INFLUENCE OF SOLDER JOINT HEIGHT TO INTERNAL STRESS IN MULTISUBSTRATE STRUCUTE

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ABSTRACT

This paper is focused on thermomechanical modelling of two substrates with different CTE, which can be used in various types of MSM. There can be used two materials, laminate FR4 and ceramic 96 % Al_2O_3. The interconnection of substrates is done by solder joints, where lead free solder SnAgCu is investigated in this work. ANSYS software is used and results from several analyses are discussed. One of the main purposes is a comparison of thermomechanical properties of MSMs when solder bumps height is changed.

1 INTRODUCTION

Very fast development of microelectronic technologies, especially semiconductor chips, and improvement in manufacturing technologies has dramatically increased the number of the leads of packages. Recently, one of the research objectives has been the interconnection technique. This technique is able to ensure the production of 3D structures, such as MCM and MSM, increasing the efficiency of packaging.

Most failures, which occur in these electronic systems, are caused by the thermal mismatch among different materials. In these electronic packing, many of materials with different Coefficient of Thermal Expansion (CTE) are assembled together. During the processing and service, the package goes through various temperature cycles. Such temperature variations cause thermal expansion, but the materials cannot expand freely, because they are constrained by the packaged assembly. Therefore, significant stresses are induced within the package.

These stresses can be mathematically modelled using ANSYS software, which is based on Finite Element Method (FEM). FEM software allows relatively quick and cheap analyses of strains and stresses, which occur in a device as a result of temperature changes.

As mentioned above the SnAgCu alloy has been known for many years. Although it has good mechanical properties, some experimental work has been carried out to find some other improvements. As a result of these experiments a SnAgCu ternary eutectic composition has been developed. Good mechanical properties, high reliability and of course melting point of 217 °C have meant a wide usage within electronics industry. It is estimated that SnAgCu alloy composition will remain the most popular replacement. Although there are several composition variations of this alloy worldwide some of them with bismuth or antimony addition the exact composition for this are still a matter of debate.

2 MULTISUBSTRATE MODULES

As it can be seen in Fig. 1 the modelled structure consists of two substrates, organic (FR4) and ceramic one (96 % Al_2O_3). Thermal and mechanical properties of these materials are listed in the table 1. Substrates are 10x10 mm, the organic substrate is 1 mm thick and the thickness of the alumina is 0.5 mm.

Fig. 1: *Modeled multisubstrate structure*

Material	FR4	Alumina	Sn-0.5Ag-4Cu
Density [kg/m^3]	1500	3900	7250
Elastic modulus [Gpa] -70 °C 20 °C 140 °C	22	303	57.3 52.6 44
Tensile strength [MPa]			47
Poisson's ratio	0.28	0.21	0.34
CTE [ppm/K] -55 °C 22 °C 100 °C	18.5	3.9 4.6 6.7	12.7 22 23.4

Tab. 1: *Mechanical and thermal properties of using materials*

Substrates are connected by four lead free solder (Sn-0.5Ag-4Cu) pads, which are 1mm diameter. This is a minimum number of pads to ensure a mechanical stability of the MSM during a soldering (reflow) process. It is chosen to use this minimal number of pads in the model because it allows analysing the maximal stresses in the structure. If more than four pads are used the stress is more distributed. The goal is to analyse possible dimensions of MSM with reliable connection and that is why the minimum number of pads is used.

The lead free solder is used, because he is considerate to environment and he has better elastic properties in a wide range of the temperatures and its CTE also shows better characteristic and better thermomechanical performance than the eutectic SnPb solder.

The solder pads are 0.3 – 0.9 mm high and they are placed in the corners on the MSMs at the distance 1 mm from edges of the substrates. The geometry of the pads is simplified to the cylindrical shape to achieve a quick and easier mathematical solution. The aim of the

ANSYS analyses is to say what height of solder bump shows better thermomechanical performance and higher reliability.

3 SOLUTION

The stresses are firstly observed on the structure with 0.3 mm pads high. This 3D structure is fixed in Y-direction in all four-bottom corners of FR4 substrate and it is fixed in all direction in one bottom corner. Stresses are calculated for the temperature range from the melting point of lead free solder, i.e. 217 °C to –20 °C. The result of analyses is illustrated in the Fig. 2.

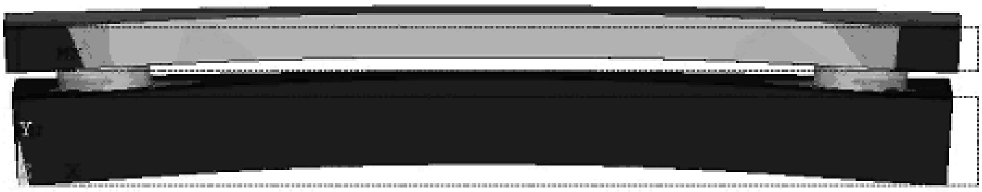

Fig. 2: Internal stresses of the structures with 0.3 mm solder high

There is shown deform shape and edge of non-deformed shape. It can be seen that refrigeration causes different curtail substrates and stress is displacement to the alumina substrate and solder joint in the main. The Fig. 3 shows detail of solder joint. There it is illustration of maximal stress. It is area where crack can be expected. Maximal stress in the solder joint is approximately 620 MPa. Maximal translation in Y-direction is in the centre of FR4 substrate and it is 47 μm.

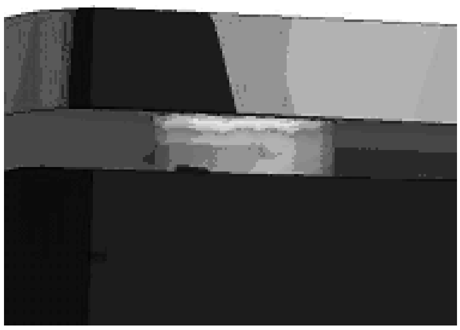

Fig. 3: Detail of maximal stress of the structures with 0.3 mm solders high

Next structure has the same dimensions of substrates and the same settings, but a height of solder joint is 0.5 mm. The result of this simulation shows Fig. 4.

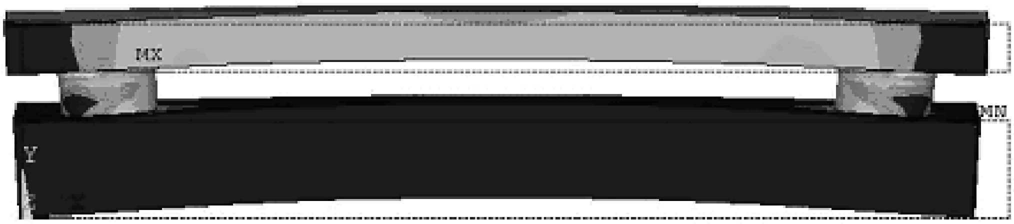

Fig. 4: Internal stresses of the structures with 0.5 mm solder high

It can be seen that stress is less displacement to the alumina substrate and the maximum stress is always on the solder pads. The value of maximum stress in this analyse is around 565 MPa. Maximal translation in Y-direction is 41 µm.
In the Fig. 5 is showing the same structure with solder pad height 0.7 mm. Maximal value of stress is approximately 540 MPa. Also in this analysis the most significant stress is in the part of solder that adjoins with alumina substrate. Maximal translation in Y-direction is 37 µm.

Fig. 5: Internal stresses of the structures with 0.7 mm solder high

Next solder joint increase confirms previous trend, i.e. stress and translation lessening. Structure with solders joint high 0.9 mm has maximal internal stress approximately 540 MPa and maximal translation in Y-direction is 33 µm.
Maximal translation is the same for all analyses and it is 70 µm in X-direction.

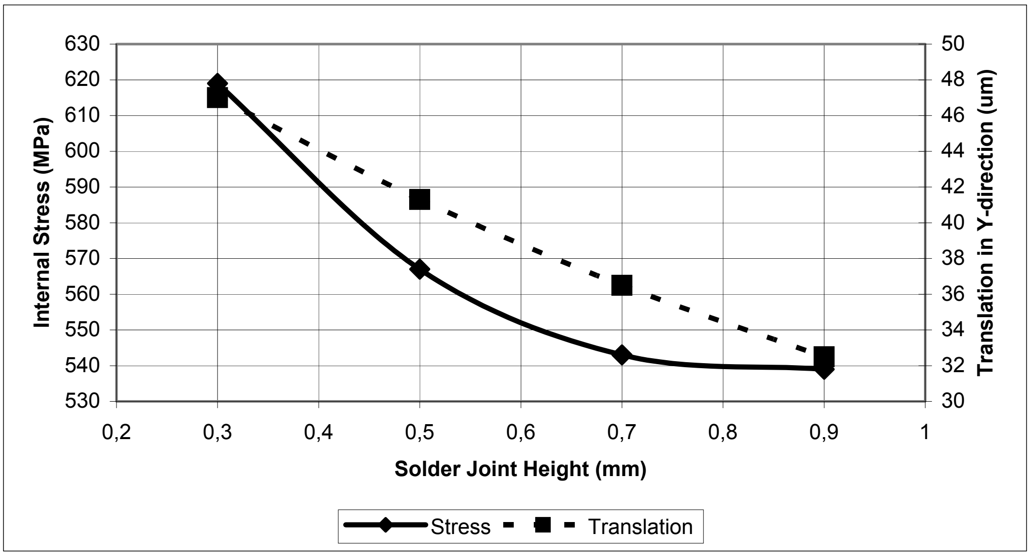

Fig. 6: Graph of internal stress and translation into dependence on solder joint height

4 CONCLUSION

It can be seen that height of solder joint is very important factor in MSMs. The results of analyses are to determine the ideal height of solder pads. There is the highest risk of crack in the first analysis, i.e. 0.3 mm solder joint high, and the structure is too much straining (see Fig. 2). As could be seen from second and third analyses (see Fig. 4, 5), there were obtained most satisfactory results. This situation is demonstrated in Fig. 6, where improving of features is evident. With increasing of solder joint height, we could achieve lower stress values with better reliability. The graph shows that increase of bump height has limit efficiency to the

stress bud maximal translation constantly decreased. It can be concluded; the structure with 0.5 mm high of solder pads shows the best results.
ANSYS analysis of the simple MSM device is presented and results can be used in improvements of the MSM design. Especially the choice of solder pads high and the determination of the places, where cracks can mostly occur, belong to the most important factors, which influence the whole design process.
It is obvious that the connection is highly stressed at the places where intermetallic compounds are created during the soldering. The mathematical model doesn't include mechanical behaviour of such materials and therefore the value of the maximal stresses in the structures has to be decreased to insure suitable reliability at the end of the production process.
There are also other simplifications and presumptions in the model of MSM and therefore the final "optimal" design has to be prototyped and analysed in various experiments.
Another problem, that has to be tackled during the design process, is a number of connection pads and their placement in the structure. This task must be solved in concrete cases to meet all design requirements such as the electrical conductivity of pads, number of pads etc. and the mathematical modelling is an ideal instrument for proving the fact that the device is going to be reliable in wide range of temperatures.

ACKNOWLEDGEMENTS

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