BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 2/2010	195 – 206	Seria Tehnică

Comparative Analysis of Quality Micro-joints Made by Means of Eutectic Bonding and Thermo Sonic Bonding Process

G. Sebeş, A. Nanciu, I. Borcan, I. Ciocionoiu

University of Craiova, Calugăreni Street No.1, Drobeta Turnu Severin
e-mail: grigore.sebes @ imst.ro

Abstract

In this paper evidence has been achieved through new processes eutectic bonding end thermo sonic bonding, processes used to produce MEMS micro devices type. The micro- bond eutectic, used copper base material thickness of 200 µ m and the added material were used eutectic solders: SAC alloy (Tin 95.5 Ag 3.6 Cu 0.7), alloy Tin 96.5 Ag 3.5 and Tin 58 Bi 42 alloy. The thermo sonic micro-bonding were made three pairs of materials: Copper-Copper, Copper-Aluminum and Aluminum-Aluminum base material thickness is δ Cu =234 µ m ,δ Al = 104 µ m. Tubes obtained by the two processes of micro-joint were subjected to tensile test (shear), to see where this will break in MB or in micro-joint, and the results are compared with each other. The results showed better thermal and electrical conductivity the mechanism of thermo sonic micro-joint and greater resistance to the combined area of eutectic micro-bonding process.

Key words: *MEMS*; *MB; eutectic micro-joining; thermo sonic micro-joining; test tube; traction.*

Introduction

November processes of eutectic micro-joining and thermo sonic micro - joining, are connecting processes with applications prevalent in MEMS technology. A MEMS device type contains at least three micro-joints, of which one is the double-circuit board assembly support on MEMS basic, micro-joining closing cap of lid support combining MEMS (MEMS encapsulation) and micro-joining of the elements of interconnection with MEMS and circuit motherboard (micro-double combination), as Figure 1.

The process of eutectic micro - joint , alloys of joining , used to run the process and the temperature at around 220°C, so about 5 times lower than the melting temperature of basic material (copper or silver). Metal has lodged a matrix composed of Tin, this is determined by the chemical composition of eutectic solder alloy (Sn95, 5%).The process of thermo sonic micro-joining mix is a combination of ultrasonic bonding process with the thermo-compression bonding process. The process of micro-joint by thermo-compression requires usually connecting interface temperatures above 300 ° C. This temperature damages plastic components of MEMS devices by type, by thermal degradation of polymers. The two processes of micro - joint, are made using heat sources to provide heating in the temperature range 100-240°C.

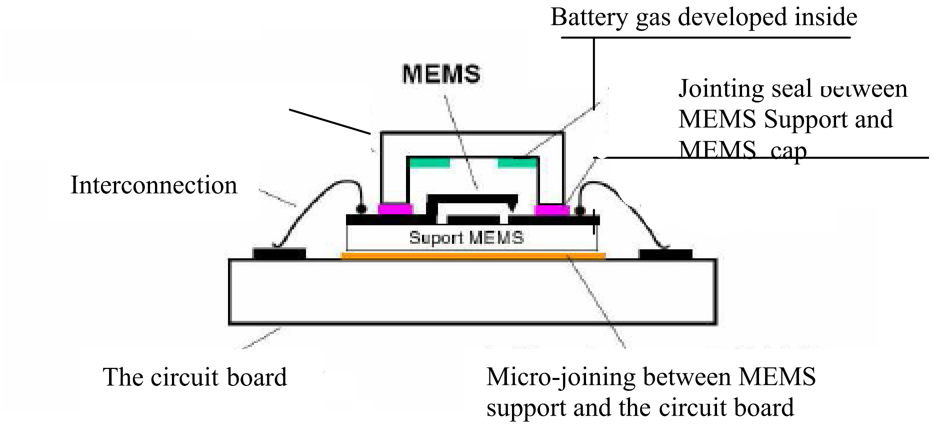


Fig. 1. Micro-electro-mechanical device (MEMS)

Figure 2 is the source of thermal heating and melting solders, with which it wetting two surfaces that come into contact with overlap, and Figure 3 presents an ultrasonic assisted installation of a hot air blower.

Fig. 2. Heat source to eutectic solder

Fig. 3. Used installation in thermo sonic micro- joining

There has been specimen for mechanical tests of micro-welded joints (9 specimens-process Eutectic, and 9 specimens-process termo sonic) according to SR EN 10003/95 and SR EN 10002/95. Were determined characteristics of mechanical resistance of tubes made by the two processes micro-joint, also followed where the break occurred in the basic material in HAZ or micro joining, followed by comparing the results of the two packages of specimen. Finally it was intended a functional characterization of micro joints overlap.

They tested various heating temperatures MB, different eutectic alloys , ranging tabling solders for micro tubes obtained by eutectic micro-joining process ,also have tested different ultrasonic activation times, more pressure values the press sonotrod tool if evidence obtained by termo sonic micro-joining.

Experimental Program

Determining characteristics of mechanical resistance of tubes

Test conditions

To determine the main characteristics of mechanical strength of those joints were subjected to tensile test. Equipment used for tensile testing of samples is of the TC100-A009 and is represented in Figure 4.

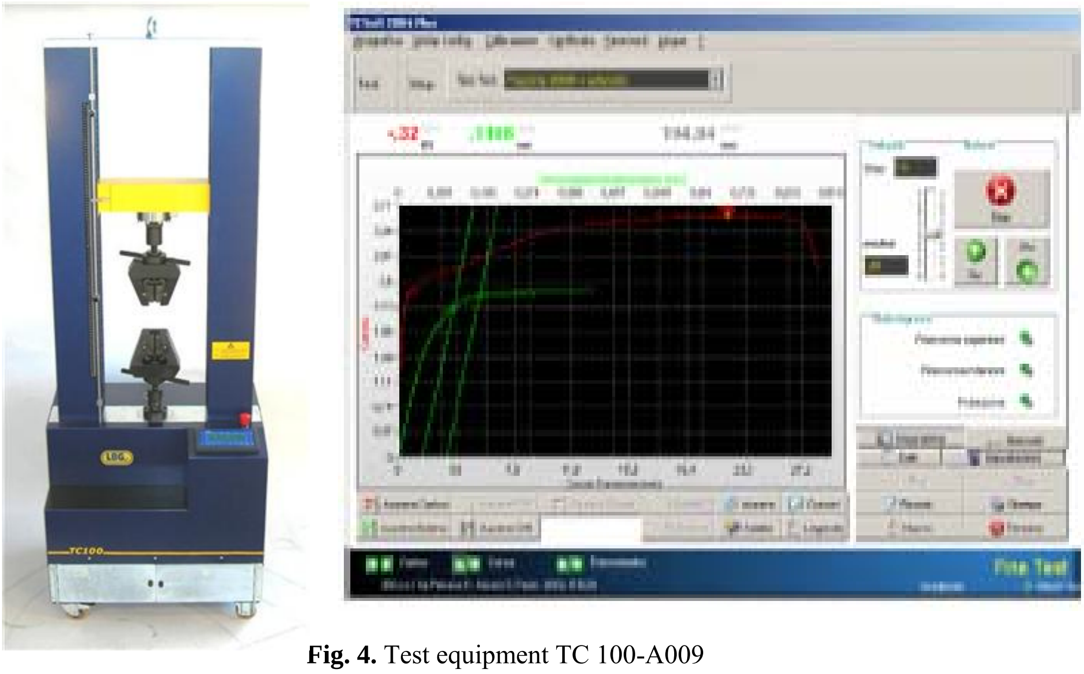


Fig. 4. Test equipment TC 100-A009

The dimensions of samples tested ar shown in Figure 5.

$$t_{MB-Cu} = 0{,}2mm$$
$$t_{aliaj} = 0{,}08...0{,}1mm$$

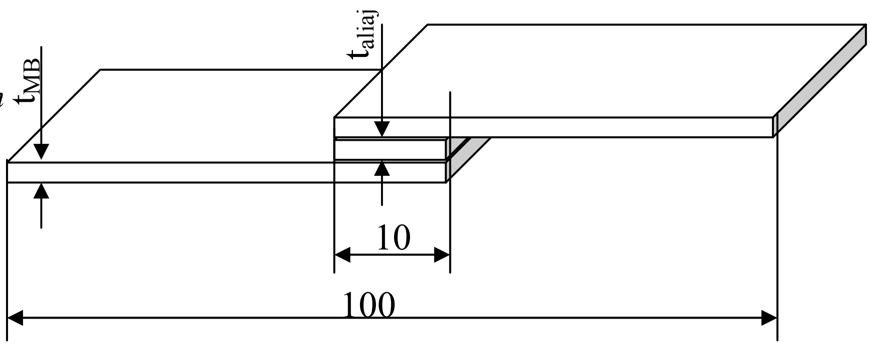


Fig. 5.Caracteristics geometric-dimensional joints tested

Types of evidence-eutectic bonding process

There were two types of samples tested.

Variant 1:

Alloy by one of the materials, heat applied from outside the base material. In preliminary tests traction 3 of the 9 samples considered broke in basic material, which is why this option was abandoned.

Variant 2:

Alloy deposited on each of the two basic materials, heat applied from outside one of the basic materials (samples considered: 1 ... 9).

Table 1 presents test tube samples made using the eutectic bonding process before the tensile testing is specified: the couple MB, MB thickness, the alloy used eutectic, eutectic alloy melting temperature, strength and fracture test-piece instead of breaking.

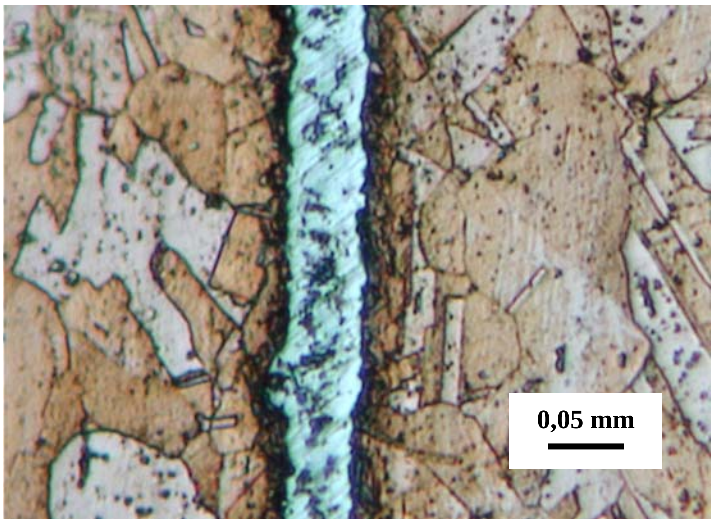


Fig. 6. Alloy connecting deposited on one of two basic materials

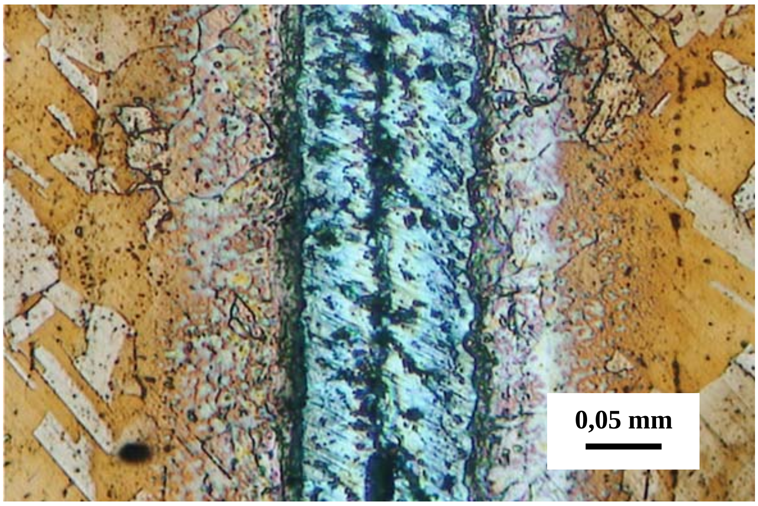


Fig.7. Alloy by connecting both base materials

Table 2 presents the situation of test tube samples obtained by Eutectic bonding after tensile testing has shown the test-piece instead of breaking. Figures 8(a-h), were given stress-strain diagram curves for test tube samples No 1, 2, 3, 4, 5, 6, 7 and 9.

Results of tensile test samples for version 2 of eutectic micro-bonding

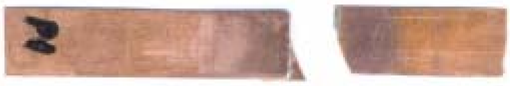
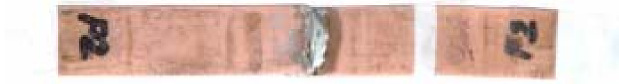
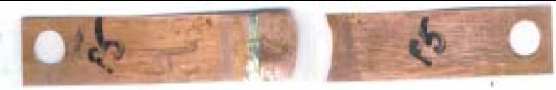
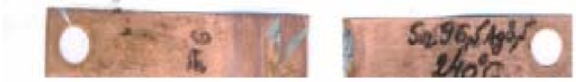
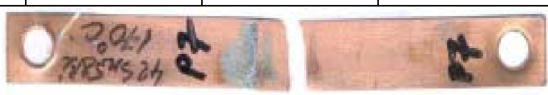
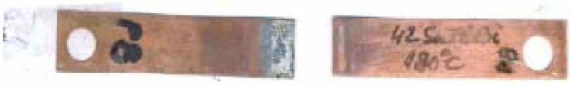
After conducting the tensile tests have found that:

- Of the 9 samples tested, 8 broke the basic material and 1 was separated (there was an actual break, but only a detachment of the bonding)
- Placental 8 number combination is likely attributed to preparation poor in which the two layers of alloy deposited oxides were formed which prevented the achievement of appropriate contact before the heat source.
- The conditions under which it made no specific training or at least gray-white cameras, cases found in the electronics industry, but in particular laboratories usual uncontrolled atmosphere.
- Whatever type of joint alloy samples showed a narrow elastic region, followed by a substantially larger flow area, a situation due to mechanical characteristics of the basic material.

Table 1. Samples of version 2

Sample Number	**Base material couple**	**Base material thickness** [μm]	**Eutectic alloy**	**Eutectic Alloy Melting Temperature** [°C]	**Fracture strength test-piece** [k N]
P1	Cooper-Cooper	200	Tin 95,5 Ag 3,6 Cu 0,7	220	0,515
					
P2	Cooper-Cooper	200	Tin 95,5Ag 3,6 Cu 0,7	230	0,605
					
P3	Cooper-Cooper	200	Tin 95,5Ag 3,6 Cu 0,7	240	0,408
					
P4	Cooper-Cooper	200	Tin 96,5 Ag 3,5	220	0,593
					
P5	Cooper-Cooper	200	Tin 96,5Ag 3,5	230	0,720
					
P6	Cooper-Cooper	200	Tin 96,5Ag 3,5	240	0,688
					
P7	Cooper-Cooper	200	42 Tin58Bi	170	0,608
					
P8	Cooper-Cooper	200	42 Tin 58 Bi	180	
					
P9	Cooper-Cooper	200	42 Tin 58 Bi	190	0,637
					

Table 2 . Samples eutectic micro-joining after tensile test (shear)

Sample number	**Base material couple**	**Base material thickness** [µm]	**Eutectic alloy**	**Eutectic alloy melting temperature** [°C]	**Fracture strength test-piece** [k N]	**Place Fracture**
P1	Cooper-Cooper	200	Tin 95,5 Ag 3,6 Cu 0,7	220	0,515	Base material
						
P2	Cooper-Cooper	200	Tin 95,5Ag 3,6 Cu 0,7	230	0,605	Base material
						
P3	Cooper-Cooper	200	Tin 95,5Ag 3,6 Cu 0,7	240	0,408	Base material
						
P4	Cooper-Cooper	200	Tin 96,5 Ag 3,5	220	0,593	Base material
						
P5	Cooper-Cooper	200	Tin 96,5 Ag 3,5	230	0,720	Base material
						
P6	Cooper-Cooper	200	Tin 96,5 Ag 3,5	240	0,688	Base material
						
P7	Cooper-Cooper	200	42 Tin58Bi	170	0,608	Base material
						
P8	Cooper-Cooper	200	42 Tin58Bi	180		Detachment
						
P9	Cooper-Cooper	200	42 Tin58Bi	190	0,637	Base material
						

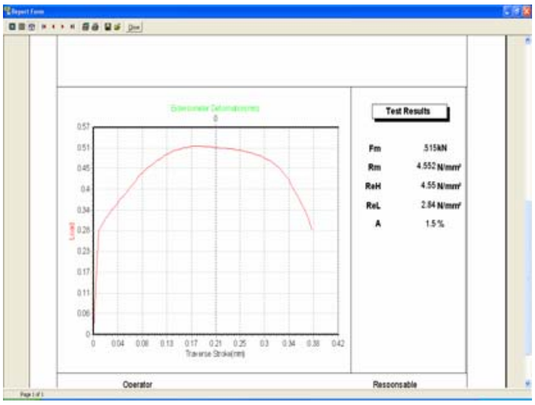


Fig. 8a. Curve stress-strain for P1sample

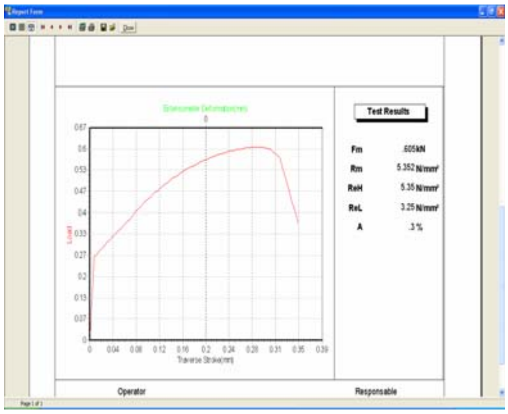


Fig. 8b. Curve stress-strain for P2 sample

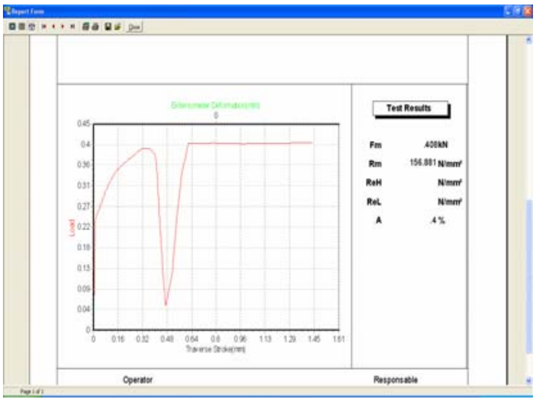


Fig. 8c. Curve stress-strain for P3sample

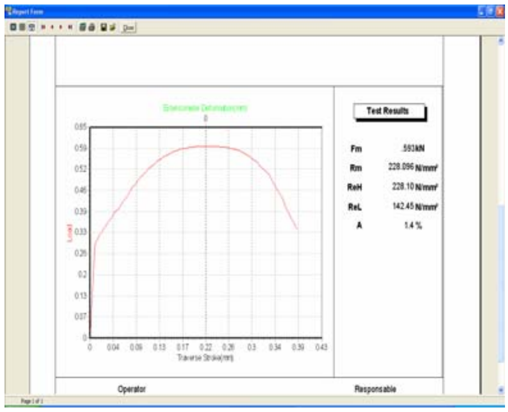


Fig. 8d. Curve stress-strain for P4 sample

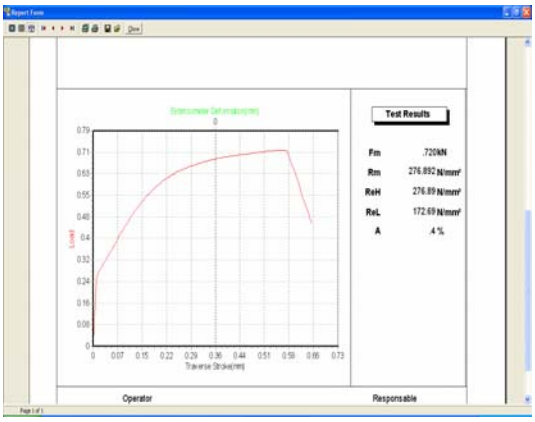


Fig. 8e. Curve stress-strain for P5 sample

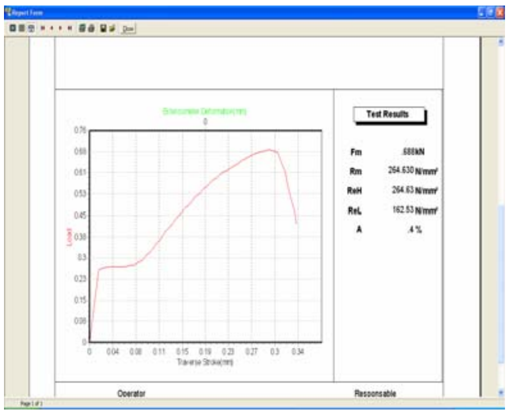


Fig. 8f. Curve stress-strain for P6 sample

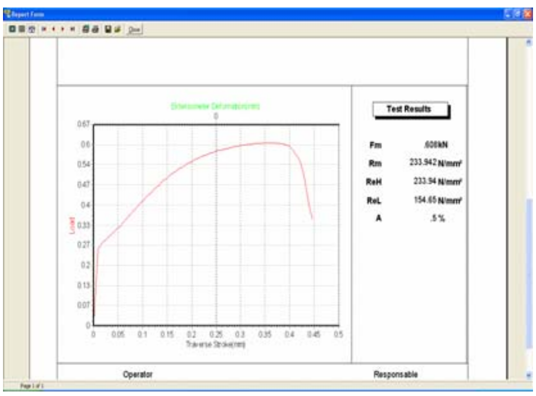


Fig. 8g. Curve stress-strain for P7sample

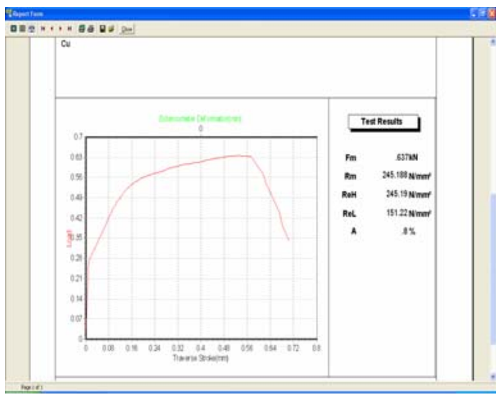


Fig. 8h. Curve stress-strain for P9 sample

- Force peak was in the field of 0.450 ... 0.700 k N value comparison with the forces that might occur in electronic circuits which are designed joints

Conclusions sample eutectic bonding

The results obtained reveal the following characteristics of joints Eutectic inspected:

- Joints have levels of flow relatively large, which translates to a rupture ductility, in time, therefore the risk of breaking fragile increases accidental calls is low relatively
- Forces that break occurred are substantially higher than the maximum forces that can occur in the operated joints, for which the risk of accidental breakage is practically nil.
- Breaking the 30% of joints made by depositing the alloy connecting only one of the basic materials has shown that this option significantly reduces the mechanical strength of fusion and may be used only when the combination is required and a single function namely the function of electrical conductor.

When connecting the system studied, the results multifunctional Preparation of starting materials before submitting alloy connecting, but before the actual conduct of the process of merging is an important step in connecting technology. The formation of oxides on the surface or between layers deposited by layer and base material significantly reduces the contact between these areas and accordingly and mechanical strength of joints.

Types of samples test-piece termo sonic bonding process

Were subjected to two types of test samples made by thermo sonic bonding as meet two separate cases:

a) Case I in figure 9a and Figure 9b the process temperature is 50 ° C respectively 100 ° C and the quantity of heat Q (joules) stored in the material is 100 J. It may be noted that 200 of inadequate micro bonding aluminum components, diffusion of the two materials does not occur eventually leading to a tensile test in mild retinal components.

b) Case II in figure 10a and figure 10b, when the process temperature is 200 ° C and 240 ° C and the quantity of heat Q stored in material that is 400 J 600 J. In this case micro bonding is appropriate, and teeth sonotrod of anvil penetrate more prominent in material and with the onset of ultrasonic and vibration is achieved diffusion two component materials

Figure 9a. Process temperature 50°C,Al-Al material couple

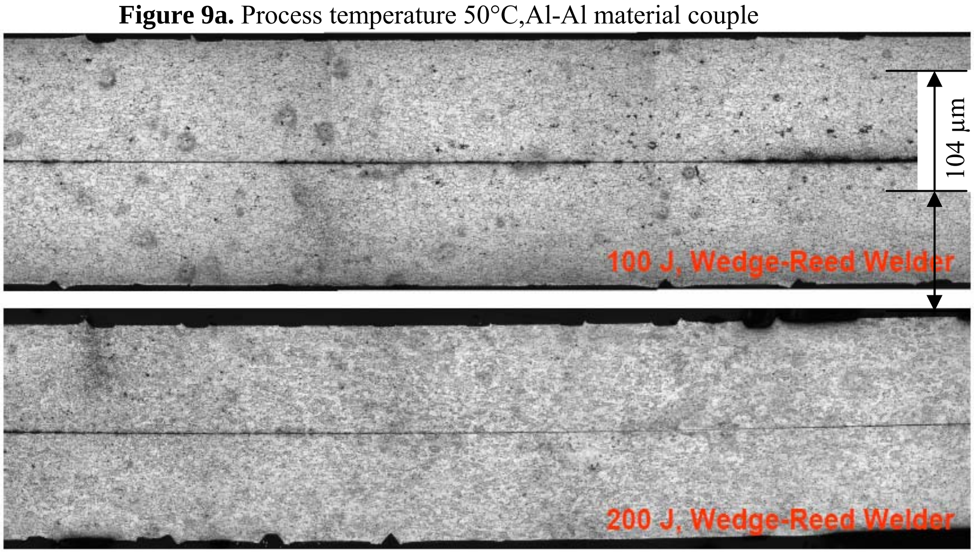
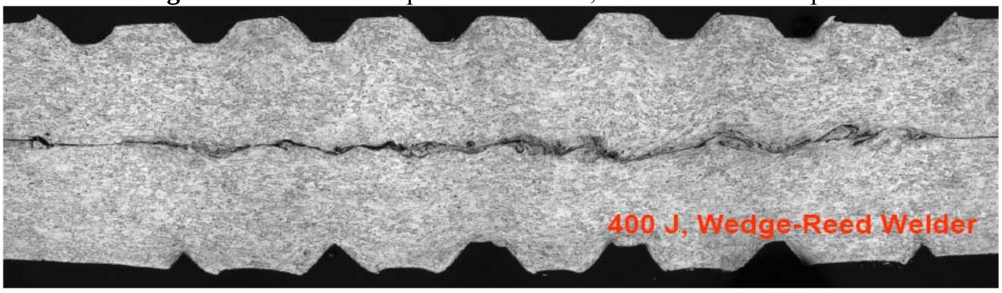


Figure 9b. Process temperature 100° C , Al-Al material couple

Figure 10. Process temperature 200° C , Al-Al material couple



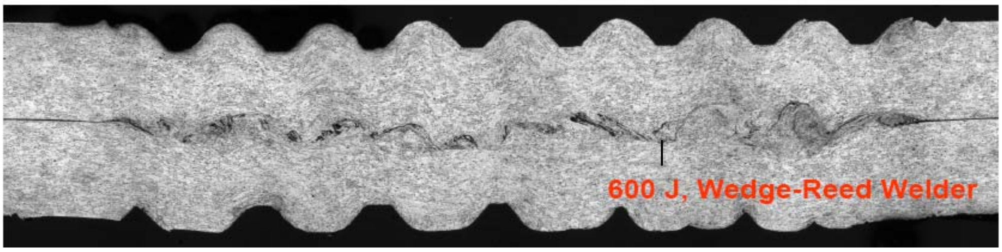


Figure 10b. Process temperature 240°C,Al-Al material couple

In Tables 3 and 4 were shown test tube samples obtained by thermo sonic micro bonding before and after tensile testing, and the couple of basic material, thickness MB, thermal heat source, the MB heating temperature, time of activation ultrasonic, pressure and location of break

Tensile test results of samples obtained by thermo sonic bonding

After conducting the tensile tests have found that:

- Of the 9 samples tested were split into 6 basic material and 3 were separated (there was an actual break, but only a detachment of micro bonding)
- Micro-bonding placental number 1, 2 and 3 is likely attributed to poor preparation, in which the two contact surfaces were not clean enough. The conditions under which it made no specific training or at least gray-white cameras, cases found in the electronics industry, but in particular laboratories usual uncontrolled atmosphere.
- Peak force was placed in 0.450 ... 0.700 k N value comparison with the forces that might occur in electronic circuits which are designed joints.
- Micro-bonding is obtained by sonotrod and the anvil teeth deformation of the aluminum component and a component of copper with a degree of deflection 20 ... 30%.

Conclusions sample thermo sonic bonding

After obtaining the results of tensile test samples reached the following conclusions:

- In terms of strength, breaking evidence is in MB, it was shown that thermo sonic bonding is particularly resistant to torque materials Cooper - Aluminum and Aluminum- Aluminum,
- If the components are heated at lower temperatures reaching a heat source, involves a pressing pressure of the spare sonotrode more joined, and conversely if high temperatures are reached, then press the power sonotrode be lower.
- combined samples that stores a small amount of heat, Q = 100-200J, not conduct a proper micro bonding, evidence is detachment, diffusion occurs, while the evidence which captures a large amount of heat, Q = 400 -- 600 J, the two components overlap ultrasound and vibration due to horizontal diffusion of atoms of the two components takes place, so it is appropriate micro bonding .

Table 3.Samples thermo sonic bonding before tensile testing

<table>
<tr><th>Sample number</th><th>Couple base material</th><th colspan="2">Thickness base material [μm]</th><th>Heat thermal source</th><th>Heating temperature basic material [°C]</th><th>Ultrasonic activation time [s]</th><th>Pressure [N/mm^{2}]</th></tr>
<tr><td>P1</td><td>Cooper-Cooper</td><td>234</td><td>234</td><td>Hot Air Blower</td><td>100</td><td>0,4</td><td>1,5x10^{5}</td></tr>
<tr><td colspan="8">
</td></tr>
<tr><td>P2</td><td>Cooper-Cooper</td><td>234</td><td>234</td><td>Hot Air Blower</td><td>150</td><td>0,4</td><td>1,5x10^{5}</td></tr>
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</td></tr>
<tr><td>P3</td><td>Cooper-Cooper</td><td>234</td><td>234</td><td>Hot Air Blower</td><td>200</td><td>0,4</td><td>1,5x10^{5}</td></tr>
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<tr><td>P4</td><td>Cooper-Aluminum</td><td>234</td><td>104</td><td>Hot Air Blower</td><td>100</td><td>0,4</td><td>1,3x10^{5}</td></tr>
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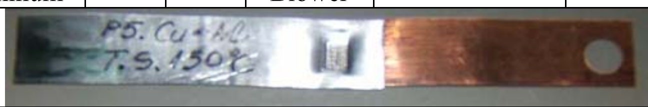
<tr><td>P5</td><td>Cooper-Aluminum</td><td>234</td><td>104</td><td>Hot Air Blower</td><td>150</td><td>0,4</td><td>1,3x10^{5}</td></tr>
<tr><td colspan="8">
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<tr><td>P6</td><td>Cooper-Aluminum</td><td>234</td><td>104</td><td>Hot Air Blower</td><td>200</td><td>0,4</td><td>1,3x10^{5}</td></tr>
<tr><td colspan="8">
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<tr><td>P7</td><td>Aluminum-Aluminum</td><td>104</td><td>104</td><td>Hot Air Blower</td><td>100</td><td>0,4</td><td>1,0x10^{5}</td></tr>
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<tr><td>P8</td><td>Aluminum-Aluminum</td><td>104</td><td>104</td><td>Hot Air Blower</td><td>150</td><td>0,4</td><td>1,0x10^{5}</td></tr>
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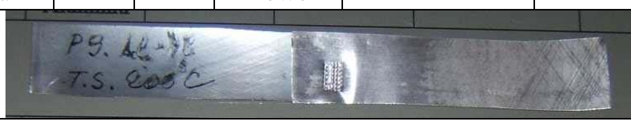
<tr><td>P9</td><td>Aluminum-Aluminum</td><td>104</td><td>104</td><td>Hot Air Blower</td><td>200</td><td>0,4</td><td>1,0x10^{5}</td></tr>
<tr><td colspan="8">
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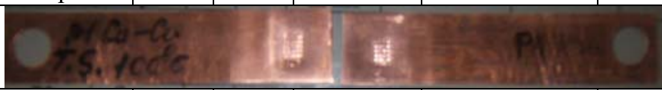
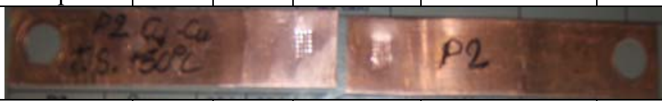
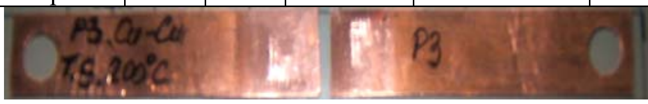
Table4. Samples thermo sonic bonding after tensile test

Sample number	**Couple base material**	**Thickness base material** [µm]		**Heat thermal source**	**Heating temperature basic material** [°C]	**Ultrasonic activation time** [s]	**Place Fracture**
P1	Cooper-Cooper	234	234	Hot Air Blower	100	0,4	Detachment
							
P2	Cooper-Cooper	234	234	Hot Air Blower	150	0,4	Detachment
							
P3	Cooper-Cooper	234	234	Hot Air Blower	200	0,4	Detachment
							
P4	Cooper-Aluminum	234	104	Hot Air Blower	100	0,4	Basic material
							
P5	Cooper-Aluminum	234	104	Hot Air Blower	150	0,4	Basic material
							
P6	Cooper-Aluminum	234	104	Hot Air Blower	200	0,4	Basic material
							
P7	Aluminum-Aluminum	104	104	Hot Air Blower	100	0,4	Basic material
							
P8	Aluminum-Aluminum	104	104	Hot Air Blower	150	0,4	Basic material
							
P9	Aluminum-Aluminum	104	104	Hot Air Blower	200	0,4	Basic material
							

- Between samples of aluminum and copper, aluminum has the highest degree of plasticity, so it is wise for aluminum plate to sit above the copper (aluminum thickness is also smaller than that of copper).
- The eutectic bonding is used added material (solders) and the thermo sonic bonding not used, resulting a high electrical conductivity and a lower electrical resistance to the termo sonic process

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Analiza comparativă a calităţii micro-îmbinărilor realizate prin procedee de micro-îmbinare eutectică şi micro-îmbinare termosonică

Rezumat

În această lucrare s-au realizat probe prin procedee noi de micro-îmbinare eutectică si de micro-îmbinare termosonică . La micro-îmbinarea eutectică , s-a folosit material de bază din cupru cu grosime de 200 µm,iar ca material de adaos s-au folosit aliaje de lipit eutectice: Aliaj SAC (Sn 95,5 Ag 3,6 Cu 0,7), Aliaj Sn 96,5 Ag 3,5 si Aliaj 42 Sn 58 Bi. La micro-îmbinarea termosonică , s-au realizat trei cupluri de materiale de bază: Cupru-Cupru; Cupru-Aluminiu si Aluminiu-Aluminiu, grosimea materialelor de bază fiind δCu = 234 µm si δAl = 104 µm. Atât la micro-îmbinarea eutectică cât si la microîmbinarea termosonică , s-au executat măsuratori ale rezistentei electrice a probelor (conductorilor sub formă de panglică), calculîndu-se apoi conductivitatea si rezistivitatea electrică a componentelor. Epruvetele obţinute prin cele două procedee de micro-îmbinare , s-au supus la încercarea de tracţiune (forfecare) , pentru a se observa unde se vor rupe , în MB sau in micro-îmbinare, iar rezultatele obţinute se compara între ele. Rezultatele au arătat o mai bună coductibilitate termică si electrica la procedeul de micro-îmbinare termosonică , şi o mai mare rezistenţă a zonei îmbinate la procedeul de micro-îmbinare eutectică.