Toward measurements of global coefficient of thermal expansion of QFN

Vincent Sisomseun[1], Hélène Frémont[2], Alexandrine Guédon-Gracia[2], Olivier Maire[1], Pascal Retailleau[1], Catherine Jéphos-Davennel[3],

[1]MBDA France; [2]IMS Bordeaux ; [3]DGA MI
vincent.sisomseun@mbda-systems.com

ABSTRACT

1. BACKGROUND

In order to enhance precision of the solder joint fatigue laws, it is necessary to understand how the different elements of the assembly behave under thermal stresses. Solder joints are the mechanical links between Surface Mounted Device and Printed Circuit Board (PCB). Hence, the way they deform have a primor effect on the stress applied on the solder joints. Analytical models like the Engelmaier model are used to rapidly determine the fatigue life duration of solder joints. In such models, global effective parameters are implemented and the Coefficient of Thermal Expansion (CTE) is commonly one of those. CTE can be calculated by Finite Element Modelisation (FEM) knowing the right set of parameters of each material. In order to check the reliability of the simulations, experimental characterizations can be deployed. For example, measurements were conducted by Nawghane et al.[1] by using the Topography Deformations Measurement (TDM). The goal was to validate a finite element model for the QFN. In our case, the goal would be to lead a parametric study and to link the QFN construction with the associated thermal strain.

2. METHODOLOGY

To evaluate thermal strain of QFN, Thermo Mechanical Analysis (TMA) was used. The principle consists in the application by a sensor, of a neglectable constant force on the test specimen and then to apply to this latter a determined thermal profile. The temperature amplitude goes from -55°C to 125°C with a temperature ramp set at 5°C/min. When the test specimen expands or contracts, the sensor will be able to follow the displacement in one direction. The sensor displacements will be transduced and treated as a strain and plotted on a thermogram as a function of temperature. Theoretically, the relation between temperature and strain is purely linear with the CTE as the slope. So, the CTE can be found by calculating the slope of the curve. The measurements are repeated on three QFN of each type and a minimum of two for the out of plane measurement and one for the in-plane measurements. In addition to the dilatometry, profilometry measurement by fringe projection observations was carried out to verify the surface state of the QFN. The different tested QFN are the QFN64, 54, 40, 32 and the sizes go from 9 to 5 mm lenght. The QFN56 is particular due to its construction. It is indeed a punch type component which mean that it is not singulated by using a saw but by applying a pressure on component (Figure 1 : (a) Microsection of the studied daisy chained QFN64 with silicon die (b) The QFN64 observed under X-rayFigure 1).

3. RESULTS

The first results are those gathered from the dilatometry experiments. The most interesting ones are from the out of plane measurements. Between -55°C and 80°C, the curve is linear and repeatable but the QFN present a negative CTE value. Moreover, the amplitude is far too high for such a parameter (Figure 2). Typically, by studying the largest QFN in the test group, the mean measured CTE is -418 ppm/°C. First, by only considering thermal expansion, this value is not possible for these materials. This behaviour is thus linked to another mechanical phenomenon than the thermal expansion. The warpage can explain this measurement. By considering warpage, the negative slope can be explained by the decrasing convexity of the QFN by heating it. This would be transduced as a shrinkage by the sensor. According to the out of plane measurements, the studied QFN should be already deformed at ambient temperature. This have been verified by the projection fringe profilometry where a warpage of around 40 µm has been measured and the direction of the warpage confirmed (Figure 3). By observing the whole set of results for all types of QFN, we can distinguish the effect of the component size. Indeed, it seems that the smaller the QFN, the smaller the out of plane warpage. Hence, the study tends to justify a parametric study on the differents QFN. Our results tend to show that all the tested QFN are warped at ambient temperature even before the assembly. This warpage is not commonly taken into account in the finite element simulations. Hence, our study presents two main interests. First, ameliorate the simulations inputs in order to rightly describe the QFN thermomechanical behavior. Then, the big challenge will be to measure this global CTE. The definition of such effective parameter is not so easy. That is why the next step of the study is to successfully model the dilatometry experiment and to extend the measurements, to deploy the use of the Thermo-mechanical Deformation Measurement, which seems to be more optimized to answer our research questions.

---

[1] C. Nawghane, T. Moncond'Huy, B. Vandevelde, P. Vernhes and R. Cruz, "Deformation analysis of QFN packages for validation of thermo-mechanical finite element simulations," 2023 24th International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems (EuroSimE), Graz, Austria, 2023, pp. 1-8, doi: 10.1109/EuroSimE56861.2023.10100821

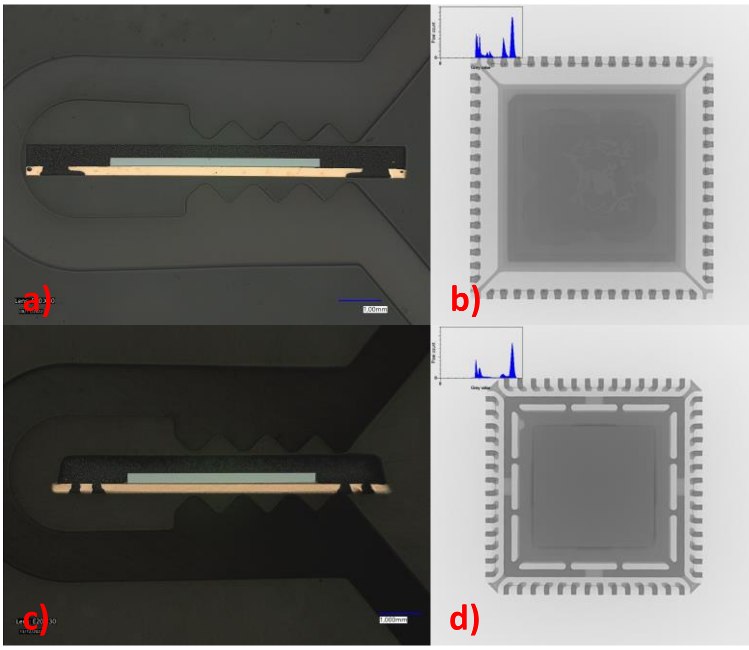

Figure 1 : (a) Microsection of the studied daisy chained QFN64 with silicon die (b) The QFN64 observed under X-ray (c) Microsection of the daisy chained punch type QFN56 (d) The QFN56 observed under X-ray with the "reinforced" leadframe

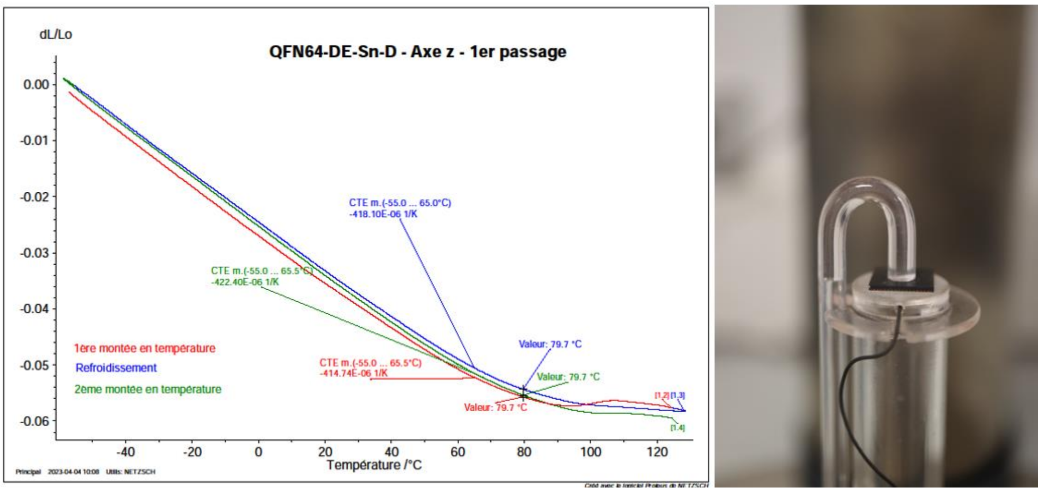

Figure 2 : (Left) Thermogram of the QFN64 out of plane measurements (Right) The experimental set up for the dilatometry experiment

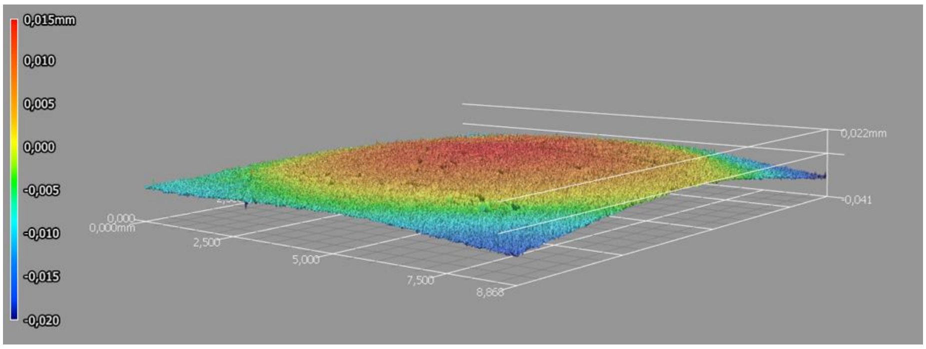

Figure 3 : View of the QFN64's warpage by fringe projection profilometry with a 2000% height magnification. For this QFN the height between the corner and the highest point has been measure at 35µm