similar for these two metals. Copper, however, has other physical and metallurgical properties that differ significantly from those of gold. The differing properties of copper lead to competing advantages and disadvantages when utilizing this material in wire bonding processes. Copper can desirably be utilized at smaller wire diameters and provide higher electrical performance (*i.e.*, lower parasitic resistance), improved thermal behavior, and greater mechanical strength (*i.e.*, increased hardness) compared to gold. However, in order to overcome the greater hardness of copper, a higher energy input can be needed in conventional copper wire bonding processes to facilitate formation of a metallurgical bond. The higher energy input can result in an increased incidence of pad splash, pad cratering, interface spreading, and electronic component damage. Increased susceptibility of copper to oxidation and corrosion can also be problematic. These combined effects can be associated with an increased incidence of device failure, lower processing reliability, and limited throughput (yield). Indeed, the wire bonding community has implemented strict processing parameters for conventional copper wire bonding processes to reduce the risk of bonding pad damage. These rigorous processing parameters can be very difficult to maintain and can severely limit throughput. An additional difficulty associated with conventional copper wire bonding processes is the higher pitch sometimes produced with this metal compared to gold, which correspondingly decreases the attainable wire density upon a bonding pad or other surface. Although copper has the potential to provide performance that is at least comparable to that of gold, the foregoing limitations of conventional copper wire bonding processes presently limit use of this metal to various low-end consumer products.

[0006] In addition to the strict processing parameters typically utilized during conventional copper wire bonding processes, the hardness of this metal can also significantly increase wear within a wire bonding system in which it is used. Specifically, a capillary bonding head providing a copper wire payout can wear much faster than when a gold wire is provided. The increased system wear associated with copper can result in significant cost increases, particularly for high-volume applications, due to process downtime and material costs of replacing broken parts. Although more robust capillary bonding heads are in development, failure of this component still remains an issue in conventional copper wire bonding processes. Despite recent advances in dispensation technology, accelerated grain growth within the free air ball and low pullout forces can remain problematic in conventional copper wire bonding processes.

[0007] In view of the foregoing, improved systems and methods to facilitate wire bonding, particularly copper wire bonding systems and methods, would be of significant interest in the art. Embodiments of the present disclosure seek to satisfy these needs and provide related advantages as well.

SUMMARY

[0008] In various embodiments, the present disclosure provides wire bonding methods that include providing a wire payout at a first location from a rolled wire source via a dispensation head, contacting a first metal nanoparticle composition and a first end of the wire payout with a bonding pad in electrical communication with an electronic component, and at least partially fusing metal nanoparticles in the first metal nanoparticle composition together to form an adhering interface between the bonding pad and the first end of the wire payout, wherein the first metal nanoparticle composition is contacted with the first end of the wire payout before the first portion of the wire payout is contacted with the bonding pad.

[0008a] In other various embodiments, the present disclosure provides methods including providing a wire payout at a first location from a rolled wire source via a dispensation head, contacting a first metal nanoparticle composition and a first end of the wire payout with a bonding pad in electrical communication with an electronic component, at least partially fusing metal nanoparticles of the first metal nanoparticle composition together to form an adhering interface between the bonding pad and the first end of the wire payout, moving the dispensation head to a second location, contacting a second end of the wire payout with a lead at the second location, adhering the wire payout to the lead, thereby forming a wire loop extending between the bonding pad and the lead, severing the wire payout from the wire loop, contacting a second metal nanoparticle composition and the second end of the wire payout with the lead, and at least partially fusing metal nanoparticles of the second metal nanoparticle composition together to form an adhering interface between the lead and the second end of the wire payout, wherein the second metal nanoparticle composition is contacted with the second of the wire payout before the second end of the wire payout is contacted with the lead.

[0009] There are also disclosed electrical packages including a bonding pad in electrical communication with an electronic component, a lead, a wire loop extending between the bonding pad and the lead, and an adhering interface having a nanoparticulate morphology disposed between the wire loop and at least one of the bonding pad and the lead.

[0010] There are also disclosed wire bonding systems including a rolled wire source, a dispensation head configured to provide a wire payout from the rolled wire source, and an applicator configured to place a metal nanoparticle composition upon at least a portion of the wire payout or upon a bonding pad.

[0011] The foregoing has outlined rather broadly the features of the present disclosure in order that the detailed description that follows can be better understood. Additional features and advantages of the disclosure will be described hereinafter. These and other advantages and features will become more apparent from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions to be taken in conjunction with the accompanying drawings describing specific embodiments of the disclosure, wherein:

[0013] FIGURE 1 shows an illustrative schematic of an electrical package in which multiple electrical connections are formed between a bonding pad and a lead;

[0014] FIGURE 2 shows a schematic illustrating various operations in a conventional wire bonding process;

[0015] FIGURE 3 shows a schematic of an illustrative wire bonding process in which metal nanoparticles are applied to the tip of a wire payout and undergo liquefication to form a

CLAIMS

What is claimed is the following:

1. A method comprising:

providing a wire payout at a first location from a rolled wire source via a dispensation head;

contacting a first metal nanoparticle composition and a first end of the wire payout with a bonding pad in electrical communication with an electronic component; and

at least partially fusing metal nanoparticles of the first metal nanoparticle composition together to form an adhering interface between the bonding pad and the first end of the wire payout,

wherein the first metal nanoparticle composition is contacted with the first end of the wire payout before the first portion of the wire payout is contacted with the bonding pad.

2. The method of claim 1, further comprising:

applying pressure and ultrasonic energy to the first metal nanoparticle composition via the dispensation head.

3. The method of claim 1, further comprising:

moving the dispensation head to a second location;

contacting a second end of the wire payout with a lead at the second location;

adhering the wire payout to the lead, thereby forming a wire loop extending between the bonding pad and the lead; and

severing the wire payout from the wire loop.

4. The method of claim 3, further comprising:

contacting a second metal nanoparticle composition and the second end of the wire payout with the lead; and

at least partially fusing metal nanoparticles in the second metal nanoparticle composition together to form an adhering interface between the lead and the second end of the wire payout.

5. The method of claim 1, wherein the wire payout comprises a copper wire, a gold wire,

an aluminum wire, a silver wire, carbon nanotube ropes, a drawn carbon nanotube fiber, or any combination thereof.

6. The method of claim 1, wherein the first metal nanoparticle composition comprises copper nanoparticles.

7. The method of claim 1, wherein the first end of the wire payout comprises a tip of the wire payout.

8. The method of claim 1, wherein the first end of the wire payout comprises a sidewall of the wire payout.

9. The method of claim 1, wherein the wire payout comprises a copper wire and the first metal nanoparticle composition comprises copper nanoparticles.

10. A method comprising:

providing a wire payout at a first location from a rolled wire source via a dispensation head;

contacting a first metal nanoparticle composition and a first end of the wire payout with a bonding pad in electrical communication with an electronic component;

at least partially fusing metal nanoparticles of the first metal nanoparticle composition together to form an adhering interface between the bonding pad and the first end of the wire payout;

moving the dispensation head to a second location;

contacting a second end of the wire payout with a lead at the second location;

adhering the wire payout to the lead, thereby forming a wire loop extending between the bonding pad and the lead;

severing the wire payout from the wire loop;

contacting a second metal nanoparticle composition and the second end of the wire payout with the lead; and

at least partially fusing metal nanoparticles of the second metal nanoparticle composition together to form an adhering interface between the lead and the second end of the wire payout,

wherein the second metal nanoparticle composition is contacted with the second of the wire payout before the second end of the wire payout is contacted with the lead.

11. The method of claim 10, further comprising:

applying pressure and ultrasonic energy to the first metal nanoparticle composition via the dispensation head.

12. The method of claim 10, wherein the wire payout comprises a copper wire, a gold wire, an aluminum wire, a silver wire, carbon nanotube ropes, a drawn carbon nanotube fiber, or any combination thereof.

13. The method of claim 10, wherein the first metal nanoparticle composition comprises copper nanoparticles.

14. The method of claim 10, wherein the first end of the wire payout comprises a tip of the wire payout.

15. The method of claim 10, wherein the first of the wire payout comprises a sidewall of the wire payout.

16. The method of claim 10, wherein the wire payout comprises a copper wire and the first metal nanoparticle composition comprises copper nanoparticles.