Advances in wide-bandgap semiconductor devices have increased the allowable operating temperature of power electronic systems by replacing silicon devices. High-temperature devices can benefit applications such as renewable energy, electric vehicles, and space-based power electronics that currently require bulky cooling systems for silicon device power electronics. Cooling systems can typically be removed by implementing wide-bandgap devices, such as silicon carbide; however, semiconductor device packaging with high reliability that can also meet high-temperature demands is necessary. Transient liquid phase (TLP) die-attach has shown in literature to be an attractive bonding technique for this packaging need and in this work it has been investigated and characterized to assess its viability in implementing it into high-temperature applications. The material reliability of TLP die-attach was investigated utilizing electrical resistivity measurement as an indicator of material diffusion in gold-indium TLP samples and the criteria of ensuring diffusive reliability was developed. Samples were fabricated by material deposition on glass substrates with multiple Au–In compositions but identical barrier layers. They were degraded with thermal cycling to simulate their operating conditions then characterized and compared. Excess indium content in the die-attach was shown to have poor reliability due to material diffusion through barrier layers while samples containing suitable indium content proved reliable throughout degradation. This was confirmed by electrical resistivity measurement, EDS, FIB, and SEM characterization. Thermal and mechanical characterization of TLP die-attached samples was performed to gain a newfound understanding of the relationship between TLP design properties and die-attach performance. TLP bonds with varying fabrication properties such as gold and indium thickness, Au–In ratio, and bonding pressure were created between silicon carbide devices and copper metalized silicon nitride substrates. They were tested for die-attach voiding, shear strength, and thermal impedance showing that the TLP bonded samples offered high average shear strength of 22.0 kg and low average thermal impedance of only 0.35 K/W. It was discovered that there are unforeseen dependencies of TLP die-attach fabrication properties on the voiding, strength, and thermal impedance of the bonds. This information is invaluable and necessary for implementing TLP die-attach into power electronic modules. A full half-bridge inverter power module for low-power space applications has been designed and analyzed with extensive finite element thermo-mechanical modeling. The outcome of the investigation on TLP bonding techniques is incorporated into the power module design.

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The public is welcome to attend.