1B showing a connector coupled with tubes, where the portion is indicated as 3A in FIG. 1B;

[0017] FIG. 3B is a cross-sectional view of a portion of the assembly shown in FIG. 3A along cross-sectional line 3B-3B indicated in FIG. 3A;

[0018] FIG. 3C shows the coupling of a tube with an adapter to be coupled with the test socket assembly shown in FIG. 1B;

[0019] FIG. 4A is a flow chart of an example method of operating the cooling system shown in FIGs. 1A-3C; and

[0020] FIG. 4B is a schematic diagram of the cooling system during operation.

DETAILED DESCRIPTION

[0021] The disclosure includes systems and methods of cooling test socket assemblies for testing semiconductor integrated circuit (IC) chips.

[0022] Consumer demands have increased drastically for next generation technologies such as high speed gaming, computer graphics, Internet of things (IoT), 5G, artificial intelligence (AI), deep learning, vehicle-to-vehicle communication, and self-driving vehicles. This increase creates a need for high speed data transfer and processing technologies. High reliability testing is essential for such high speed, multi-function devices.

[0023] In testing IC chips, a fundamental component of a test system that enables the testing is a test socket assembly for the IC chips. The test socket assembly may be re-used many times to test large quantities of IC chips. The test socket assembly connects, both electrically and mechanically, the IC chip to a printed circuit board (PCB) or a load board. The degree to which the test socket assembly may be re-used is quantified by how many "cycles" the test socket assembly can withstand without degradation in performance, e.g., signal performance. Each time that an IC chip is inserted, or set, into the test socket assembly is referred to as one cycle. Generally, over the course of many cycles, electrical and mechanical properties of the contacts and structures of the test socket assembly begin to degrade. One cause of the

degradation is repeated heating and deformation of the test socket assembly from the heat generated by the IC chips during testing. The IC chip and spring probes of the test socket assembly generate a relatively large amount of heat during testing. Due to the limitations in heat dissipation by the test socket assembly, the heat is not readily dissipated, and may damage chip melt balls and spring probes. The degradation eventually impacts integrity of the testing itself, at which point the test socket assembly reaches the end of useful life.

[0024] FIGs. 1A-1E show an example cooling system 100 for cooling a test socket assembly 102 used in testing an IC chip 104. FIG. 1A is a schematic diagram of cooling system 100. FIG. 1B shows a portion of a circulation assembly 103 of cooling system 100 coupled with test socket assembly 102. FIG. 1C shows example probes 108 of test socket assembly 102. FIG. 1D shows an example control station 105 of cooling system 100 with a cover 107 of control station 105 partially removed. FIG. 1E shows an example operation panel 111 of control station 105.

[0025] In the example embodiment, a test system 101 includes test socket assembly 102, semiconductor IC chip 104, and a PCB 106. IC chip 104 is to be tested. PCB 106 includes test circuits. Test socket assembly 102 provides electrical and mechanical connection between IC chip 104 and PCB 106. Test system 101 further includes a plurality of probes 108. Probes 108 may include a ground probe 108-g, a signal probe 108-s, and a power probe 108-p. Probes 108 are placed in test socket assembly 102 and used to establish electrical connections between IC chip 104 and PCB 106. Specifically, ground probe 108-g is connected to the ground. Signal probe 108-s transmits signals between IC chip 104 and PCB 106. Power probe 108-p is configured to be connected to a power supply. Power, grounding, and signals are provided through probes 108 from PCB board 106 to IC chip 104. The dimensions of test socket assembly 102 may, for example, be approximately 7 centimeters (cm) to 8 cm. Of course, the dimensions may vary, depending on the size of IC chip 104.

[0026] In operation, test socket assembly 102 is mounted on PCB 106. To test IC chip 104, IC chip 104 is received in test socket assembly 102. Tests are run to exercise various functionalities of IC chip 104.

[0027] Test socket assembly 102 serves as a re-usable interface for connecting many IC chips 104 to PCB 106. The high performance, e.g., high speeds, of IC chip 104 generate

a relatively large amount of heat. For example, the rate of heat transferred by a 63 millimeter (mm) x 95 mm IC chip may reach 1.2 kilo-Watts (kW). However, test socket assembly 102 generally needs to maintain high reliability without being adversely affected by the amount of heat generated during testing of IC chip 104.

[0028] Conventional socket frames for a test socket assembly are fabricated from plastic, a thermally-nonconductive material. In such implementations, the IC chip is cooled by heat transfer through a heat sink in contact with the IC chip top surface (i.e., the surface of the IC chip that faces away from the test socket assembly). This cooling mechanism is effective in removing heat away from the top surface of the IC chip. However, as performance of IC chips increases, the amount of heat generated increases drastically (e.g., from 100 Watts (W) to 200 W, 300 W, or even 900 W or higher. Further, additional issues arise from high heat generated at contact points between the IC chip and the test socket assembly such as contact points between the IC chip and the probes. The high heat at the contact points is on the bottom side of the IC chip, which is opposite from the top surface of the IC chip. Heat sinks placed on the top surface of the IC chip may be insufficient or have increased difficulties in dissipating the high heat generated at the contact points. Dissipating that much heat efficiently and effectively is, therefore, a relatively-new problem that exists in reliably testing high-performing IC chips.

[0029] The high heat generated at the contact points may degrade the performance and life of the test socket assembly. With repeated use of the test socket assembly, the relatively large amount of heat may deform and/or damage the test socket assembly, affecting the electrical performance of conventional test systems, and causing the systems to be unable to transmit high-frequency signals. As a result, conventional test systems may have limited lifetime and unsatisfactory performance, especially with respect to high-frequency signals.

[0030] In at least one known method, compressed air is pumped into a gap between the IC chip and the test socket. However, this cooling method may be unsatisfactory in removing the heat due to the limited capacity of air in dissipating heat.

[0031] In contrast, systems and methods described herein provide solutions to the problems of dissipating heat from high performing IC chips during testing to ensure the testing quality and to prolong the life of the testing systems. Cooling systems and methods disclosed herein are intended to keep test socket assemblies cooled by removing heat between

the test socket assembly and the IC chip using liquid cooling, thereby improving life of test sockets, reducing maintenance, and ultimately reducing downtime of the test system. Systems and methods described herein control the flow rate, the level, and/or the temperature of the liquid coolant to effectively dissipate heat from the test socket assembly.

[0032] In the example embodiment, cooling system 100 includes circulation assembly 103 and a controller 110 that controls the operation of cooling system 100. Fluid flows through circulation assembly 103. Fluid may be gaseous, such as air, or liquid, such as water. Liquid fluid is used as liquid coolant for test socket assembly 102.

[0033] In the example embodiment, circulation assembly 103 includes a plurality of tubes 120 configured to carry fluid therethrough. At least one tube 120 may be an input tube 120 sized to be coupled with socket inlet 124-i of test socket assembly 102 and to carry fluid into test socket assembly 102. Further, at least one tube 120 may be an output tube 120 sized to be coupled with socket outlet 124-o of test socket assembly 102 and to carry fluid out of test socket assembly 102. Circulation assembly 103 further includes a connector 132. In this embodiment, connector 132 is a three-way connector, in which one end of connector 132 is coupled with two tubes 120 while the other end is coupled with one tube 120. Of the two tubes 120 coupled with one end of connector 132, one tube 120-a is used to carry a gaseous fluid and the other tube 120-l is used to carry a liquid fluid. Liquid fluid is generally used to cool test socket assembly 102. Gaseous fluid is generally used in removing liquid fluid from test socket assembly 102 after the testing.

[0034] In the example embodiment, circulation assembly 103 may include a tank 121 that serves as a reservoir for the liquid fluid. A cooler 122 may be coupled with tank 121 to cool the liquid fluid. Circulation assembly 103 may further include one or more pumps 126 configured to drive the flow of liquid fluid through cooling system 100. Circulation assembly 103 may further include one or more flowmeters 464 (see FIG. 4B) configured to measure the flow rate of liquid fluid flowing into or out of pump 126.

[0035] In the example embodiment, controller 110 includes a processor-based microcontroller including a processor 116 and a memory device 118 wherein executable instructions, commands, and control algorithms, as well as other data and information needed to satisfactorily operate cooling system 100, are stored. Memory device 118 may be, for example, a

random access memory (RAM), and other forms of memory used in conjunction with RAM memory, including but not limited to flash memory (FLASH), programmable read only memory (PROM), and electronically erasable programmable read only memory (EEPROM).

[0036] As used herein, the term "processor-based" microcontroller shall refer not only to controller devices including a processor or microprocessor as shown, but also to other equivalent elements such as microcomputers, programmable logic controllers, reduced instruction set circuits (RISC), field programmable gate arrays (FPGA), application specific integrated circuits and other programmable circuits, logic circuits, equivalents thereof, and any other circuit or processor capable of executing the functions described herein. The processor-based devices listed above are exemplary only, and are thus not intended to limit in any way the definition and/or meaning of the term "processor-based."

[0037] In the example embodiment, controller 110 is configured to monitor the temperature of the liquid coolant. The temperature is measured by a temperature sensor 460 (see FIG. 4B). Temperature sensor 460 may be placed in tank 121. When the temperature exceeds a predefined value, cooler 122 is activated to lower the temperature of the coolant. Another temperature sensor 460 may be used to measure temperature of test socket assembly 102 to ensure that test socket assembly 102 does not become overheated. Temperature sensor 460 for measuring temperature of test socket assembly 102 may be a thermocouple.

[0038] In the example embodiment, cooling system 100 further includes control station 105. In the example embodiment, control station 105 is a single contained unit, and is portable. In the depicted example, control station 105 includes a handle 134 to facilitate carrying control station 105. Components of cooling system 100 may be assembled into control station 105. Control station 105 includes controller 110 configured to control the operation of cooling system 100. Control station 105 further includes tank 121 sized to receive liquid fluid. Pump 126 may be included in control station 105. Pump 126 is used to pump the liquid fluid from or into tank 121. A filter (not shown) may be included in the circulation path of liquid fluid to remove debris from the liquid fluid. The filter may be placed at an inlet and/or an outlet of tank 121. A cooler 122 may be included in control station 105 and is configured to cool the warm liquid fluid flowing from test socket assembly 102. Cooler 122 may include a cold radiator and a thermoelectric cooler, for example.

[0039] In the example embodiment, control station 105 may further include a power source 136. Power source 136 may include one or more batteries. In some embodiments, power source 136 includes a plug configured to be electrically coupled with an external power source, and power source 136 may include one or more power converters configured to convert the power from the external power source to desired voltage and/or current ranges of controller 110, pump 126, and/or other devices in control station 105. In some embodiment, multiple power sources 136 configured to supply power at different voltage/current/power levels may be included in cooling system 100. For example, one power source 136 is configured to supply power for the operation of controller 110, and another power source 136 is configured to supply power for the operation of pump 126 and/or other devices in cooling system 100. In some embodiment, control station 105 includes an optical amplifier (not shown) configured to amplify optical waves to be transmitted to a level sensor 138 (also see FIGs. 2A-2D) or reflected optical waves received from level sensor 138.

[0040] In the example embodiment, control station 105 further includes operation panel 111 as a user interface between cooling system 100 and a user. Operation panel 111 includes an operation interface 142. Operation interface 142 may be a touch screen, such that the interactions between the user and cooling system 100 are conducted by pressing or tapping on the touch screen. A user may select programs and/or parameters to control the operation of cooling system 100 by interacting with operation interface 142. Operation panel 111 further includes a power switch to turn power source 136 on or off. A start button 144-start and a stop button 144-stop may be included in operation panel 111 for manually starting and stopping the operation of cooling system 100.

[0041] In the example embodiment, operation panel 111 further includes a host communication interface 147 configured to communicate with a tester computing device 462 (see FIG. 4B). Host communication interface 147 may further include a storage port 148 sized to receive a storage device such as a universal serial bus (USB) device for storing data detected and/or generated by cooling system 100. Host communication interface 147 may further include a communication port 149, such as a wireless communication port, which is configured to be coupled with a communication interface for communicating with a remote computing device such as tester computing device 462.

[0042] In some embodiments, tester computing device 462 is in communication with cooling system 100 and configured to remotely control operation of cooling system 100. Tester computing device 462 may also be configured to program controller 110 and transfer executable instructions to cooling system 100, such that when the instructions are executed by controller 110, the operation of cooling system 100 is controlled according to the instructions.

[0043] In the example embodiments, operation panel 111 further includes tube ports 152 sized to receive tubes 120. In this embodiment, four tube ports 152 are included in control station 105. Two of the tube ports 152-l, inlet 152-l-i and outlet 152-l-o, are for liquid tubes 120. The other two tube ports 152-a are for air tubes 120, with one coupled with a compressed air device 456 (see FIG. 4B) and the other coupled with a vacuum 458. Alternatively, operation panel 111 may include any suitable number of tube ports 152. Operation panel 111 may also include a thermocouple interface 155 configured to be connected with a thermocouple.

[0044] Cooling system 100 configured as including a control station 105 is described as an example for illustration purposes only. Components of cooling system 100 may be assembled into other configurations that enable cooling system 100 to function as described herein. For example, in some embodiments, the components of cooling system 100 may be distributed at different locations and are not packaged into a single unit of control station 105.

[0045] To assemble cooling system 100, four tubes 120 are inserted into tube ports 152. Two tubes 120, an air tube 120-a and a liquid tube 120-l, extend from two of the four tube ports 152 on operation panel 111, and are coupled to an end of connector 132. One more tube 120 is coupled with the other end of connector 132 and extends to socket inlet 124-i (see FIG. 1B). From socket outlet 124-o, a tube 120 extends to an end of another connector 132. The other end of another connector 132 is coupled with two more tubes 120, an air tube 120-a and a liquid tube 120-l. The two more tubes 120 are received in the other two tube ports 152 on operation panel 111. As a result, two flow paths are formed, where one path is for liquid fluid and the other path is for gaseous fluid. The flow circuit of liquid fluid is defined from tank 121 through tubes 120 via socket inlet 124-i into test socket assembly 102, circulating and cooling test socket assembly 102, exiting from socket outlet 124-o, flowing through tubes 120, and returning back to tank 121. The path for air follows a similar path. Compressed air exits tube port

152-a, flows along air tube 120-a, enters socket inlet 124-i via tube 120, pushes liquid in test socket assembly 102 toward socket outlet 124-o, flows to tube 120, and enters into a vacuum 458 or back to tank 121 via pump 126 (see FIG. 4B). Accordingly, fluid carries heat away from test socket assembly 102. After testing of IC chip 104 is completed, cooling may be stopped and any liquid remaining in test socket assembly 102 may be removed from test socket assembly 102.

[0046] FIGs. 2A-2D show an example level sensor 138 for detecting the level of liquid coolant in socket assembly 102. FIG. 2A shows a test socket assembly 102 coupled with level sensors 138. FIG. 2B is an enlarged view of a portion identified as 2B in FIG. 2A. FIG. 2C is a cross-sectional view of a sensor head 202 of level sensor 138 along cross-sectional line 2C-2C as marked in FIG. 2B. FIG. 2D is a schematic diagram illustrating detecting the liquid level, where a front view of level sensor 138 is shown.

[0047] In the example embodiment, level sensor 138 is an optical level sensor, which uses optical waves, such as lasers, to detect the level of liquid coolant. Level sensor 138 includes an optical fiber 204 configured to propagate optical waves. Level sensor 138 further includes a sensor head 202 coupled with optical fiber 204. Sensor head 202 is transparent such that light passes through sensor head 202. In operation, light 206 travels through optical fiber 204 and into sensor head 202. At an end of sensor head 202 opposite optical fiber 204, surfaces 208 of sensor head 202 intersect with one another. Surfaces 208 may be relatively flat such that when parallel rays strike surfaces 208, the rays form the same angles or approximately the same angle with surfaces 208. In at least some embodiment, an angle of incidence of a ray striking surface 208 (i.e., the angle between the ray and a normal of surface 208), is less than a critical angle of the ray such that part of the ray is reflected by surface 208 and part of the ray is refracted into the medium outside sensor head 202. Accordingly, when light 206 strikes surface 208 of sensor head 202, part of light 206 is reflected by surface 208 and travels back through sensor head 202 and optical fiber 204, and part of light 206 is refracted into the medium outside sensor head 202. The medium outside sensor head 202 may be air or liquid coolant 210, depending on the level of liquid coolant. When the level of the liquid coolant 210 has not reached the level of light 206, the medium is air. When the level of liquid coolant 210 reaches or exceeds the level of light 206, the medium is liquid coolant 210. Because the refractive index of liquid coolant is different from that of air, the refracted light 206 and therefore the reflected light 206 change when the media changes from air to liquid or vice versa. Based on a change in the

measured reflected light 206, it can be determined whether the level of liquid flowing in test socket assembly 102 has reached a certain level.

[0048] In the example embodiment, two level sensors 138 are included to detect two different levels (see FIG. 2A). For example, a first level sensor 138-1 is configured to detect whether liquid coolant 210 has reached a first threshold, and a second level sensor 138-2 is configured to detect whether liquid coolant 210 has reached a second threshold. The amount of liquid coolant 210 in test socket assembly 102 may be controlled to be between the first threshold and the second threshold. The first threshold and the second threshold may be predefined, or user defined through operation interface 142 or tester computing device 462.

[0049] FIGs. 3A-3C show coupling of tubes 120 with connector 132. FIG. 3A is an enlarged view of a portion indicated as 3A in FIG. 1B. FIG. 3B is a cross-sectional view of the coupling along cross-sectional line 3B-3B as marked in FIG. 3A. FIG. 3C shows the coupling of tube 120 with an adapter 302, which is couplable with test socket assembly 102.

[0050] In the example embodiment, circulation assembly 103 includes tubes 120 and connector 132. Connector 132 includes first end 154 and second end 154 opposite first end 154. Connector 132 defines an tube aperture 304 at first end 154 and two tube apertures 304 at second end 154. Tube aperture 304 is sized to receive one tube 120. End 154 is a flared end, where connector 132 expands further outwards at end 154. A wall 310 at end 154 defines a recess 308. Connector 132 further includes an O-ring 306 received in recess 308. To couple tube 120 with connector 132, tube 120 is pushed into tube aperture 304, squeezing O-ring 306. The pressure from O-ring 306 holds tube 120 in place. Connector 132 may further include one or more spacers 312 to further increase the coupling strength between tube 120 and connector 132.

[0051] In the example embodiment, tube 120 is coupled with socket inlet/outlet 124 of socket assembly via adapter 302. The coupling of adapter 302 with tube 120 shown in FIG. 3C is similar to the coupling of connector 132 with tube 120 shown in FIG. 3B. Different from flared end 154 in FIG. 3B, adapter 302 includes threads 314 on an exterior of a neck of adapter 302. Threads 314 are complimentary to interior threads of a screw 156 (see FIG. 1B) of socket inlet/outlet 124, thereby coupling adapter 302 with socket inlet/outlet 124.

[0052] In the example embodiment, the coupling mechanisms of tube 120 with connector 132 or with socket inlet/outlet 124 provide sealing and prevent leakage of fluid out of cooling system 100. The sealing is facilitated by O-ring 306 and/or spacers 312.

[0053] FIGs. 4A and 4B show an example method 400 of operating a cooling system to cool a test socket assembly during testing of an IC chip. Example cooling systems are cooling system 100 described herein. FIG. 4A is a flow chart of method 400. FIG. 4B is a schematic diagram of the flow of fluid and signals in cooling system 100.

[0054] In the example embodiment, method 400 includes providing 402 a first level sensor. Method 400 further includes providing 404 a second level sensor. Example first and second level sensors are level sensors 138 described herein. Method 400 also includes adjusting 406 flow rates of liquid coolant flowing in the socket assembly during testing of an IC chip based on the detection by the first level sensor and the detection by the second level sensor. The level of liquid coolant 210 in test socket assembly 102 is maintained between a first threshold and a second threshold during the testing of IC chip 104.

[0055] In the example embodiment, electrical power flows along a power path 452-p. Power source 136 supplies power to controller 110, pump(s) 126, and cooler 122.

[0056] In the example embodiment, tester computing device 462 is in communication with controller 110 via a communication path 452-cm. For example, tester computing device 462 may remotely control operation of cooling system 100 by communicating commands to controller 110 via communication path 452-p. Tester computing device 462 may also write and/or program operation and/or parameters for operating cooling system 100 via communication path 452-p. Signals acquired by cooling system 100 may also be transmitted to tester computing device 462 via communication path 452-p.

[0057] In the example embodiment, controls from controller 110 are sent from controller 110 along a control path 452-c to pump 126, compressed air device 456, and/or vacuum 458 for controlling the operation of pump 126, compressed air device 456, and/or vacuum 458. For example, controller 110 is configured to control the rotational speed of pump 126 based on the collected signals of levels and temperatures of the liquid. Alternatively,

controller 110 is configured to control the rotational speed of pump 126 according to a set program based on the flow rate of liquid coolant.

[0058] In the example embodiment, signals flow along a signal path 452-s. Signals measured by flowmeters 464, temperature sensors 460, level sensors 138, and/or a content gauge 454 for measuring the level of liquid coolant in tank 121 are transmitted to controller 110 to be processed and used to control operation of cooling system 100.

[0059] In the example embodiment, circulation assembly 103 may further include compressed air device 456 configured to produce compressed air to be input into cooling system during the removal of liquid fluid after testing of IC chip 104. Vacuum 458 may be included in circulation assembly 103 for the removal. Compressed air device 456 and/or vacuum 458 may be included in control station 105 or positioned separately from control station 105.

[0060] In the example embodiment, fluid flows along fluid paths 452-f. During testing, liquid fluid flows from tank 121 to pump 126, flows through flowmeter 464 to test socket assembly 102, exits from test socket assembly 102, and flows through flowmeter 464 to pump 126, which pumps the liquid fluid back into tank 121. Liquid coolant is recirculated back to socket assembly 102 along liquid fluid path 452-f. Liquid coolant may be cooled by cooler 122. In the depicted embodiment, cooler 122 is positioned in or adjacent tank 121. Temperature sensor 460 is configured to measure the temperature of liquid in tank 121. Controller 110 is configured to operate cooler 122 based on the measured temperature. For example, if the temperature reaches a threshold, cooler 122 is turned on. In some embodiments, cooler 122 is in the flow path of liquid, where heated liquid flows from pump 126 directly to cooler 122 to be cooled before flowing back into tank 121, and/or liquid exiting tank 121 flows to cooler 122 first before being pumped by pump 126 into test socket assembly 102.

[0061] In the example embodiment, during removal of liquid from test socket assembly 102 after testing, the remaining liquid in socket assembly 102 is drawn from socket assembly 102 by compressed air device 456 and/or vacuum 458 into a reservoir. Compressed air device 456 and vacuum 458 may be used alone or together.

[0062] In the example embodiment, level sensors 138 are used to control the amount of liquid flowing through test socket assembly 102. For example, the level of liquid is

controlled to be between a first threshold and a second threshold. The second threshold is greater than the first threshold. One level sensor 138 is set at the level of the first threshold by setting the level of light 206 (see FIG. 2D) at the level of the first threshold. Another level sensor 138 is set at the level of the second threshold. When the level of liquid coolant 210 is below the first threshold, the input flow rate of the liquid coolant input into test socket assembly 102 and the output flow rate of the liquid coolant output from test socket assembly 102 are adjusted such that the input flow rate is greater than the output flow rate, thereby increasing the level of liquid in test socket assembly 102. The flow rate may be adjusted by adjusting the rotational speed of pump 126. When the measured level of liquid coolant 210 is at or above the second threshold, the flow rates are adjusted such that the input flow rate is smaller than the output flow rate, thereby reducing the level of liquid in test socket assembly 102. When the level of liquid coolant 210 is between the first threshold and the second threshold, the input flow rates is maintained to be the same as the output flow rate, thereby maintaining the level of liquid coolant 210 to be between the first threshold and the second threshold. An example liquid level in test socket assembly 102 is in the range of 4 mm – 5 mm.

[0063] The systems and methods described herein are advantageous in simplifying the detection of the level of the liquid for controlling of the circulation of liquid. Whether liquid reaches a threshold level is detected, instead of providing a measurement of the liquid level, thereby simplifying the design of level sensor 138.

[0064] If cooling system 100 does not include level sensors 138 or level sensors 138 are turned off, the flow rates may be predefined such that the level of liquid coolant 210 is maintained at a predefined level or a predefined range of levels. For example, at the beginning of testing IC chip 104, the input flow rate is greater than the output flow rate for a period of time such that the level of liquid rises to be between a first threshold and a second threshold, and then the flow rates remain equal to one another until the completion of testing.

[0065] After testing of IC chip 104, if not removed, liquid remaining in test socket assembly 102 may spill during the removal or movement of test socket assembly 102, potentially causing damage to the circuits. Liquid remaining in test socket assembly 102 may also cause deterioration of test socket assembly 102. Referring back to FIG. 1B, in the example embodiment, after testing, liquid coolant 210 remaining in test socket assembly 102 is removed

from test socket assembly 102. Compressed air may be input into socket inlet 124-i through air tube 120-a. The compressed air pushes liquid inside test socket assembly 102 toward socket outlet 124-o and further out of socket outlet 124-o. The liquid may be extracted out of socket outlet 124-o via a vacuum coupled to air tube 120-a. Alternatively, the liquid may be extracted out of socket outlet 124-o via a pump 126 coupled with liquid tube 120-l. During removal of the liquid, the pump or the valves on air tubes 120-a may be turned on or off to control the direction of the flow of the fluid. For example, the pump coupled to liquid input tube 120-l at the side of socket inlet 124-i is turned off when compressed air is used. If compressed air is not used, the valve at the end of air tube 120-a that is coupled with compressed air device 456 is turned off. If vacuum is used, the pump coupled to liquid tube 120-l at the side of socket outlet 124-o is turned off. If the liquid in test socket assembly 102 is removed by a pump coupled to liquid tube 120-l, the valve at the end of air tube 120-a that is coupled with vacuum is turned off such that liquid removed from test socket assembly 102 flows into liquid tube 120-l. Removal via vacuum is the faster than by pumping.

[0066] The technical effects of the systems, apparatuses, and methods described herein may include: (a) improved cooling of a test socket assembly; (b) a cooling system for improved cooling of a test socket assembly; (c) using level sensors to control the liquid coolant used in cooling of the test socket assembly; and (d) detecting the level of liquid in the test socket assembly using optical level sensors.

[0067] In the foregoing specification and the claims that follow, a number of terms are referenced that have the following meanings.

[0068] As used herein, an element or step recited in the singular and preceded with the word “a” or “an” should be understood as not excluding plural elements or steps, unless such exclusion is explicitly recited. Furthermore, references to “example implementation” or “one implementation” of the present disclosure are not intended to be interpreted as excluding the existence of additional implementations that also incorporate the recited features.

[0069] “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not.

[0070] Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about," "approximately," and "substantially," are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here, and throughout the specification and claims, range limitations may be combined or interchanged. Such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise.

[0071] Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is generally understood within the context as used to state that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present. Additionally, conjunctive language such as the phrase "at least one of X, Y, and Z," unless specifically stated otherwise, should also be understood to mean X, Y, Z, or any combination thereof, including "X, Y, and/or Z."

[0072] The systems and methods described herein are not limited to the specific embodiments described herein, but rather, components of the systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein.

[0073] Although specific features of various embodiments of the disclosure may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the disclosure, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0074] This written description uses examples to provide details on the disclosure, including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to

be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

WHAT IS CLAIMED IS:

1. A cooling system of a test socket assembly for testing a semiconductor integrated circuit (IC) chip, the cooling system comprising:

a first level sensor configured to detect that a level of a liquid coolant in a test socket assembly is at or above a first threshold;

a second level sensor configured to detect that the level of the liquid coolant is at or above a second threshold, wherein the second threshold is greater than the first threshold; and

a controller configured to adjust flow rates of the liquid coolant based on detection by the first level sensor and detection by the second level sensor such that the level of the liquid coolant is maintained between the first threshold and the second threshold.

2. The system of claim 1, wherein the controller is configured to:

adjust the flow rates by:

adjusting an input flow rate of the liquid coolant input into the test socket assembly and an output flow rate of the liquid coolant output from the test socket assembly.

3. The system of claim 2, wherein the controller is configured to:

adjust the flow rates such that the input flow rate is greater than the output flow rate when detection by the first level sensor indicates that the level is below the first threshold.

4. The system of claim 2, wherein the controller is configured to:

adjust the flow rates such that the input flow rate is less than the output flow rate when detection by the second level sensor indicates that the level is at or above the second threshold.

5. The system of claim 2, wherein the controller is configured to:

maintain the input flow rate and the output flow rate to be the same when the detection by the first level sensor indicates that the level is at or above the first threshold and the detection by the second level sensor indicates that the level is below the second threshold.

6. The system of claim 1, wherein the first level sensor comprises an optical level sensor.

7. The system of claim 1, further comprising a circulation assembly, wherein the circulation assembly comprises a tank and a cooler coupled with the tank, the system further comprising a temperature sensor configured to measure a temperature of the liquid coolant in the tank, the controller further configured to:

control operation of the cooler based on the measured temperature.

8. The system of claim 1, further comprising a circulation assembly, wherein the circulation assembly comprises one or more air tubes, one or more liquid tubes, and a connector, wherein one end of the connector is coupled to one of the one or more air tubes and one of the one or more liquid tubes.

9. The system of claim 1, wherein the controller is configured to:

remove the liquid coolant from the test socket assembly after testing of an IC chip.

10 The system of claim 1, wherein the cooling system is configured as a portable one-unit control station.

11. A method of cooling a test socket assembly for testing a semiconductor integrated circuit (IC) chip, the method comprising:

positioning a first level sensor, the first level sensor configured to detect that a level of a liquid coolant in a test socket assembly is at or above a first threshold;

positioning a second level sensor, the second level sensor configured to detect that the level of liquid coolant is at or above a second threshold, wherein the second threshold is greater than the first threshold; and

adjusting flow rates of the liquid coolant based on detection by the first level sensor and detection by the second level sensor such that the level is maintained between the first threshold and the second threshold.

12. The method of claim 11, wherein adjusting the flow rates further comprises:

adjusting an input flow rate of the liquid coolant input into the test socket assembly and an output flow rate of the liquid coolant output from the test socket assembly.

13. The method of claim 12, wherein adjusting the flow rates further comprises:

adjusting the flow rates such that the input flow rate is greater than the output flow rate when detection by the first level sensor indicates that the level is below the first threshold.

14. The method of claim 12, wherein adjusting the flow rates further comprises:

adjusting the flow rates such that the input flow rate is smaller than the output flow rate when detection by the second level sensor indicates that the level is at or above the second threshold.

15. The method of claim 12, wherein adjusting the flow rates further comprises:

maintaining the input flow rate and the output flow rate to be the same when the detection by the first level sensor indicates that the level is at or above the first threshold and the detection by the second level sensor indicates that the level is below the second threshold.

16. The method of claim 11, further comprising:

providing a circulation assembly, wherein the circulation assembly includes one or more air tubes, one or more liquid tubes, and a connector, wherein one end of the connector is coupled to one of the one or more air tubes and one of the one or more liquid tubes ;

circulating the liquid coolant through the circulation assembly during testing of an IC chip using the one or more liquid tubes; and

removing the liquid coolant from the test socket assembly.

17. The method of claim 11, wherein the first level sensor is an optical level sensor.

18. The method of claim 11, further comprising controlling operation of a cooler based on a temperature of the liquid coolant in a tank.

19. The method of claim 11, further comprising:

removing the liquid coolant from the test socket assembly after testing of an IC chip.

20. The method of claim 11, wherein adjusting the flow rates further comprises:

remotely operating cooling of the test socket assembly.