Numerical study of a printed circuit board with embedded components under thermal cycling: influence of the manufacturing process

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Abstract

Over the time, the structure of printed circuit boards (PCBs) has gotten more and more complex, evolving from single-layer PCBs to multi-layer assemblies. The materials constituting these layers present very different coefficients of thermal expansion (CTEs). This mismatch induces stress inside a PCB when it undergoes thermal loading.
Furthermore, to improve thermal and electrical properties as well as to increase interconnexion density, a new generation of PCBs is under development (1). This technology consists in embedding components inside the PCB during its manufacturing process. However, by doing so, the material heterogeneity of the assembly is increased. Therefore, the reliability of this technology needs to be assessed.

A PCB has to successfully pass several qualification tests, among which the thermal cycling test. More precisely, (-55◦C/125◦C) thermal cycles have been applied on a 3D finite element model, whose geometry is based on an actual four-layer PCB with embedded components. This study focuses on the vicinity of one of these components. Since the latter is connected to the copper tracks via solder bars, a particular attention has been given to the geometry of the solder connections and the copper layers. Furthermore, a precise description of the thermo-mechanical constitutive behavior of the materials is proposed. Hence, the dielectric materials (the woven composite and its resin) were fully characterized by a combination of experimental and numerical methods (2). Based on a literature survey, the thermo-elasto-viscoplastic behavior of the solder material (SAC305) has also been implemented in ABAQUSTM via an UMAT subroutine (3).

A first model, considering that the assembly stress free before thermal cycling has shown that the solder pads represent the most critical region due to an important plastic strain accumulation, leading to a possible low-cycle fatigue (4). This is mainly due to the combined tension-bending loading of the component. It also appears, via a parametric study, that the resin-filled cavity, which encapsulates the chip, plays a primary role in this response.

For this reason, a second model, representative of the manufacturing process has been developed. This model is based on an experimental evaluation of the dielectric chemical shrinkage

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during curing (5). With the latter model, the stress fields inside the PCB after processing have been evaluated. A significant change in the response of the PCB to thermal cycling has been observed when these residual stresses are introduced. Therefore, it appears that when numerically studying the reliability of a PCB with an embedded component, it is of paramount importance to also model the manufacturing process.

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Keywords: Printed Circuit Boards; Embedded component; Finite element modelling; Solder bars; Manufacturing process

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