or may not, include a heated thermocompression bonding tool) is provided. The method includes the steps of: (a) carrying a semiconductor element with a transfer tool; and (b) transferring the semiconductor element from the transfer tool to a bonding tool of the bonding machine without the transfer tool and the bonding tool contacting the semiconductor element at the same time. Before steps (a) and (b) a calibration step is performed. During the calibration step another semiconductor element including a non-conductive film is transferred from the transfer tool to the bonding tool. During the calibration step the non-conductive film has a viscosity of greater than 20,000 Poise. During the calibration step the transfer tool and the bonding tool contact the another semiconductor element at the same time to provide a relative position between the transfer tool and the bonding tool. After the calibration step the relative position is used for transfer of the semiconductor element to determine a gap between the transfer tool and the bonding tool during step (b).

[0006] According to the disclosure, a bonding machine (e.g., a thermocompression bonding machine which may, or may not, include a heated thermocompression bonding tool) is provided. The bonding machine includes: a bonding tool for bonding a semiconductor element to a substrate; a transfer tool for transferring the semiconductor element to the bonding tool before the semiconductor element is bonded to the substrate; and a gap defining tool for providing a predetermined gap between (a) a contact surface of the bonding tool and (b) a contact surface of the transfer tool, during transfer of the semiconductor element to the bonding tool.

[0007] According to the disclosure, a method of operating a bonding machine (e.g., a thermocompression bonding machine which may, or may not, include a heated thermocompression bonding tool) is provided. The method includes the step of: (a) carrying a semiconductor element with a transfer tool; (b) providing a predetermined gap between (i) a contact surface of the semiconductor element and (ii) a contact surface of a bonding tool, the predetermined gap being provided by a gap defining tool of the bonding machine; and (c) transferring the semiconductor element from the transfer tool to a bonding tool of the bonding machine after step (b).

[0008] According to the disclosure, a bonding machine (e.g., a thermocompression bonding machine which may, or may not, include a heated thermocompression bonding tool) is provided. The bonding machine includes: a bonding tool for bonding a semiconductor element to a substrate; and a transfer tool for transferring the semiconductor element to the bonding tool before the semiconductor element is bonded to the substrate. The transfer tool includes a cooling system for cooling a contact surface of the transfer tool.

[0009] According to another exemplary embodiment of the invention, a method of operating a bonding machine (e.g., a thermocompression bonding machine which may, or may not, include a heated thermocompression bonding tool) is provided. The method includes the steps of: (a) carrying a semiconductor element with a transfer

tool, the transfer tool including a cooling system for cooling a contact surface of the transfer tool; and (b) transferring the semiconductor element from the transfer tool to a bonding tool of the bonding machine after step (a) without the transfer tool and the bonding tool contacting the semiconductor element at the same time. Before steps (a) and (b) a calibration step is performed. During the calibration step another semiconductor element including a non-conductive film is transferred from the transfer tool to the bonding tool. During the calibration step the non-conductive film has a viscosity of greater than 20,000 Poise. During the calibration step the transfer tool and the bonding tool contact the another semiconductor element at the same time to provide a relative position between the transfer tool and the bonding tool. After the calibration step the relative position is used for transfer of the semiconductor element to determine a gap between the transfer tool and the bonding tool during step (b).

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention is best understood from the following detailed description when read in connection with the accompanying drawings. It is emphasized that, according to common practice, the various features of the drawings are not to scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. Included in the drawings are the following figures:

[0011] FIGS. 1A-1E are block diagram views illustrating a conventional semiconductor element transfer process where a semiconductor element is transferred from a transfer tool to a bonding tool;

[0012] FIGS. 2A-2E are block diagram views illustrating a semiconductor element transfer process in accordance with an exemplary embodiment of the invention where a semiconductor element is transferred from a transfer tool to a bonding tool;

[0013] FIGS. 3A-3B are block diagram views of elements of a bonding machine in accordance with an exemplary embodiment of the invention;

[0014] FIGS. 4A-4B are block diagram views of elements of another bonding machine in accordance with an exemplary embodiment of the invention; and

[0015] FIGS. 5A-5B are block diagram views of elements of a yet another bonding machine in accordance with an exemplary embodiment of the invention.

DETAILED DESCRIPTION

[0016] As used herein, the term “semiconductor element” is intended to refer to any structure including (or configured to include at a later step) a semiconductor chip or die. Exemplary semiconductor elements include a bare semiconductor die, a semiconductor die on

a substrate (e.g., a leadframe, a PCB, a carrier, a semiconductor chip, a semicondcutor wafer, a BGA substrate, a semiconductor element, etc.), a packaged semiconductor device, a flip chip semiconductor device, a die embedded in a substrate, a stack of semiconductor die, amongst others. Further, the semiconductor element may include an element configured to be bonded or otherwise included in a