NEW SYSTEM FOR MICRO-JOINING "WEDGE BONDING" OF GOLD WIRES IN METALLIC FOILS, USING A LASER-ULTRASONIC HYBRID ACTIVE HEAD

Grigore SEBEŞ [1], Danut SAVU[2], Gabriela DEMIAN [3]

Această lucrare prezintă un procedeu nou de micro-îmbinare procedeul termosonic utilizat pentru micro-îmbinarea firelor din aur pe folii metalice. Procedeul termosonic s-a realizat cu ajutorul unui cap activ hibrid ce s-a ataşat unei sonotrode, şi prin concepţia sa se asigură trei funcţii principale. S-au realizat câteva simulări de micro-îmbinare prin procedeul termosonic al firelor din aur cu grosimi în diametru de 300µm îmbinate pe folii subţiri din cupru de 400µm, şi s-au reprezentat micro şi macrostructurile îmbinărilor. Aceste micro-îmbinări au mari aplicaţii în confecţionarea micro-dispozitivelor electromecanice MEMS .

This paper presents a new micro-joining process – thermo sonic process used for gold wires micro-joining on the metallic foil. A thermosonic process was carried out with a hybrid active head which was attached to a tool, and by design to ensure three main functions. There have been made several simulations of the thermo sonic micro- joining process of gold wire in diameter of 300µm thick on thin copper foil of 400µm, and the micro and macrostructural joints were illustrated graphically. These micro-joining processes have great appliances in MEMS manufacturing of electromechanical systems.

Key words: micro-joining, wedge bonding, thermosonic, hybrid active head, laser beam MEMS.

1. Introduction

The thermosonic micro-joining process is one of the micro-joining processes of electronic circuits and MEMS components which are being increasingly implemented. It consists of a combination of the ultrasonic joining process with the thermo-compression joining process and exploits the positive features of each of the two processes separately.

Predominant variants of this process are:

- Micro joining of the ball-heads type (ball-bonding) - the amount of variance in its application in the microprocessor industry: approx. 90% of the total thermo sonic micro joining processes.
- Micro joining of plated heads / wedge (wedge bonding) - the amount of variance in its application in the microprocessor industry: approx. 10% of the total micro thermo sonic joints.

[1] PhD Student, University of Craiova, e-mail: grigoseb@yahoo.com
[2] Assoc. prof., University of Craiova, Romania
[3] Assoc. prof., University of Craiova, Roamnia

Compared to the thermo compress micro-joining process or the eutectic micro joining process, the thermosonic micro-bonding process interface's temperature has typical values in the range 100-150 ^{0}C. At these temperatures damage risk of MEMS components is relatively low [1]. Fig. 1 is an example of thermosonic micro-joining of single line wires through the option "Wedge bonding".

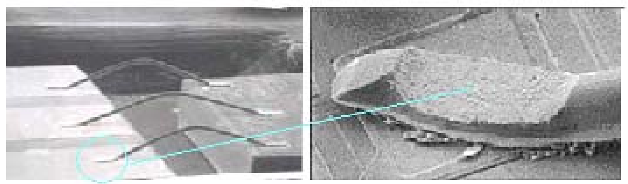


Fig. 1 Thermo sonic micro joining, individual wedge wire bonding method

The development of thermosonic bonding process was the result of the need to improve the productivity of the bonding process with ultrasound. Empirically it was concluded that in order to achieve micro-joining speed without the risk of destroying any neighboring components through prolonged vibrations, additional heat intervention is needed to improve the conditions under which the ultrasonic micro-joining process runs.

The intervention consists of bringing the material in a state in which bonding can become possible by applying additional heat. [3]

The main role in the process is given to ultrasound energy. In addition, it continues to address a specific problem of micro-joining processes: it disperses the elements that contaminate the mating surfaces of base materials.

2. The thermosonic micro-joining process of gold wires

Thermosonic micro-joining of gold wires is a joint process that combines the other end of the gold wire as a "wedge bonding" with a copper foil and joined by ultrasonic and thermal energy consummation under a certain pressure, illustrated in Fig. 2. An example of a thermo sonic micro joining system of gold wires is represented in Fig. 3.

It consists of an ultrasonic generator of "phase-locked loop", a piezoelectric actuator, a coil, a cone-shaped funnel, and a capillary joint. Ultrasonic transducer converts electrical energy into mechanical wave vibrations. Axial vibration produced by piezoelectric actuators is transmitted and amplified by the funnel-shaped cone.

The wave is converted to flexible vibrations that merge into the capillary, and is then transmitted to the bond interface during a bonding process. Therefore, under the influence of an ultrasonic energy environment (strictly controlled temperature and pressure) the marginal atoms of the gold sphere and the substrate will spread and will interpenetrate each other, which leads to the formation of an interface I / O in an IC chip. Micro-joining temperature is thus defined to meet the various processes of thermosonic bonding process while connecting all other parameters, such as energy coupling, the time for joint implementation and joint pressure remaining unchanged.

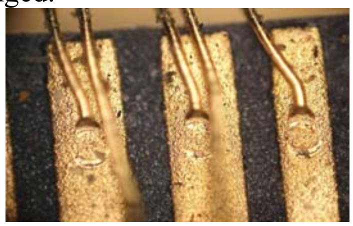


Fig. 2 Micro-joining types of "wedge bonding" the golden wires

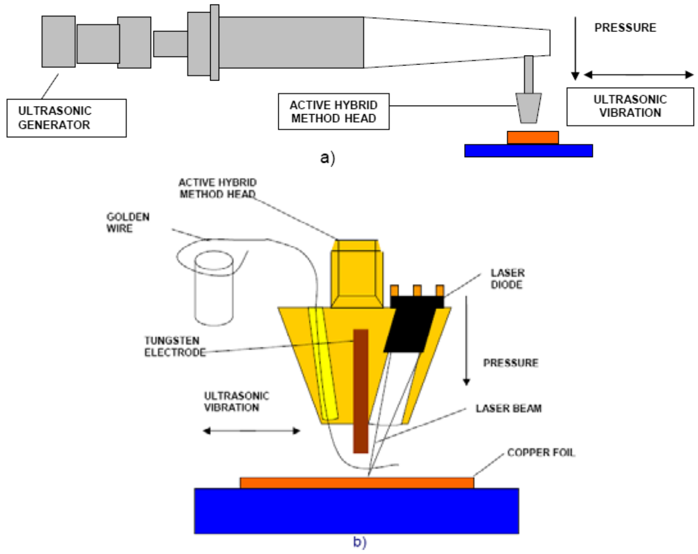


Fig.3 Thermosonic bonding system of gold wires
(a) Structure of the system, (b) Interface bonding model "Wedge bonding" (Bonding parameters: frequency: 60 kHz, pressure: 5 N; time: 50 ms; ultrasonic beam power: 2, 25 W, gold wire diameter 300µm)

3. Description of the laser-ultrasound hybrid active head

The concept refers to an active head attached to a sonotrode head which has a hybrid character by joining two separate power sources (ultrasonic vibration-kinetic energy, laser beam-caloric energy).

The hybrid active head sonotrode is a new type of active component for devices which have to do with micro joining/ joining ultrasound processes. Hybrid active head sonotrode is shown in Figure 4 in the sketch below and the right image.

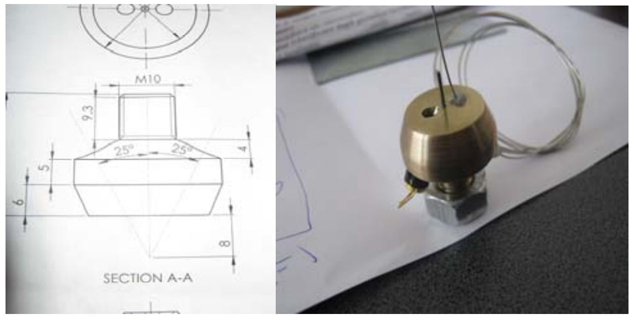


Fig.4 Manufacture hybrid head sonotrode. a) Sketch sonotrode head, b) hybrid head overview

Active head, between thermosonic micro-joining, comprises a body (1) which provides positioning and fixing of three component elements: a tungsten pin (3 '), a laser diode (5') and a filler material transport tube, golden thread (7 ').
The beam emitted by laser diode preheats the basic materials at temperatures between 150-200 ^{0}C, the guidance tube inserts in the joint area an added material in the form of a wire and tungsten pin forward kinetic energy ultrasonic vibration by welding assembly.

Hybrid active head together with any type of sonotrode is intended for wire joining / micro-joining with metal foils smaller than 0.7mm and with thicknesses smaller than 0.7 mm, as well as for joining and micro-joining wires on metallic foils.

Hybrid head for sonotrode provides three main functions:

- The appliance of ultrasonic vibrations through a pine tungsten or tungsten alloy, with zirconium, thorium
- Preheating of base materials, undergo the process of joining/ micro joining, using a laser beam emitted by a diode laser with a power of 200-500mW
- Guiding the added material in the form of a wire, which has depending on the application, a diameter of 0.2 - 0.5mm.

The component parts of hybrid active head are represented in detail in Fig. 5:

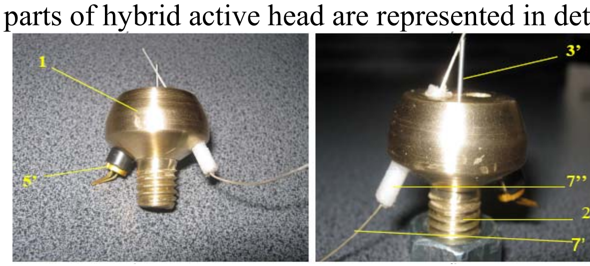


Fig. 5 Active head sonotrode mode a) horizontal view, b) general view of the vertical head

Advantages of using this type of hybrid heads are:

- Hybrid active head character, a character given by joining two separate power sources: tungsten pin - kinetic energy, thermal energy-laser beam.

- Time reduction of ultrasonic joint, by introducing in the process the preheating heat treatment provided by the laser beam.
- Modular construction allows you to change any of the five elements, body-mounted active: attack pin, laser diode, focusing lens, and the polymer guide tube and support pin
- Distinct element sonotrode body, the latter easily mountable
- Body made of steel / stainless steel / brass, different from currently used expensive materials: tungsten, titanium, zirconium, or various special ceramic.
- Making access using easier machining processes

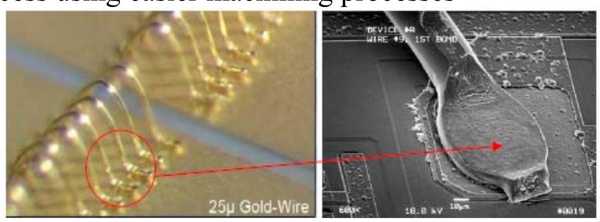


Fig.6 Golden wire micro-joining a) multiple threads of gold b) detail

Hybrid active head sonotrode is made in modular construction, consisting of an accessible body (1) and made of an alloy (steel, stainless steel or brass) by substituting titanium, zirconium or special ceramics. Active head body is provided by its form design with a removable assembly (screw) (2) the body sonotrode. Active head body is provided with three holes, two pierced and one non pierced, to ensure the three main functions:

- The application of ultrasonic vibration with an attack pin.
- Preheating of base materials using a laser beam to weld
- Guiding added material to joint area

, and a secondary function: supporting the attack pin to avoid local deformity of the active head. Attack pin installation hole (3) is murky and has a diameter depending on the diameter of the attack pin.

The attack pin, the first element of the hybrid structure, with active participation in the joint (role: the kinetic energy contribution) is meant to transmit vibration from the starting materials sonotrode simultaneously with the transmission of force necessary to achieve the connection. The attack pin is made of tungsten or tungsten alloy with thorium, zirconium, or rare metals, to withstand the mechanical loads specific joining process (for pure tungsten micro joints is sufficient to merge the base material thickness of 0.3...0.7mm, sometimes tungsten is necessary to become an alloy with the metals mentioned above).

The free end of the pin will be worked up in a conical shape, the end diameter being the same with the wire diameter with to it joins or equal to 1.0 - 1.5 x thickness of the metal film with to it joins. Attack pin length will be equal to (4+ pin hole length) mm. The pin will be supported by a bolt from a harder material than the material hardness of the active head body. Laser diode (5 ') is the second element of the hybrid welding, bringing heat input for the preheating of the starting materials and preparing them for the joining process.

With power ranging from 200-500 mV (depending on the nature and thickness of base materials), the starting materials will heat up at temperatures between 150-200 ^{0}C. For laser diode assembly process a hole (5) under a 30 ° angle is worked up so that the beam intersects the attack pin axis at about 0.5-1.5mm before its free end. The establishing of the laser diode is done by stitching it to a surface of maximum 1mm x1mm.

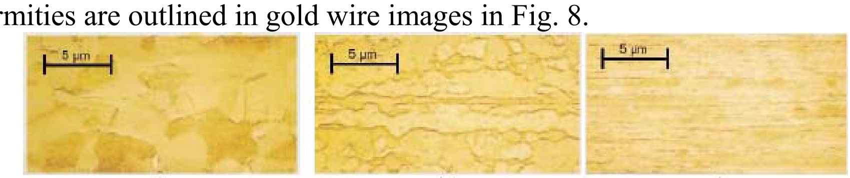
For base material thickness greater than 0.3mm, the beam will be mounted in a lens (6) for an additional focus. For inserting under the attack pin a filler material, a hybrid head body will be provided with a hole (7). Wires used as filler materials are made of relatively soft materials (gold, silver, copper) and with a diameter of 0.2 -0.5mm. For these reasons their being transported through a simple hole processed in a harder metallic material could lead to their deformation and their possible jamming inside the lock hole.

In order to avoid these phenomena a polymer tube will be inserted into the hole (7 ") so that the coefficient of friction between wire and hole will be reduced to a minimum. The guiding polymer tube inner diameter will be 10-20 % larger than the diameter of the filler wire. Positioning of the guiding tube hole will create an angle of 30° so that the free end of the wire to the pin axis intersects with tungsten to about 1mm in front of its peak.

4. Results and discussion

Microjoints temperature can be measured using a thermocouple type heat sensor with a measuring range between 0 and 500 ^{0}C. Such sensors are put in direct contact with the substrate, the experiments can be carried out for temperatures between 40 and 360 ^{0}C.

Micrographs of gold wire are represented in Fig. 7, also the types of deformities are outlined in gold wire images in Fig. 8.



a) b) c)

Fig.7 Micrographs of a grain of gold a) Gold wire micro contact area b) Micro golden thread in the adjacent area HAZ c) Micro free wireless in the remaining MB

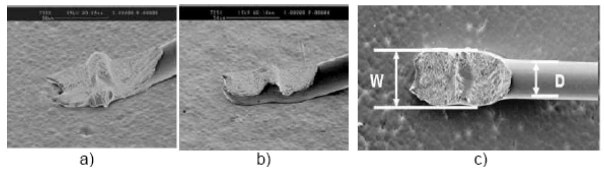


Fig.8.Gold wire deformation: (a) large deformation; (b) narrow strain; (c) distortion ratio W / D [4]

In Fig. 9 are the two charts and diagrams with micro-joining force profiles for the process of ultrasonic ultrasound enhanced deformation and deformation at the impact.

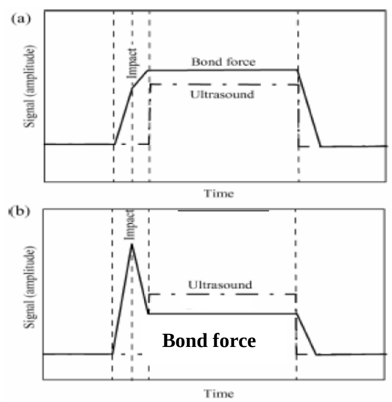


Fig.9 Graphics for used force and ultrasound profiles for (a) Improved ultrasonic deformation process and (b) the impact deformation

Percentage of accession of gold wire copper PAD varies by micro-bonding atmospheric temperatures and is shown in Fig.10.

Percentage of accession of gold wire copper PAD increased with increasing joining temperature from 90^0C to 180^0C and then decreased with increasing temperature to 200^0C. Only 53% of the entire wire joining was actually carried out at 180^0C. Fig. 10 also shows that the joint strength increased with increasing stage temperature from 90^0C to 150^0C and then decreased with increasing temperature on the growth stage at 180^0C and above [5].

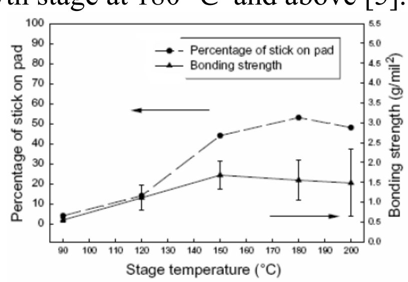


Fig.10 Influence of temperature on the percentage of state to join the PAD and micro Cu joint resistance. Micro joining parameters are: 0.5N joint force, ultrasonic power 0.15W, and 20 ms bonding time.

5. Conclusions

In this paper, thermosonic micro-bonding of gold wire copper medium was investigated. Experimental and theoretical studies have been conducted to examine the effects of preheating temperature and ultrasonic power to the resistance of thermo sonic wire micro joining and the following observations resulted:

- This activity is linked to the resistance phenomena of the thermo sonic joint interface between micro joining materials. It clearly demonstrated that proper preheat temperatures, energy intensity is increased, increasing shear force, which reaches a maximum and then decreases.
- Energy intensity which reaches a maximum thrust of energy intensity is called saturation. After saturation, namely the determination of atomic bonds, any further energy input will damage the micro joining, decrease of the shear force. A study of surface temperature also shows the saturation phenomenon: there is an optimum temperature for maximum adhesion to the surface.
- Increasing the preheat temperature increases the number of metallic bonds and the transfer of power from the interface when the ultrasonic power is increased, however, excessive temperature, micro joining preheating can cause damage to the interface because of excessive energy and greater oxidation, thus decreasing wire shear.
- A lower preheat temperature must be accompanied by a higher power to achieve a saturated energy intensity, a much too high ultrasonic power leads to a thin micro joints, friction force leading to a deterioration of the micro bonding.

R E F E R E N C E S

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