

lower semiconductor die 102. As such, upper semiconductor die 106 may be termed an "overhang die".

[0005] In FIG. 1, it is desirable to form another wire loop between upper semiconductor die 106 and another location (e.g., substrate 100). FIG. 1 illustrates the beginning of the bonding process, as a ball bond 112 is being bonded (as a first bond) to a bonding location on upper semiconductor die 106 using a wire bonding tool 110 (where wire bonding tool 110 is carried by a bond head assembly 114). Because upper semiconductor die 106 is an overhang die, the die bends (i.e., die deflection, as shown in FIG. 1). This die deflection can result in damage to the overhang die itself (e.g., cracking, etc.) or damage through contact with other structures below the overhang die (e.g., such as wire loop 108).

[0006] Thus, it would be desirable to provide improved methods of controlling potential damage in connection with wire bonding in overhang die applications.

SUMMARY

[0007] According to an exemplary embodiment of the invention, a method of providing a z-axis force profile applied to a plurality of bonding locations during a wire bonding operation is provided. The method includes: (a) determining a z-axis force profile specific to each of a plurality of bonding locations on an unsupported portion of at least one reference semiconductor device; and (b) applying the z-axis force profile during subsequent bonding of a subject semiconductor device.

[0008] A method of determining a maximum bond force to be applied to a bonding location during formation of a wire bond is also provided. The method includes: (a) providing a maximum z-axis deflection value for at least one reference semiconductor device; (b) measuring z-axis deflection values at a plurality of bonding locations on at least one reference semiconductor device at a plurality of bond force values; and (c) determining the maximum bond force for each of the bonding locations.

[0009] A method of determining a z-axis constant velocity profile for formation of a wire bond is also provided. The method includes: (a) providing a maximum z-axis deflection value for a semiconductor device; (b) measuring z-axis deflection values at a plurality of bonding locations on at least one reference semiconductor device at a plurality of z-axis

constant velocity profiles; and (c) determining a z-axis constant velocity profile for each of the bonding locations.

[0010] According to yet another exemplary embodiment of the invention, a method of determining a maximum bonded ball diameter is provided. The method includes: (a) determining a maximum bond force for a bonding location on an unsupported portion of a semiconductor device for the formation of wire bonds; (b) determining a z-axis constant velocity profile for formation of wire bonds at the bonding location; and (c) determining, on a computer, a maximum bonded ball size for the bonding location using the maximum bond force determined in step (a) and the z-axis constant velocity profile in step (b).

According to another embodiment of the invention, a method of determining bonding parameters to be applied to each a plurality of bonding locations of a semiconductor device during a wire bonding operation is provided. The method includes: (a) measuring z-axis deflection values at a plurality of bonding locations on an unsupported portion of at least one reference semiconductor device at a plurality of bond force values; and (b) determining bonding parameters for each of the bonding locations using the z-axis deflection values measured during step (a), wherein the bonding parameters determined in step (b) includes at least one of optimal damping gain, maximum die settle time, maximum safe contact velocity, and maximum safe bond force.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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:

[0012] FIG. 1 is a block diagram side view of a portion of a conventional stacked die device including an overhang die;

[0013] FIG. 2 is a timing diagram illustrating a z-axis position profile of a portion of a bond head assembly of a wire bonding machine during formation of first bond of a wire loop useful in illustrating various exemplary embodiments of the invention;

[0014] FIG. 3 is a timing diagram illustrating a z-axis position profile of a portion of a bond head assembly of a wire bonding machine during formation of first bond of a wire loop in accordance with an exemplary embodiment of the invention;

[0015] FIG. 4 is a force profile illustrating a force applied by a bonding tool of a wire bonding machine during formation of a wire bond useful in illustrating various exemplary embodiments of the invention;

[0016] FIG. 5A is a simplified overhead block diagram view of an overhang die including three bonding locations useful in illustrating various exemplary embodiments of the invention;

[0017] FIG. 5B is a timing diagram illustrating a z-axis position of a portion of a bond head assembly of a wire bonding machine during formation of wire bonds at

What is Claimed:

1. A method of providing a z-axis force profile applied to a plurality of bonding locations during a wire bonding operation, the method comprising the steps of:

(a) determining a z-axis force profile specific to each of a plurality of bonding locations on an unsupported portion of at least one reference semiconductor device; and

(b) applying the z-axis force profile during subsequent bonding of a subject semiconductor device.

2. The method of claim 1 wherein step (a) includes measuring a z-axis oscillation at each of the plurality of bonding locations to determine the z-axis force profile for each of the plurality of bonding locations.

3. The method of claim 2 wherein step (a) further includes measuring the z-axis oscillation at each of the plurality of bonding locations at a plurality of z-axis force values to determine the z-axis force profile for each of the plurality of bonding locations.

4. The method of claim 2 wherein the z-axis oscillation is measured using a z-axis encoder of a bond head assembly of a wire bonding machine.

5. The method of claim 2 where the z-axis oscillation is measured in connection with an iterative process such that the z-axis force profile determined for each of the bonding locations at step (a) results in an acceptable z-axis deflection profile for each of the bonding locations.

6. The method of claim 5 where a maximum deflection value included in the z-axis deflection profile is below a predetermined threshold.

7. The method of claim 1 wherein the z-axis force profile determined in step (a) includes a profile corresponding to a portion of a wire bonding cycle including lift off of a bonding tool after a wire bond is formed.

8. The method of claim 1 wherein the z-axis force profile determined in step (a) includes a profile corresponding to a portion of a wire bonding cycle including initial impact of a free air ball with a bonding location of the semiconductor device.

9. A method of determining a maximum bonded ball diameter, the method comprising the steps of:

(a) determining a maximum bond force for a bonding location on an unsupported portion of a semiconductor device for the formation of wire bonds;

(b) determining a z-axis constant velocity profile for formation of wire bonds at the bonding location; and

(c) determining, on a computer, a maximum bonded ball size for the bonding location using the maximum bond force determined in step (a) and the z-axis constant velocity profile in step (b).

10. The method of claim 9 wherein the computer is a computer on a wire bonding machine.

11. The method of claim 9 wherein step (c) includes using at least one data structure including values related to a maximum bonded ball size, along with the maximum bond force and the z-axis constant velocity profile, to determine the maximum bonded ball size.

12. A method of determining bonding parameters to be applied to each a plurality of bonding locations of a semiconductor device during a wire bonding operation, the method comprising the steps of:

(a) measuring z-axis deflection values at a plurality of bonding locations on an unsupported portion of at least one reference semiconductor device at a plurality of bond force values; and

(b) determining bonding parameters for each of the bonding locations using the z-axis deflection values measured during step (a), wherein the bonding parameters determined in step (b) includes at least one of optimal damping gain, maximum die settle time, maximum safe contact velocity, and maximum safe bond force.

13. The method of claim 12 wherein the bonding parameters determined in step (b) includes optimal damping gain.

14. The method of claim 12 wherein the bonding parameters determined in step (b) includes maximum die settle time.

15. The method of claim 12 wherein steps (a) and (b) are performed using feedback and an iterative process.

16. The method of claim 12 wherein the bonding parameters determined in step (b) includes each of optimal damping gain, maximum die settle time, maximum safe contact velocity, and maximum safe bond force.

17. The method of claim 12 further comprising, before step (a), the step of providing a maximum z-axis deflection value for the semiconductor device.

18. The method of claim 17 wherein the step of providing the maximum z-axis deflection value includes a user providing the maximum z-axis deflection value.

19. The method of claim 17 wherein the step of providing the maximum z-axis deflection value includes automatically determining the maximum z-axis deflection value to be a value at which damage to the semiconductor device does not result.

20. The method of claim 12 wherein step (a) includes measuring the z-axis deflection values at the plurality of bonding locations at unsupported portions of the at least one reference semiconductor device.