Development and Assessment of Power Module Using TLPS Attach

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Abstract

- Current interconnect technology fails to withstand excessive thermal cycling.
- Transient liquid phase sintering (TLPS) joins metallic surfaces at low process temperatures and without pressurization.
- TLPS has high melting temperatures post-processing expanding its applications to extreme thermal loading such as space exploration and under-the-hood in EVs.
- By using improved power module configurations, transient liquid phase sintering can be more successfully implemented. The configurations used in this work utilize the idea of CTE symmetry about the die.

Background

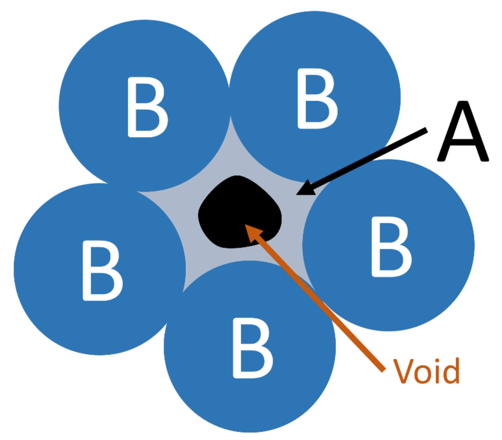
- Conventional power modules cannot withstand extreme temperatures because solders have various problems.
- Sinter, as opposed to solders has low processing temperature but maintain a high melting temperature.
- Both Sinter and Package design must be improved to create reliable power modules that can withstand extreme conditions.

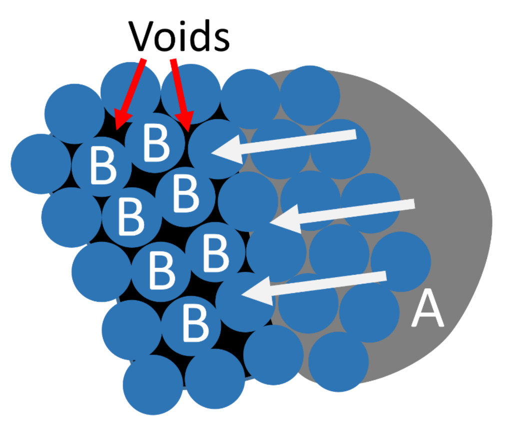
Other Solders

Sn37Pb	Low melting point
Bi-Ag	Poor thermal conductivity
Solder with Pb as main component	Increasing regulations
Solder with Au as main component	Expensive

A. Moeini, H. Greve, P.McCluskey, "Strength and reliability of high temperature transient liquid phase sintered joints," International Conferencce on High Temperature Electronics, 2014.

Sinter Composition Ratios





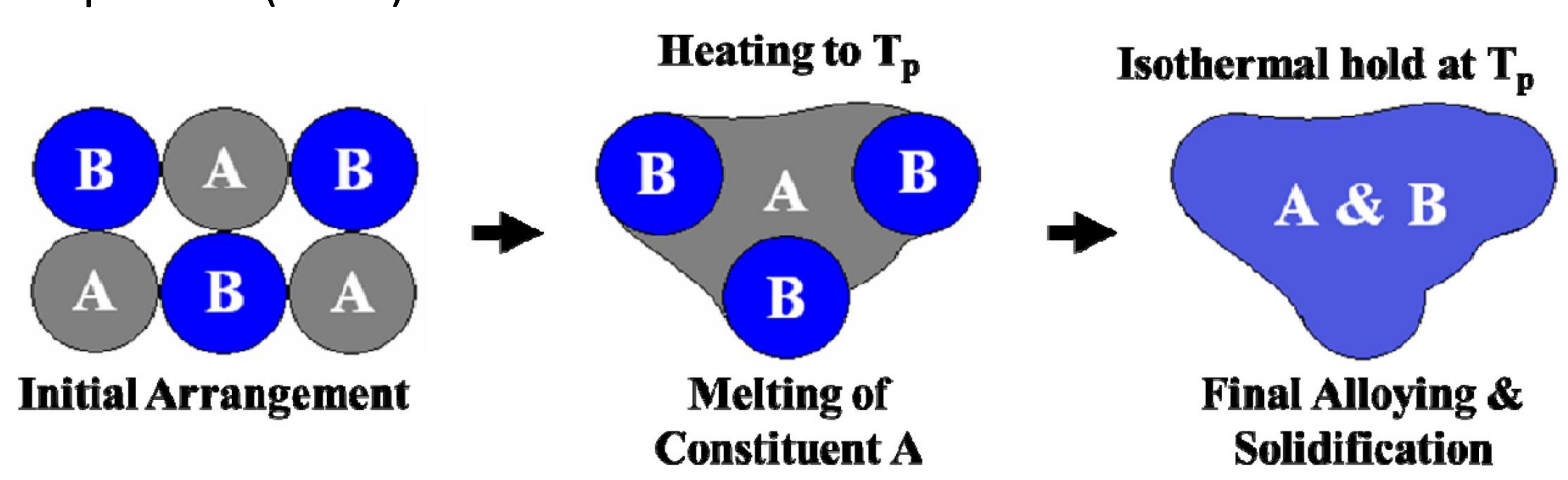
- This project used Ni (B in diagram) and Sn (A in diagram) as sinter components.
- Using different quantities of Ni and Sn particles can change the properties of the sinter.
- Using all large or all small high melting temperature constituents can cause voiding.
- Ensuring an optimized ratio of A to B is essential to creating a useful sinter.

Transient Liquid Phase Sintering

- TLPS is made of a low melting temperature constituent A, a high melting temperature constituent B, and a flux/binder made from resin or organic acid.
- As the TLPS is processed, the flux/binder evaporates and initiates capillary forces to draw in the now liquid A.
- A and B form Intermetallic compounds (IMCs).

Sintering Process

1) Low melting temperature constituent and binder, are mixed.
2) Mixture is stencil printed with high melting constituent onto substrate.
3) Diode is placed on sinter layer and processed in an oven.



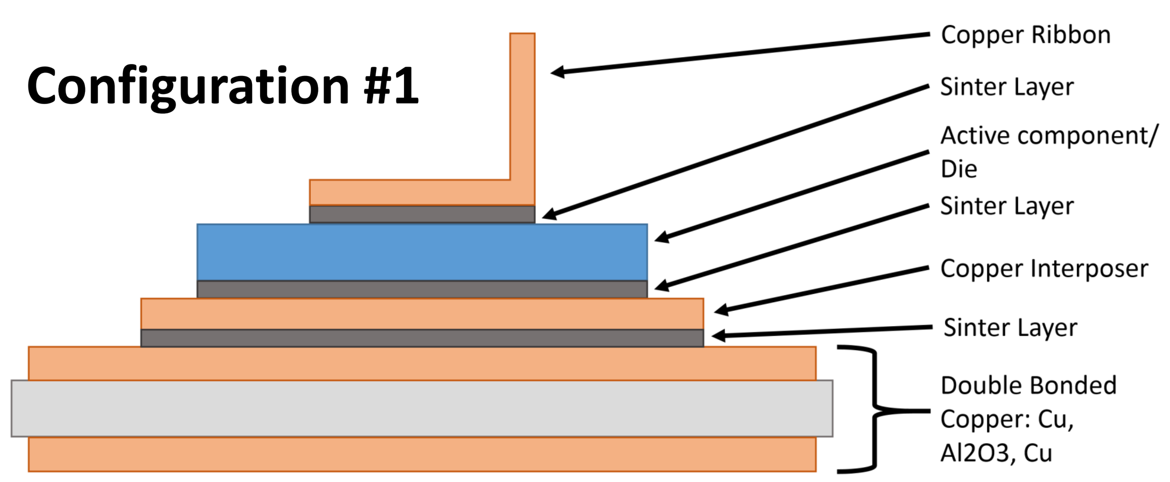
H. Greve, L. Chen, I. Fox, P. McCluskey, "Transient liquid phase sintered attach for power electronics," 63rd IEEE Electronic Components and Technology Conference (ECTC), 2013

- The resulting melting temperature of the new solid is greater than the temperature used for processing.
- If not enough A is present, voids will be left behind and can initiate cracking in a package

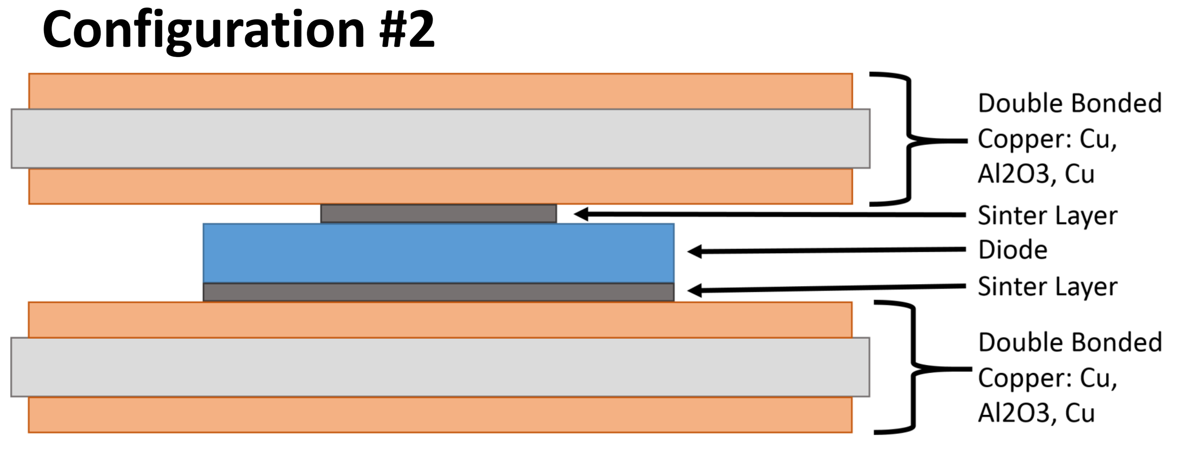
Power Module Assembly

- Currently used top attaches, i.e. wire bonds, easily fatigue, fracture, and separate from active components due to thermal expansion.
- Two configurations were proposed to minimize CTE-mismatch.
- By placing materials that have the same CTE about the diode, thermal strain will be minimized and the occurrence of fractures will be reduced.
- TLPS is used to attach each layer together.
- A Double Bonded Copper (DBC) substrate is used to conduct electricity to other components but insulate from anything below the substrate.

Configuration #1

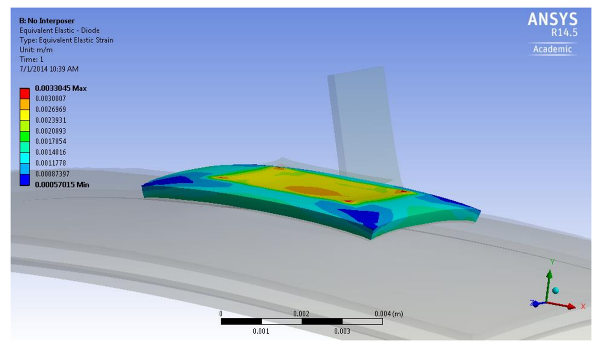


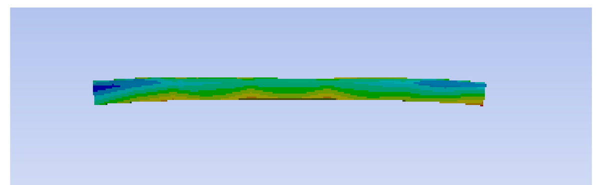
Configuration #2



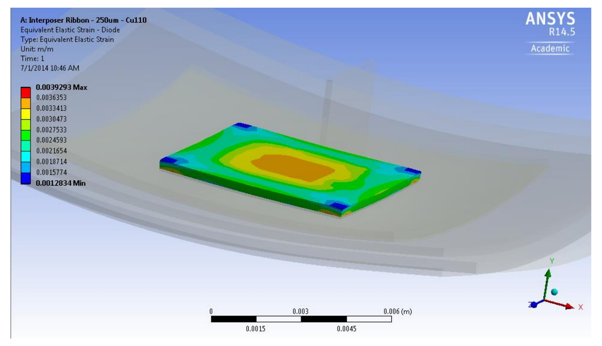
Simulation

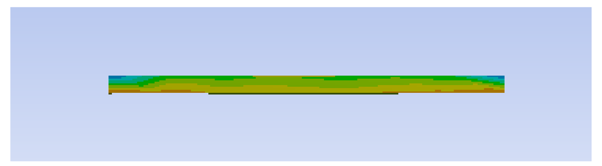
- Only configuration #1 was simulated since it has a complex structure and is not perfectly symmetrical.





- The pictures to the left depict strain simulations of a diode in a power module that lacks an interposer.
- Without an interposer, the die is more likely to bend because of the uneven forces acting on the top and bottom of it.

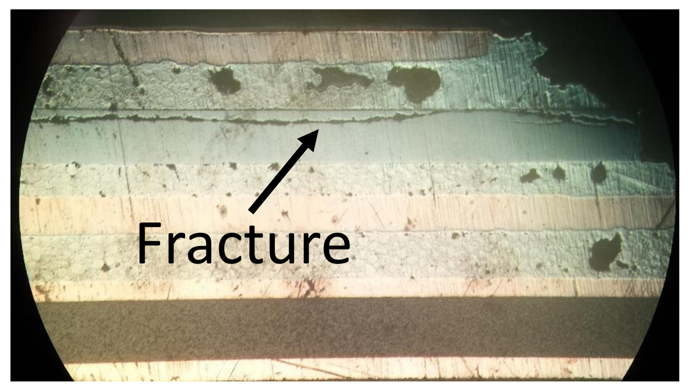




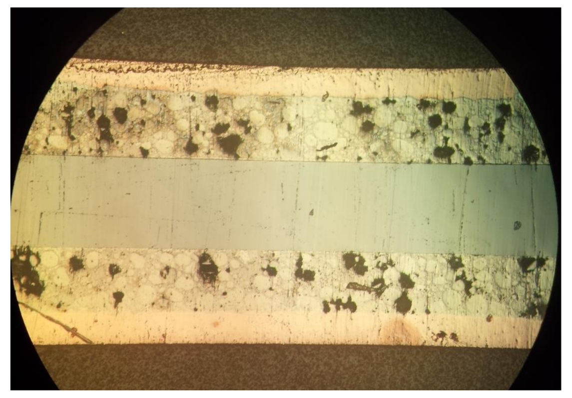
- To the right are simulations depicting the strain of a power module that has an interposer.
- The straight profile of the die suggests that less fatiguing will encourage fracturing to be mitigated.

Analysis

- Each package made with an interposer had a cracked die.
- Using optical microscopy we were able to verify that equalizing forces around a diode in the double DBC configuration improved CTE symmetry and resisted fracturing.
- Number of voids can be reduced by altering ratios of particle sizes, amount of constituents and binder/flux.



Configuration #1



Configuration #2

Conclusion

The use of power module configuration #2 and TLPS provides a promising solution to thermal cycling fatigue and CTE mismatch. Future work can include minimizing voids by changing ratios of large to small particle or altering the amount of binder/flux.