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(71) Applicant (*for all designated States except US*): **ORION SYSTEMS INTEGRATION PTE LTD** [SG/SG]; Blk 342, Ang Mo Kio, Avenue 1, #03-1561D, Singapore 560342 (SG).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **SEN, Amlan** [IN/SG]; 2, Hougang Street 92, #04-07, Singapore 538683 (SG). **KHAW, Chin Guan** [MY/SG]; 122C, Sengkang East Way, #15-35, Singapore 543122 (SG).

(74) Agent: **ELLA CHEONG SPRUSON & FERGUSON (SINGAPORE) PTE LTD**; 1531, Robinson Road Post Office, Singapore 903031 (SG).

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(54) Title: PRE-HEATING SYSTEM AND METHOD FOR SILICON DIES

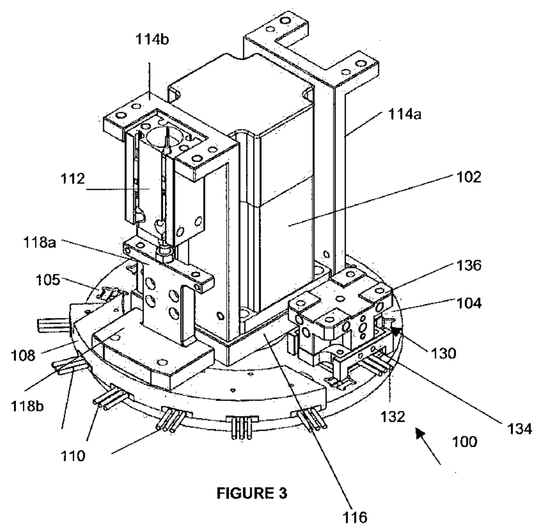

FIGURE 3

(57) Abstract: Aspects of the present invention provide a system and method for pre-heating dies and bonding the pre-heated dies to various media. The system includes a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating each of the plurality of dies at a desired average rate until a desired temperature is reached; a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and means for indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached.

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PRE-HEATING SYSTEM AND METHOD FOR SILICON DIES

FIELD OF INVENTION

Embodiments of the present invention relate to a die pre-heater for use in bonding dies to various electrical media, and a method for using the die pre-heater.

BACKGROUND

Flip Chip microelectronic assembly is the direct electrical connection of face-down, i.e. "flipped" electronic components onto substrates, circuit boards, or carriers, using conductive bumps on the chip bond pads. In conventional Flip Chip bonding, fluxing and chip placement is accomplished, then the chip is moved to a reflow oven, where the solder tip of the leads are melted and joined to the pads of the circuit board. In Thermal Compression Bonding, simultaneous chip placement and reflow is performed. During the placement process, heat is applied to the die as well as to the substrate to melt the solder bumps forming solder joints between the bumps and the bond pads on the circuit.

One problem associated with current Flip Chip assembly techniques is that the silicon dies are prone to thermal shocks. The dies, which have a low dielectric constant, can suffer circuitry fatigues at sudden high temperature exposures.

The thermal compression process requires the die to be heated from room temperature to a solder melting temperature, which can be as high as 240 °C. In order to reduce the possibility of thermal shock, a ramp rate of 10deg/sec or lower is needed. In existing thermal compression bonders, the bond tool itself preheats the die using a series of pre-programmed temperature steps. In order to achieve a desired ramp rate, the bond tool has to wait for more than 20 seconds before commencing the bonding process. This delay results in very low productivity rates for existing systems.

Another problem is the mismatch between the coefficients of thermal expansion for the dies and the substrates. Figures 1a and 1b illustrate this problem. Figure 1A shows a portion of a typical assembled system 10. The system 10 includes a component 12 connected to a substrate 14. In the construction shown below, the coefficient of thermal expansion (CTE) of the component 12 and the substrate 14 can be assumed to be different. The thermal mismatch Δu is given by Formula 1 below:

$$\Delta u = \Delta e \ X \ L \ X \ \Delta T \qquad (1)$$

where,

Δe = the difference in CTE between the materials;

L = the longest dimension of the component (often the diagonal); and

ΔT= the temperature change.

Figure 1B illustrates three examples of the system 10, assuming that the CTE of the substrate 12 is greater than the CTE of the component 12. In the first example 20, the system 10 is in thermal equilibrium. In the second example 22, the components are in a cooling stage, causing a relative shrinking of the substrate 14 with respect to the component 12. In the third example 24, the components are in a heated stage, causing a relative expansion of the substrate 14 with respect to the component 12.

SUMMARY

A first aspect of the present invention provides a system including a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating each of the plurality of dies at a desired average rate until a desired temperature is reached; a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and means for indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached.

Embodiments of the present invention may further include a bond tool assembly capable retrieving a preheated die and bonding the die to a substrate. The plurality of pre-heaters may include at least two pre-heaters. In alternate embodiments, the plurality of pre-heaters includes 6 pre-heaters. The indexing means may include a device capable of rotary indexing or linear indexing. The die holder may include a turret and the indexing means may also include a servo motor that drives the turret.

Each of the plurality of dies may be sequentially indexed for a desired time with respect to each of the pre-heaters to achieve the desired average rate. The desired indexing time may be 3 seconds. Each of the plurality of dies may be sequentially located 0.2mm from each of the plurality of heaters. The average rate may be 10 °C per second.

In some embodiments, the indexing means may move the die with respect to the pre-heaters. Alternately, the indexing means may move the pre-heaters with respect to the die.

The bond assembly may attach the die to the substrate using flip chip bonding. The die may have a bump structure selected from a group consisting of a pillar bump, a solder bump, a standard flux, a p-coat flux, and a no-flow underfill.

The system may also include a computer control system, said computer control system capable of independently controlling the desired temperature, the average rate, the indexing time, a temperature of each of the pre-heaters, and a temperature of the bond heater.

An alternate aspect of the present invention provides a method of pre-heating a die from a base temperature to a desired temperature, for subsequent attachment to a substrate, the method including the steps of: providing a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating the dies at a desired average rate until a desired temperature is reached; providing a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached.

In the method the plurality of pre-heaters may include six pre-heaters, and the temperature of the dies may be increased at an average rate of 10 °C per second.

The indexing step may include sequentially moving each or the plurality of dies with respect to each of the pre-heaters. Alternately, the indexing step may include sequentially moving each of the plurality of pre-heaters sequentially with respect to each of the plurality of dies.

In some embodiments, a temperature of each of the plurality of pre-heaters and the rate of indexing may be controlled by a computer.

The method may also include a step for joining the pre-heated die to a substrate using a using a bond heater.

Another aspect of the present invention provides a bonding system for bonding a die to a substrate, the bonding system including: a die pre-heater system including a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating each of the plurality of dies at a desired average rate until a desired temperature is reached; a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and means for indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached; and a bond tool assembly capable retrieving the preheated die and bonding the die to the substrate.

The die holder may include a turret. The indexing means may include a servo motor that drives the turret.

The plurality of pre-heaters may include 6 pre-heaters. Each of the plurality of dies may be sequentially indexed for a desired time with respect to each of the pre-heaters to achieve said desired average rate.

The bond tool assembly may attach the die to the substrate using flip chip bonding. The die may include a bump structure selected from a group consisting of a pillar bump, a solder bump, a standard flux, a p-coat flux, and a no-flow underfill.

The bonding system may also include a die pickup tool capable of picking up an individual die and placing the die into the die station. The die holder may include a turret. The indexing means may include a servo motor that drives the turret. Each of the plurality of dies may be sequentially indexed for a desired time with respect to each of the pre-heaters to achieve the desired average rate. The desired indexing time may be 3 seconds. Each of the plurality of dies may be sequentially located 0.2mm from each of the plurality of heaters. The average rate may be 10 °C per second.

The bonding system may also include a computer for controlling the indexing time, the desired temperature, the average rate, and a temperature of the bond tool assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figures 1A and 1B illustrate the problem of thermal coefficient of expansion mismatch between various components in an electrical system;

Figure 2 illustrates an exploded perspective view of one embodiment of a die pre-heater according to the present invention;

Figure 3 illustrates an assembled perspective view of the die pre-heater of Figure 2;

Figure 4 illustrates one embodiment of a die bonding machine that can be used with the die pre-heater of Figures 2 and 3;

Figure 5 illustrates a partial exploded view of a portion of the die pre-heater of Figures 2 and 3;

Figure 6 illustrates one embodiment of a method for preheating dies using the die pre-heater of Figures 2 and 3; and

Figure 7 illustrates a computer system that can be used to control the pre-heater of Figures 2 and 3 and the die bonding machine of Figure 4.

DETAILED DESCRIPTION

One aspect of the present invention provides a die pre-heater that is capable of overcoming the limitations discussed above. The die pre-heater allows the die temperature to be gradually increased from, for example, room temperature, to a desired pre-heating temperature prior to bonding the dies onto a substrate. As mentioned above, the dies can contain various electrical/electronic circuitry that may suffer fatigue if the temperature of the die is increased too rapidly.

Figure 2 illustrates an exploded perspective view of a die pre-heater, designated generally as reference numeral 100, according to the present invention. Figure 3 illustrates a perspective view of an assembled die pre-heater 100. The die pre-heater 100 can include a servo motor 102 that drives a turret 104 by means of a turret holder 106. The turret 104 can contain a plurality of die stations 105 used to pre-heat the dies prior to bonding to a substrate. The turret 104 is one example of a die holder that can be used to hold a plurality of dies for use with the die pre-heater 100. It is understood that different configurations of die holders can be used, depending on the specific types of dies to be used. The die pre-heater 100 can also include a heater holder 108 that is capable of holding a plurality of pre-heaters 110. A compact actuator 112 can be attached to the servo motor 102. The compact actuator 112 moves the pre-heater 100 away from the dies if the pre-heating process is interrupted to avoid overheating the dies. For example, if the machine jams, is idle for an extended period, or is stopped for any reason by the operator, the compact actuator 112 is automatically engaged to prevent overheating the dies.

The embodiment shown in Figures 2 and 3 illustrates 6 pre-heaters 110. However, it is understood that a larger or smaller number of pre-heaters 110 can be used. For example, as many as 15 pre-heaters 110 may be used, depending on the specific requirements of the dies being heated, and the ramp rate that is to be achieved. Similarly, the pre-heaters 110 shown in Figures 2 and 3 heat the dies by means of radiation, i.e., the dies are placed in close proximity to the pre-heaters 110. However, it is understood that convection heating of the dies using, for example, a blower motor, or conduction heating, where the pre-heaters 110 make physical contact with the dies, could also be used.

A plurality of brackets can be used to connect the various functional parts of the pre-heater 100, and to connect the pre-heater 100 to a bonding machine. This will be discussed in more detail below with respect to Figure 4. It is understood that the specific bracket(s) shown here are provided by way of illustration only. Various systems of brackets or holders can be used to connect the various functional parts of the die pre-heater 100.

In the embodiment shown in Figures 2 and 3, the pre-heater 100 can include left and right mounting brackets 114a, 114b, a turret motor bracket 116, and one or more pre-heater mounting brackets 118a, 118b. A bond tool assembly 130, that includes a bond heater 132, an insulator 134 and a bond heater mounting bracket 136 is also shown. As described in greater detail below, the bond tool assembly 130 is not attached to the pre-heater assembly 100.

The servo motor 102, pre-heaters 110, bond tool assembly 130 and bond heater 132 can include a plurality of electrical connections that provide for their operation (not shown). In some embodiments, the operation of these components can be computer controlled to provide for specific preheat times to ensure the efficiency of the bonding process, without sacrificing quality control.

The servo motor 102 can be any type of motor capable of controlling the turret 104. In some embodiments, the servo motor can be a 400 watt Mitsubishi servo motor, such as model number HFKP43K, capable of indexing the preheat turret 104 for a programmed duration. It is understood that other types of motors can be used.

In the embodiment shown in Figures 2 and 3, the die pre-heaters 110 can be an ULTRAMIC 600 Advanced Ceramic Heater, Part # CER-1-01-00130. This model is a 24 volt, 72 watt heater with a maximum temperature of 400 °C. Likewise, the bond heater 132 can be an ULTRAMIC 600 Advanced Ceramic Heater, Part # CER-1-01-00129. This model is a 240 volt, 750 watt heater with a maximum temperature of 400 °C. It is understood that different models and/or types of pre-heaters and heaters, having different electrical properties and heating characteristics, can also be used.

Figure 4 illustrates one embodiment of a bonding machine, designated generally as reference numeral 200, that can be used with the pre-heater 100 to assemble the pre-heated dies to a substrate. The bonding machine 200 can include, by way of example and not limitation, a wafer magazine 202 that feeds a wafer tensioner 204. The wafer magazine is used to feed a plurality of wafer sheets (not shown), each containing a plurality of dies for bonding in later steps to a substrate. In some embodiments, the wafer sheets can include a thin tape (blue tape), having a thickness of 20 to 30 microns, on one side. The wafer sheets can then be pre-sawn into the individual dies. The wafer tensioner is then used to stretch the pre-sawn sheets to release individual dies for pickup by a die pickup tool 216.

A tray buffer 206 can be positioned next to the substrate tensioner 204. A substrate feeder gantry 208 and a die feeder gantry 210 provide the substrates and dies that are being assembled. The die pickup tool 216 can be mounted on the die feeder gantry 210 to pick up the dies from the wafer tensioner 204 and place them into one of the die stations 105. An orientation and bump height check may be performed at this step. The dies are then preheated as described below. Once preheated, the dies are transferred to the bond tool assembly 130. Simultaneously, a substrate/PCB can be picked up and checked for print flux and substrate height, and the substrate is loaded onto a hotplate for preheating. A vision alignment and correction step is performed, and the bond tool assembly 130 is then used to bond the dies to the substrates, as described below. In some embodiments, the vision alignment is accomplished entirely by a computer 600 (Figure 7). This process is known in the art and will not be further described.

At least one die pre-heater 100 is positioned within the bonding machine 200. The die pre-heater 100 can be attached, for example, using the left and right mounting brackets 114a, 114b. The bonding machine 200 may also include the computer 600 (Figure 7) for controlling the various functions of the machine. Alternately, an external computer could be used. In these embodiments, the computer 600 can be used to individually control the temperature of the pre-heaters, the proximity of the dies on the indexing tray to the pre-heaters, the temperature of the substrate to be bonded, the temperature of the bonding tool, etc. It is understood that many different variations of the control parameters can be used depending on the specific materials being bonded and/or on the types of bonds to be performed. In some embodiments, multiple pre-heaters 100 and bond tool assemblies 130 can be used to provide for an increased bonding rate. For example, using two pre-heaters 100 and bond tool assemblies 130, 2400 bonds per hour can be performed with the bonding machine 200.

Figure 5 illustrates a partial perspective view of a portion of the pre-heater 100. As previously discussed, the turret 104 includes a plurality of die stations 105 for receiving the dies. It is understood that the die stations 105 can have various shapes and sizes depending on the type of die being used. A series of die stations 105 are labeled with sequential reference numerals 151 through 159, to represent positions 1 through 9. Figure 4 also shows the heater holder 108 containing a plurality of pre-heaters 110, and the bond tool assembly 130.

One method of pre-heating a die from a base temperature to a desired temperature, for subsequent attachment to a substrate, is illustrated in Figure 6, and designated generally as reference numeral 500. The method 500 can include a first step of providing a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating the dies at a desired average rate until a desired temperature is reached, as illustrated with reference numeral 502. A second step of providing a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies is illustrated by reference numeral 504. A final step of indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached is illustrated by reference numeral 506. Further details are discussed below.

With reference to Figures 2-6, the operation of the die pre-heater 100 as installed in the bonding machine 200 will now be described. However, it is understood that the use of the pre-heater 100 is not restricted to the specific bonding machine 200 illustrated. The pre-heater 100 can be used in any type of bonding machine that may require a die to undergo a temperature change at a desired rate before bonding takes place.

Additionally, multiple pre-heaters 100 could be used in a single bonding machine. All such applications are considered to fall within the scope of the embodiments.

The die pickup tool 216 deposits a die at position 1 (151). Every time the servo motor 102 indexes the turret 104, another die is placed at position 1 (151). When used with the bonding machine 200, the turret 104 on the pre-heater 100 can be indexed at varying time intervals in order to pre-heat a die at a desired rate and to a desired temperature. Since the turret 104 rotates to sequentially move the dies with respect to the pre-heaters 110, this form of indexing is know as rotary indexing.

For the purposes of the description, apparatus, and methods outlined in this patent application, the terms "index" and "indexing" refer to sequentially moving a die with respect to a plurality of pre-heaters to bring the die up to a desired temperature prior to bonding. While the example described provides for rotary indexing of the dies with respect to the substrate to pre-heaters 110 (i.e. the dies are moved with respect to the pre-heaters 110), it is understood that other indexing methods can also be used. For example, linear indexing can be used, in which the dies are moved in a straight line with respect to the heaters. Similarly, it is not relevant for purposes of the invention that the dies are moved with respect to the pre-heaters. It is equally possible to move the pre-heaters with respect to the dies. It is understood that all such indexing methods are to be considered as falling within the scope of the embodiments.

As the indexing of the turret 104 continues, dies sequentially move to pre-heat positions 3-8 (153-158). At the end of the indexing step at position 8 (158), the dies are heated to the desired temperature. After the next indexing step, the dies are picked up at position 9 (159) by the bond tool assembly 130. The bond tool assembly 130 then increases the temperature of the die, using bond heater 132, and the die is then bonded to a substrate.

For the embodiment discussed above, the actual amount of time it takes the turret to move is 0.2 seconds, with a 2.8 second delay to provide for the pre-heating of the die. A fresh die is therefore placed at position 1 (151) i.e. indexed, every three seconds. In this embodiment, each of the pre-heaters 110 is set at a constant temperature of 223 °C. The die temperature then ramps up from 20 °C to 200 °C in 18 seconds. This provides an average ramp rate for the dies of 10 °C/second. Similarly, the bond heater 132 temperature is set at 260 °C to effectively perform the bonding step between the die and the substrate.

For this embodiment, the silicon dies are 10mm by 10mm with a thickness of 0.75mm. The dies are positioned 0.2mm below the pre-heaters 110. In some embodiments, the indexing times, pre-heater 110 and bond heater 132 temperatures, die positioning, etc., can be controlled by computer input. This is discussed in more detail below with respect to Figure 7. It is understood that the invention is not limited to the embodiment described. Different die sizes, different pre-heater 110 and bond heater 132 temperatures, different indexing times and different die positions can also be used, depending on the specific desired parameters applied. All such changes to the individual elements are considered to fall within the scope of the present embodiments.

The bonding machine 200 and die pre-heater 100 can be used to perform various types of bonds. By way of example and not limitation, the bonder can perform thermo-compression bonding for fine pitch paper leadframes, memory modules, high pin count dies on a substrate, chip of glass, and chip on chip processes. The bonding machine 200 can create bellow shaped joints for optimum strength by precision height control and by compression-retraction techniques. The bonding machine 200 can also support different bump structures, such as, but not limited to, pillar bump, solder bump, standard flux, P-coat flux and no-flow underfill.

Some portions of the description above are explicitly or implicitly presented in terms of algorithms and functional or symbolic representations of operations on data within a computer memory. These algorithmic descriptions and functional or symbolic representations are the means used by those skilled in the manufacturing arts to control various machines and processes and to convey most effectively the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities, such as electrical, magnetic or optical signals capable of being stored, transferred, combined, compared, and otherwise manipulated.

Unless specifically stated otherwise, and as apparent from the following, it will be appreciated that throughout the present specification, discussions utilizing terms such as "calculating", "determining", "replacing", "generating", "initializing", "outputting", or the like, refer to the action and processes of a computer system, or similar electronic device, that manipulates and transforms data represented as physical quantities within the computer system into other data similarly represented as physical quantities within the computer system or other information storage, transmission or display devices. Such data can be output as electrical signals used to control various aspects of the manufacturing process described above. By way of example and not limitation, such output data can be used to control the pre-heater 110 temperature, the bond heater 132 temperature, the indexing time and the distance or gap between the die and the pre-heaters which, therefore, controls the ramp rate for the die, etc.

The present specification also discloses apparatus for performing the operations of the methods. Such apparatus may be specially constructed for the required purposes, or may comprise a general purpose computer or other device selectively activated or reconfigured by a computer program stored in the computer. The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose machines may be used with programs in accordance with the teachings herein. Alternatively, the construction of more specialized apparatus to perform the required method steps may be appropriate. The structure of a conventional general purpose computer will appear from the description below.

In addition, the present specification also implicitly discloses a computer program, in that it would be apparent to the person skilled in the art that the individual steps of the methods and manufacturing processes described herein may be put into effect by computer code. The computer program is not intended to be limited to any particular programming language and implementation thereof. It will be appreciated that a variety of programming languages and coding thereof may be used to implement the teachings of the disclosure contained herein. Moreover, the computer program is not intended to be limited to any particular control flow. There are many other variants of the computer program, which can use different control flows without departing from the spirit or scope of the invention.

Furthermore, one or more of the steps of the computer program may be performed in parallel rather than sequentially. Such a computer program may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a general purpose computer. The computer readable medium may also include a hard-wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in the GSM mobile telephone system. The computer program when loaded and executed on such a general-purpose computer effectively results in an apparatus that implements the steps of the preferred method.

The computer control of the manufacturing process may also be implemented as hardware modules. More particularly, in the hardware sense, a module is a functional hardware unit designed for use with other components or modules. For example, a module may be implemented using discrete electronic components, or it can form a portion of an entire electronic circuit such as an Application Specific Integrated Circuit (ASIC). Numerous other possibilities exist. Those skilled in the art will appreciate that the system can also be implemented as a combination of hardware and software modules.

The method and system of the example embodiment can be implemented on a computer system 600, schematically shown in Figure 7. It may be implemented as software, such as a computer program being executed within the computer system 600, and instructing the computer system 600 to control the various components of the pre-heater 100 and die bonding machine 200. For example, the computer can be used to independently control the temperature of the pre-heaters 110, the bond heater 132, the indexing time of the servo motor 102 that controls the turret 106, and the distance between the dies and the pre-heaters 106.

The computer system 600 comprises a computer module 602, input modules such as a keyboard 604 and mouse 606 and a plurality of output devices such as a display 608, and printer 610. The computer module 602 is connected to a computer network 612 via a suitable transceiver device 614, to enable access to e.g. the

Internet or other network systems such as Local Area Network (LAN) or Wide Area Network (WAN).

The computer module 602 in the example includes a processor 618, a Random Access Memory (RAM) 620 and a Read Only Memory (ROM) 622. The computer module 602 also includes a number of Input/Output (I/O) interfaces, for example I/O interface 624 to the display 608, and I/O interface 626 to the keyboard 604. The components of the computer module 602 typically communicate via an interconnected bus 628 and in a manner known to the person skilled in the relevant art.

The application program can be supplied to the user of the computer system 600 encoded on a data storage medium such as a CD-ROM or flash memory carrier and read utilizing a corresponding data storage medium drive of a data storage device 630. The application program is read and controlled in its execution by the processor 618. Intermediate storage of program data maybe accomplished using RAM 620.

The die pre-heater 100 detailed above provides several advantages over the prior art. Since the bond heater is no longer used for preheating, the cycle time to produce a die bonded to a substrate can be greatly reduced. For example, in laboratory tests using a single pre-heater, one assembled die/substrate can be produced every three seconds. As also noted above, multiple pre-heaters can be incorporated into a single die bonding machine to increase the efficiency of the die bonding process.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A system comprising:

a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating each of the plurality of dies at a desired average rate until a desired temperature is reached;

a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and

means for indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached.

2. The system of claim 1, further comprising a bond tool assembly capable retrieving a preheated die and bonding the die to a substrate.

3. The system of claims 1 or 2, wherein the plurality of pre-heaters comprises at least two pre-heaters.

4. The system of any one of the preceding claims, wherein the plurality of pre-heaters comprises 6 pre-heaters.

5. The system of any one of the preceding claims, wherein the indexing means comprises a device capable of rotary indexing or linear indexing.

6. The system of any one of the preceding claims, wherein the die holder comprises a turret and the indexing means comprises a servo motor that drives the turret.

7. The system of claim 6, wherein each of the plurality of dies is sequentially indexed for a desired time with respect to each of the pre-heaters to achieve said desired average rate.

8. The system of claim 7, wherein the desired indexing time is 3 seconds, each of the plurality of dies is sequentially located 0.2mm from each of the plurality of heaters, and the average rate is 10 °C per second.

9. The system of any one of the preceding claims, wherein the indexing means moves the die with respect to the pre-heaters.

10. The system of any one of claims 1-8, wherein the indexing means moves the pre-heaters with respect to the die.

11. The system of any one of claims 2-10, wherein the bond assembly attaches the die to the substrate using flip chip bonding, and wherein the die comprises a bump structure selected from a group consisting of a pillar bump, a solder bump, a standard flux, a p-coat flux, and a no-flow underfill.

12. The system of any one of claims 7-11, further comprising a computer control system, said computer control system capable of independently controlling the desired temperature, the average rate, the indexing time, a temperature of each of the pre-heaters, and a temperature of the bond heater.

13. A method of pre-heating a die from a base temperature to a desired temperature, for subsequent attachment to a substrate, the method comprising the steps of:

providing a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating the dies at a desired average rate until a desired temperature is reached;

providing a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and

indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached.

14. The method of claim 13, wherein the plurality of pre-heaters comprises six pre-heaters.

15. The method of one of claims 13 and 14, wherein the temperature of the dies is increased at an average rate of 10 °C per second.

16. The method of any one of claims 13-15, wherein the indexing step comprises sequentially moving each or the plurality of dies with respect to each of the pre-heaters.

17. The method of any one of claims 13-15, wherein the indexing step comprises sequentially moving each of the plurality of pre-heaters sequentially with respect to each of the plurality of dies.

18. The method of any one of claims 13-17, wherein a temperature of each of the plurality of pre-heaters and the rate of indexing is controlled by a computer.

19. The method of any one of claims 13-18, further comprising a step for joining the pre-heated die to a substrate using a using a bond heater.

20. A bonding system for bonding a die to a substrate, the bonding system comprising:

a die pre-heater system comprising:

a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating each of the plurality of dies at a desired average rate until a desired temperature is reached;

a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and

means for indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached; and

a bond tool assembly capable retrieving the preheated die and bonding the die to the substrate.

21. The bonding system of claim 20, wherein the die holder comprises a turret and the indexing means comprises a servo motor that drives the turret.

22. The bonding system of claims 20 or 21, wherein the plurality of pre-heaters comprises 6 pre-heaters, and wherein each of the plurality of dies is sequentially indexed for a desired time with respect to each of the pre-heaters to achieve said desired average rate.

23. The bonding system of any one of claims 20-22, wherein the bond tool assembly attaches the die to the substrate using flip chip bonding, and wherein the die comprises a bump structure selected from a group consisting of a pillar bump, a solder bump, a standard flux, a p-coat flux, and a no-flow underfill.

24. The bonding system of any one of claims 20-23, further comprising a die pickup tool capable of picking up an individual die and placing the die into the die station.

25. The bonding system of any one of claims 20-24, wherein the die holder comprises a turret and the indexing means comprises a servo motor that drives the turret.

26. The bonding system of claim 25, wherein each of the plurality of dies is sequentially indexed for a desired time with respect to each of the pre-heaters to achieve said desired average rate.

27. The bonding system of claim 26, wherein the desired indexing time is 3 seconds, each of the plurality of dies is sequentially located 0.2mm from each of the plurality of heaters, and the average rate is 10 °C per second.

28. The bonding system of claims 27, further comprising a computer for controlling the indexing time, the desired temperature, the average rate, and a temperature of the bond tool assembly.

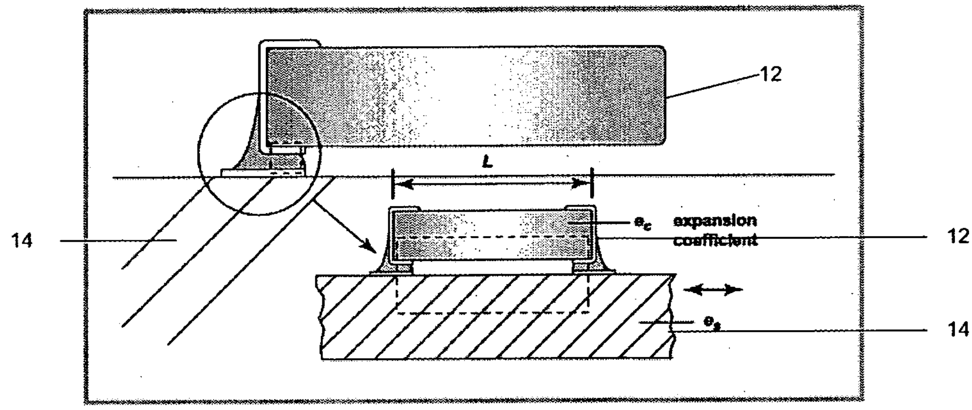
12
L
e_c expansion coefficient
12
14
e_s
14

FIG 1A

10

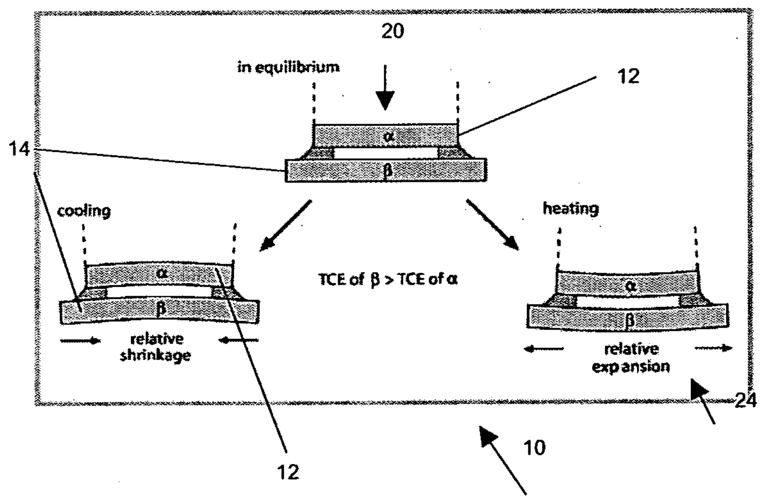
20
in equilibrium
12
14
α
β
cooling
heating
TCE of β > TCE of α
relative shrinkage
relative expansion
24
10
12

FIG 1B

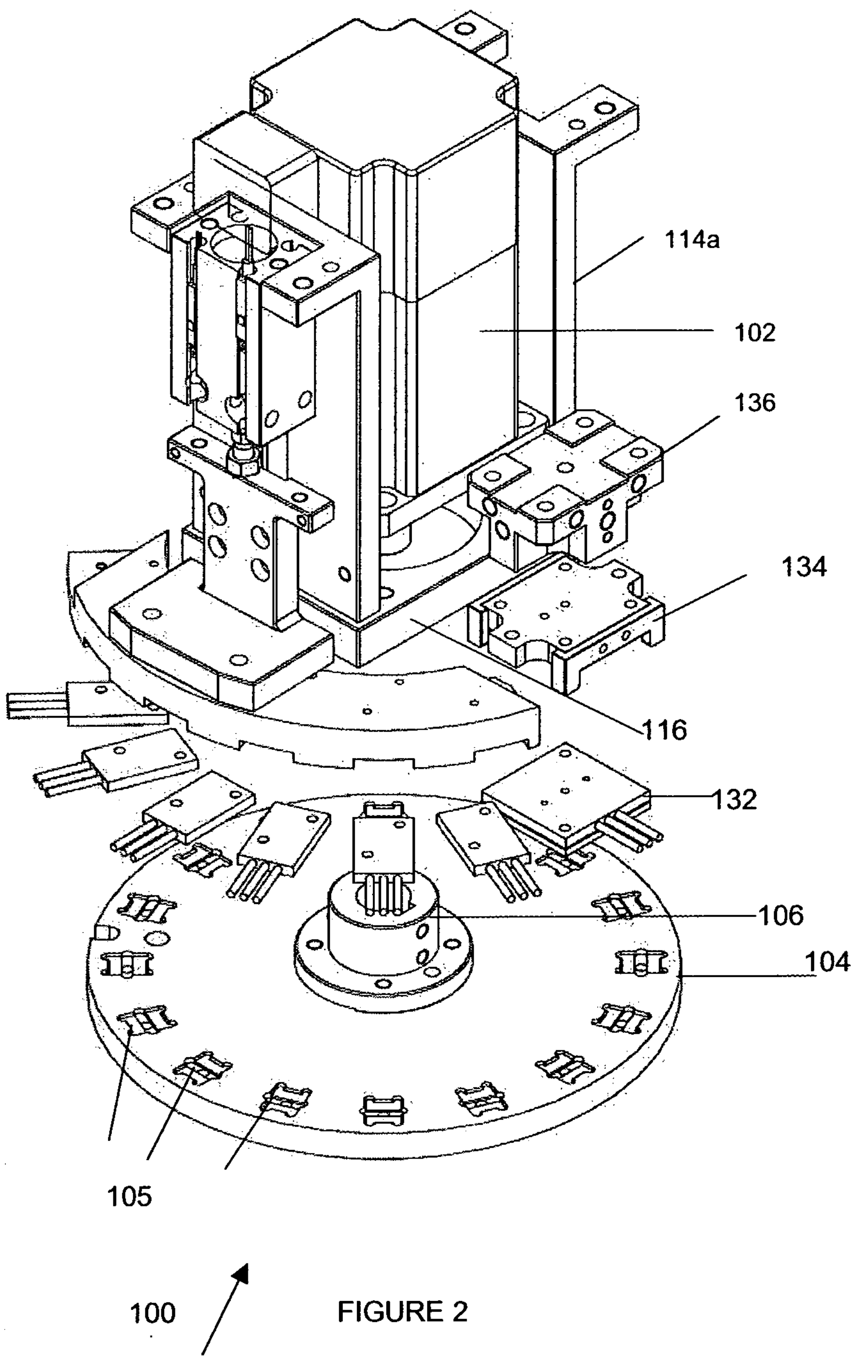

FIGURE 2

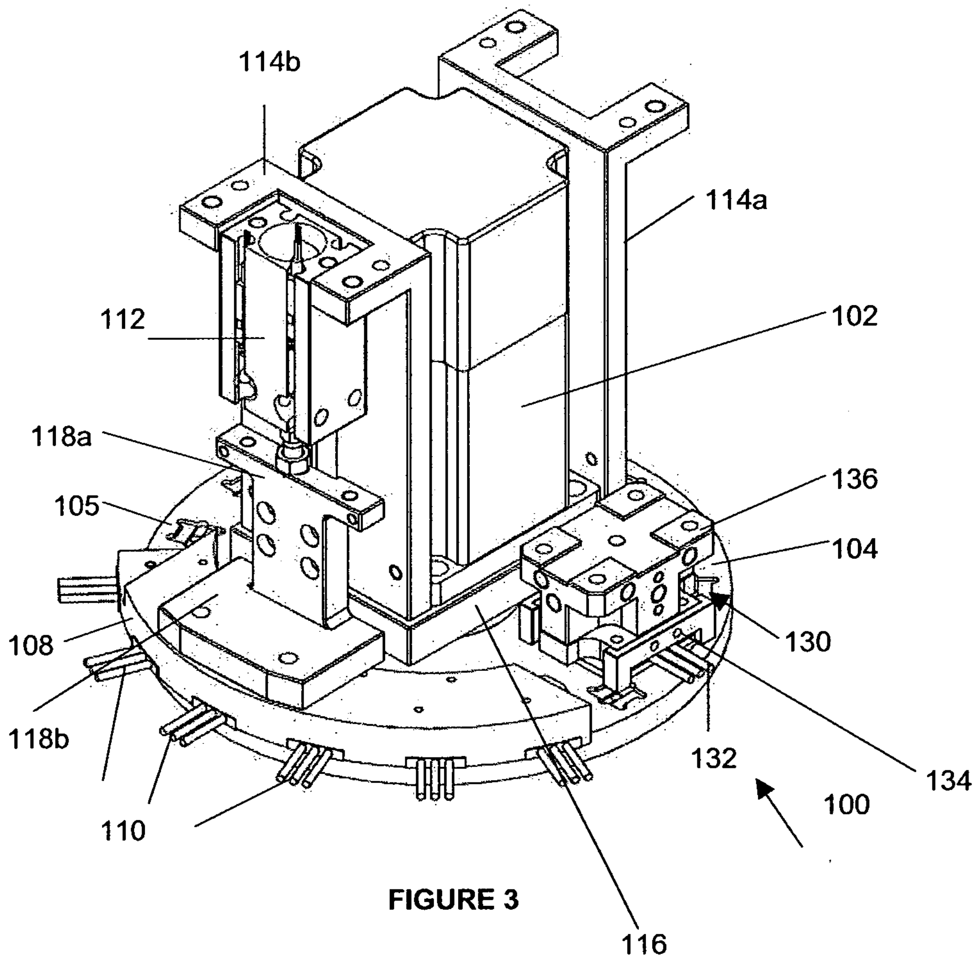
114b
114a
112
102
118a
136
105
104
130
108
118b
132
134
110
100
116

FIGURE 3

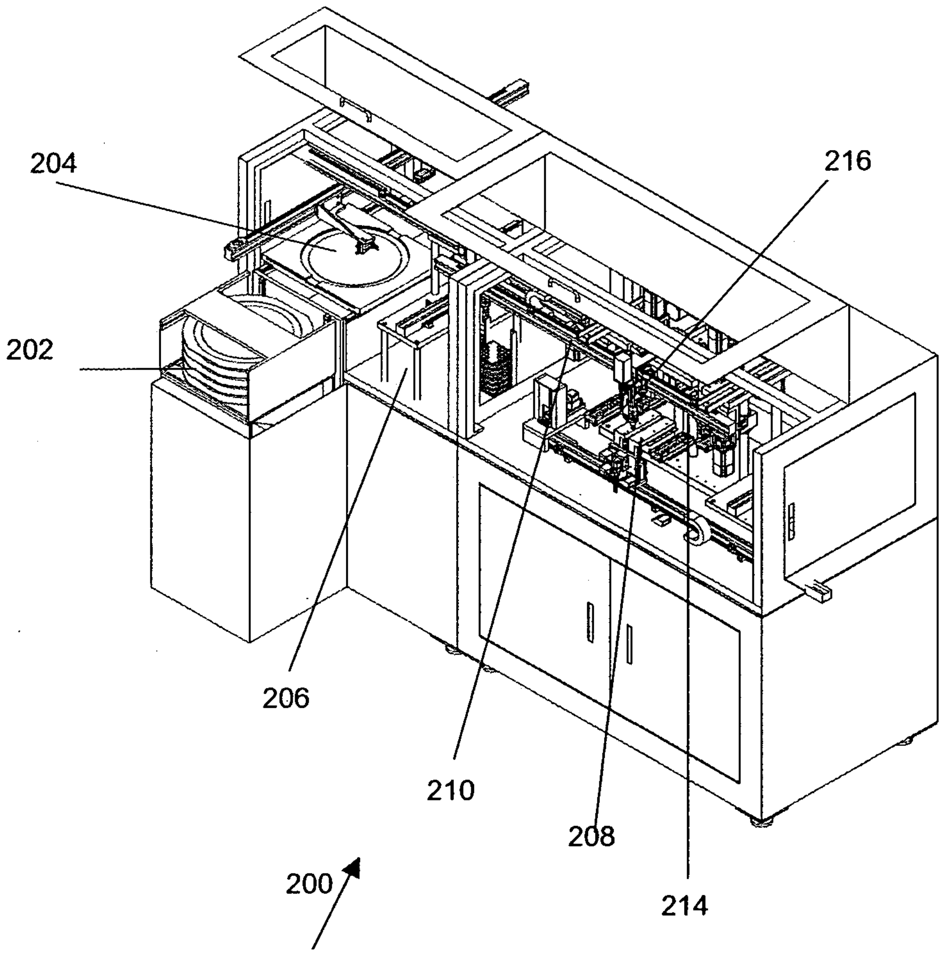

FIGURE 4

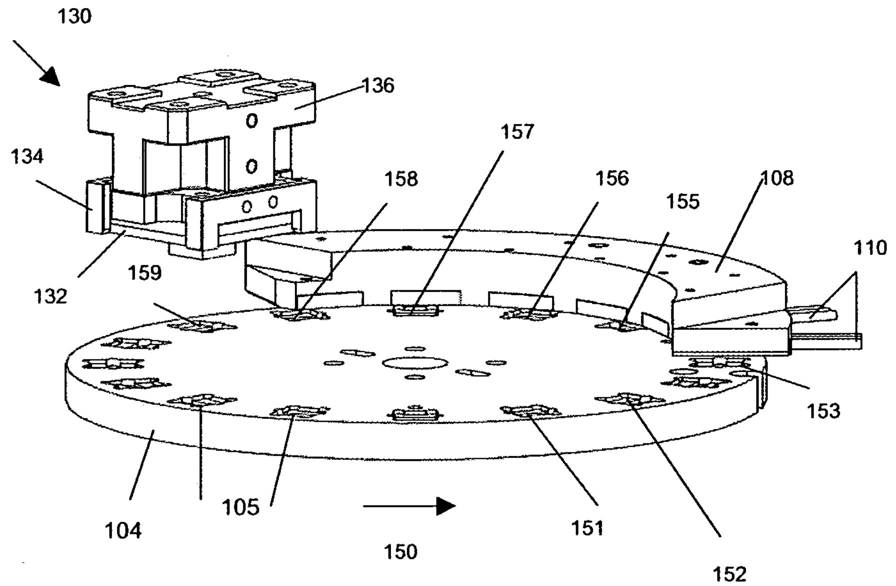
130
136
134
157
158
156
108
155
110
159
132
153
104
105
150
151
152

FIGURE 5

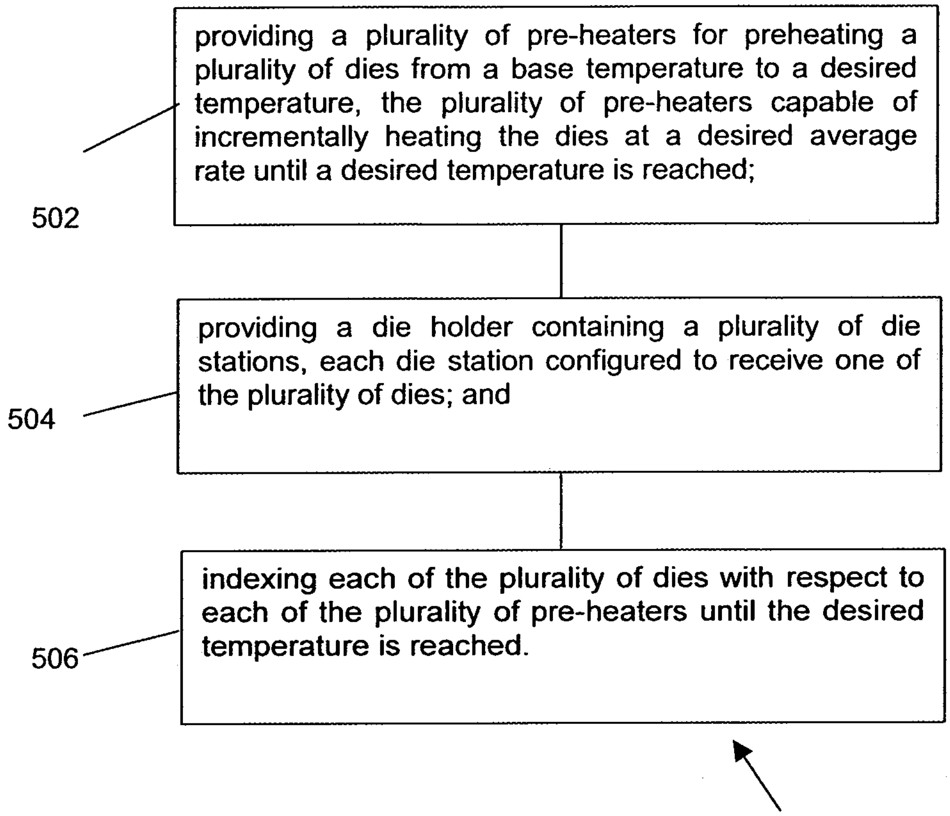
providing a plurality of pre-heaters for preheating a plurality of dies from a base temperature to a desired temperature, the plurality of pre-heaters capable of incrementally heating the dies at a desired average rate until a desired temperature is reached;
502
providing a die holder containing a plurality of die stations, each die station configured to receive one of the plurality of dies; and
504
indexing each of the plurality of dies with respect to each of the plurality of pre-heaters until the desired temperature is reached.
506
500

Figure 6

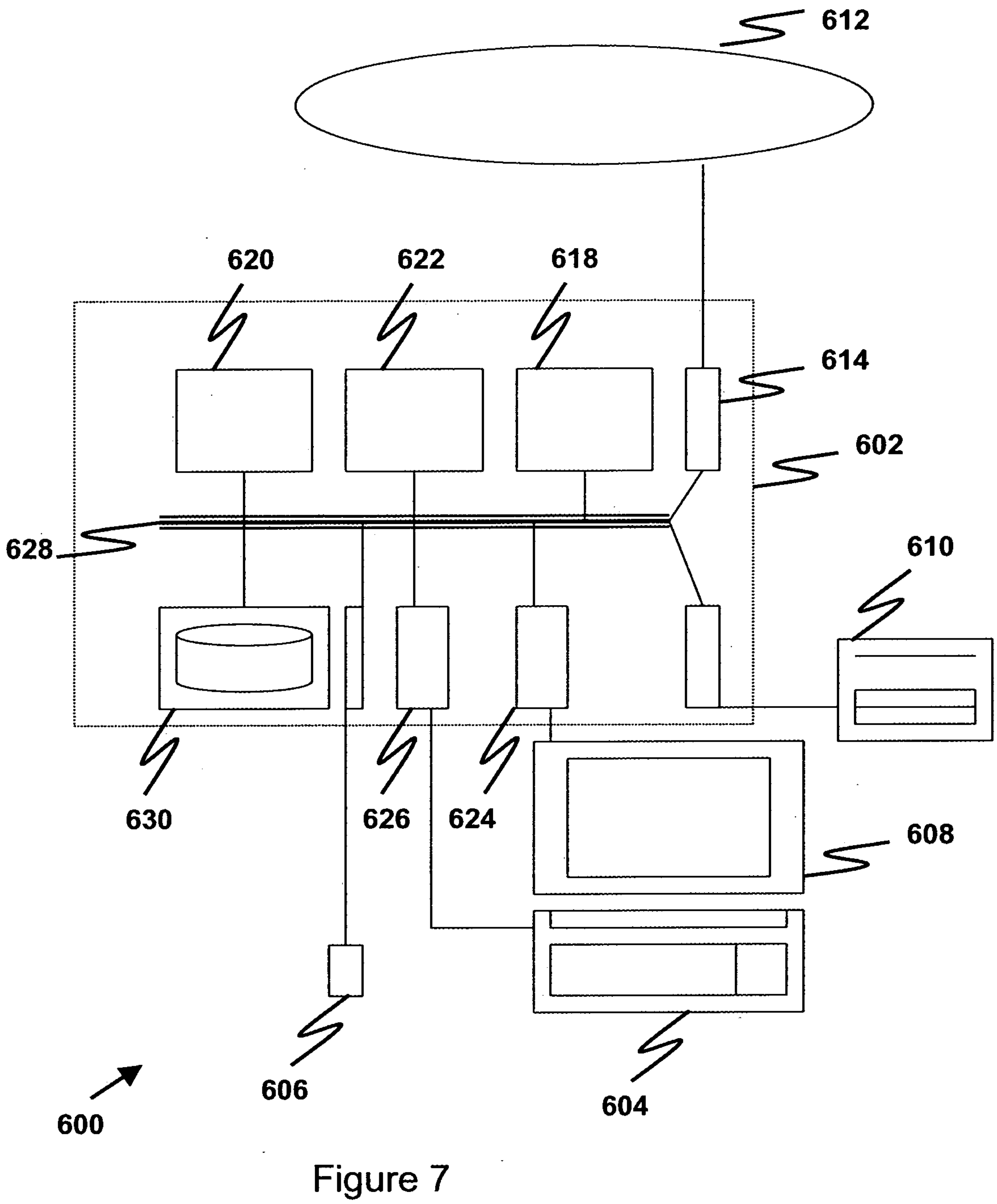

Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2007/000441

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H05K 13/04 (2006.01) ***H01L 23/34*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05K, H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI, ESP@CE, USPTO, Google Patents, Google: die, silicon, semiconductor, increment, heat, temperature, and similar words.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7,153,788 B2 (SCHROCK et al.) 26 December 2006 (See for example the abstract)	
A	US 6,911,624 B2 (KOOPMANS) 28 June 2005 (See for example the abstract, column 3 lines 35-39)	
A	US 5,259,545 A (HUANG) 9 November 1993 (See for example the abstract, figs. 1-3, column 2 lines 14-40)	

☐ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

"A"	document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 06 March 2008	Date of mailing of the international search report 17 MAR 2008
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **SAMRAT SEN** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : (02) 6283 7916

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	7153788	US	6110805	US	6562277	US	2003/0178475
		US	2007/0095280				
US	6911624	US	2004/0035840				
US	5259545	US	5188982				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX