Thermo-Mechanical Optimisation of Press Pack IGBT Packaging using Finite Element Method Simulation

Michael Varley, Ashley Plumpton, Chas Tonner, Robin Simpson

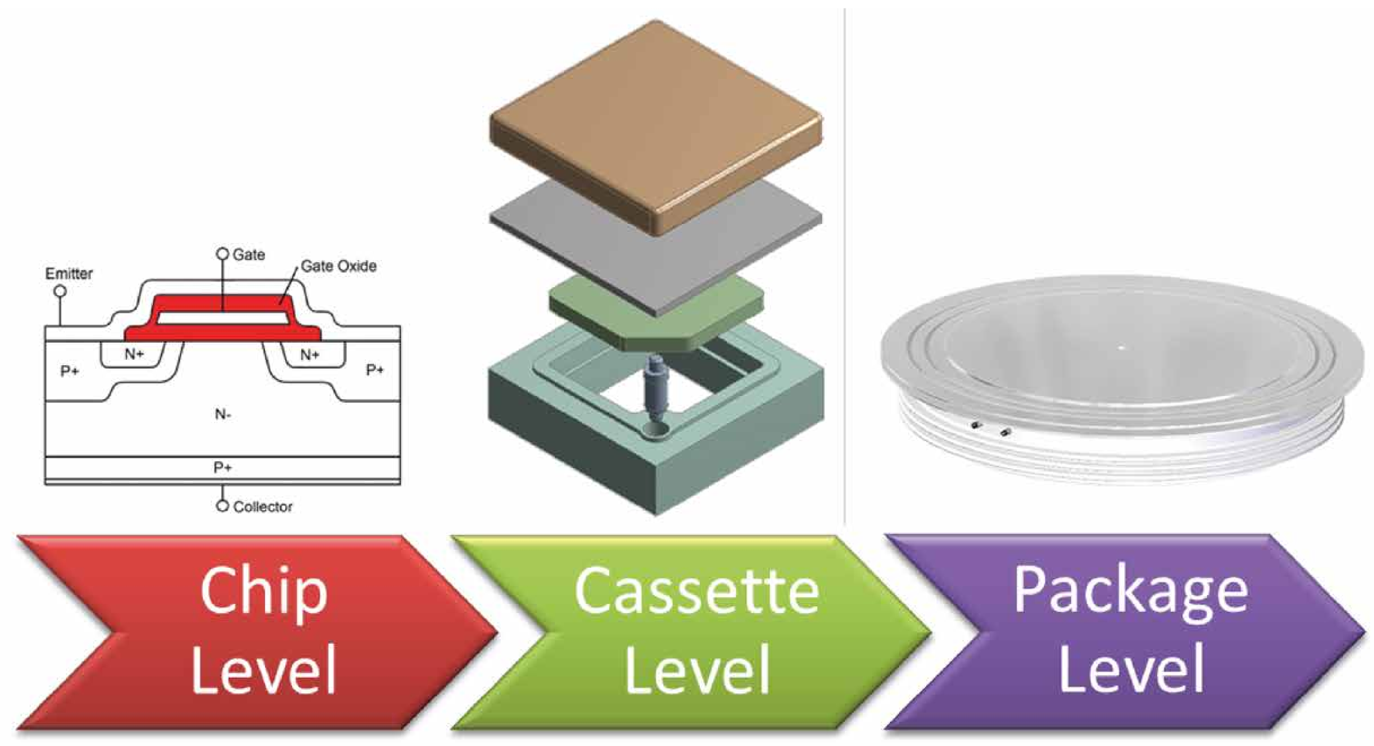
Introduction

Design of Press Pack IGBT packaging needs to take into consideration of a number of requirements:

1. Protection of the IGBT structure
2. Minimisation of bulk stress in the IGBT
3. Minimisation of thermal resistance
4. Maximisation of compliance
5. Maximisation of reliability

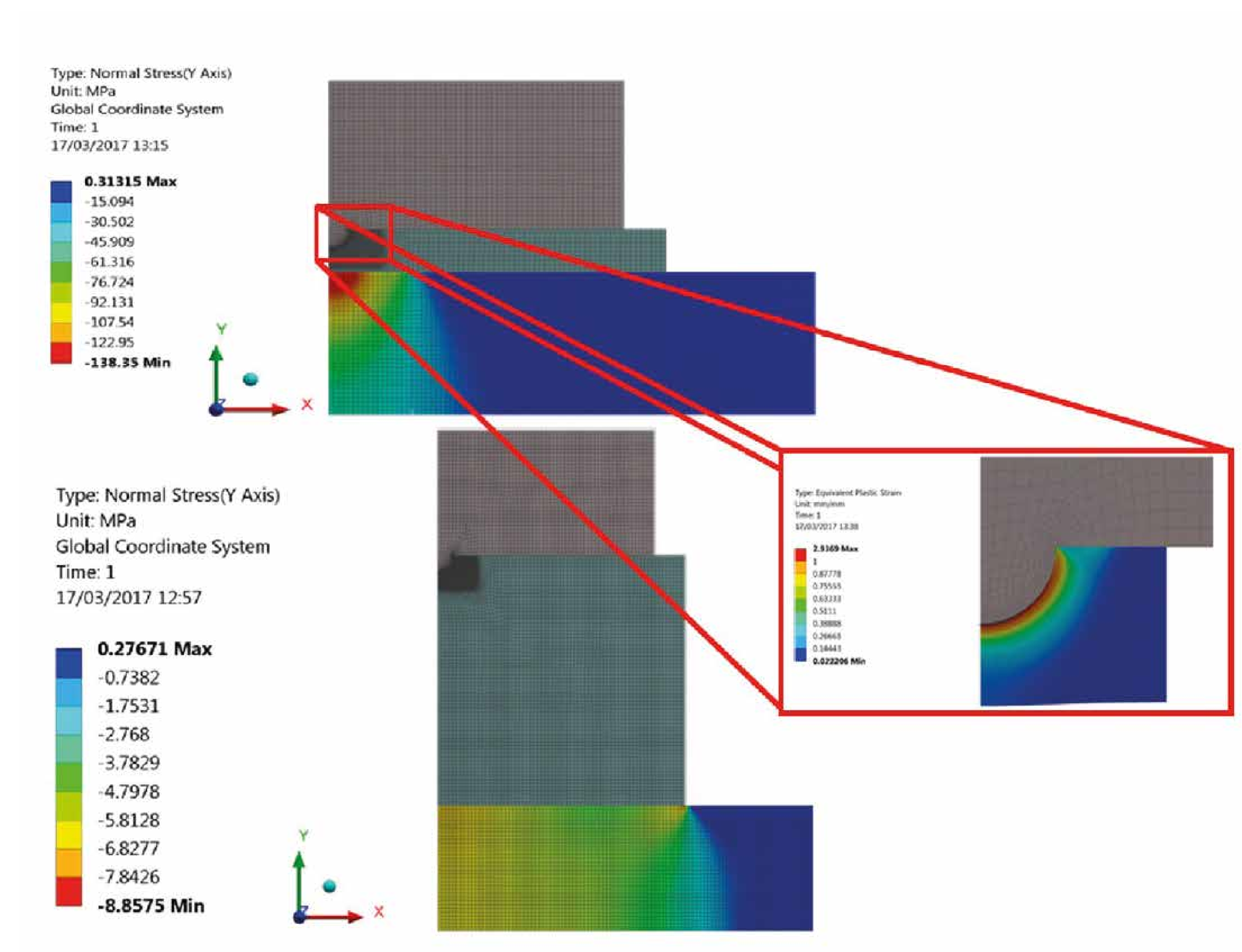
These represent chip, cassette and package level requirements.

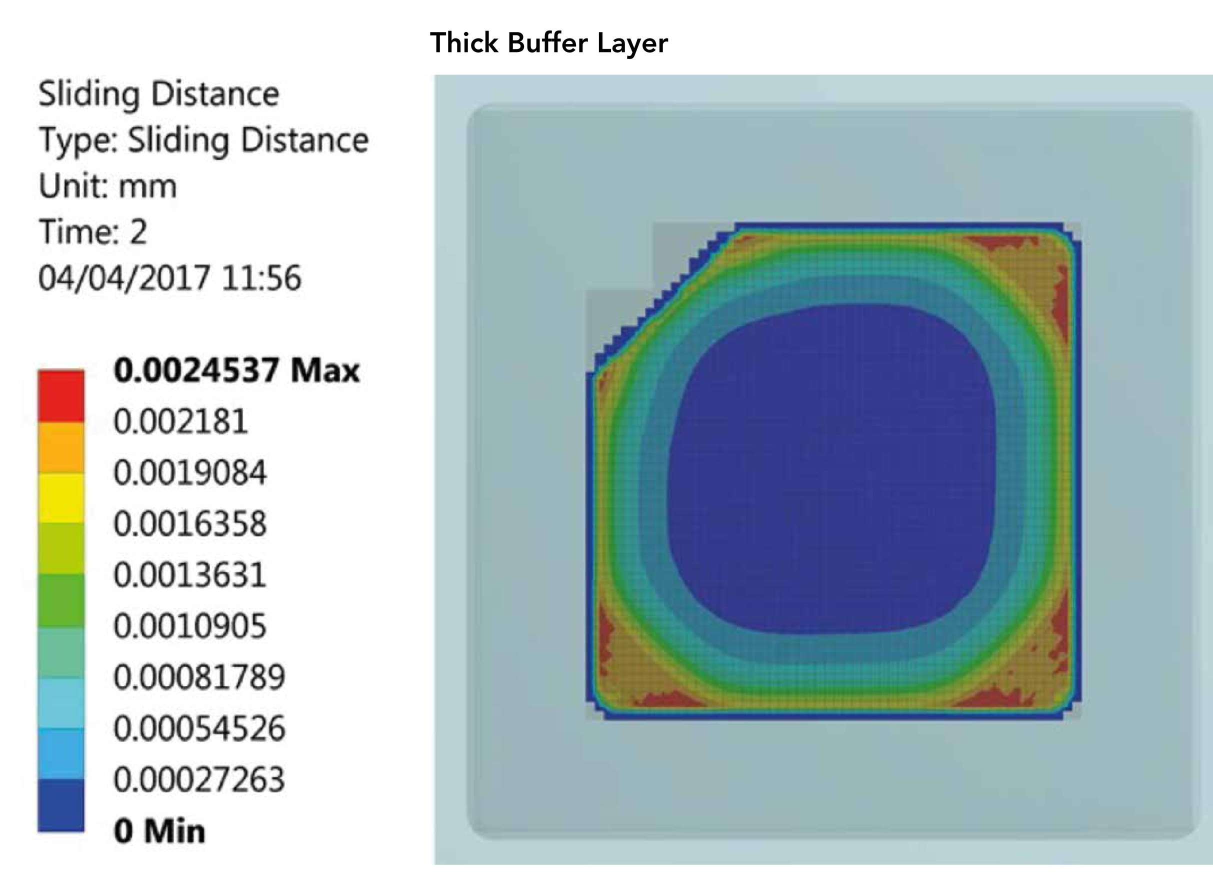
Stages of Press Pack Optimisation

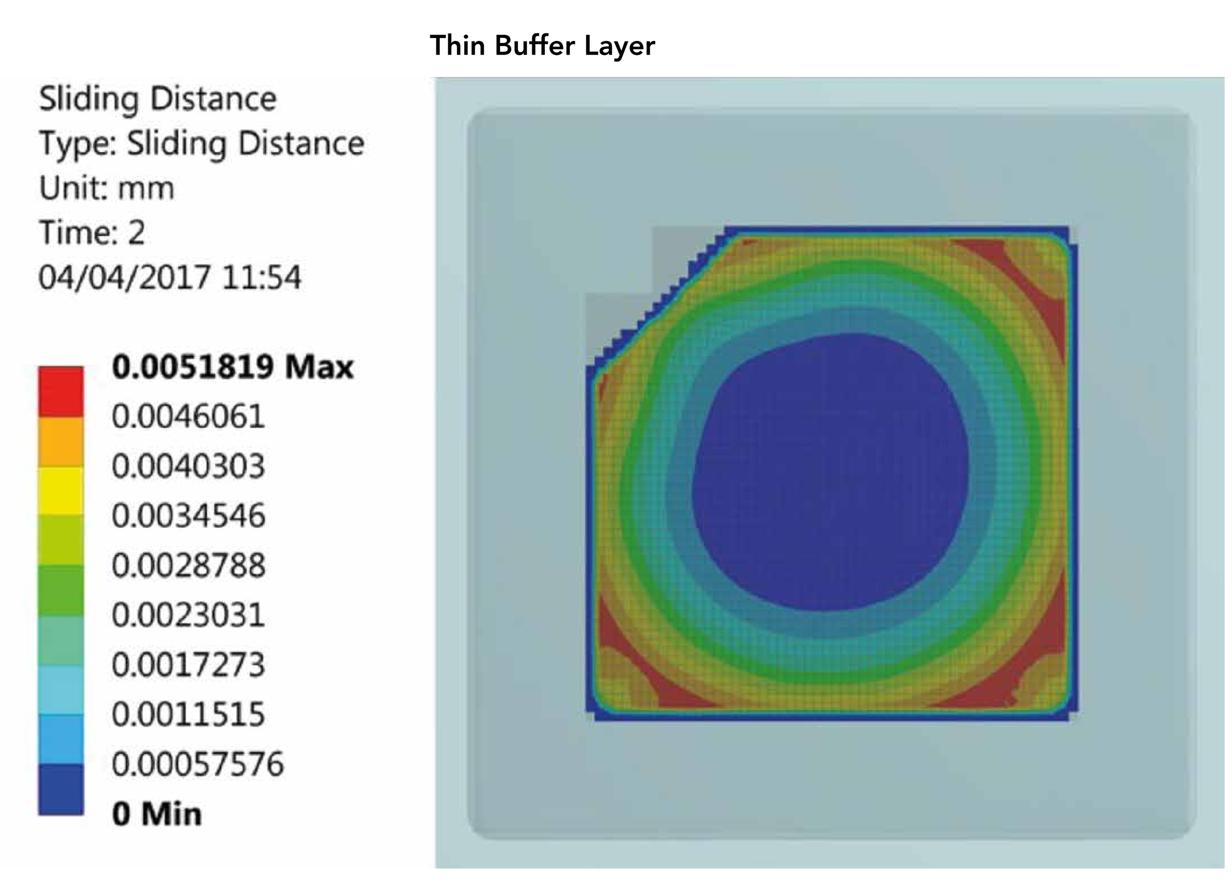


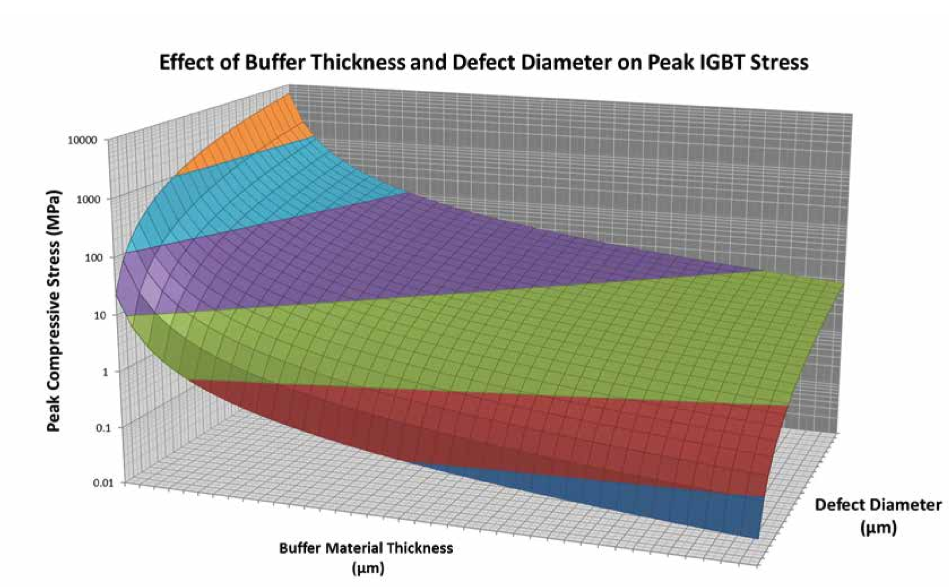
Chip Level Optimisation

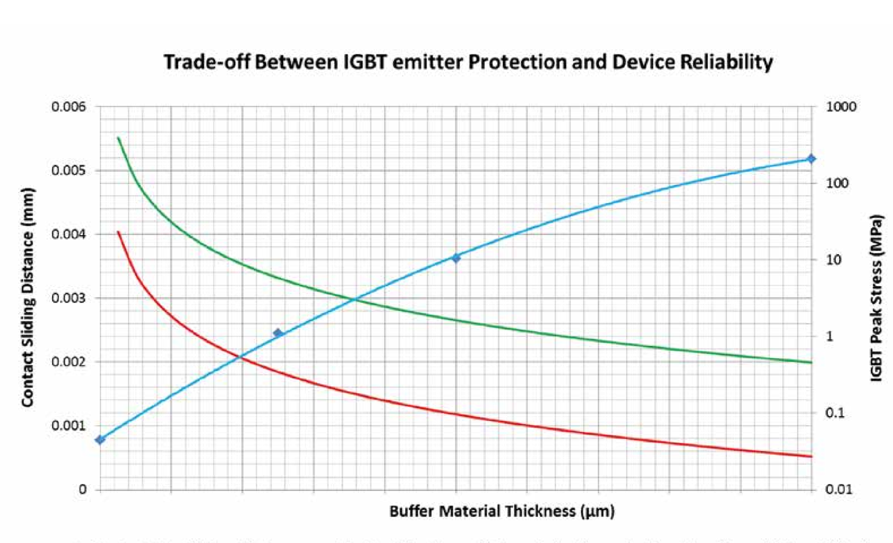
- Microscopic defects on components reduces electrical performance, and can lead to failure of the chip
- Introducing a softer buffer between the molybdenum and IGBT emitter improves both yield and electrical performance
- 2D axisymmetric FEM simulation of defect indentation demonstrates how localised stresses may be redistributed.
- Buffer material has higher CTE than Silicon IGBT and Molybdenum Strain Buffer which may affect reliability
- Sliding distance used as metric for wear rate from Archards equation $Q = \frac{kWL}{H}$
- 3D Transient thermal-structural FEM highlights how the sliding distance across the emitter surface changes with increasing buffer layer thickness.
- The trade off between IGBT surface protection, which correlates to switching performance, and reliability is demonstrated. Careful consideration must be paid to design and product requirements.











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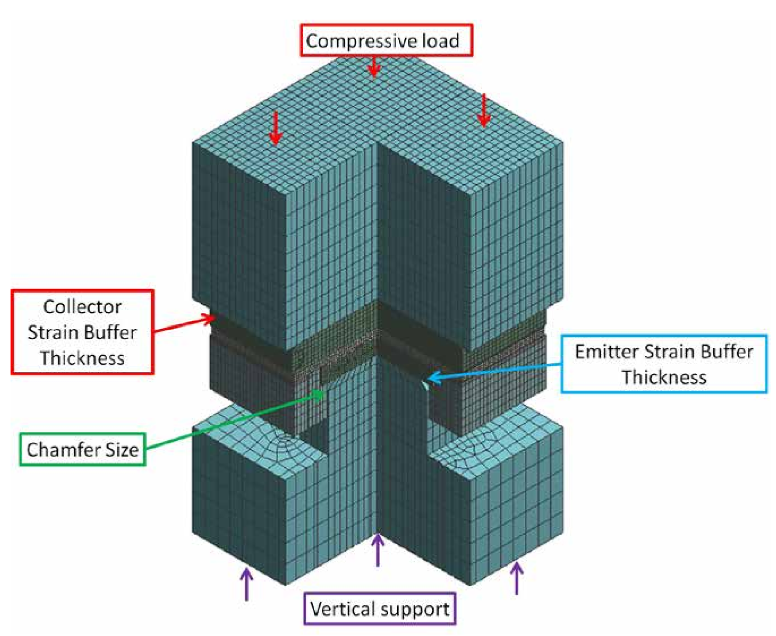
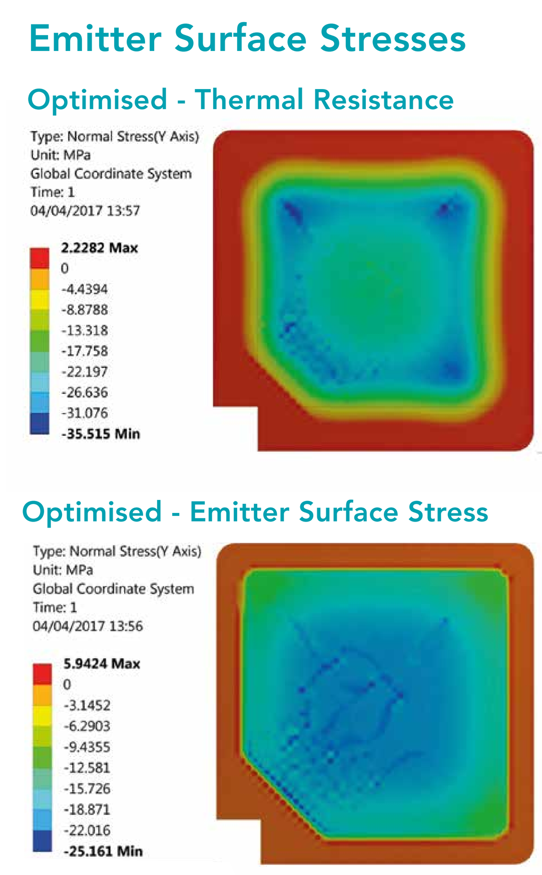
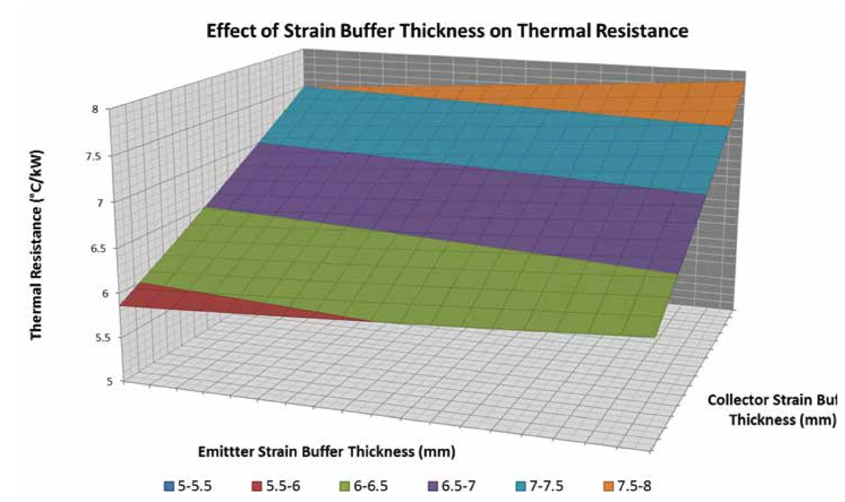
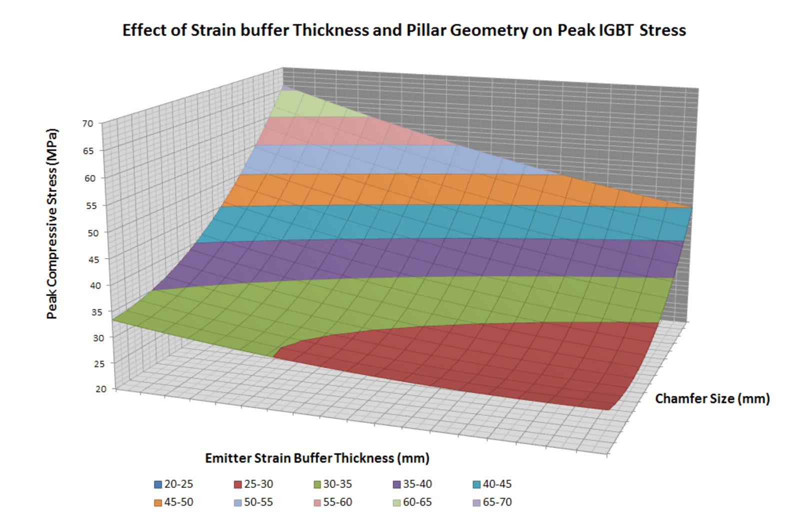
Cassette Level Optimisation

- Cassette level optimisation focuses on stress across the individual IGBT improve cassette yield and electrical performance.
- Parameterised FEM provides response surface for optimisation.
- Key performance indicators are:
  - Peak Stress
  - Thermal resistance
  - Stress Range



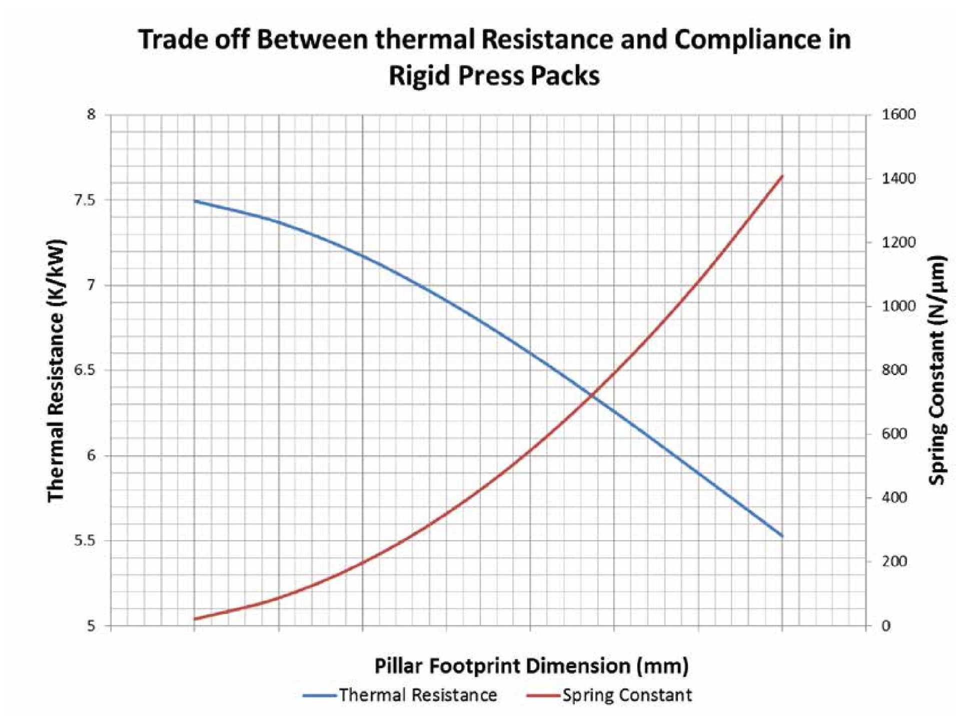


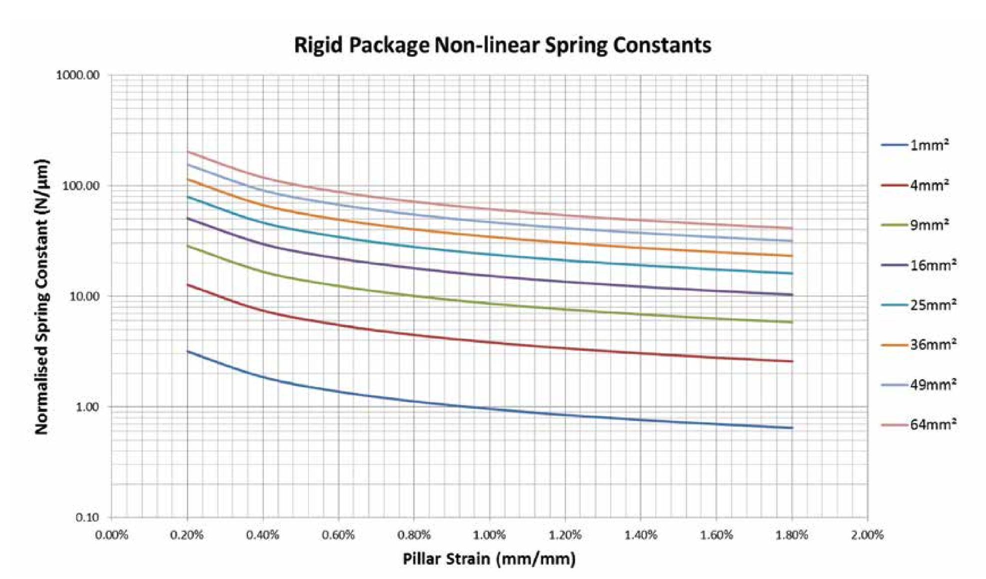




Package Level Optimisation

- Package level optimisation requires consideration of compliance to accommodate component tolerances and providing an effective cooling solution.
- There are two packaging concepts : 'rigid' and compliant...
  - Rigid devices offer double side cooling
  - Compliant devices offer spring constants several orders of magnitude smaller than rigid devices.
- Assuming linear elastic response, in order to have a meaningful con-tribution from the emitter side cooling, pillar geometry the results in a spring constant over 1000N/μm is required
- Given the tolerances of the Press-Pack components the rigid device will experience plastic deformation under clamping load
- Even factoring in plastic deformation, the rigid package cannot meet a compliant designs tolerance for component variations





Conclusions

Development of Press-Pack IGBTs is a multifaceted process.
There are three key considerations:

1. Optimising IGBT protection vs reliability.
2. Optimising IGBT stress vs Thermal resistance
3. Optimising Packaging compliance vs thermal resistance.

Points 1 & 2 may be considered by FEM simulation, however, packaging design should be considered on an application basis -

- Compliant designs offer the best switching performance and therefore are required for the highest current ratings
- Rigid Packages are appropriate for small diameter packages e.g. GTO replacements

Sample Data