Non-intrusive multi-physics PGD-based reduced model for the modeling of power electronic modules

L. Schuler[1,2], L. Chamoin[1], Z. Khatir[4], M. Berkani[5], M. Ouhab[2], and N. Degrenne[2]

[1] *Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS - Laboratoire de Mécanique Paris-Saclay, France*
[2] *Mitsubishi Electric R&D Centre Europe (MERCE), France*
[4] *Université Gustave Eiffel, SATIE, France*
[5] *Université Paris EST Créteil, SATIE, CNRS, ENS Paris-Saclay, France*

Power electronic modules transform the electrical grid current with respect to the need of the motor, and are key components of numerous electrical systems. Power modules are made of an assembly of multiple materials with different constitutive properties (Fig. 1). The self-heating of the chip by Joule's effect and the difference of thermal expansion coefficients generate thermal stresses leading to crack propagation. In return, the crack modifies the module behavior by increasing electrical and thermal resistances. Cracks ultimately lead to module failure [1]. The accurate modeling of the electro-thermo-mechanical module behavior is of paramount importance to predicting the module lifetime. However, multiple uncertainty sources decrease the reliability of lifetime models. Uncertainty quantification studies need to evaluate the lifetime model a high number of times and thus require a reduced model.

In this work, we developed a reduced-order model based on the Proper Generalized Decomposition (PGD) [2, 3] to obtain an explicit representation of the solution with respect to space, time, and design parameters. The considered types of design parameters are material properties and geometric parameters. The studied model is a realistic industrial model that requires commercial finite element software, ANSYS. PyAnsys python packages are used to work interactively with ANSYS and to develop a non-intrusive approach to build the reduced model. To solve the multi-physics problem, a specific method has been developed. First, a strongly coupled electro-thermal problem is solved using an iterative method in which the crack length is parametrized. Then, the mechanical problem is solved in which the temperature field is the input. The crack length evolution, modeled with a cohesive zone model, is then obtained from the mechanical solution.

References

[1] N. Dornic, A. Ibrahim, Z. Khatir, S.H. Tran, J.-P. Ousten, J. Ewanchuk, and S. Mollov. Analysis of the degradation mechanisms occurring in the topside interconnections of igbt power devices during power cycling. *Microelectronics Reliability*, 88-90:462–469, 2018. (ESREF 2018).

[2] F. Chinesta, P. Ladeveze, and E. Cueto. A short review on model order reduction based on proper generalized decomposition. *Archives of Computational Methods in Engineering*, 18(4):395, 2011.

[3] L. Schuler, L. Chamoin, Z. Khatir, M. Berkani, M. Ouhab, and N. Degrenne. Iterative pgd model reduction for the strongly-coupled thermomechanical analysis of crack propagation in power electronic modules. *Computational Mechanics*, 2022. (*under review*).

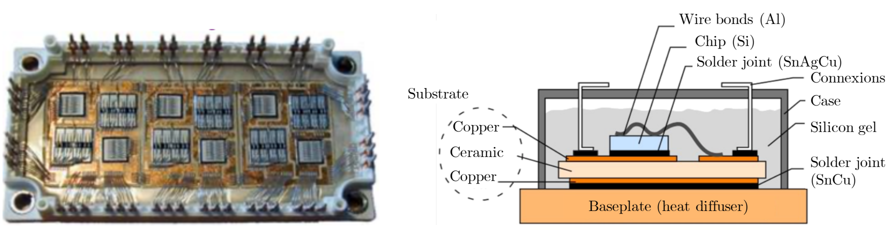

Figure 1: IGBT power electronic module and schematic representation of its components.