Microvia homogenised behavior for the mechanical modelling of PCB with embedded components

Flora Dailland*†[1], Gautier Girard[1], Mounira Bouarroudj[2], Marion Martiny[1], and Sébastien Mercier[1]

[1]Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux – University of Lorraine, France, Centre National de la Recherche Scientifique - CNRS, École Nationale Supérieure d'Arts et Métiers (ENSAM) – France

[2]Systèmes et Applications des Technologies de l'Information et de l'Energie – Université Paris Est Créteil, Université Paris Saclay, Centre National de la Recherche Scientifique - CNRS – France

Abstract

The transition to "all-electric" is leading to a growing demand for power electronics. In order to include more components in an ever-smaller volume, the embedding of active components in the core volumes of printed circuit boards (PCBs) appears to be a suitable solution (Huesgen 2022) (Bouarroudj 2023). There are various technologies for embedding components, such as chip-on cavity technology (R. Aschenbrenner 2000), chip-on-substrate technology (Tao-Chih Chang 2015) or double-side-microvias (Huesgen 2022). The interconnection in these technologies is usually ensured by microvias (John H. Lau 2000) which provides good electrical and thermal contact between PCB and component. However, incorporating a ceramic chip (Silicon or Silicon Carbide) inside the printed circuit board can lead to new failure mechanisms occuring during the thermal cycle or when the device is active (Young Todd 2000) (Maarten Cauwe 2022). The interface response between the chip and the microvia needs particular attention (Birch 2009) (Li-Na Ji 2010).
In the present work, the embedded chip is connected by multiple microvias while classical SMT (Surface Mounted Technology) used solder paste. A centimetre-sized chip can accommodate several hundred of microvias. Numerical modelling of such a structure using finite element method (FEM) is unrealistic because of the extremely time-consuming nature of meshing operation and calculations. Then we propose to replace the microvia structure and the FR4 material in its neighbourhood by its homogenised thermomechanical response (W. Kpobie 2014).

Lots of homogenisation methods exist in literature for heterogeneous materials containing ellipsoidal inclusions (Eshelby 1957) (Hill 1963) (Mori et Tanaka 1973). The microvia geometry is complex, so no analytical solution is available for the microvia shape. Then a numerical study is compulsory. In the present work, the Representative Volume Element (RVE) is referred to as the elementary pattern of a periodic medium describing the chip interconnexion method. The periodicity of the medium is reproduced from the RVE using Periodic Boundary Conditions (PBC). After calculation, the elastic response of the microvia structure is found to be orthotropic.

*Speaker
†Corresponding author: flora.dailland@univ-lorraine.fr

The homogenised mechanical response of the microvia is next implemented in finite element model of different configurations facing thermal cycles from -55∘C to 125∘C. Simulations where the microvia is geometrically represented are carried out at the same time. Average quantities (stress and strain) at the level of the RVE are compared between the two configurations to validate the homogeneous model.

Predictive capabilities of the present work are illustrated for two classical configurations in the PCB industry. First a grid of 9 microvias connected to a component made of silicon is subjected to thermal cycles. It is found that adopting the homogenised response for eight microvias does not change much the mean stress and strain faced by the central microvia. In the second case, three stacked microvias are considered. Once again, the overall response for each level of microvias is well reproduced.

Acknowledgment: The authors acknowledge the support of ANR through the project MODUFEET ANR-21- CE05-0040-04.

References

Birch, Bill. "Reliability testing for microvias in printed wire boards." 2009.

Bouarroudj, Bensebaa, Petit, Lefebvre. "Power Cycling Test of PCB-Embedded Power Packaging." PCIM Europe 2023; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management. 2023.

Eshelby, John Douglas. "The determination of the elastic field of an ellipsoidal inclusion, and related problems." 1957.

Hill. "ELASTIC PROPERTIES OF REINFORCED SOLIDS : SOME THEORETICAL PRINCIPLES." 1963.

Huesgen, Till. "Printed circuit board embedded power semiconductors: A technology review." Power Electronic Devices and Components, 2022.

John H. Lau, Chris Chang. "An overview of microvia technology." 2000.

Li-Na Ji, Yi Gong, Zhen-Guo Yang. "Failure investigation on copper-plated blind vias in PCB." Microelectronics Reliability, 2010.

Maarten Cauwe, Chinmay Nawghane, Marnix Van De Slyeke, Stan Heltzel, ESA-ESTEC, Jason Furlong, Bob Neves. "Design and testing of three levels of microvias for high-reliability PCBs." 2022.

Mori, T., et K. Tanaka. "AVERAGE STRESS IN MATRIX AND AVERAGE ELASTIC ENERGY OF MATERIALS WITH MISFITTING INCLUSIONS." 1973.

R. Aschenbrenner, A. Ostmann, E. Jung, C. Landesberger, H.Reichl. "A new approach for system integrated packaging." 2000.

Tao-Chih Chang, Chang-ChunLeea, Chia-Ping Hsieh , Sheng-Che Hung , Ren-Shin Cheng. "Electrical characteristics and reliability performance of IGBT power device packaging by chip embedding technology." Microelectronics Reliability, 2015.

W. Kpobie, N. Bonfoh, C. Dreistadt, M. Fendler, P. Lipinski. "Three-Dimensional Thermomechanical Simulation of Fine-Pitch High-Count Ball Grid Array Flip-Chip Assemblies." Journal of Electronic Materials , 2014.

Young Todd, Frank Polakovic, Michael Carano. "Thermal Reliability of Laser Ablated Microvias and Standard Through-Hole Technologies as a Function of Materials and Processing."

Electrochemicals Inc, 2000.