Eutectic Microbonding of Copper Lamellar Elements of MEMS

Gabriela Demian, Danut Savu, Mihai Demian, Aurel Sebes

Abstract— **MEMS' elements assemble and MEMS packaging use different types of bonding processes. Such processes have one or more functions as: hermeticity, insulation, mechanical resistance, electrical connection or else. To have two functions simultaneously is difficult to reach. The paper aims is to present a research that was performed in order to obtain continuous joints of copper surfaces, joints that should not be fragile because the welding components are functioning in elastic mode. For that, eutectic bonding experiments have been performed and structural analysis to evaluate the intermetallic compounds was in target.**

Index Terms—**Eutectic bonding, ternary bonding alloy, intermetallic compounds, copper-copper joints**

I. INTRODUCTION

Micro-Electromechanical Systems are specific devices [1] that perform different actions for commanding systems: sensing or actuations.

They are composed of elements that are fabricated by using different types of materials from metals to polymers or ceramics.

They should be bonded by using different processes and the bonds should have specific characteristics and functions.

One of such type of applications is the assembling of two copper lamellar elements that are working in elastic regimes and should have enough elasticity and mechanical resistance to have a good behavior for a large number of bending cycles (Fig.1).

Eutectic microbonding process could answer to the specified joining problem.

The eutectic microbonding is a process that uses the property of some alloy systems to form at specific composition a eutectic structure with very low melting temperature comparing to the components of the alloy.

The low temperature is required because of the main condition that governs the MEMS technology: lower than 240°C heating to avoid high distortions, to avoid damages of neighboring elements, to avoid high quantity of emitted fume and to avoid future malfunctions of the MEMS during exploitation.

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Fig.1. Copper lamellar elements assembling

The paper aims is to present the results of an experimental research that was performed in order to obtain continuous joints on copper lamellar elements of MEMS, joints that should be no fragile because of the elastic mode of exploitation.

II. PROBLEM FORMULATION

The main problems discussed by the research were as follows:

- To reveal a bonding alloy that are able to reach the next conditions:
  - o To have lower than 240°C melting point
  - o To have a chemical composition very close to the eutectic composition, but together with the diffusion processes of copper to the bond to reach the eutectic composition [2,5,6,7,8,9]
  - o To avoid the formation of intermetallic compounds that usually brittle the structure [2,3,4,5,7,10]
- To obtain knowledge regarding the appropriate elements of the bonding process technology

A. BONDING ALLOYS

The main alloys that can be used in bonding processes of copper comes from a few alloying systems: Au-Si, Sn-Ag, Sn-Bi, Sn-Ag-Cu, and else.

Some of them are better from the melting temperature point of view, but are very expensive.

Some are very cheap and a low enough melting temperature but are not usable because they contain Pb. Starting with February 2003 the European Commission Directives, ROHS Directive 2002/95/EC and WEEE Directive 2002/96/EC, are forbidding the use of Pb in the

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bonding alloys, so the cheap and fast to melt alloys that contain Pb are not legally anymore.

New bonding alloys have been developed and a ternary alloy, Sn-Ag-Cu, has been chosen for the experimental program.

The alloys system Sn-Ag-Cu (Fig.2) has a ternary eutectic to the point: Sn95,5-Ag3,8-Cu0,7 [2,3,4,6,8,10,11].

The melting temperature of this eutectic is 217^{o}C.

The choice was based on the low temperature of melting, together with a low price because of the small quantity of Ag.

More than that, the low bonding temperature will not produce an intense diffusion, so the increasing of the copper inside the bond, by diffusion from the base material will be at a low level.

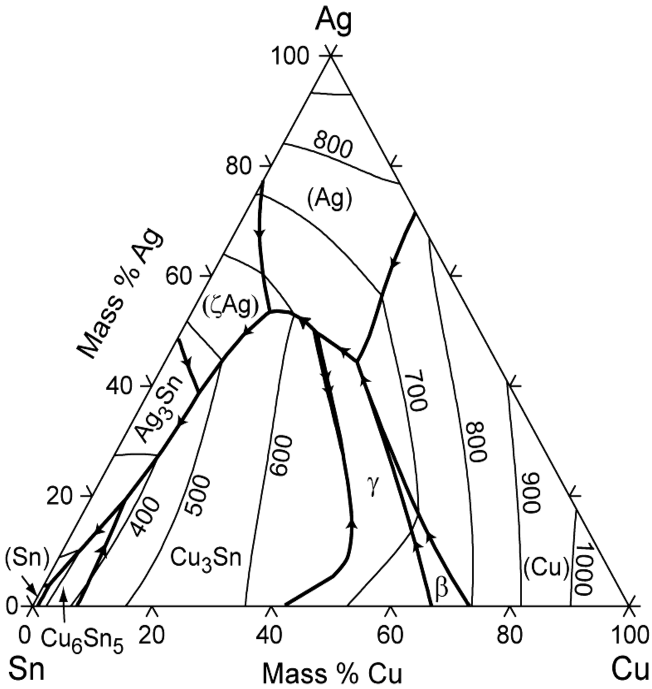

Fig. 2. Diagram of alloys system Sn-Ag-Cu

B. EXPERIMENTS CONDITION

The experimental program consisted in the bonding probes performing by resistive heating, as follows:

- Base materials: Cu-Cu (thin plates)
- Base material thickness: 0,3x0,3mm, 0,6x0,6mm
- Bonding alloy: Sn95,5-Ag3,8-Cu0,7
- Bonding process temperature: 220/230/240^{o}C
- Surfaces preparation: polishing, pure alcohol cleaning and flux cleaning
- Application of the bonding alloy: deposition before bonding by direct resistive heating
- Bonding process: the deposited surfaces were put in contact and indirect heating was applied.

Some of the realized joints are presented in fig. 3.

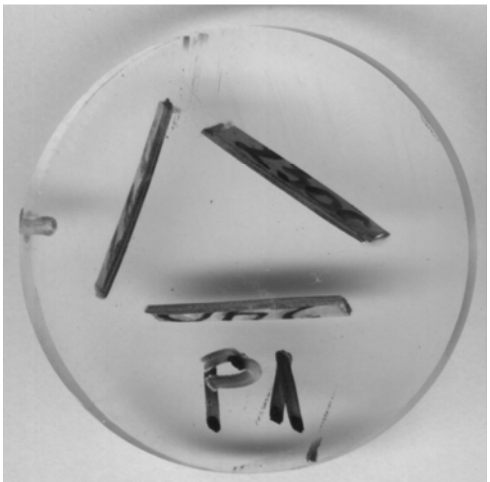

Fig. 3. Samples of joints

C. STRUCTURAL EXAMINATION

The joints were microstructural examined and in all the cases (for all the applied bonding temperatures) the structure showed (fig. 4):

- Base metal: solid solution Cu α with rare spherical inclusions of Cu_2O
- Bond area: solid solution Sn α with eutectic and intermetallic compounds Cu-Ag and Cu-Sn.

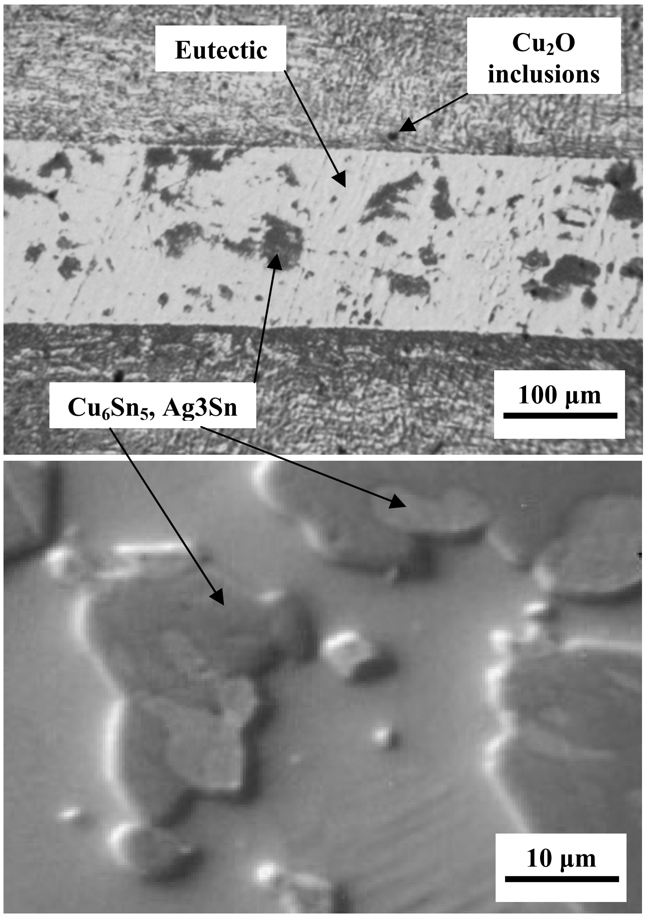

Fig.4. Samples of microstructure joints

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III. DISCUSSION AND CONCLUSIONS

Analyzing the structure of the joint a few discussion on the results can rise:

The bonding alloy permits the performing of the bonding process at about 220^{o}C, so about 5 times lower than the melting temperature of the base material (copper);

The material of the deposited material has a Sn matrix; this is done by the matrix of the bonding alloy (Sn95,5%);

The bonding alloy was exactly in the chemical composition of the eutectic, so large amount of eutectic can be detected in the bond metal;

During heating copper diffusion has been developed but no intense process was happened; that was because of the low temperature of the bonding process;

The diffused copper created instability inside the structure and reactions with the eutectic composition took place. The result of those reactions was the appearance of some types of intermetallic compounds. At 221^{o}C a reaction between Sn and Ag permitted the formation of the compound Ag_3Sn and at 227^{o}C Sn from the matrix reacted with the Cu and a new compound has been formed: Cu_6Sn_5.

The both types of the formed intermetallic compounds appear as small islands and the density of the islands depends on the temperature that is touched during process. When heat up to 220^{o}C the formation of the intermetallic compounds had low intensity because of the low level of the diffusion and because of not reaching the formation temperature. That gives appropriate mechanical properties of the bond's metal (plasticity). In the same time a negative influence is detected and that one was the long duration of the heating: up to 6 minutes for 1 cm^2. For a heating up to 240^{o}C the amount of intermetallic compounds was sensibly higher than in the previous case and the dimension of the compounds were increased comparing to the lower heating. The positive result of the high heating is the speed of the process.

There is another possibility to decrease the amount of the intermetallic compound Cu_6Sn_5 and that is the choice of a bonding alloy that has lower than 0,7%Cu. In this case, even if the melting temperature is increasing with 1-3^{o}C, the diffusion of the copper from the base metal will not be able to create a large amount of intermetallic compound.

The copper oxides that appear at the interface between bonding material and the base material could be because of an inappropriate preparation of the surface. After the alcohol cleaning a hot air drying of the cleaned surface should be apply in order to avoid any wet areas before the deposition of the bonding alloy.

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