Innovative Ceramic Submounts & Heat Spreaders

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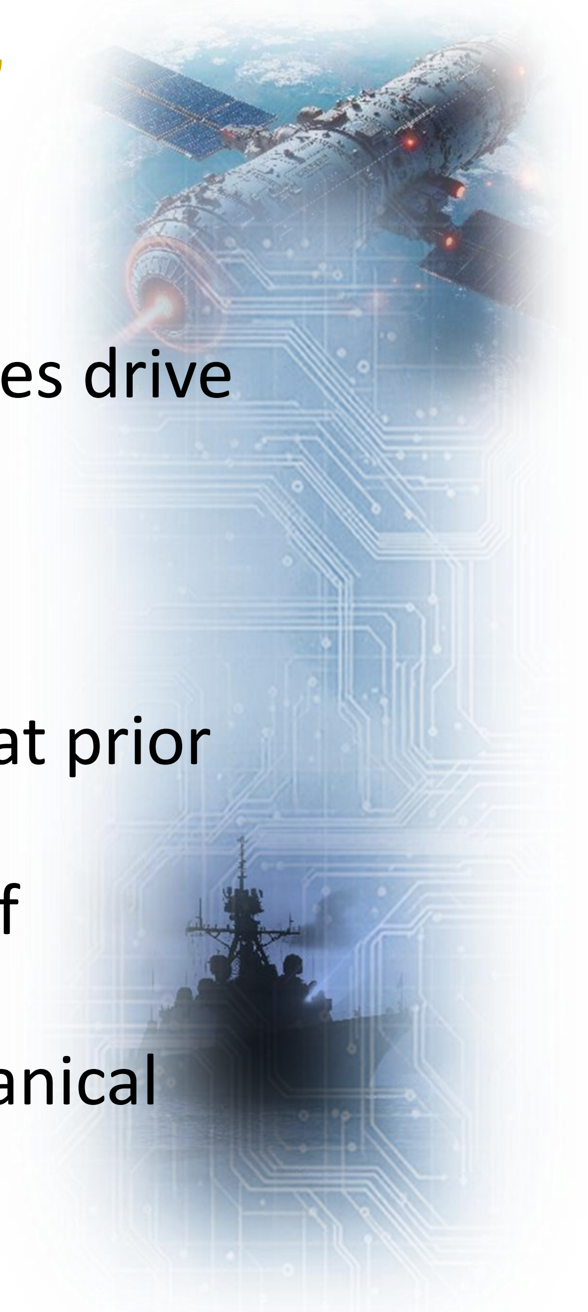
Introduction – Need for Submounts & Heat Spreaders



- Power densities in GaN HEMTs, SiC MOSFETs, and laser diodes drive junction temperatures >300 °C
- Localized heat fluxes approaching or exceeding 1 kW cm^{-2}.
- Submounts and heat spreaders mitigate these loads
- Providing efficient conduction pathways and distributing heat prior to system-level heat sinks.
- Thermal performance, mechanical reliability, & coefficient of thermal expansion (CTE) compatibility with the die,
- Metallization/bonding compatibility for electrical and mechanical integration.

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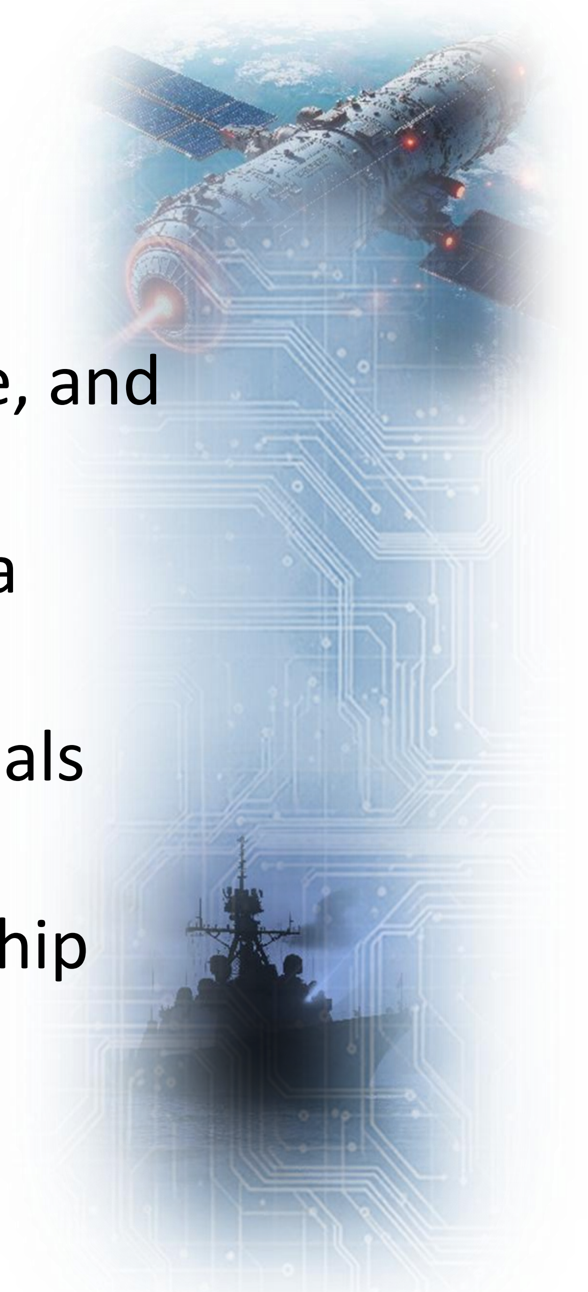
Thermal Challenges



- Thermal gradients in stacked dies increase hotspots, leakage, and aging
- Mechanical stresses from CTE mismatch induce warpage, via fatigue, delamination, and EM/stress-migration
- Need for high thermal conductivity thermal interface materials (TIMs),
- Efficient heat removal from semiconductors, ICs and multi-chip on substrates (single and multilayer) and packages

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Thermal Management

- Use of submounts, and heat spreaders
- Thermal vias
- Air and liquid cooling
- Size range: sizes as needed, standard and custom
- Applications – Laser (LiDAR), LED, converters, inverters, RF, microwave and mm-wave

Junction-to-Case Thermal Resistance

- The total thermal path from a semiconductor junction to ambient can be represented as

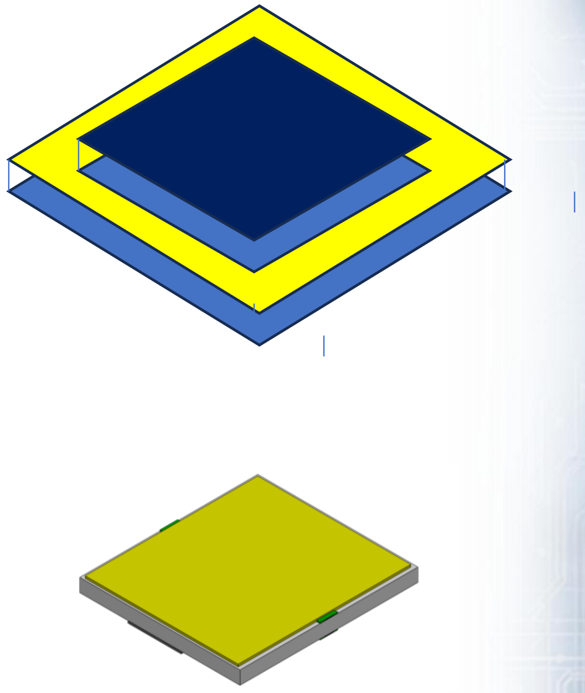
  R_total = R_jc + R_cs + R_sa

  Rjc = **Junction-to-Case thermal resistance** (°C/W)
  $\mathbf{R_{cs}}$ = **Case-to-Sink thermal resistance** (°C/W)
  $\mathrm{R_{sa}}$ = **Sink-to-Ambient thermal resistance** (°C/W)

- Reduce the junction-to-case resistance (R_jc). Dominated by the die attach, submount, and heat spreader—is often the most effective lever for lowering junction temperature when the external sink is already optimized.

Heat Spreading Behavior

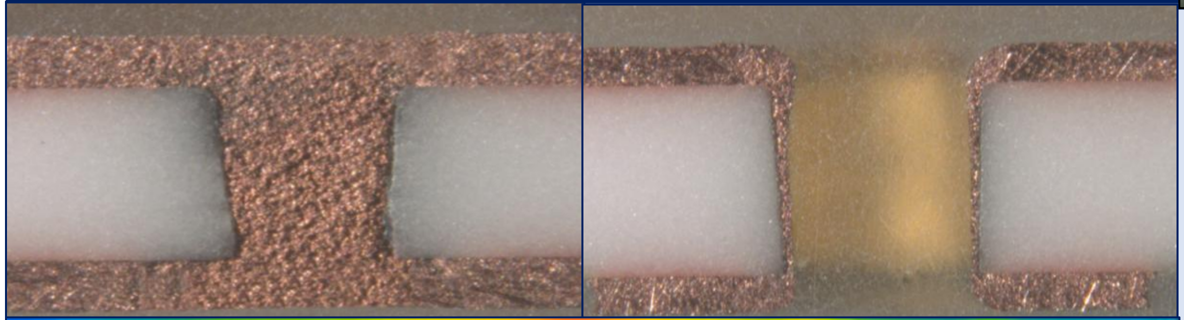
- Localized hot spots arise when power is concentrated in narrow active regions (e.g., laser emitters, GaN channels).
- High-conductivity submounts of adequate thickness act as spreading layers that decrease peak temperature by increasing the effective conduction area.
- Materials with isotropically high conductivity (such as SiC) are especially effective as spreaders.

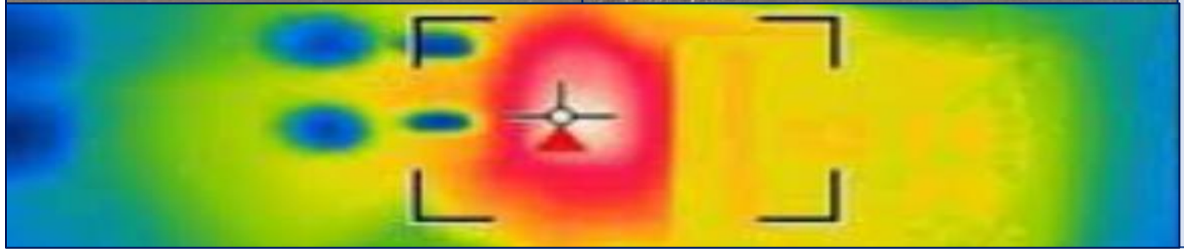


Vias

Challenge

- Increased power handling and compact modules cause single-layer copper to struggle with heat and current.
- Plugged vias help transfer power and heat vertically, allowing efficient thermal dissipation and reliable soldering, and improved performance.





Solution

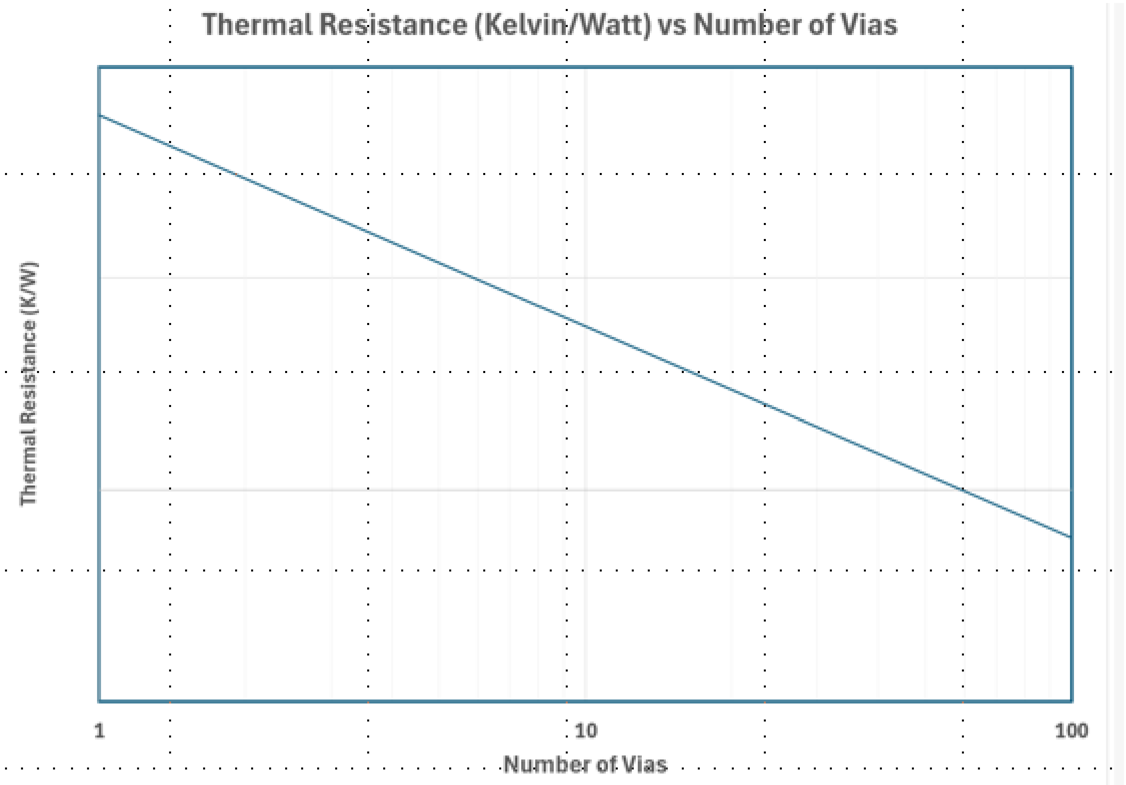
- Our plugged vias deliver consistent electrical functionality, strong mechanical durability, and efficient thermal control.
- In multilayer substrates, vias enable electrical connections while preserving creepage and clearance distances necessary for high-voltage insulation.

VIA THERMAL RESISTANCE

Thermal Resistance of a Single Via

- **Diameter**: 0.3 mm
- **Length**: 1.6 mm
- **Material**: Copper (thermal conductivity = 385 W/m·K)
- **Calculated Resistance**: ≈ **58.8 K/W** per via

Thermal resistance decreases with increasing vias and is inversely proportional.



Note: This plot is on a log-log scale

Materials for Submounts

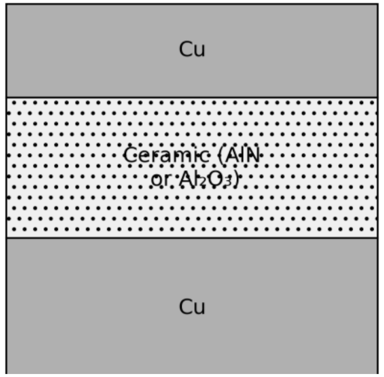
Material	Thermal Conductivity (W/m·K)	CTE (ppm/°C)	Electrical Properties	Typical Applications
Alumina (Al_2O_3)	20–30	~7.0	Insulator	Cost-sensitive electronics; moderate-power modules
Aluminum Nitride (AlN)	140–180	~4.5	Insulator	Laser diodes; RF modules; high-power LED
Silicon Carbide (SiC)	300–490	~4.0	Semiconductor	GaN HEMTs; high-temperature power modules
CVD Diamond	1200–2000	~1.0	Insulator	Extreme power density; defense/aerospace
Beryllium Oxide (BeO)*	200–280	~8.0	Insulator	Legacy high-power modules (*toxic, limited use*)

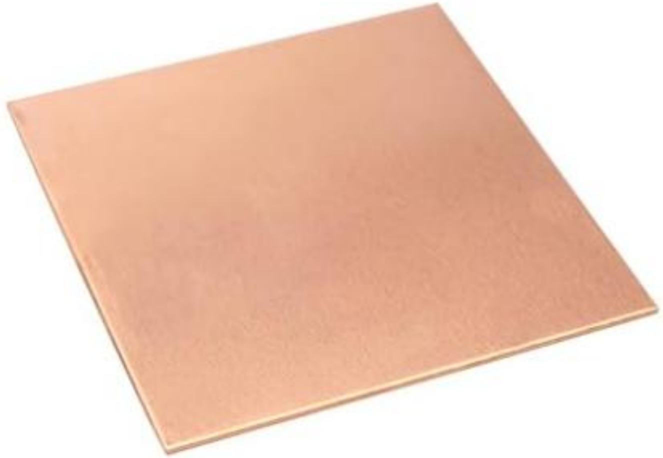
Heat Spreaders and Composite Structures

Material	Thermal Conductivity (W/m·K)	CTE (ppm/°C)	Notes
Copper (Cu)	~390	17	High conductivity; poor CTE match to semiconductors
Copper–Tungsten (CuW)	150–220	6–9	CTE match to Si/GaAs; widely used in RF power modules
Copper–Molybdenum (CuMo)	160–190	6–7	Good stability; used in laser diode packages
Pyrolytic Graphite	>1500 (in-plane)	Anisotropic	Thin, lightweight spreaders; mobile/aerospace

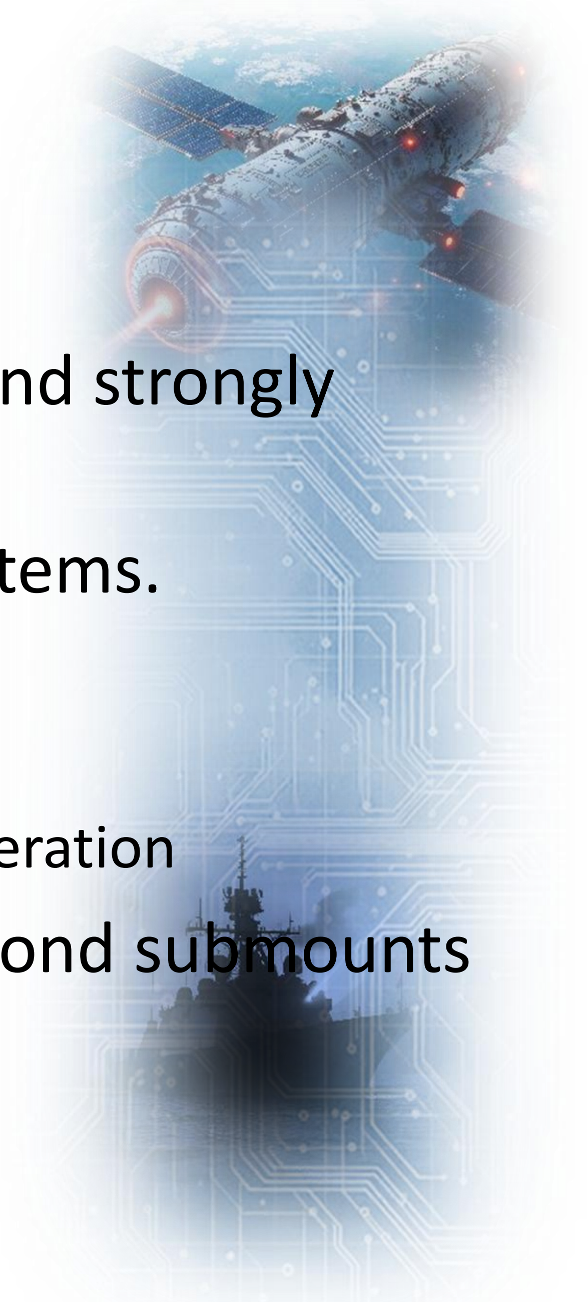
Metal–Ceramic Composite Substrates

- Direct bonded copper (DBC) and active metal brazed (AMB) structures bond copper to ceramics (AlN or Al_2O_3) to create electrically insulating, high-thermal-performance substrates for power modules.





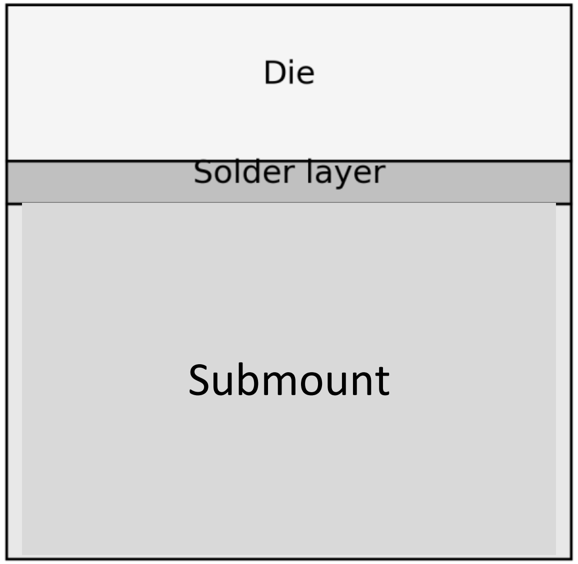
Die Attach Technologies



- Die attach dominates thermal resistance at the microscale and strongly affects reliability.
- AuSn (80/20) eutectic solder is favored in high-reliability systems.
- Sintered silver provides 200–300 W/m·K
  - excellent fatigue resistance
  - transient liquid phase (TLP) bonding enables high-temperature operation
- These choices are often paired with AlN, Si3N4, SiC, or diamond submounts depending on power density and temperature targets.

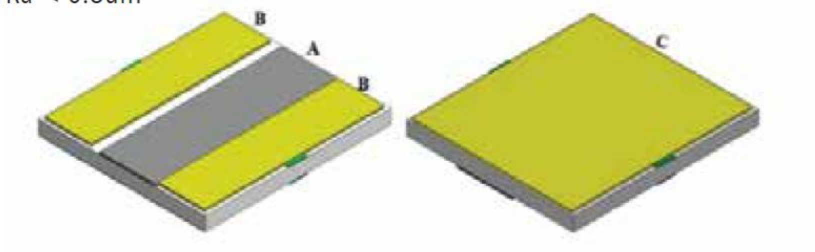
Mechanical and Thermal Reliability

- **Thermomechanical Stress:** CTE mismatch between die, submount, and metallization induces shear and tensile stresses during thermal cycling, leading to delamination, die cracking, solder fatigue, or brittle intermetallic formation.
- **Voiding and Bond Integrity:** Void formation in solder or sintered layers increases local thermal resistance and promotes hot spots. X-ray and C-SAM non-destructive inspection help identify.



Submounts & Heat Spreaders

- Metallization:
  - A. Diode attach area (Ag 15 um, Cu 50 um, Ni 3 um, AuSn 4-6 um
  - B. Wire bond area (Ag 15 um, Cu 50 um, Ni 3 um, Au 0.75 um
  - C. Backside solder attach area (Ag 15 um, Cu 50 um, Ni 3 um, Au 0.15 um
- Surface roughness Ra < 0.8um



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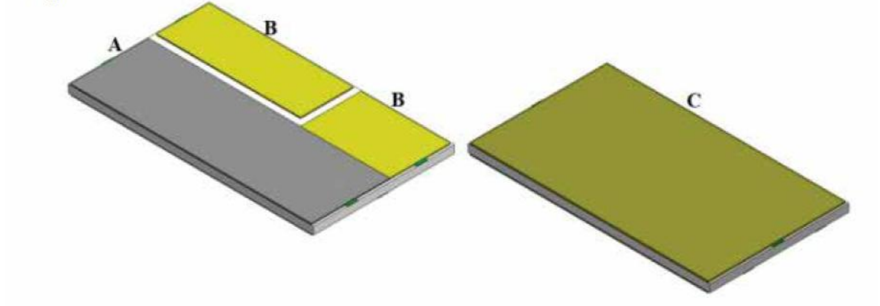

Available as catalog and custom configurations

BeO comparison with metal heat spreaders

Material	Thermal Conductivity (W/m·K)	CTE (ppm/°C)	Density (g/cm^3)
BeO	285	9	2.85
85Mo–15Cu	172	7.4	10.0
85W–15Cu	180	8.6	16.4

Key Features

- Wide Size Range: 0.040” × 0.40” to 1” × 1”; thickness: 0.015”–0.060”
- Metallization: Cu/Ag (25–40 µm) conductor with Ni/Au finish
- Die Mounting: AuSn or Sn solder options available for die attachment
- Backside Finish: Solderable surface
- Weight: Lightweight (2.8–3.2 g/cm^3)
- Durability: High resistance to oxidation and corrosion

Emerging Trends

- Diamond-composite spreaders (e.g., diamond-Cu)
  - preserving high thermal conductivity
  - favorable CTE
- Microchannel cooling, and weight optimization
- Packaging for wide-bandgap electronics emphasizes high-temperature die attach and low-CTE substrates.

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Discussion

- Submounts and heat spreaders are central to the thermal–mechanical design of high-power microelectronics.
- Material selection must balance thermal conductivity, CTE compatibility, mechanical integrity, and process constraints.
- Advances in AlN, SiC, Si3N4, diamond, metal–ceramic composites advance performance
- Joining processes continue to push reliability
- Wide range of applications ranging from power electronics, photonics, lasers, and RF.

Thankyou.
Q&A

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