removal of the component from a source, such as a wafer, as opposed to a warmer temperature at the time of thermocompressive bonding to a substrate).

[0005] Unpredictable expansion and contraction of the heater, resulting from heating and cooling of the heater, tends to undesirably affect the placement accuracy in thermocompression bonding applications.

[0006] Thus, it would be desirable to provide improved structures and methods for thermocompression bonding to desirably maintain the relative position of a heater during thermocompression bonding processes.

SUMMARY

[0007] According to an exemplary embodiment of the invention, a bond head assembly (also referred to as a "bond head" or "bonding head") for bonding a semiconductor element to a substrate is provided. The bond head assembly includes: base structure; a heater; and a clamping system securing the heater to the base structure, the clamping system including a plurality of elastic elements constraining the heater along a plurality of axes. The plurality of elastic elements maintain a center of the heater with respect to at least one of the plurality of axes during (i) a heating phase of a thermocompression bonding process and (ii) a cooling phase of the thermocompression bonding process.

[0008] Various exemplary details related to such a bond head assembly may include: the heater including a contact portion contacting the semiconductor element during a bonding process; the bond head assembly includes a tool secured to the heater, the tool contacting the semiconductor element during a bonding process; the heater is formed of a ceramic material; the elastic elements of the clamping system comprise a material having a coefficient of thermal expansion in a range of between 8–10 x 10^{-6} per degree Celsius, and a thermal conductivity in a range of between 5-10 Watts/(meter x degree Celsius); the base structure includes an insulating structure having a coefficient of thermal expansion in a range of between 6-12 x 10^{-6} per degree Celsius, and a thermal conductivity in a range of between 1-3 Watts/(meter x degree Celsius); the base structure defines at least one vacuum channel through which a vacuum is drawn for temporarily securing the semiconductor element to the heater during a bonding process; the base structure defines at least one cooling channel configured to transmit a cooling fluid to the heater; wherein the base structure receives electrical contacts bringing electrical energy to the heater; the plurality of elastic elements includes a plurality of elements constraining the heater along at least one substantially horizontal axis of the bond head assembly; the plurality of elastic elements includes a plurality of

elements constraining the heater along a z-axis of the bond head assembly; the clamping system includes two clamping structures arranged on opposite sides of the heater; each of the two clamping structures includes ones of the plurality of elastic elements constraining the heater along a plurality of axes of the bond head assembly; each of the two clamping structures includes ones of the plurality of elastic elements constraining the heater along a substantially horizontal axis of the bond head assembly and a substantially vertical axis of the bond head assembly; each of the two clamping structures is formed from a unitary piece of material; another elastic element is secured to each of the two clamping structures and constrains the heater along another substantially horizontal axis of the bond head assembly; at least a portion of the plurality of elastic elements are preloaded with the heater; the portion of the plurality of elastic elements are preloaded with the heater such that the portion of the preloaded plurality of elastic elements is held in tension; the preloaded portion of the plurality of elastic elements are arranged along a substantially horizontal axis of the bond head assembly; the preloaded portion of the plurality of elastic elements are arranged along a substantially vertical axis of the bond head assembly; and the plurality of elastic elements are configured to maintain the heater in a substantially balanced state along at least one of the plurality of axes of the bond head assembly, such that an elastic force acting on the heater is substantially equal along the at least one axis of the bond head assembly.

[0009] According to another exemplary embodiment of the invention, a thermocompression bonder is provided. The thermocompression bonder includes: a semiconductor element supply station including a plurality of semiconductor elements; a bonding station for holding a substrate configured to receive at least one of the semiconductor elements; and a bond head assembly for bonding the at least one semiconductor element to the substrate. The bond head assembly includes a base structure, a heater, and a clamping system for securing the heater to the base structure. The clamping system includes a plurality of elastic elements constraining the heater along a plurality of axes. The plurality of elastic elements maintain a center of the heater with respect to at least one of the plurality of axes during (i) a heating phase of a thermocompression bonding process and (ii) a cooling phase of the thermocompression bonding process.

The bond head assembly of the thermocompression bonder may include any of the various exemplary details recited in the previous paragraph. Further, the thermocompression bonder may include one or more transfer stations (e.g., see transfer station 170 in FIG. 1).

[0010] According to yet another exemplary embodiment of the invention, a method of assembling a bond head assembly is provided. The method includes the

steps of: securing a heater to a base structure using a clamping system; constraining the heater along a plurality of axes of the bond head assembly with a plurality of elastic elements of the clamping system; and using the plurality of elastic elements maintain a center of the heater with respect to at least one of the plurality of axes during (i) a heating phase of a thermocompression bonding process and (ii) a cooling phase of the thermocompression bonding process.

[0011] Various exemplary details related to such a method of assembling a bond head assembly may include: the heater including a contact portion for contacting a semiconductor element during a bonding process; a step of securing a tool to the heater wherein the tool is configured to contact the semiconductor element during a bonding process; the heater being formed of a ceramic material; the plurality of elastic elements of the clamping system comprising titanium; the plurality of elastic elements of the clamping system comprising a material having a coefficient of thermal expansion in a range of between 8–10 (10-6/°C), and a thermal conductivity in a range of between 5-10 (W/m•°C); the base structure including an insulating structure having a coefficient of thermal expansion in a range of between 6-12 (10-6/°C), and a thermal conductivity in a range of between 1-3 (W/m•°C); the base structure defining at least one vacuum channel through which a vacuum is drawn for temporarily securing a semiconductor element to the heater; the base structure defining at least one cooling channel configured to transmit a cooling fluid to the heater; the base structure receiving electrical contacts for bringing electrical energy to the heater; the heater is constrained along at least one substantially horizontal axis with ones of the plurality of elastic elements; the heater being constrained along an x-axis and a y-axis of the bond head assembly with ones of the plurality of elastic elements; the heater being constrained along a z-axis of the bond head assembly with ones of the plurality of elastic elements; the step of arranging two clamping structures of the clamping system on opposite sides of the heater; the heater being constrained along the plurality of axes using ones of the plurality of elastic elements included in each of the two clamping structures; the heater being constrained along a substantially horizontal axis of the bond head assembly and a substantially vertical axis of the bond head assembly using ones of the plurality of elastic elements of each of the two clamping structures; each of the two clamping structures being formed from a unitary piece of material; the step of securing another elastic element to each of the two clamping structures such that the heater is constrained along another substantially horizontal axis of the bond head assembly; the step of preloading at least a portion of the plurality of elastic elements using at least one of the base structure and the heater; the step of arranging the preloaded portion of the plurality of elastic elements along a substantially horizontal axis of the bond head

assembly; the step of arranging the preloaded portion of the plurality of elastic elements along a substantially vertical axis of the bond head assembly; the step of preloading at least a portion of the plurality of elastic elements with at least one of the base structure and the heater such that the preloaded portion of the plurality of elastic elements are held in tension; and the step of configuring the plurality of elastic elements to maintain the heater in a substantially balanced state along at least one of the plurality of axes, such that an elastic force acting on the heater is substantially equal along the at least one of the plurality of axes.

[0012] According to yet another exemplary embodiment of the invention, a method of operating a bond head assembly of a thermocompression bonding machine is provided. The method includes the steps of: securing a heater to a base structure using a clamping system, the clamping system including a plurality of elastic elements constraining the heater along a plurality of axes; operating the heater in connection with a thermocompression bonding process; and using the plurality of elastic elements maintain a center of the heater with respect to at least one of the plurality of axes during (i) a heating phase of a thermocompression bonding process and (ii) a cooling phase of the thermocompression bonding process.

[0013] Various exemplary details related to such a method of operating a bond head assembly may include: heating the heater, thereby expanding the heater in at least one substantially horizontal axis, and maintaining the expanded heater in a position relative to the bond head assembly by constraining the heater along the at least one substantially horizontal axis using the plurality of elastic elements; the at least one substantially horizontal axis including an x-axis and a y-axis of the thermocompression bonding machine; the step of securing the heater to the base structure including constraining the heater with ones of the elastic elements along the x-axis and the y-axis of the thermocompression bonding machine; expansion of the heater in at least one of the x-axis and the y-axis results in substantial equalization of elastic bending in the ones of the elastic elements along the at least one of the x-axis and the y-axis; a position of a center of the heater along the x-axis and the y-axis of the thermocompression bonding machine is substantially maintained during operation of the heater; the step of cooling the heater while maintaining a contact between the heater and the base structure using the clamping system; the contact between the heater and the base structure is maintained by preloading ones of the plurality of elastic elements along a z-axis of the thermocompression bonding machine; the heater includes a contact portion for contacting a semiconductor element during the thermocompression bonding process; the step of securing a tool to the heater wherein the tool is configured to contact the semiconductor element during the thermocompression bonding