Gold Use in Electronics: Bonding Wire

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Gold is used in field of electronics manufacturing as bonding wire that connects the IC chip and circuit board. World fabrication of gold bonding wire is about 150 tons in 2004, which represents a threefold increase over the last 10 years.

The reasons for using gold are due to the metal's basic properties, which include low electrical resistance, ductility and no oxidation. Gold is drawn to a thinness of less than 30 microns in the manufacture of bonding wire.

There are some threats to bonding wire and the wire bonding process from new technological developments in semiconductor manufacturing. However, high-strength gold wire and high-reliability gold alloy wire are useful in the mass production field of electronics manufacturing in the future.

Wire Bonding Process

The integrated circuit (IC) in the wafer process is made on a Si chip, which is cut out from a single crystal Si ingot.

Wire bonding is one of the important steps in the assembly process. After the wafer process, the IC chip is cut into pieces and put onto a circuit board. The wire bonding process makes a gold wire loop and completes the electrical contact between the IC chip and the outer electrode of the circuit board.

After this wire bonding, the circuit board is covered by mould resin to protect it from outer stress and marking is put on the moulded package, then the IC device is complete.

Details of the wire bonding process are shown in Figure 1 and explained as follows.

a) Gold bonding wire goes through a ceramic cylinder tool, called a capillary.

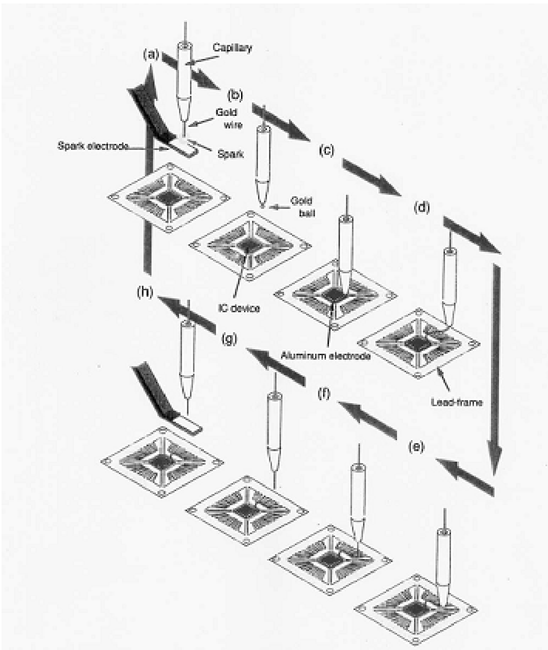


Fig.1 – Wire bonding process

b) A ball is made on a wire tip under a capillary by the discharge from a spark electrode of bonding machine.

c) IC chips on a circuit board are heated to not less than 473 K. A gold ball with a capillary is lowered onto the electrode of an IC chip and an ultrasonic vibration is added, then the gold ball on the wire tip is bonded to the IC chip.

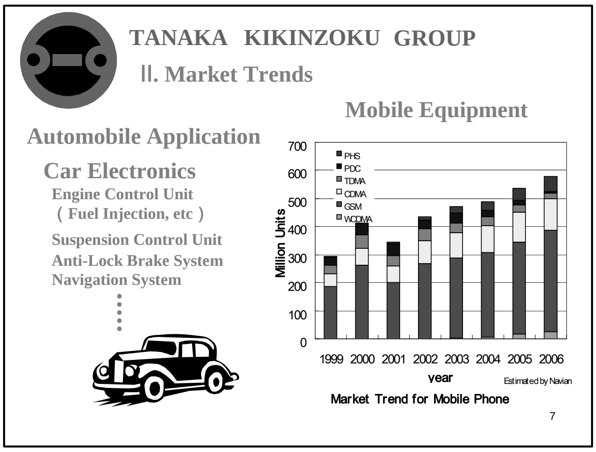
d) After the IC chip bonding, the capillary goes up and moves to the electrode of the circuit board. The wire goes through the capillary and makes a loop between the IC chip and the electrode of the circuit board.

e) On the electrode of the circuit board, the capillary is lowered again and ultrasonic vibration is added. The gold wire is bonded to the electrode of circuit board without making a ball as in IC bonding.

The reason for the use of high purity gold has to do with the basic property needs of the wire bonding process. Bonding wire is an electrical wire, so it requires low electrical resistance. Gold has the third lowest electrical resistance of all metals. Making a ball on a wire tip also requires no oxidation. Gold doesn't oxidize and is also a very ductile metal, corresponding to the complicated movements of the bonding machine.

Market Trends

The market areas for growth are mobile phone equipment and automotive applications.



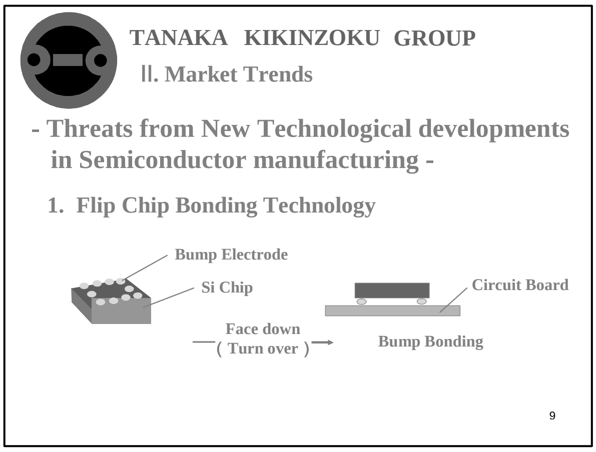
The growth in mobile phone usage is amazing. Except for the newest models, the phones are very cheap, which requires reduced costs in manufacturing.

There are strong requirements for reducing the cost of fine wire, because most of the cost of bonding is material cost.

There are various electrical units and systems in a car. The internal temperature of a car increases very sharply in summer and decreases to very low levels in winter in cold northern regions. Recently, there are increasing cases of electrical units being placed near the engine, which has a very high temperature. Automotive application needs for bonding wire therefore must correspond to the severe environmental conditions.

In 1994, world fabrication of gold bonding wire was about 50 tons. In 2003, it reached nearly 150 tons – representing a threefold increase over the last ten years.

However, there are some threats to bonding wire and the wire bonding process from new technological developments in semiconductor manufacturing.



One of these is flip chip (FC) bonding technology, which has the advantage of low electrical resistance, thus it is applied to the high-speed clock devices of high technology.

Another threat from the most advanced technology is Cu through electrode in a Si chip. This process is able to achieve chip stacking that FC bonding technology couldn't, since, of course, the electrical resistance is low. Cu through electrode is in development by ASET (Associated of Super-Advanced Electronics Technologies) in Japan.

Wire bonding technology continues to be used widely in the manufacture of low-end products and low-cost applications, but the threat posed by the new technological developments is increasing.

Technical Trends

There is a strong requirement of fine pitch bonding to correspond to high-density composition for mobile equipment manufacturing. The bonding pad becomes a small area to achieve a small-sized package. The electrode pitch on a Si chip has become smaller due to the fine technology of the wafer process.

In order to realise fine pitch bonding, a small ball and a fine wire of less than 20 microns are required. High strength is necessary for bonding wire as a material property.

Fig.2 indicates IC bonding part of 40-micron pitch bonding sample.

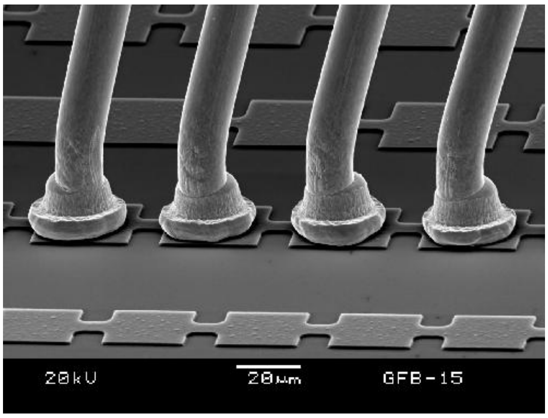


Fig.2 – Fine pitch bonding

A second technical trend is stacked bonding. Si chips are stacked in one device at SiP technology. Stacked bonding requires short and low loop making for lower chip bonding and long and high loop making for upper chip bonding as shown in Figure 3.

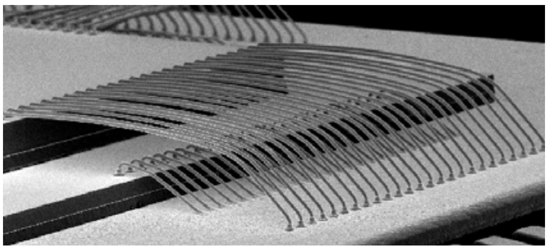


Fig.3 – Stacked bonding

Short contact of lower wire and upper wire should not occur, of course for wires next to each other, but also if outer stress is added during the molding process.

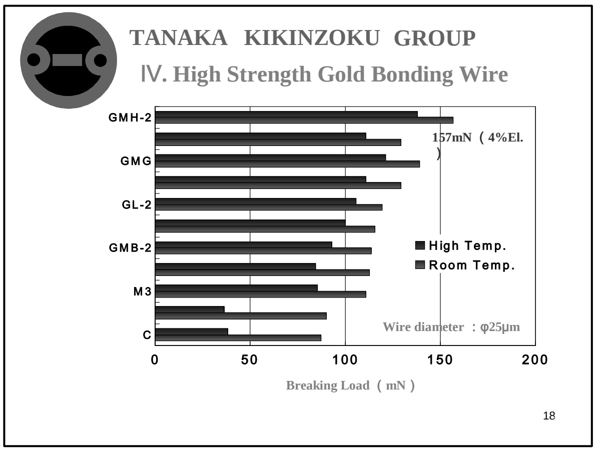
Thus high strength is necessary for bonding wire to realise stacked bonding.

The third technical trend is high reliability. When bonding interface in the high temperature storage, Au_5Al_2 appears in the bonding boundary as the first inter-metallic compound (IMC). Au_5Al_2 is easily transformed into Au_4Al. Au_4Al is corroded by mould resin.

The electric resistance of the bonding point is rapidly increased by the Au_4Al corrosion phase – then IC device failure occurs.

High Strength Gold Bonding Wire

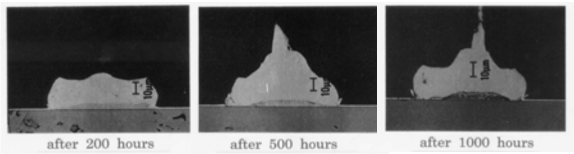
Many kinds of gold bonding wire are made to meet the various manufacturing requirements of semiconductor and electrical devices. High strength gold bonding wire's breaking load is over 150 mN, which means 300 MPa at φ25 micron and 4% elongation. Over 300 MPa of high strength, gold bonding wire's tensile strength is three times greater than 5N-purity gold.



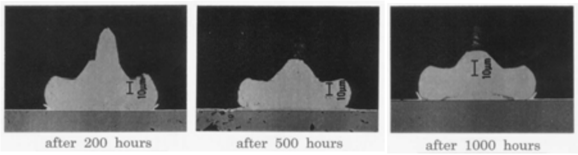
High strength methods are types, volume and mixing of elements. General gold bonding wire keeps 4N-purity. This drastic change of property by less than 100 wtppm elements is based on field results in high purity metal research.

High Reliability Gold Alloy Bonding Wire

Cross-sections of encapsulated samples at 473 K for each hour comparing gold and a gold alloy including 1% palladium are shown in Figure 4 on the next page.



4N-Gold



Gold Alloy

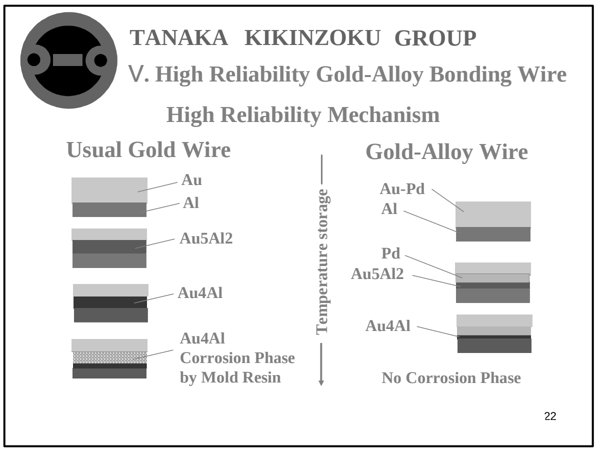
Fig.4 – Cross-section observations of temperature storage samples

During temperature storage, an IMC phase appears and grows in the bonding boundary. After 200 hours of storage, the IMC has grown about 3 microns thick. The IMC of 4N-Au is thicker than that of the gold alloy.

After 500 hours of storage, the upper part of the IMC in 4N-Au turns brown. There is no change in the gold alloy sample. After 1,000 hours, all of the IMC in the 4N-Au changes into a dark brown phase. However, only the peripheral region of the IMC in the gold alloy turns brown.

The electrical resistance of the 4N-Au sample rapidly increases after 200 hours, corresponding to the IMC phase's colour change, which is confirmed in the cross-section observation shown in Figure 4. The electrical resistance of the gold alloy sample doesn't change over the course of 1,000 hours.

Gold alloy makes a palladium barrier in the bonding boundary and blocks diffusion of Au atoms, so it may be difficult for Au_5Al_2 to transform into Au_4Al. Thus gold alloy bonding wire guarantees high reliability.



Conclusion

There are some threats from new technological developments in semiconductor manufacturing to bonding wire and the wire bonding process. However, gold bonding wire will be useful in the mass production of electronics manufacturing in the future. The main trends of bonding wire are in demand due to cost reduction and corresponding to severe environmental conditions.

Fine pitch bonding and stacked package manufacturing can be achieved by using Tanaka gold bonding wire and it is useful in the reduction of costs in electronics manufacturing. And Tanaka gold alloy bonding wire guarantees high reliability requirement. ■