FINITE ELEMENT ANALYSIS OF ACTIVE METAL BRAISED SEMICONDUCTOR PACKAGE FOR WARPAGE REDUCTION

Roberto Louis Moran[1,2a], Aristotle T. Ubando[1,2b], Jeremias Gonzaga[1,2c]
[1]Mechanical Engineering Department, De La Salle University, Manila, Philippines
[2]Thermomechanical Analysis Laboratory, De La Salle University – Manila: Laguna Campus, LTI Spin Road, Laguna Blvd, Biñan, Laguna, Philippines
[a]aristotle.ubando@dlsu.edu.ph, [b]moran_roberto_louis@dlsu.edu.ph, [c]jeremias.gonzaga@dlsu.edu.ph

ABSTRACT

Warpage in the AMB ceramic substrate can lead to device failure even before the product leaves the production line. This is induced by thermal processes in manufacturing and presents a challenge when manufacturing semiconductor packaging. Back-side channel pattern cutting is proposed. Layer geometry and the coefficient of thermal expansion of each material influences deformation rate and direction. Finite Element Analysis is used to design channel patterns, coupled with direct optimization to get the best configuration possible.

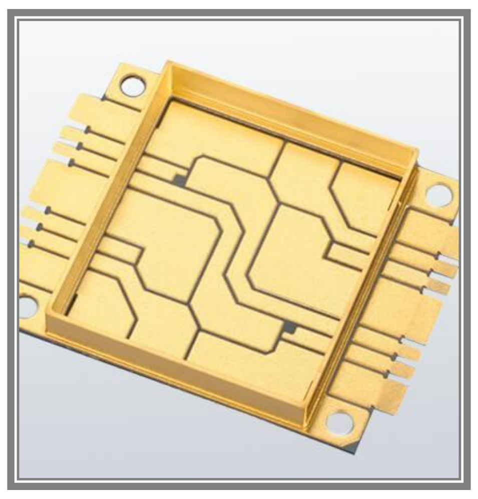


Fig. 1. Sample design Kyocera semiconductor components ("Power - AMB substrates)

METHODOLOGY

MODEL GEOMETRY: The model and top and bottom channel patterns are drawn as shown. Interconnections and discreet parts below a certain size threshold are removed, which simplifies the simulation. A top layer has dies and its own channel layers that only the user can adjust via the CAD modeler.

MESH GENERATION: data from Zhang et al., (2019) helps validate our mesh and model. Their research guides helps us find the minimum refinement needed to get accurate results.

BOUNDARY CONDITIONS: Al_2O_3-AMB and Si_3N_4-AMB ceramics were simulated. Materials assigned to each domain are shown on table 1. Thermal cycling from room temperature to 160° C was simulated.

DIRECT OPTIMIZATION: controls channel dimensions and placement via controlled parameters attached to the Design Modeler on ANSYS Mechanical and uses a screening method based on the shifted Hammersley sampling algorithm.

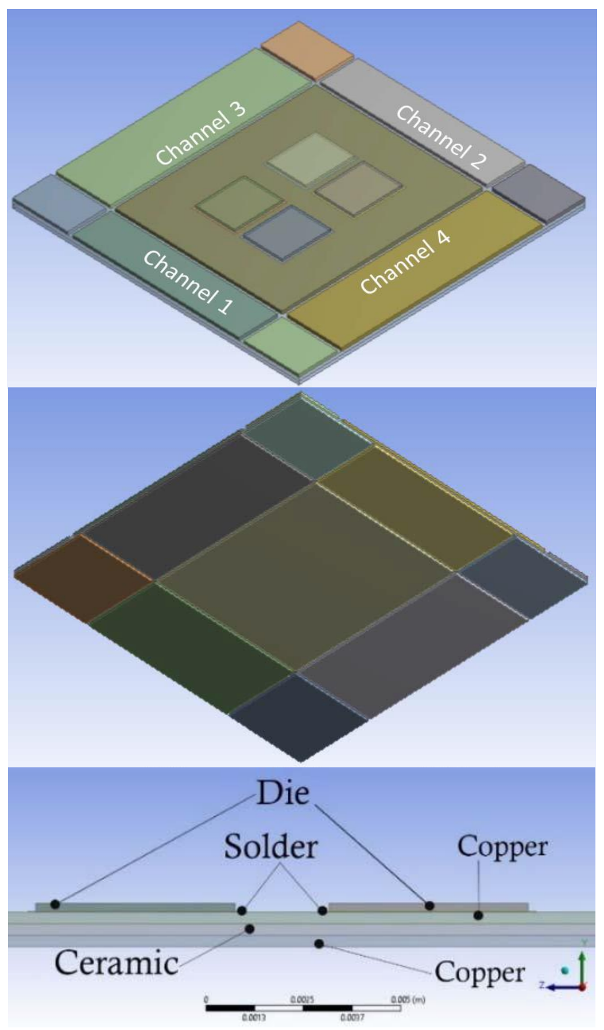


Fig. 3. Channel placement and AMB assembly

Component		**CTE** (×10^{-6} C^{-1})	**Young's Modulus(GPa)**	**Poisson's Ratio**
Copper Layer	Cu	17.7	127	0.34
Solder	Ag	20.6	72	0.37
Die	SiC	4.6	451	0.16

Table 1 Material Assignments

CONCLUSIONS

Direct optimization proved to be an effective tool in engineering design, specifically adjusting geometry dimensions. The use of back-side channel patterns also proved useful in minimizing warpage. Die placement and channel position and length can be inferred as having the greatest influence on deformation, more than thickness and die-size. In image is the final design created by the DO, based on results generated on each simulation.

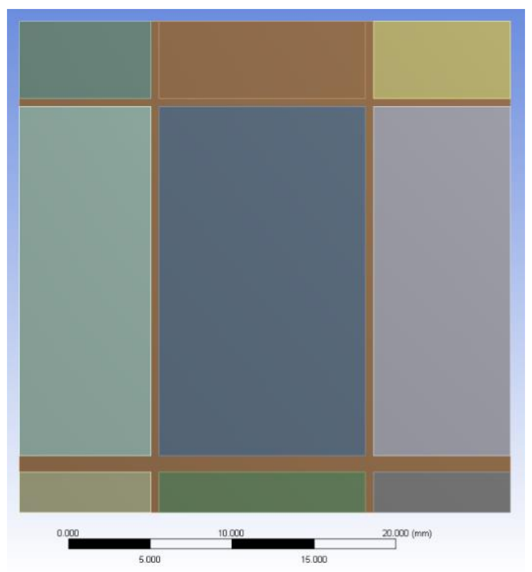


Fig. 5. Final pattern designed by DO

INTRODUCTION

The AMB substrate is a key semiconductor packaging technology for automotive power module electronics. These packages are composites of copper and ceramic, which has optimal heat-dissipation characteristics (Lim et al., 2018; Zhang et al., 2019). Current electronics technology is expected to increase in complexity and transistor density (Moore, 1965).

Arriola et al. (2019) simulates a composite aluminum nitrate AMB package on ANSYS FEA. This demonstrates how channel cutting on the coper layer can take advantage mechanical properties of the composite materials and dictate deformation rate and direction, as shown in the image on the right. Zhou et al. (2015) notes that adjusting the distance between ceramic bases of DBC plates on a power module can reduce over-all warpage without increasing experienced stresses. This current study adds the use of direct optimization (DO), built-in ANSYS Design Explorer, to design more complex channel patterns on a larger design.

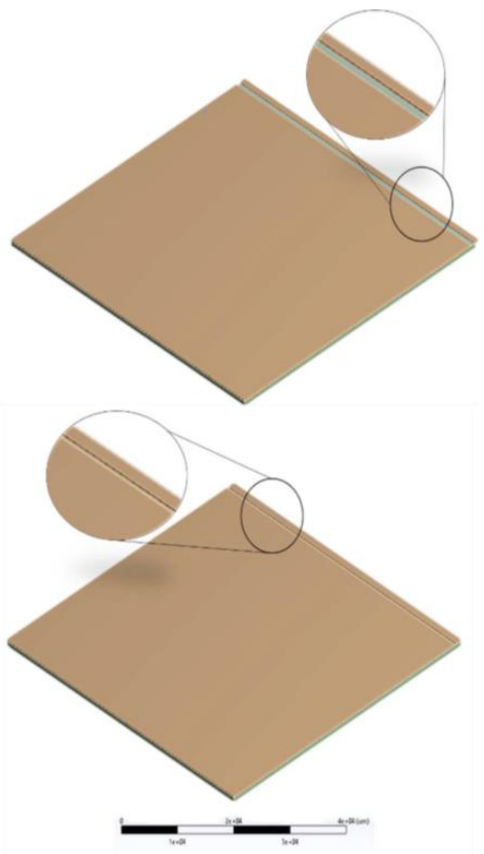
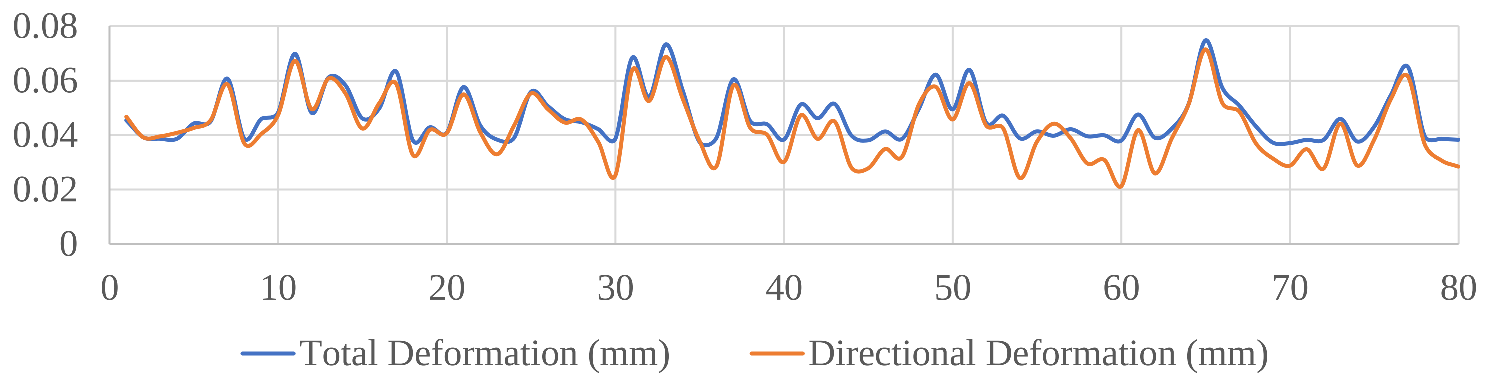


Fig. 2. Simple copper pattern on ceramic-copper composite(Arriola et al., 2019)

RESULTS AND DISCUSSIONS

Using optimization to run the structural simulations, several candidate configurations were found, and the best was chosen. Along with this, maps of stress, strain, and warpage propagation were output. A base design with no back-side channels was tested to assess both warpage strength and potence of the DO algorithm. A separate correlation study was done on the base design and found that the greatest influence on warpage is the placement of channel 2 from the center. In the correlation study, the distance of each channel-tip from the edge is varied, allowing the effect of channel length to be assessed. The length of channel 3 has the second strongest correlation strength. In the optimization, channels are cut edge-to-edge as originally shown in figure 2. A maximum warpage of 510 micrometers was found on the unoptimized design, as shown in Figure 3. Using DO, warpage was reduced by 27.8 micrometers, nearly 93%.



Graph 1. For each optimization run, Design Explorer created 80 iterations and outputs each iteration's distance to the goal (0 mm total/directional deformation)

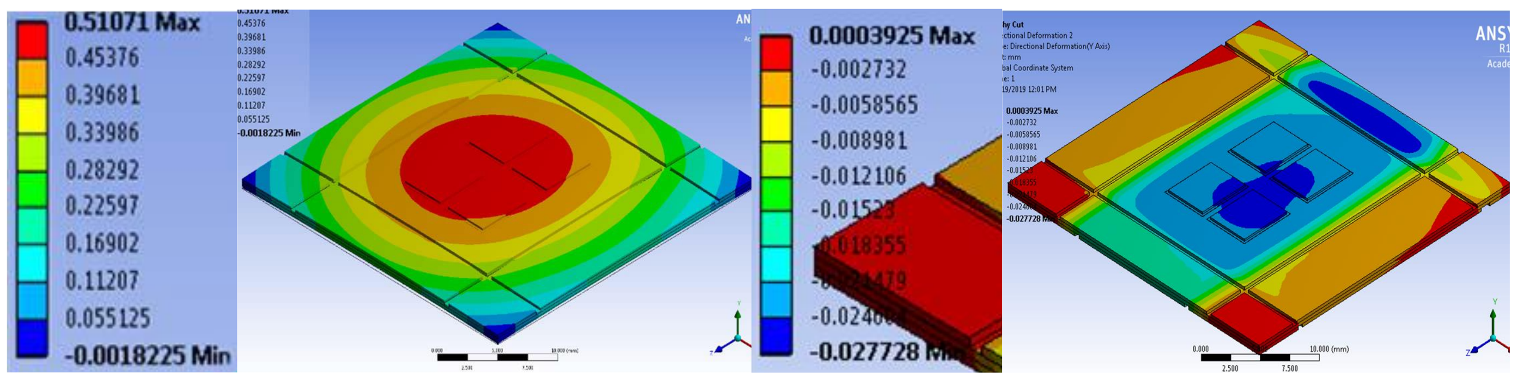


Fig. 4. (left)Total deformation of the initial design, with no back-side pattern, and (right) optimized design

Parameter	**Total deformation**	**Directional deformation**
Vertical die placement	17.0%	17.4%
Gap between dies	14.5%	14.6%
Channel 2, distance from die center	38.6%	39.0%
Channel 3, length	27.6%	27.6%
Channel 2, thickness	15.6%	15.7%

Table 2 The sensitivity of warpage to the strongest geometry dimensions