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Advanced Multiphysics Simulation for High Performance Power Electronic Packaging Design

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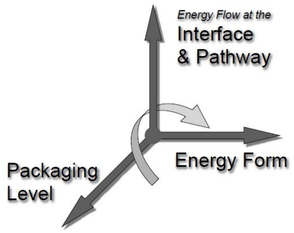
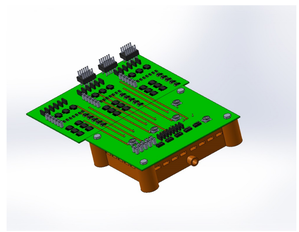
Multi-physics Simulation

- Finite Element Method based analysis approach
- Investigate interactions between thermal, electrical and mechanical aspects within Power Electronics Packaging

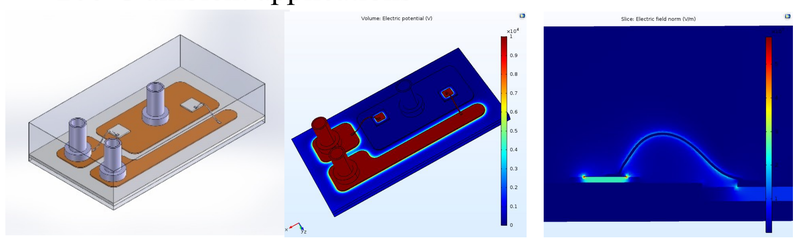




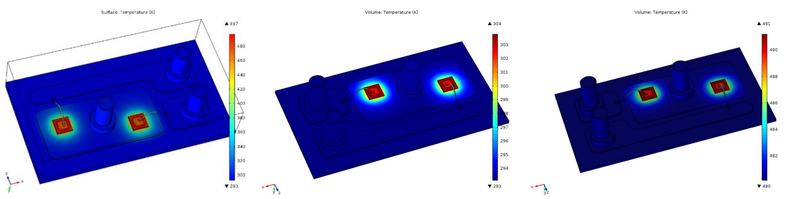
- Applications
  - Power Electronic Packaging Design
  - Manufacturing Processes Optimization
  - Reliability Assessment

High Voltage High Temperature Power Module Development

- Multiphysics simulations to verify SiC power module layout design and components selection for >10kV and >200ºC ambient applications



- 10kV applied to the power module
- Electric field distribution verified 10kV capability of designed power module



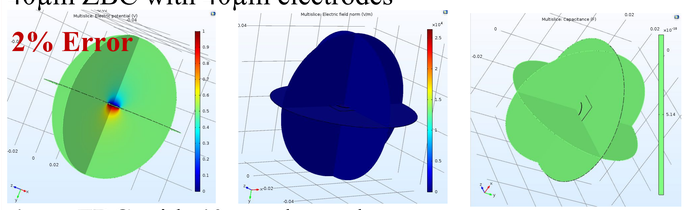
- Power Module Thermal Impedance was 0.4398ºC/W obtained by simulation results
- Temperature distribution verified highest operation temperature was 214ºC

20µm / 40µm ZrO_2 based ceramic as Power Module Substrate

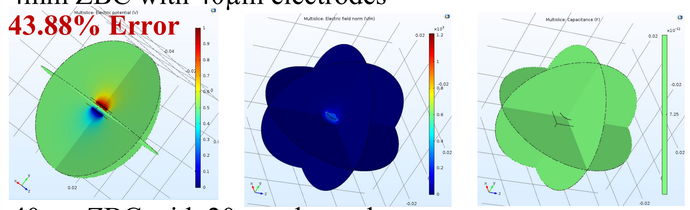
Fringing Effect

- Estimate error induced by fringing effect for relative permittivity measurement of ultra-thin ZBC substrate
- Ceramic model placed at the center of air sphere (r=40mm)

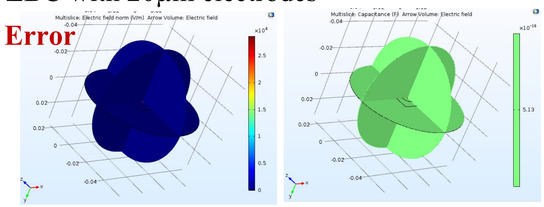
40µm ZBC with 40µm electrodes



4mm ZBC with 40µm electrodes

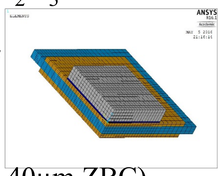


40µm ZBC with 20µm electrodes

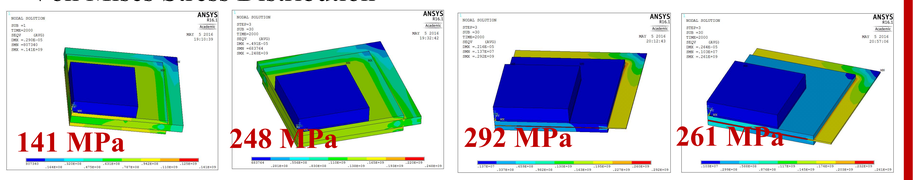


Pre-stress Analysis

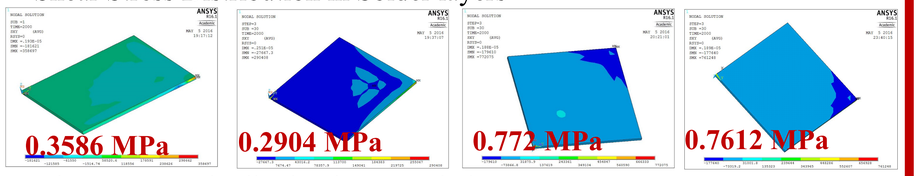
- Comparison between 10mil AlN, 10mil Al_2O_3 and ZBC
- 2kV ~ 3kV application
- Anand Consititutive Model for Sn63Pb37
- Center point at bottom face was fixed
- From 180ºC to 25ºC in 160s



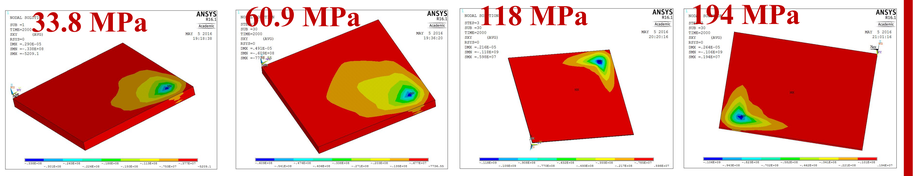
- Stress Distribution in Models (AlN, Al_2O_3, 20µm ZBC, 40µm ZBC)
- Von Mises Stress Distribution



- Shear Stress Distribution in Solder layers



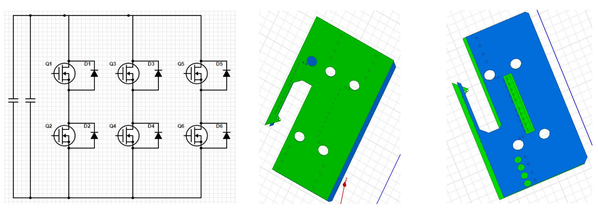
- Shear Stress Distribution in Ceramic layers



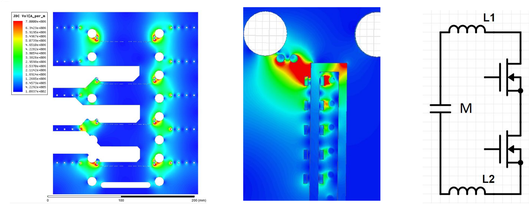
- **Maximum Von Mises Stresses were located at far end corner of the interface between ceramic layers and Cu layers**

Parasitics Extraction of 50kW EV Motor Drive Busbar

- 4-layer PCB board busbar with 4 oz copper on each layer, FR4 dielectric thickness was 0.2mm
- Schematic of three phase inverter with DC link capacitors and busbar model



- Current distribution on the busbar and parasitics distribution on the busbar



$$L = L_1 + L_2 - 2M$$

- Parasitics on the ceramic capacitor loop was 4 nH
- Parasitics on the film capacitor loop was 9 nH

Conclusions

- Multiphysics simulation is a powerful tool to investigate interactions between thermal, electrical, mechanical aspects in power electronics packaging
- Layout design and components selections were verified for 10 kV power module applications
- Parasitics on 50kW EV motor drive busbar was extracted
- Fringing effects and pre-stress of ZBC substrate were investigated

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