DYNAMIC ISOLATION OF ULTRASONIC TRANSDUCERS") relate to ultrasonic transducers and are herein incorporated by reference in their entirety. Ultrasonic bonding energy is typically applied using an ultrasonic transducer, where the bonding tool is attached to the transducer. The transducer typically includes a driver such as a stack of piezoelectric elements (e.g., piezoelectric crystals, piezoelectric ceramics, etc.). Electrical energy is applied to the driver, and converts the electrical energy to mechanical energy, thereby moving the bonding tool tip in a scrubbing motion. This scrubbing motion of the bonding tool tip is typically linear motion along the longitudinal axis of the transducer.

[0006] It would be desirable to provide improved transducers for use in connection with wire bonding machines, and improved methods of forming wire bonds using transducers.

SUMMARY OF THE INVENTION

[0007] According to an ~~exemplary embodiment~~aspect of the present invention, there is provided a method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a driver, the method comprising the steps of: (1) applying electrical energy to the driver at a first frequency; and (2) applying electrical energy to the driver at a second frequency concurrently with the application of the electrical energy at the first frequency, the first frequency and the second frequency being different from one another, the method further comprising the step of providing the driver to include a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another~~a method of forming a wire bond using a bonding tool coupled to a transducer is provided. The method includes the steps of: (1) applying electrical energy to a driver of the transducer at a first frequency; and (2) applying electrical energy to the driver at a second frequency concurrently with the application of the electrical energy at the first frequency, the first frequency and the second frequency being different from one another~~.

[0008] According to another ~~exemplary embodiment~~aspect of the present invention, there is provided a method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a driver, the method comprising the steps of: (1) applying electrical energy to the driver at a first frequency; and (2) applying electrical energy to the driver at a second frequency concurrently with the application of the electrical energy at the first frequency, the first frequency and the second frequency being different from one another, wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool, the bonding tool being directly carried by the transducer, wherein the driver includes at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another~~another method of forming a wire bond using a bonding tool coupled to a transducer is provided. The method includes the steps of: (1) applying electrical energy to a driver of the transducer at a first frequency to drive a tip of the bonding tool in a first direction; and (2) applying electrical energy to the driver at a second frequency to drive a tip of the bonding tool in a second direction, the first direction being different than the second direction~~.

[0009] According to another ~~exemplary embodiment~~aspect of the present invention, there is provided a method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a single driver, the method comprising the steps of: (1) applying electrical energy to the driver at a first frequency to drive a tip of the bonding tool in a first direction; and (2) applying electrical energy to the driver at a second frequency to drive a tip of the bonding tool in a second direction, the first direction being different than the second direction.~~a transducer for use in a wire bonding operation is provided. The transducer includes an elongated body portion configured to support a bonding tool. The transducer also includes a driver for providing vibration to the elongated body portion, the driver including a plurality of piezoelectric elements, each of the plurality of piezoelectric~~

~~elements being separated into at least two regions electrically isolated from one another.~~

[0010] There is also disclosed~~According to another exemplary embodiment of the present invention,~~ a transducer for use in a wire bonding operation~~ is provided~~. The transducer includes an elongated body portion configured to support a bonding tool. The transducer also includes a driver for providing vibration to the elongated body portion, the driver being configured to receive electrical energy and to provide a non-linear scrub of a tip of the bonding tool.

[0011] There is also disclosed~~According to another exemplary embodiment of the present invention,~~ a transducer for use in a wire bonding operation~~ is provided~~. The transducer includes an elongated body portion configured to support a bonding tool. The transducer also includes a driver for providing vibration to the elongated body portion, the driver including at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] 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 deformed or reduced for clarity. Included in the drawing are the following figures:

FIG. 1 is a perspective view of a transducer of a wire bonding machine and related components useful in explaining various exemplary embodiments of the present invention;

FIGS. 2A-2B are front and back perspective views of a piezoelectric element for use in a transducer in accordance with an exemplary embodiment of the present invention;

FIG. 2C is a front view of the piezoelectric element of FIGS. 2A-2B;

FIG. 2D is a front view of an shim electrode for use in connection with a transducer in accordance with an exemplary embodiment of the present invention;

What is Claimed:

1. A method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a driver, the method comprising the steps of:

(1) applying electrical energy to the driver at a first frequency; and

(2) applying electrical energy to the driver at a second frequency concurrently with the application of the electrical energy at the first frequency, the first frequency and the second frequency being different from one another.

2. The method of claim 1 wherein step (1) includes applying the electrical energy to the driver at the first frequency of approximately 115 kHz.

3. The method of claim 1 wherein step (2) includes applying the electrical energy to the driver at the second frequency of approximately 120 kHz.

4. The method of claim 1 wherein step (1) includes applying the electrical energy to the driver at the first frequency of approximately 115 kHz, and step (2) includes applying the electrical energy to the driver at the second frequency of approximately 120 kHz.

5. The method of claim 1 further comprising the step of providing the driver to include a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another.

6. The method of claim 5 wherein step (1) includes applying the electrical energy at the first frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying the electrical energy at the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

7. The method of claim 5 wherein step (1) includes applying electrical energy at the first frequency and the second frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying electrical energy at the first frequency and the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

8. The method of claim 7 wherein the electrical energy applied to the first region and the second region at the first frequency are in phase with one another, and the electrical energy applied to the first region and the second region at the second frequency are out of phase with one another.

9. The method of claim 1 wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool.

10. The method of claim 1 wherein the driver includes at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another.

11. The method of claim 10 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is along a Y-axis of the wire bonding machine.

12. The method of claim 10 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is an XY shear direction.

13. The method of claim 10 wherein the first direction is along a Y-axis of the wire bonding machine and the second direction is an XY shear direction.

14. The method of claim 10 wherein the at least one piezoelectric element configured to deform in the first direction deforms in the first direction upon the application of electrical energy at the first frequency, and the at least one piezoelectric element configured to deform in the second direction deforms in the second direction upon the application of electrical energy at the second frequency.

15. The method of claim 10 wherein deformation of the at least one piezoelectric element configured to deform in the first direction results in a scrub of a bonding tool tip along an X-axis of the wire bonding machine, and deformation of the at least one piezoelectric element configured to deform in the second direction results in a scrub of a bonding tool tip along a Y-axis of the wire bonding machine.

16. A method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a driver, the method comprising the steps of:

(1) applying electrical energy to the driver at a first frequency to drive a tip of the bonding tool in a first direction; and

(2) applying electrical energy to the driver at a second frequency to drive a tip of the bonding tool in a second direction, the first direction being different than the second direction.

17. The method of claim 16 wherein the application of the electrical energy to the driver at the first frequency is concurrent with the application of the electrical energy to the driver at the second frequency.

18. The method of claim 16 wherein the application of the electrical energy to the driver at the first frequency is not concurrent with the application of the electrical energy to the driver at the second frequency.

19. The method of claim 16 wherein step (1) includes applying the electrical energy to the driver at the first frequency of approximately 115 kHz.

20. The method of claim 16 wherein step (2) includes applying the electrical energy to the driver at the second frequency of approximately 120 kHz.

21. The method of claim 16 wherein step (1) includes applying the electrical energy to the driver at the first frequency of approximately 115 kHz, and step (2) includes applying the electrical energy to the driver at the second frequency of approximately 120 kHz.

22. The method of claim 16 wherein the application of the electrical energy in step (1) results in a scrub of the tip of the bonding tool substantially along an X-axis of the wire bonding machine, and wherein the application of the electrical energy in step (2) results in a scrub of the tip of the bonding tool substantially along a Y-axis of the wire bonding machine.

23. The method of claim 16 wherein further comprising the step of providing the driver to include a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another.

24. The method of claim 23 wherein step (1) includes applying the electrical energy at the first frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying the electrical energy at the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

25. The method of claim 23 wherein step (1) includes applying electrical energy at the first frequency and the second frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying electrical energy at the first frequency and the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

26. The method of claim 25 wherein the electrical energy applied to the first region and the electrical energy applied to the second region at the first frequency are in phase with one another, and the electrical energy applied to the first region and the electrical energy applied to the second region at the second frequency are out of phase with one another.

27. The method of claim 16 wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool.

28. The method of claim 16 wherein the driver includes at least one piezoelectric element configured to deform in a first direction upon the application of the electrical energy at the first frequency, and at least one piezoelectric element configured to deform in the second direction upon the application of the electrical energy at the second frequency, the first direction and the second direction being different from one another.

29. The method of claim 28 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is along a Y-axis of the wire bonding machine.

30. The method of claim 28 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is an XY shear direction.

31. The method of claim 28 wherein the first direction is along an Y-axis of the wire bonding machine and the second direction is an XY shear direction.

32. A transducer for use in a wire bonding operation, the transducer comprising:

(a) an elongated body portion configured to support a bonding tool; and

(b) a driver for providing vibration to the elongated body portion, the driver including a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another.

33. The transducer of claim 32 wherein electrical energy at a first frequency is configured to be applied to a first of the at least two regions of each of the plurality of piezoelectric elements, and electrical energy at a second frequency is configured to be applied to a second of the at least two regions of each of the plurality of piezoelectric elements.

34. The method of claim 33 wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool.

35. The transducer of claim 33 wherein the first frequency is approximately 115kHz and the second frequency is approximately 120 kHz.

36. The transducer of claim 33 wherein application of the electrical energy at the first frequency to the first region results in a scrub of a tip of the bonding tool in a first direction, and wherein application of the electrical energy at the second frequency to the second region results in a scrub of a tip of the bonding tool in a second direction, the first direction being different from the second direction.

37. The transducer of claim 36 wherein the first direction extends along an X-axis of a wire bonding machine, and the second direction extends along a Y-axis of the wire bonding machine.

38. The transducer of claim 36 wherein the first direction extends substantially parallel to a longitudinal axis of the transducer, and the second direction extends substantially perpendicular to the longitudinal axis of the transducer.

39. The transducer of claim 36 wherein the first direction is substantially perpendicular to the second direction.

40. The transducer of claim 32 wherein electrical energy at a first frequency and a second frequency is configured to be applied to a first of the at least two regions of each of the plurality of piezoelectric elements, and electrical energy at the first frequency and the second frequency is configured to be applied to a second of the at least two regions of each of the plurality of piezoelectric elements.

41. The transducer of claim 40 wherein the electrical energy applied to the first region and the second region at the first frequency are in phase with one another, and the electrical energy applied to the first region and the second region at the second frequency are out of phase with one another.

42. The transducer of claim 32 wherein the body portion defines a driver aperture, and the plurality of piezoelectric elements are positioned in the driver aperture.

43. The transducer of claim 32 wherein the plurality of piezoelectric elements includes at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another.

44. A transducer for use in a wire bonding operation, the transducer comprising:

(a) an elongated body portion configured to support a bonding tool; and

(b) a driver for providing vibration to the elongated body portion, the driver being configured to receive electrical energy and to provide a non-linear scrub of a tip of the bonding tool.

45. The transducer of claim 44 wherein the driver includes a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another.

46. The transducer of claim 45 wherein electrical energy at a first frequency is configured to be applied to a first of the at least two regions of each of the plurality of piezoelectric elements, and electrical energy at a second frequency is configured to be applied to a second of the at least two regions of each of the plurality of piezoelectric elements.

47. The transducer of claim 46 wherein the first frequency is approximately 115kHz and the second frequency is approximately 120 kHz.

48. The transducer of claim 46 wherein (1) application of the electrical energy at the first frequency to the first region, without application of the electrical energy at the second frequency to the second region, results in a scrub of the tip of the bonding tool in a first direction, (2) application of the electrical energy at the second frequency to the second region, without application of the electrical energy at the first frequency to the first region, results in a scrub of the tip of the bonding tool in a second direction, the first direction being different from the second direction, and (3) application of the electrical energy at the first frequency to the first region and application of the electrical energy at the second frequency to the second region results in the non-linear scrub of the tip of the bonding tool.

49. The transducer of claim 48 wherein the first direction extends along an X-axis of a wire bonding machine, and the second direction extends along a Y-axis of the wire bonding machine.

50. The transducer of claim 48 wherein the first direction extends substantially parallel to a longitudinal axis of the transducer, and the second direction extends substantially perpendicular to the longitudinal axis of the transducer.

51. The transducer of claim 48 wherein the first direction is substantially perpendicular to the second direction.

52. The transducer of claim 48 wherein electrical energy at a first frequency and a second frequency is configured to be applied to a first of the at least two regions of each of the plurality of piezoelectric elements, and electrical energy at the first frequency and the second frequency is configured to be applied to a second of the at least two regions of each of the plurality of piezoelectric elements.

53. The transducer of claim 52 wherein the electrical energy applied to the first region and the second region at the first frequency are in phase with one another, and the electrical energy applied to the first region and the second region at the second frequency are out of phase with one another.

54. The transducer of claim 44 wherein the non-linear scrub follows a Lissajous pattern.

55. The transducer of claim 44 wherein the non-linear scrub follows a circular pattern.

56. The transducer of claim 44 wherein the non-linear scrub follows an elliptical pattern.

57. The transducer of claim 44 wherein the non-linear scrub follows a mesh-shaped pattern.

58. The transducer of claim 44 wherein the driver includes at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another.

59. The transducer of claim 58 wherein the first direction is along an X-axis of a wire bonding machine and the second direction is along a Y-axis of the wire bonding machine.

60. The transducer of claim 58 wherein the first direction is along an X-axis of a wire bonding machine and the second direction is an XY shear direction.

61. The transducer of claim 58 wherein the first direction is along an Y-axis of a wire bonding machine and the second direction is an XY shear direction.

62. The transducer of claim 58 wherein the at least one piezoelectric element configured to deform in the first direction deforms in the first direction upon the application of electrical energy at a first frequency, and the at least one piezoelectric element configured to deform in the second direction deforms in the second direction upon the application of electrical energy at a second frequency, the first frequency being different from the second frequency.

63. The transducer of claim 44 wherein the body portion defines a driver aperture, and the plurality of piezoelectric elements are positioned in the driver aperture.

64. A transducer for use in a wire bonding operation, the transducer comprising:

(a) an elongated body portion configured to support a bonding tool; and

(b) a driver for providing vibration to the elongated body portion, the driver including at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another.

65. The transducer of claim 64 wherein the at least one piezoelectric element configured to deform in the first direction deforms in the first direction upon the application of electrical energy at a first frequency, and the at least one piezoelectric element configured to deform in the second direction deforms in the second direction upon the application of electrical energy at a second frequency, the first frequency being different from the second frequency.

66. The transducer of claim 64 wherein the first direction is along an X-axis of a wire bonding machine and the second direction is along a Y-axis of the wire bonding machine.

67. The transducer of claim 64 wherein the first direction is along an X-axis of a wire bonding machine and the second direction is an XY shear direction.

68. The transducer of claim 64 wherein the first direction is along an Y-axis of a wire bonding machine and the second direction is an XY shear direction.

69. The transducer of claim 65 wherein the first frequency is approximately 115kHz and the second frequency is approximately 120 kHz.

70. The transducer of claim 65 wherein (1) application of the electrical energy at the first frequency, without application of the electrical energy at the second frequency, results in a scrub of the tip of the bonding tool in a first direction, (2) application of the electrical energy at the second frequency, without application of the electrical energy at the first frequency, results in a scrub of the tip of the bonding tool in a second direction, the first direction being different from the second direction, and (3) application of the electrical energy at the first frequency and the second frequency results in the non-linear scrub of the tip of the bonding tool.

71. The transducer of claim 70 wherein the first direction of the scrub extends along an X-axis of a wire bonding machine, and the second direction of the scrub extends along a Y-axis of the wire bonding machine.

72. The transducer of claim 70 wherein the first direction of the scrub extends substantially parallel to a longitudinal axis of the transducer, and the second direction of the scrub extends substantially perpendicular to the longitudinal axis of the transducer.

73. The transducer of claim 70 wherein the first direction of the scrub is substantially perpendicular to the second direction of the scrub.

74. The transducer of claim 64 wherein the first direction and second direction are substantially perpendicular to one another.

75. The transducer of claim 64 wherein the body portion defines a driver aperture, and the plurality of piezoelectric elements are positioned in the driver aperture.

What is Claimed:

1. A method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a driver, the method comprising the steps of:

(1) applying electrical energy to the driver at a first frequency; and

(2) applying electrical energy to the driver at a second frequency concurrently with the application of the electrical energy at the first frequency, the first frequency and the second frequency being different from one another, the method further comprising the step of providing the driver to include a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another.

2. The method of claim 1 wherein step (1) includes applying the electrical energy at the first frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying the electrical energy at the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

3. The method of claim 1 wherein step (1) includes applying electrical energy at the first frequency and the second frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying electrical energy at the first frequency and the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

4. The method of claim 3 wherein the electrical energy applied to the first region and the second region at the first frequency are in phase with one another, and the electrical energy applied to the first region and the second region at the second frequency are out of phase with one another.

5. The method of claim 1 wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool.

6. A method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a driver, the method comprising the steps of:

(1) applying electrical energy to the driver at a first frequency; and

(2) applying electrical energy to the driver at a second frequency concurrently with the application of the electrical energy at the first frequency, the first frequency and the second frequency being different from one another,

wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool, the bonding tool being directly carried by the transducer, wherein the driver includes at least one piezoelectric element configured to deform in a first direction upon the application of electrical energy, and at least one piezoelectric element configured to deform in a second direction upon the application of electrical energy, the first direction and second direction being different from one another.

7. The method of claim 6 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is along a Y-axis of the wire bonding machine.

8. The method of claim 6 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is an XY shear direction.

9. The method of claim 6 wherein the first direction is along a Y-axis of the wire bonding machine and the second direction is an XY shear direction.

10. The method of claim 6 wherein the at least one piezoelectric element configured to deform in the first direction deforms in the first direction upon the application of electrical energy at the first frequency, and the at least one piezoelectric element configured to deform in the second direction deforms in the second direction upon the application of electrical energy at the second frequency.

11. The method of claim 6 wherein deformation of the at least one piezoelectric element configured to deform in the first direction results in a scrub of a bonding tool tip along an X-axis of the wire bonding machine, and deformation of the at least one piezoelectric element configured to deform in the second direction results in a scrub of a bonding tool tip along a Y-axis of the wire bonding machine.

12. A method of forming a wire bond using a bonding tool coupled to a transducer of a wire bonding machine, the transducer including a single driver, the method comprising the steps of:

(1) applying electrical energy to the driver at a first frequency to drive a tip of the bonding tool in a first direction; and

(2) applying electrical energy to the driver at a second frequency to drive a tip of the bonding tool in a second direction, the first direction being different than the second direction.

13. The method of claim 12 wherein the application of the electrical energy to the driver at the first frequency is concurrent with the application of the electrical energy to the driver at the second frequency.

14. The method of claim 12 wherein the application of the electrical energy to the driver at the first frequency is not concurrent with the application of the electrical energy to the driver at the second frequency.

15. The method of claim 12 wherein the application of the electrical energy in step (1) results in a scrub of the tip of the bonding tool substantially along an X-axis of the wire bonding machine, and wherein the application of the electrical energy in step (2) results in a scrub of the tip of the bonding tool substantially along a Y-axis of the wire bonding machine.

16. The method of claim 12 wherein further comprising the step of providing the driver to include a plurality of piezoelectric elements, each of the plurality of piezoelectric elements being separated into at least two regions electrically isolated from one another.

17. The method of claim 16 wherein step (1) includes applying the electrical energy at the first frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying the electrical energy at the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

18. The method of claim 16 wherein step (1) includes applying electrical energy at the first frequency and the second frequency to a first of the at least two regions of each of the plurality of piezoelectric elements, and step (2) includes applying electrical energy at the first frequency and the second frequency to a second of the at least two regions of each of the plurality of piezoelectric elements.

19. The method of claim 18 wherein the electrical energy applied to the first region and the electrical energy applied to the second region at the first frequency are in phase with one another, and the electrical energy applied to the first region and the electrical energy applied to the second region at the second frequency are out of phase with one another.

20. The method of claim 12 wherein the application of the electrical energy to the driver at the first frequency and the second frequency results in a non-linear scrub by a tip of the bonding tool.

21. The method of claim 12 wherein the driver includes at least one piezoelectric element configured to deform in a first direction upon the application of the electrical energy at the first frequency, and at least one piezoelectric element configured to deform in the second direction upon the application of the electrical energy at the second frequency, the first direction and the second direction being different from one another.

22. The method of claim 21 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is along a Y-axis of the wire bonding machine.

23. The method of claim 21 wherein the first direction is along an X-axis of the wire bonding machine and the second direction is an XY shear direction.

24. The method of claim 21 wherein the first direction is along an Y-axis of the wire bonding machine and the second direction is an XY shear direction.