

SYSTEM FOR AND METHOD OF CLEANING OF COPPER BONDING WIRE USING PLASMA, ACTIVATED OR REDUCED GAS ATMOSPHERE

FIELD OF THE INVENTION

(001) The present invention relates to methods and apparatus for the cleaning of bonding wires for wire bonding processes used in electronic device interconnection and packaging.

BACKGROUND OF THE INVENTION

(002) Wire bonding is a basic method of making interconnection between the terminals on an integrated circuits (chip) or other electronic components with the external leads on the lead frames or substrates. In addition, wire bonding can be used to connect integrated circuits to other electronic devices or other integrated circuits as well as to connect multiple lead frames, substrates or printed circuit boards together. Wire bonding offers a cost-effective and flexible interconnect method and is therefore used in a majority of electronic device manufacturing.

(003) Wire bonding methods fall into two main categories; i.e. ball bonding and wedge bonding, wherein the wire is attached to the electronic components at both ends using combinations of heat, pressure, or ultrasonic energy to make a tight bond or weld. Wires used in wire bonding generally have a diameter from 15 μm to several hundred μm and originally were primarily made of gold, silver or aluminum. However, with cost savings in mind, the use of copper or copper alloy wires has increased.

(004) However, the use of copper or copper alloy wire results in a significant problem, i.e. copper can become quickly and easily oxidized. The resulting oxide contamination or layers that form on the wire often hinders bond adhesion and increases contact resistance. Further, the desired tight bond may be compromised because of the presence of the oxide. This may be the result of separation of the core wire and the oxide contamination or layer caused by package stress. Therefore, when using copper or copper alloy wires in wire bonding methods, the process results are sometimes unstable and inconsistent. The wire also has a limited shelf life and short usage life when attached to the bonder.

(005) Therefore there remains a need in the art for improvements to the methods of cleaning bonding wire for use in wire bonding methods.

SUMMARY OF THE INVENTION

(006) The present invention provides apparatus and methods for cleaning oxides and other contaminants from bonding wires wherein the disadvantages associated with prior art methods are avoided. In particular, the present invention provides an apparatus and method that uses a plasma, activated or reducing gas to clean the bonding wire as part of the wire bonding process.

BRIEF DESCRIPTION OF THE DRAWINGS

(007) Figure 1 is a schematic drawing of the bonding wire cleaning apparatus in accordance with one embodiment of the present invention.

(008) Figure 2 is a magnified image showing an example of a copper wire that has not been treated by the method according to the present invention.

(009) Figure 3 is a magnified image showing an example of a copper wire that has been treated by the method according to the present invention

DETAILED DESCRIPTION OF THE INVENTION

(010) The present invention provides improved apparatus and methods for cleaning oxides and other contaminants from bonding wires that are to be used in a wire bonding processes. The present invention provides methods and apparatus for cleaning the bonding wires within the bonder using a plasma, activated or reducing gases prior to using the wire in a wire bonding step.

(011) With reference to Figure 1, the present invention will be described in more detail. Figure 1 is a schematic drawing of an apparatus for cleaning bonding wire using a plasma, activated or reducing gas according to the present invention. In particular, Figure 1 shows the

apparatus 100, having a wire coil 10, that supplies a wire strand 20, through a capillary 30, to a wire bonding process 40. The wire while being stored in the coil or while being feed as a strand to the wire bonding process can become oxidized and require cleaning to avoid the problems with bonding noted above.

(012) In accordance with the present invention, the wire strand 20, is exposed to a plasma, activated or reducing gas atmosphere which acts to clean the wire of oxides. To contain the plasma or activated gas atmosphere, a tube is provided through which the wire passes. As shown in Figure 1, a tube 50A or 50B can be installed along the path of the wire strand 20, from the wire coil 10, to the capillary 30. In particular, the tube can be located near the wire coil 10, as shown in Figure 1 as tube 50A, or the tube can be located near the capillary 30, as shown in Figure 1 as tube 50B. Alternatively, the tube can be located at any other location along the path of the wire strand 20, or multiple tubes can be provided, for example, both tubes 50A and 50B can be used. The tube used to contain the cleaning gas can be made of any suitable material, such as glass, plastic, ceramic, dielectric material or other material resistant to plasma etching.

(013) The plasma, activated or reducing gas can be generated or activated outside of the tube and then filled into the tube or it may be introduced as a gas to the tube and then activated within the tube. In particular, the gas or plasma may be generated by any known generation method exterior to the tube and then be introduced to the tube through a "T" or "Y" type connection through the side of the tube or into one end or both ends of the tube. The gas or plasma generator can be any known type or generator including those that operate in the kHz, MHz or GHz ranges. In addition, a microwave type generator may be used. Alternatively, gas may be introduced into the tube and then plasma can be generated or the gas may be activated within the tube by any known plasma generation technique, such as a barrier discharge method.

(014) The gas used for the plasma may be hydrogen, argon, nitrogen, oxygen, or mixtures of one or more thereof. Some particularly useful gas mixtures according the present invention are argon with up to ten percent hydrogen and nitrogen with up to ten percent hydrogen. The plasma may be introduced at room temperature or may be heated to temperatures from room temperature up to 900°C. Pressures of the gas within the tube should be below 1 barg. Preferably, the plasma gas flows through the tube at flow rates of less than 2 Sm/hr.

(015) The apparatus and method of the present invention provides several advantages. In particular, oxides and other contaminants can be easily and safely removed from the wire prior to wire bonding. This allows for the use of previously contaminated wire, wire that has been over aged and wire that may have been stored under the wrong conditions. By using the apparatus and methods of the present invention, the need for floor life control of the wire material can be eliminated. Further, by using wire that has been cleaned using the apparatus and methods of the present invention, resulting bonds are more reliable and consistent, resulting in higher bond quality, larger process windows, less contact resistance of the bond and better reliability performance.

(016) Testing of the apparatus and methods of the present invention has been conducted, yielding the results set forth below. The tests performed used two different plasma sources, i.e. Varigon™ gas (argon with 5% hydrogen, available from Linde AG) and forming gas (nitrogen with 5% hydrogen). In addition, two different operating modes were tested. Test runs 1-4 used a DBE plasma source consisting of a glass capillary with two outer electrodes isolated from each other and having a 15 kHz power supply. The gas for the plasma is injected at the upper end of the glass capillary through a T-piece. The opposite end of the glass capillary has a reduced diameter. Test runs 5-7 used a CPM plasma source consisting of a glass capillary with a meshed outer electrode and a inner metal capillary that contacts the wire to be cleaned at low potential, and a power supply of 1MHz. The gas for the plasma is injected between the two capillaries.

(017) Test Run 1. Varigon gas was injected into the capillary at 8 slm with one electrode set on high voltage and the second electrode set on low voltage. The plasma ignited and the bonding process ran without problems.

(018) Test Run 2. Varigon gas was injected into the capillary at 8 slm with both electrodes on high voltage and the wire to be cleaned having a low voltage applied. The bonding process was affected and need further optimization in needed.

(019) Test Run 3. Forming gas was injected into the capillary at 1 slm with both electrodes on high voltage and the wire to be cleaned having a low voltage applied. The plasma ignited, but the bonding process was affected and need further optimization is needed.

(020) Test Run 4. Forming gas was injected into the capillary at 1 slm with one electrode set on high voltage and the second electrode set on low voltage. The plasma ignited and the bonding process ran without problems.

(021) Test Run 5. Varigon gas was injected at 5 slm between the capillaries along cooling air to the power supply. The meshed electrode was set on high potential and the metal capillary and wire were set on low potential. The plasma ignited and the bonding process ran without problems.

(022) Test Run 6. No inner capillary was used. Varigon gas was injected at 5 slm through the glass capillary with the meshed electrode set on high potential and the wire set on low potential. The plasma ignited and the bonding process ran without problems.

(023) Test Run 7. No inner capillary was used. Forming gas was injected at 5 slm through the glass capillary with the meshed electrode set on high potential and the wire set on low potential. The plasma ignited and the bonding process ran without problems.

(024) The tests above show that the plasma sources can be positioned on the bonding head and that the electrical operation mode does not impact the bonding machine operation. Further, the bonding wire was not harmed by the capillaries nor by the plasma and the bonding process can run while the plasma is on. Both plasma sources DBE and CPM can be operated with Varigon gas or forming gas.

(025) Figures 2 and 3 clearly show the cleaning advantages of the present invention. In particular, Figure 2 shows a bonding wire that has not been treated by the present invention, and clearly shows significant oxide contamination appearing as the black spots along the surface of the wire. Figure 3 shows a bonding wire following plasma treatment according to the present invention wherein oxides have been removed and the surface of the wire is very clean.

(026) As noted above, the present invention provides numerous advantages, including easy and safe removal of oxides from wire prior to wire bonding, resulting in more reliable and consistent wire bonds. In addition, nearly any wire can be treated by the methods of the

present invention and then used in wire bonding processes, including wire that has been contaminated, over ages or stored under the wrong conditions.

(027) It will be understood that the embodiments described herein are merely exemplary and that one skilled in the art may make variations and modifications without departing from the spirit and scope of the present invention. All such variations and modifications are intended to be included within the scope of the invention as described above. Further, all embodiments disclosed are not necessarily in the alternative, as various embodiments of the invention may be combined to provide the desired result.

What is claimed is:

1. A system for cleaning bonding wire comprising:
a coil of bonding wire;
a wire bonding apparatus;
a capillary feed for feeding bonding wire to the wire bonding apparatus;
an extension of bonding wire running from the coil to the capillary feed; and
a means for enclosing at least a portion of the extension of bonding wire in a plasma,
activated or reducing gas atmosphere.
2. The system of claim 1 wherein the means for enclosing comprises a tube.
3. The system of claim 2 further including two electrodes located on the outer surface of the tube, the electrodes being isolated from one another.
4. The system of claim 2 further including a meshed electrode on the outer surface of the tube and a metal capillary sized to fit within the tube.
5. The system of claim 2 wherein the tube is made of glass, plastic, ceramic, a dielectric material or other materials resistant to plasma etching.
6. The system of claim 1 wherein the bonding wire is gold, silver, aluminum, copper or a copper alloy wire.
7. The system of claim 1 wherein the plasma atmosphere is hydrogen, argon, nitrogen, oxygen or mixtures of one or more thereof.

8. A method of cleaning a bonding wire for a wire bonding process, comprising:
extending the bonding wire from a supply coil to a capillary feed into the wire bonding process;
establishing a plasma, activated or reducing gas atmosphere along at least a portion of the extension of the bonding wire between the coil and the capillary feed; and
cleaning the bonding wire in the plasma atmosphere.
9. The system of claim 8 wherein the bonding wire is gold, silver, aluminum, copper or a copper alloy wire.
10. The method of claim 8 wherein the plasma atmosphere is hydrogen, argon, nitrogen, oxygen or mixtures of one or more thereof.
11. The method of claim 8 wherein establishing a gas atmosphere comprises providing a tube enclosing a portion of the extension of the bonding wire and providing the gas atmosphere within the tube.
12. The method of claim 11 wherein the tube is made of glass, plastic, ceramic, a dielectric material or other materials resistant to plasma etching.
13. The method of claim 11 wherein providing the gas atmosphere within the tube comprises injecting gas generated from an external source into the tube.
14. The method of claim 13 wherein injecting gas comprises injecting the gas through a T or Y type connection associated with the tube.
15. The method of claim 13 wherein injecting gas comprises injecting the gas through one end or both ends of the tube.
16. The method of claim 8 wherein providing the gas atmosphere within the tube comprises injecting gas into the tube and exciting the gas inside the tube.
17. The method of claim 16 wherein injecting gas comprises injecting gas through a T or Y type connection associated with the tube.

18. The method of claim 16 wherein injecting gas comprises injecting gas through one end or both end of the tube.
19. The method of claim 8 wherein the gas atmosphere is a mixture of argon and hydrogen.
20. The method of claim 8 wherein the gas atmosphere is a mixture of nitrogen and hydrogen.