

- 1 -

WIRE FEED SYSTEM WITH MOVEABLE GUIDE MEMBER FOR A WIRE BONDING MACHINE

FIELD OF THE INVENTION

[0001] The present invention relates to wire feed systems and, more particularly, to improved wire feed systems for wire bonding machines.

BACKGROUND OF THE INVENTION

[0002] In the processing and packaging of semiconductor devices, wire bonding continues to be the primary method of providing electrical interconnection between two locations within a package (e.g., between a die pad of a semiconductor die and a lead of a leadframe). More specifically, using a wire bonder (also known as a wire bonding machine) wire loops are formed between respective locations to be electrically interconnected.

[0003] Such wire bonding machines (e.g., ball bonding machines, wedge bonding machines, etc.) typically include a wire feed system for feeding a wire on a wire spool to a bond head of the wire bonding machine. The bond head of the wire bonding machine typically carries a transducer (e.g., an ultrasonic transducer) and a bonding tool (e.g., a capillary tool, a wedge tool, etc.).

[0004] One function of the wire feed system of a wire bonding machine is to apply air pressure (or the like) to the wire for controlling the wire, for example, to prevent wire damage and the like during high speed motions. The wire typically extends from the wire feed system to a wire tensioning device adjacent the bond head.

[0005] United States Patent No. 5,402,927 entitled "Adjustable Wire Tensioning Apparatus," United States Patent Application Publication No. US 2006/0065695 entitled "Wire Feed System For A Wire Bonding Apparatus," and International Application No. PCT/US2006/043760 (U.S. Patent Application No. 11/917,181, filed December 11, 2007) entitled "Wire Feed System for a Wire Bonding Machine and Configured to Apply a Variable Tension to the Wire; Method of Operating the Same" relate to wire bonding technology and, in particular, to wire feed and tensioning systems, and are herein incorporated by reference in their entirety.

- 2 -

[0006] FIGS. 1 and 2 are illustrations of a well-known prior art wire bonding machine and wire feed system, respectively. In FIG. 1, wire bonding machine 100 includes wire feed system 102 (sometimes referred to as the "upper console") and optics housing/bondhead 104 (both wire feed system 102 and optics housing/bondhead 104 are partially covered by a microscope in FIG. 1). Conventional wire tensioner 106 (see FIG. 2) may be mounted to optics housing/bondhead 104. Various other components of wire bonding machine 100 are not shown in FIG. 1 for simplicity.

[0007] FIG. 2 is a more detailed view of certain components of wire bonding machine 100 including (1) wire feed system 102 and (2) components of optics housing/bondhead 104. The illustrated components of optics housing/bondhead 104 include wire tensioner 106, wire clamp assembly 108, ultrasonic transducer 110, and wire bonding tool 112 (other components of optics housing/bondhead 104, including certain components providing interconnection between the illustrated components of optics housing/bondhead 104, are not shown in FIG. 2).

[0008] Wire feed system 102 (of which certain components are omitted for clarity) includes a wire supply, such as wire spool 116, fixed wire guide bar 120 (e.g., diverter bar 120), and air guide 118. As a unit, these components are stationary elements of wire bonding machine 100 and do not travel with optics housing/bondhead 104. Wire spool 116 is directly driven by a motor (not shown) to rotate in order to move wire 114 from wire spool 116 to air guide 118. As illustrated in FIG. 2, wire 114 extends from wire spool 116 and rides along fixed wire guide bar 120 and through air guide 118, ultimately being routed downward to wire bonding tool 112.

[0009] FIG. 3 is a block diagram of wire feed system 102 showing a detailed representation of conventional air guide 118. Air guide 118 includes capstans 122a, 122b, and sensor 124 (shown adjacent capstan 122a). Pressurized fluid (e.g., air) is injected into air guide 118 at air inlet 126 as wire 114 extends from wire spool 116 and rides along fixed wire guide bar 120 and through air guide 118. As illustrated, movement of wire 114 (urged by injected air) is limited by capstans 122a, 122b, and the relative position of wire 114 is monitored by sensor 124. More specifically, sensor 124 may be, for example, a detection element for use in a control scheme, or a stop/guide element for defining a specified boundary.

[0010] It will be appreciated by those skilled in the art that wire tension is provided by wire tensioner 106 (represented in FIG. 2) and air guide 118. It will further be appreciated that wire in relatively close proximity to air inlet 126 (as

represented by, e.g., wire 114a) is under more tension from the pressurized fluid entering air guide 118 at air inlet 126 as compared to wire that is relatively distant from air inlet 126 (as represented by, e.g., wire 114b). More specifically, wire 114b is in a slack condition (as compared to wire 114a) in slack area 128 of air guide 118.

[0011] In broad terms, conventional wire feed system 102 includes a member (fixed wire guide bar 120) located between the point at which wire 114 is directly driven (wire spool 116) and air guide 118. Thus, wire 114 rides along such a member (fixed wire guide bar 120) and may experience drag due to the resultant friction. More specifically, wire guide bar 120 of conventional wire feed system 102 is fixed and, as such, wire 114 continuously rides along substantially the same point on the outer surface of fixed wire guide bar 120 as wire 114 extends from wire spool 116 through air guide 118. Due in part to the vertical position of fixed wire guide bar 120 relative to wire spool 116 and air guide 118, as wire 114 is fed through wire feed system 102, wire 114 contacts substantially one point of fixed wire guide bar 120 in a dragging motion. Such continuous movement of wire 114 along one point of fixed wire guide bar 120 may cause at least one of the following conditions, each resulting in impaired operation of wire feed system 102: (1) excessive wear, corrosion, or damage to wire guide bar 120 at the point of contact (requiring, e.g., cleaning or premature replacement of wire guide bar 120 and/or causing damage to wire 114); (2) a build-up of contaminants transferred from wire 114 to the point of contact on wire guide bar 120 (causing, e.g., damage to wire 114); (3) excessive drag on wire 114 (impacting, e.g., the tension of wire 114 through air guide 118); and (4) a limited electrical connection (based on the substantially one-point contact between wire 114 and fixed wire guide bar 120) for detecting the integrity of a wire bond formed by wire bonding machine 100, amongst others.

[0012] Thus, it would be desirable to provide an improved wire feed system for a wire bonding machine to overcome one or more of the deficiencies of the prior art.

SUMMARY OF THE INVENTION

[0013] According to a first aspect of the present invention, there is provided a wire feed system for a wire bonding machine, the wire feed system comprising: a wire supply; an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire; and a moveable guide member, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the movement of the moveable guide member is rotation, wherein the wire supply comprises a wire spool configured to rotate in order to move the length of wire from the wire supply to the air guide, and wherein the moveable guide member and the wire spool are configured for simultaneous rotation.

[0014] According to a second aspect of the present invention, there is provided a wire feed system for a wire bonding machine, the wire feed system comprising: a wire supply; an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire; and a moveable guide member, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the moveable guide member is positioned such that the moveable guide member is above (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

[0015] According to a third aspect of the present invention, there is provided a wire feed system for a wire bonding machine, the wire feed system comprising: a wire supply; an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire; and a moveable guide member, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the moveable guide member is positioned such that the moveable guide member is below (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

[0015a] According to a fourth aspect of the present invention, there is provided a wire feed system for a wire bonding machine, the wire feed system comprising: a wire supply including a wire spool; an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, the wire spool configured to rotate in order to move the length of wire from the wire supply to the air guide; and a rotatable diverter bar, wherein rotation of the rotatable diverter bar guides wire between the wire supply and the air guide, the diverter bar and the wire spool being configured for simultaneous rotation.

[0015b] According to a fifth aspect of the present invention, there is provided a wire bonding machine comprising: a wire bonding tool for receiving wire and for bonding the wire to bonding locations; and a wire feed system for feeding wire to the wire bonding tool, the wire feed system including a wire supply, an air guide for

receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, and a moveable guide member, the guide member being conductive, wherein movement of the moveable guide member guides wire between the wire supply and the air guide wherein the movement of the moveable guide member is rotation, wherein the wire supply of the wire feed system comprises a wire spool configured to rotate in order to move the length of wire from the wire supply to the air guide, and wherein the moveable guide member and the wire spool are configured for simultaneous rotation.

[0015c] According to a sixth aspect of the present invention, there is provided a wire bonding machine comprising: a wire bonding tool for receiving wire and for bonding the wire to bonding locations; and a wire feed system for feeding wire to the wire bonding tool, the wire feed system including a wire supply, an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, and a moveable guide member, the guide member being conductive, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the moveable guide member is positioned such that the moveable guide member is above (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

[0015d] According to a seventh aspect of the present invention, there is provided a wire bonding machine comprising: a wire bonding tool for receiving wire and for bonding the wire to bonding locations; and a wire feed system for feeding wire to the wire bonding tool, the wire feed system including a wire supply, an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, and a moveable guide member, the guide member being conductive, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the moveable guide member is positioned such that the moveable guide member is below (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention is best understood from the following detailed description when read in connection with the accompanying drawing. It is emphasized that, according to common practice, the various features of the drawing are not to scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. Included in the drawing are the following figures:

FIG. 1 is a front elevation of a conventional wire bonding machine;

FIG. 2 is a detail view of certain components of the wire bonding machine of FIG. 1;

FIG. 3 is a block diagram of a wire feed system of FIG. 2;

FIG. 4 is a block diagram of a wire feed system in accordance with an exemplary embodiment of the present invention;

FIG. 5 is a block diagram of a wire feed system in accordance with another exemplary embodiment of the present invention;

- 5 -

FIG. 6 is a block diagram of a wire feed system in accordance with yet another exemplary embodiment of the present invention;

FIG. 7 is a block diagram of a wire feed system in accordance with yet another exemplary embodiment of the present invention;

FIG. 8 is a block diagram of a wire feed system in accordance with yet another exemplary embodiment of the present invention; and

FIG. 9 is a detail view of certain components of a wire bonding machine in accordance with yet another exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] As explained above, an improved wire feed system for a wire bonding machine is desirable in the processing of semiconductor devices. Generally, as wire is fed through a conventional wire feed system, the wire contacts substantially one point of a fixed wire guide bar in a dragging motion. According to certain exemplary embodiments of the present invention, an improved wire feed system includes a moveable guide member (e.g., an improved, strategically positioned, rotatable wire guide bar) that effectively guides the wire from a wire spool through an air guide of the wire feed system. Such an improved wire feed system may improve the overall performance of the wire feed system by, for example, (1) utilizing the entire circumferential (i.e., 360°) outer surface of the wire guide bar for contact with the wire due to the rotation of the wire guide bar, and (2) increasing the points of contact between the wire and the wire guide bar at any given time during a wire feed operation due to a strategic vertical position of the rotatable wire guide bar relative to an exit portion of the wire spool and an entry portion of the air guide, resulting in wrapping of the wire around a substantial portion of the rotating wire guide bar.

[0018] Regarding the rotation of the wire guide bar, as the wire is guided from the wire spool through the air guide, the wire contacts the wire guide bar. Because the wire guide bar is rotating, its contact points with the wire are circumferential (i.e., 360°) around the outer surface of the wire guide bar. In other words, as the wire is fed from the wire spool, it is guided by the rotating wire guide bar resulting in continuous contact between points along the wire and points around the substantially curved outer surface of the wire guide bar. Such an exemplary configuration of substantially continuous contact along various circumferential points of the rotatable guide bar reduces the likelihood of (1) excessive wear, corrosion, or damage to the wire guide bar

- 6 -

at any one point of contact, and (2) a build-up of contaminants transferred from the wire to any one point of contact on the wire guide bar. Furthermore, the rotation of the wire guide bar in a particular direction facilitates movement of the wire in that same direction, thereby reducing the likelihood of excessive drag on the wire.

[0019] As to the strategic vertical position of the rotatable wire guide bar, for example, positioning of the wire guide bar (1) above the wire exit portion of the wire spool and the wire entry portion of the air guide (as will be described in greater detail below with reference to FIGS. 5 and 6), or (2) below the wire exit portion of the wire spool and the wire entry portion the air guide (as will be described in greater detail below with reference to FIGS. 7 and 8), tends to result in increased wrapping of the wire around a portion of the wire guide bar. This wrapping feature, in turn, results in increased points of contact (i.e., multi-point contact) between the wire and the wire guide bar at any given time during a wire feed operation. Such an exemplary configuration of a wire guide bar strategically positioned higher or lower in relation to the exit portion of the wire spool and the entry portion of the air guide improves the electrical connection (due to the multi-point contact between the wire and the wire guide bar) for detecting the integrity of a wire bond formed by a wire bonding machine (as will be described in greater detail below with reference to FIG. 9) as compared to conventional wire feed systems.

[0020] Referring to FIG. 4, wire feed system 402 for a wire bonding machine (not shown) includes a wire supply (e.g., wire spool 416) and air guide 418 for receiving a length of wire 414 from wire spool 416 and provides a fluid tension to the length of wire 414. Similar to the components of wire feed system 102 described above with reference to FIG. 3, air guide 418 of wire feed system 402 may include capstans, a sensor, and an air inlet for the injection of pressurized fluid (e.g., air) into air guide 418. For the sake of clarity, however, these components of air guide 418 are not represented in FIG. 4, nor are they represented in the various exemplary embodiments of FIGS. 5 - 9. Furthermore, although two capstans 122a, 122b, one sensor 124, and one air inlet 126 are represented in FIG. 3, the invention is not limited to such a configuration. The present invention may include any number of capstans, sensors, and air inlets in a variety configurations, and other components, as desired.

[0021] Wire spool 416 is configured to rotate in order to move the length of wire 414 from the wire supply to air guide 418. Wire feed system 402 further includes a moveable guide member (i.e., rotatable diverter bar 420). Rotation of diverter bar 420 guides wire 414 between the wire supply (i.e., wire spool 416) and air guide 418. As

- 7 -

wire 414 is guided between wire spool 416 and air guide 418, exit portion 416b represents the point at which wire 414 is released from wire spool 416 and extends toward diverter bar 420, and entry portion 418a represents the point at which air guide 418 receives wire 414 from wire spool 416.

[0022] Belt 430 links diverter bar 420 and wire spool 416 together to facilitate simultaneous rotation of diverter bar 420 and wire spool 416. Diverter bar 420 has a length that extends along a plane substantially perpendicular to that of the page of FIG. 4. As shown, wire 414 wraps around wire spool 416 in a clockwise direction, extends from exit portion 416b, is guided by diverter bar 420, extends to entry portion 418a, and passes downward to a wire bonding tool (not shown in FIG. 4, but represented as 912 in FIG. 9). Due to the front elevation view of wire feed system 402 in FIG. 4 (and wire feed systems 502, 602, 702, 802, 902 of FIGS. 5 - 9, respectively), the portion of belt 430 and wire 414 that extend between wire spool 416 and diverter bar 420 in a clockwise direction appear to overlap one another. In other words, the portion of belt 430 that extends between wire spool 416 and diverter bar 420 wraps around diverter bar 420 at a point along the length of diverter bar 420, and the portion of wire 414 that extends from exit portion 416b to entry portion 418a contacts diverter bar 420 at another point along the length of diverter bar 420 (either behind or in front of belt 430 as viewed in FIG. 4). This configuration is consistent throughout the various exemplary embodiments of the present invention illustrated in FIGS. 4 - 9, and is represented by different line weights of belt 430 and wire 414 for the sake of clarity.

[0023] Rotation of diverter bar 420 is directly driven by a motor (not shown). Alternatively, rotation of wire spool 416 may be directly driven by a motor (not shown). In another example, an indirect motor coupling may be used to rotate one or both of diverter bar 420 and wire spool 416. In any of these examples, both components (diverter bar 420 and wire spool 416) rotate simultaneously in the same direction (clockwise or counterclockwise) due to belt 430. The present invention is not limited to belt 430, as diverter bar 420 and wire spool 416 may be linked via a chain or any other closed loop component that achieves the desired linking feature.

[0024] In use, diverter bar 420 is generally driven by a motor to rotate in a clockwise direction. Wire spool 416 is driven simultaneously with diverter bar 420 in a clockwise direction via belt 430. Such clockwise rotation of wire spool 416 causes wire 414 to be fed from wire spool 416 and guided by diverter bar 420 through air guide 418 and passed downward to a wire bonding tool (not shown in FIG. 4, but represented as 912 in FIG. 9).

- 8 -

[0025] The rotation of diverter bar 420 in a clockwise direction facilitates movement of wire 414 toward air guide 418, thereby reducing the likelihood of excessive drag on wire 414. Because diverter bar 420 is rotating, the contact points between diverter bar 420 and wire 414 are circumferential (i.e., 360°) around the outer surface of diverter bar 420. In other words, as wire 414 is fed from wire spool 416, it is guided by rotating diverter bar 420 resulting in continuous contact between points along wire 414 and points around the substantially curved outer surface of diverter bar 420. Such substantially continuous contact along various circumferential points of diverter bar 420 reduces the likelihood of excessive wear, corrosion, or damage to diverter bar 420 at any one point of contact. In other words, any wear or corrosion pattern that forms from the continuous movement of wire 414 along diverter bar 420 will be distributed around the entire circumference of diverter bar 420, thereby helping to minimize any negative impact of such wear or corrosion. These advantages are consistent throughout the various exemplary embodiments of the present invention illustrated in FIGS. 5 - 9, more specifically, the reduction of the likelihood of excessive wear, corrosion, or damage to diverter bar 520, 620, 720, 820, 920 at any one point of contact.

[0026] The substantially continuous contact along various circumferential points of diverter bar 420 also reduces the likelihood of a build-up of contaminants (e.g., grease, oil, dirt, etc.) transferred from wire 414 to any one point of contact on diverter bar 420. In other words, any contaminants that are transferred from wire 414 as it is guided by diverter bar 420 will be distributed around the entire circumference of diverter bar 420, thereby helping to minimize any negative impact of a build-up of such contaminants. These advantages are consistent throughout the various exemplary embodiments of the present invention illustrated in FIGS. 5 - 9, more specifically, the reduction of the likelihood of a build-up of contaminants at any one point of contact on diverter bar 520, 620, 720, 820, 920.

[0027] As represented by the two-headed arrow in FIG. 4, diverter bar 420 (and wire spool 416 via belt 430) may optionally be driven in a counterclockwise direction resulting in the return of wire 414 onto wire spool 416. Such optional counterclockwise movement may be desired, for example, to assist in the tension adjustment of wire 414 or to assist in other aspects of a wire feed operation. This optional rotation principle is consistent throughout the various exemplary embodiments of the present invention illustrated in FIGS. 5 - 9. More specifically, diverter bar 520, 620, 920 may optionally be driven in a counterclockwise direction resulting in the return of wire 514, 614, 914 onto wire spool 516, 616, 916. Similarly, diverter bar 720, 820 may optionally be

- 9 -

driven in a clockwise direction resulting in the return of wire 714, 814 onto wire spool 716, 816.

[0028] Referring to FIG. 5, wire feed system 502 includes a wire supply (i.e., wire spool 516) and air guide 518 for receiving a length of wire 514 from wire spool 516. Similar to wire feed system 402 described above with reference to FIG. 4, wire feed system 502 further includes rotatable diverter bar 520 configured to guide wire 514 between wire spool 516 and air guide 518. As wire 514 is guided between wire spool 516 and air guide 518, exit portion 516b represents the point at which wire 514 is released from wire spool 516 and extends toward diverter bar 520, and entry portion 518a represents the point at which air guide 518 receives wire 514 from wire spool 516. Belt 530 links diverter bar 520 and wire spool 516 together to facilitate simultaneous rotation in the same direction (clockwise or counterclockwise, as represented by the two-headed arrow in FIG. 5) of diverter bar 520 and wire spool 516. Rotation of diverter bar 520 is directly driven by a motor (not shown) and, alternatively, rotation of wire spool 516 may be directly driven by a motor (not shown).

[0029] Diverter bar 520 is positioned such that it is above (1) exit portion 516b of wire spool 516 where wire 514 exits wire spool 516 and extends toward diverter bar 520, and (2) entry portion 518a of air guide 518 where air guide 518 receives wire 514 from wire spool 516, resulting in wrapping of wire 514 around a substantial portion of diverter bar 520. In other words, the positioning of diverter bar 520 above exit portion 516b of wire spool 516 and entry portion 518a of air guide 518 (as represented in FIG. 5) results in increased wrapping of wire 514 around a portion of diverter bar 520 (as compared to the configuration of conventional wire feed system 102 represented in FIG. 3). This wrapping feature, in turn, results in increased points of contact (i.e., multi-point contact) between wire 514 and diverter bar 520 at any given time during a wire feed operation. Such higher placement of diverter bar 520 in relation to exit portion 516b and entry portion 518a improves the electrical connection (due to the multi-point contact between wire 514 and diverter bar 520) for detecting the integrity of a wire bond formed by a wire bonding machine (as will be described in greater detail below with reference to FIG. 9) as compared to conventional wire feed systems.

[0030] In use, diverter bar 520 is generally driven by a motor to rotate in a clockwise direction, and wire spool 516 is driven simultaneously with diverter bar 520 in a clockwise direction via belt 530. Such clockwise rotation of wire spool 516 causes wire 514 to be fed from wire spool 516 and guided by diverter bar 520 through air

- 10 -

guide 518 and passed downward to a wire bonding tool (not shown in FIG. 5, but represented as 912 in FIG. 9).

[0031] The rotation of diverter bar 520 in a clockwise direction facilitates movement of wire 514 toward air guide 518, thereby reducing the likelihood of excessive drag on wire 514.

[0032] Referring to FIG. 6, wire feed system 602 is similar in most respects to wire feed system 502 described above with reference to FIG. 5, with the exception of diverter bar 620 being positioned further from exit portion 516b of wire spool 616 (toward the right-hand side of FIG. 6) as compared to diverter bar 520 of wire feed system 502. More specifically, wire feed system 602 includes wire spool 616 having exit portion 616b, air guide 618 for receiving a length of wire 614 from wire spool 616 (air guide 618 having entry portion 618a), rotatable diverter bar 620 directly driven by a motor (not shown), and belt 630 to facilitate simultaneous rotation of diverter bar 620 and wire spool 616.

[0033] Similar to diverter bar 520 described above with reference to FIG. 5, diverter bar 620 is positioned such that it is above exit portion 616b of wire spool 616 and entry portion 618a of air guide 618, resulting in wrapping of wire 614 around a substantial portion of diverter bar 620. The placement of diverter bar 620 further from exit portion 616b of wire spool 616 (as represented in FIG. 6) tends to result in even greater wrapping of wire 614 around a portion of diverter bar 620 (as compared to the configuration of wire feed system 502 represented in FIG. 5). This increased wrapping feature, in turn, results in further increased points of contact (i.e., multi-point contact) between wire 614 and diverter bar 620 at any given time during a wire feed operation, thereby further improving the electrical connection (as will be described in greater detail below with reference to FIG. 9).

[0034] In use, diverter bar 620 is generally driven by a motor to rotate in a clockwise direction, and wire spool 616 is driven simultaneously with diverter bar 620 in a clockwise direction via belt 630. Such clockwise rotation of wire spool 616 causes wire 614 to be fed from wire spool 616 and guided by diverter bar 620 through air guide 618 and passed downward to a wire bonding tool (not shown in FIG. 6, but represented as 912 in FIG. 9).

[0035] The rotation of diverter bar 620 in a clockwise direction facilitates movement of wire 614 toward air guide 618, thereby reducing the likelihood of excessive drag on wire 614.

- 11 -

[0036] Referring to FIG. 7, wire feed system 702 includes wire spool 716 having exit portion 716b, air guide 718 for receiving a length of wire 714 from wire spool 716 (air guide having entry portion 718a), rotatable diverter bar 720 directly driven by a motor (not shown), and belt 730 to facilitate simultaneous rotation of diverter bar 720 and wire spool 716.

[0037] Similar to diverter bar 520, 620 described above with reference to FIGS. 5 and 6, respectively, diverter bar 720 is mounted in a strategic vertical position relative to exit portion 716b of wire spool 716 and entry portion 718a of air guide 718, resulting in wrapping of wire 714 around a substantial portion of diverter bar 720. In contrast, however, to diverter bar 520, 620, diverter bar 720 is positioned such that it is below exit portion 716b of wire spool 716 and entry portion 718a of air guide 718. Such positioning of diverter bar 720 below exit portion 716b and entry portion 718a results in increased wrapping of wire 714 around a portion of diverter bar 720 (as compared to the configuration of conventional wire feed system 102 represented in FIG. 3). This increased wrapping feature, in turn, results in increased points of contact (i.e., multi-point contact) between wire 714 and diverter bar 720 at any given time during a wire feed operation, thereby improving the electrical connection (as will be described in greater detail below with reference to FIG. 9).

[0038] In use, diverter bar 720 is generally driven by a motor to rotate in a counterclockwise direction, and wire spool 716 is driven simultaneously with diverter bar 720 in a counterclockwise direction via belt 730. Such counterclockwise rotation of wire spool 716 causes wire 714 to be fed from wire spool 716 and guided by diverter bar 720 through air guide 718 and passed downward to a wire bonding tool (not shown in FIG. 7, but represented as 912 in FIG. 9).

[0039] The rotation of diverter bar 720 in a counterclockwise direction facilitates movement of wire 714 toward air guide 718, thereby reducing the likelihood of excessive drag on wire 714.

[0040] Referring to FIG. 8, wire feed system 802 is similar in most respects to wire feed system 702 described above with reference to FIG. 7, with the exception of diverter bar 820 being positioned further from exit portion 816b of wire spool 816 (toward the right-hand side of FIG. 8) as compared to diverter bar 720 of wire feed system 702. More specifically, wire feed system 802 includes wire spool 816 having exit portion 816b, air guide 818 for receiving a length of wire 814 from wire spool 816 (air guide 818 having entry portion 818a), rotatable diverter bar 820 directly driven by

- 12 -

a motor (not shown), and belt 830 to facilitate simultaneous rotation of diverter bar 820 and wire spool 816.

[0041] Similar to diverter bar 720 described above with reference to FIG. 7, diverter bar 820 is positioned such that it is below exit portion 816b of wire spool 816 and entry portion 818a of air guide 818, resulting in wrapping of wire 814 around a substantial portion of diverter bar 820. The placement of diverter bar 820 further from exit portion 816b of wire spool 816 (as represented in FIG. 8) tends to result in even greater wrapping of wire 814 around a portion of diverter bar 820 (as compared to the configuration of wire feed system 702 represented in FIG. 7). This increased wrapping feature, in turn, results in further increased points of contact (i.e., multi-point contact) between wire 814 and diverter bar 820 at any given time during a wire feed operation, thereby further improving the electrical connection (as will be described in greater detail below with reference to FIG. 9).

[0042] In use, diverter bar 820 is generally driven by a motor to rotate in a counterclockwise direction, and wire spool 816 is driven simultaneously with diverter bar 820 in a counterclockwise direction via belt 830. Such counterclockwise rotation of wire spool 816 causes wire 814 to be fed from wire spool 816 and guided by diverter bar 820 through air guide 818 and passed downward to a wire bonding tool (not shown in FIG. 8, but represented as 912 in FIG. 9).

[0043] The rotation of diverter bar 820 in a counterclockwise direction facilitates movement of wire 814 toward air guide 818, thereby reducing the likelihood of excessive drag on wire 814.

[0044] Wire feed systems 502, 602, 702, 802 of FIGS. 5 - 8, respectively, represent only four configurations of diverter bar 520, 620, 720, 820 mounted in a strategic vertical position relative to exit portion 516b, 616b, 716b, 816b of wire spool 516, 616, 716, 816 and entry portion 518a, 618a, 718a, 818a of air guide 518, 618, 718, 818. The present invention, however, is not limited to any particular configuration, and it is understood that the moveable guide member (e.g., the diverter bar) may be provided in any desired position to achieve a desired result.

[0045] As explained above with reference to conventional wire feed system 102 represented in FIG. 3, conventional wire feed systems typically include a member (e.g., fixed wire guide bar 120) located between (1) the point at which wire 114 is directly driven (e.g., wire spool 116) and (2) air guide 118. That is, in many conventional wire bonding machines, the wire spool is driven by a motor to pass wire toward the air

- 13 -

guide, where a fixed guide bar contacts the wire between the driven wire spool and the air guide. When the wire contacts (or rides along) the fixed guide bar, an undesirable drag is experienced, for example, due to the resultant friction and the like. According to certain exemplary embodiments of the present invention, because the guide member is moveable (e.g., rotatable), the drag is substantially reduced.

[0046] It is understood that the present invention may include various different drive configurations. Four exemplary drive configurations are now described. According to a first exemplary drive configuration, the moveable guide member (e.g., rotatable diverter bar) may be directly driven by a motor, where a belt coupling or the like causes the wire supply to be rotated in tandem with the rotation of the diverter bar by the diverter bar motor. In such an example, it is desirable that there is no contact point (causing friction or the like) between the drive member (in this example, the drive member is the rotatable diverter bar) and the air guide. According to a second exemplary drive configuration, the wire supply (e.g., the wire spool) may be directly driven by a motor, where a belt coupling or the like causes the rotatable guide member to be rotated in tandem with the rotation of the wire spool by the wire spool motor. In this example, drag/friction is still reduced by the rotation of the guide member. According to a third exemplary drive configuration, each of the guide member and the wire supply may be driven by independent motor systems. According to a fourth exemplary drive configuration, an indirect motor coupling may be used to rotate one or both of the moveable guide member and the wire spool.

[0047] According to certain exemplary embodiments of the present invention, the diverter bar is formed from conductive material. The conductive material may be, for example, polished nickel, tungsten carbide, titanium carbide, steel, stainless steel, etc.

[0048] FIG. 9 is a detailed view of certain components of a wire bonding machine in accordance with an exemplary embodiment of the present invention including (1) wire feed system 902 and (2) components of optics housing/bondhead 904. The illustrated components of optics housing/bondhead 904 include wire tensioner 906, wire clamp assembly 908, ultrasonic transducer 910, and wire bonding tool 912 (other components are not shown for clarity).

[0049] Wire feed system 902 (of which certain components are omitted for clarity) includes wire spool 916, air guide 918, and rotatable diverter bar 920 configured to guide wire 914 between wire spool 916 and air guide 918. Belt 930 links

- 14 -

diverter bar 920 and wire spool 916 together to facilitate simultaneous rotation of diverter bar 920 and wire spool 916. In this example, rotation of diverter bar 920 is directly driven by a motor (not shown).

[0050] Wire 914 extends from wire spool 916 and rides along rotatable diverter bar 920 and through air guide 918, ultimately being routed downward to wire bonding tool 912. Ball bond 934 is formed on die pad 936 of semiconductor die 938, which is mounted to substrate or leadframe 940. Leadframe 940 is positioned on support structure 942 (e.g., heatblock 942).

[0051] Detection system 932 is utilized to detect the integrity of a wire bond (e.g., ball bond 934) formed by the wire bonding machine. As explained above with reference to the various exemplary embodiments of the present invention, the increased points of contact between wire 914 and conductive diverter bar 920 improves the electrical connection for detecting the integrity of wire bond 934. As represented in FIG. 9, detection system 932 is connected on one side to, for example, heatblock 942 via path B. In order to complete the circuit and obtain a signal for the purposes of detecting the integrity of ball bond 934, detection system 932 may be connected on its other side via path A to a conductive component such as, for example, (1) wire spool 916 via path C, (2) diverter bar 920 via path D, (3) air guide 918 via path E, or (4) wire clamp assembly 908 via path F. The present invention is not limited to connection paths C, D, E, F, and may include any other path or paths resulting in the desired closed loop circuit.

[0052] In use, detection system 932 sends a signal through the closed loop circuit formed by the above-described connection paths. Qualities of the signal are then evaluated to determine the integrity of ball bond 934. The increased points of contact between wire 914 and conductive diverter bar 920 of wire feed system 902 of the present invention provide an increased electrical connection as compared to conventional wire feed systems and, thus, connection path D is improved over a similar path in conventional wire feed systems.

[0053] The guide members (e.g., diverter bars) of the various exemplary embodiments of the present invention have been illustrated having substantially the same diameter. The present invention, however, is not limited to a guide member of any particular size. For example, the diameter of a diverter bar of the wire feed system of the present invention may be less than or greater than those illustrated to achieve a desired bending or shaping of the wire as the wire is guided by the diverter bar during

- 15 -

the wire bonding process. More specifically, a diverter bar having a particular diameter may be selected for a wire feed system to counteract (or complement) the coiling effect that the wire spool has on the shape and/or behavior (i.e., movement) of the wire.

[0054] Although the present invention has been illustrated and described primarily with respect to a ball bonding operation it is not limited thereto. For example, the wire feed system disclosed herein may be applicable to other types of wire bonding such as, for example, wedge bonding operations.

[0055] Although the invention is illustrated and described herein with reference to specific embodiments, the invention is not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

What is Claimed:

1. A wire feed system for a wire bonding machine, the wire feed system comprising:

a wire supply;

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire; and

a moveable guide member, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the movement of the moveable guide member is rotation, wherein the wire supply comprises a wire spool configured to rotate in order to move the length of wire from the wire supply to the air guide, and wherein the moveable guide member and the wire spool are configured for simultaneous rotation.

2. The wire feed system of claim 1, wherein the moveable guide member is a diverter bar.

3. The wire feed system of claim 1, wherein rotation of the moveable guide member is directly driven by a motor.

4. The wire feed system of claim 1, wherein rotation of the wire spool is directly driven by a motor.

5. The wire feed system of claim 1, further comprising a belt configured to link the moveable guide member and the wire spool together, thereby facilitating simultaneous rotation.

6. The wire feed system of claim 1, further comprising a chain configured to link the moveable guide member and the wire spool together, thereby facilitating simultaneous rotation.

7. A wire feed system for a wire bonding machine, the wire feed system comprising:

a wire supply;

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire; and

a moveable guide member, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the moveable guide member is positioned such that the moveable guide member is above (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

8. A wire feed system for a wire bonding machine, the wire feed system comprising:

a wire supply;

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire; and

a moveable guide member, wherein movement of the moveable guide member guides wire between the wire supply and the air guide, wherein the moveable guide member is positioned such that the moveable guide member is below (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

9. The wire feed system of claim 1, wherein the moveable guide member is formed from conductive material.

10. A wire feed system for a wire bonding machine, the wire feed system comprising:

a wire supply including a wire spool;

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, the wire spool configured to rotate in order to move the length of wire from the wire supply to the air guide; and

a rotatable diverter bar, wherein rotation of the rotatable diverter bar guides wire between the wire supply and the air guide, the diverter bar and the wire spool being configured for simultaneous rotation.

11. The wire feed system of claim 10, wherein rotation of the diverter bar is directly driven by a motor.

12. The wire feed system of claim 10, wherein rotation of the wire spool is directly driven by a motor.

13. The wire feed system of claim 10, further comprising a belt configured to link the rotatable diverter bar and the wire spool together, thereby facilitating simultaneous rotation.

14. The wire feed system of claim 10, further comprising a chain configured to link the rotatable diverter bar and the wire spool together, thereby facilitating simultaneous rotation.

15. The wire feed system of claim 10, wherein the rotatable diverter bar is positioned such that the rotatable diverter bar is above (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the rotatable diverter bar, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

16. The wire feed system of claim 10, wherein the rotatable diverter bar is positioned such that the rotatable diverter bar is below (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the rotatable diverter bar, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

17. The wire feed system of claim 10, wherein the rotatable diverter bar is formed from conductive material.

18. A wire bonding machine comprising:

a wire bonding tool for receiving wire and for bonding the wire to bonding locations; and

a wire feed system for feeding wire to the wire bonding tool, the wire feed system including

a wire supply,

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, and

a moveable guide member, the guide member being conductive, wherein movement of the moveable guide member guides wire between the wire supply and the air guide

wherein the movement of the moveable guide member is rotation, wherein the wire supply of the wire feed system comprises a wire spool configured to rotate in order to move the length of wire from the wire supply to the air guide, and wherein the moveable guide member and the wire spool are configured for simultaneous rotation.

19. The wire bonding machine of claim 18, further comprising a detection system for monitoring the quality of a wire bond formed using the wire bonding machine, the detection system defining a signal path including a portion of wire and the moveable guide member.

20. The wire bonding machine of claim 18, wherein the moveable guide member of the wire feed system is a diverter bar.

21. The wire bonding machine of claim 18, wherein rotation of the moveable guide member is directly driven by a motor.

22. The wire bonding machine of claim 18, wherein rotation of the wire spool is directly driven by a motor.

23. The wire bonding machine of claim 18, wherein the wire feed system further comprises a belt configured to link the moveable guide member and the wire spool together, thereby facilitating simultaneous rotation.

24. The wire bonding machine of claim 18, wherein the wire feed system further comprises a chain configured to link the moveable guide member and the wire spool together, thereby facilitating simultaneous rotation.

25. A wire bonding machine comprising:

a wire bonding tool for receiving wire and for bonding the wire to bonding locations; and

a wire feed system for feeding wire to the wire bonding tool, the wire feed system including

a wire supply,

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, and

a moveable guide member, the guide member being conductive, wherein movement of the moveable guide member guides wire between the wire supply and the air guide,

wherein the moveable guide member is positioned such that the moveable guide member is above (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.

26. A wire bonding machine comprising:

a wire bonding tool for receiving wire and for bonding the wire to bonding locations; and

a wire feed system for feeding wire to the wire bonding tool, the wire feed system including

a wire supply,

an air guide for receiving a length of wire from the wire supply and providing a fluid tension to the length of wire, and

a moveable guide member, the guide member being conductive, wherein movement of the moveable guide member guides wire between the wire supply and the air guide,

wherein the moveable guide member is positioned such that the moveable guide member is below (1) an exit portion of the wire supply where the wire exits the wire supply and extends toward the moveable guide member, and (2) an entry portion of the air guide where the air guide receives wire from the wire supply.