Aluminum Silicon Carbide (AlSiC) Waveguide Substrate for Commercial Communications Application: A Case Study

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Waveguide Plate Summary

- Commercial High Frequency Wireless Telecommunications Equipment

- Design Supports
  - Dual waveguide antenna and location features
  - Mounting of RF devices
  - Interconnection between devices and PWB
    - Platform provides co-planarity of circuitry
Waveguide Plate Requirements

- **Low Cost**

- Precision Tolerances
  - Waveguides (+/- 0.001) and platform height and position (+/- 0.002)

- Matched Thermal Expansion (CTE)
  - R/F device attachment
  - Al$_2$O$_3$ Substrates

- Thermal Conductivity and Density were secondary requirements due to low power dissipation and plate size.
Waveguide Material Candidates

- 416 Stainless Steel
  - CTE did not match CuW/Al₂O₃ of the RF Packages
  - Costly Machining

- Alloy 46
  - Material form factor not available
  - High Machining Costs
  - Plate too Large for Metal Injection Molding
# Material Survey

<table>
<thead>
<tr>
<th>Material</th>
<th>Common Material Use</th>
<th>Density (g/cm³)</th>
<th>CTE (ppm/°C 30-150°C)</th>
<th>Thermal Conductivity (W/m K)</th>
<th>Young’s Modulus (GPa)</th>
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</thead>
<tbody>
<tr>
<td>Si IC</td>
<td>2.3</td>
<td>4.2</td>
<td>151</td>
<td>112</td>
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<td>GaAs IC</td>
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AlSiC Performance Advantage

- CTE Compatibility
  - CTE Tailored to Application

- Net-Shape Fabrication - No Costly Machining
  - Precision Geometrical Capability
  - Inexpensive Raw Materials - Al and SiC
  - Robust Process Technology - Product Delivered in 8 weeks ARO

- Compatible with Conventional Plating, and Soldering and Brazing Assembly Processes
Net-Shape Fabrication: Material And Geometry in One Process Step
CPS QuickSet™/QuickCast™
AlSiC Fabrication

1. SiC QuickSet™
   Preform

2. QuickCast™
   Al-Metal Infiltration
   AlSiC

3. Machining

4. Coating

IMAPS 1999 Boston, Ceramics Process Systems Corp.
AlSiC - SiC Particles (Gray Contrast) in Continuous Al-Metal Phase (Bright Contrast).

IMAPS 1999 Boston, Ceramics Process Systems Corp.
Silicon Carbide Preform (L) and Infiltrated AlSiC Composite Waveguide (R)

IMAPS 1999 Boston, Ceramics Process Systems Corp.
AlSiC Material Properties

- IC/Substrate CTE Compatible (Adjustable) Value
- Thermal Conductivity 175 W/mK
- Low Material Density - Lightweight Application
- High Strength & High Stiffness
- Compatible with Conventional Plating Techniques
CPS AlSiC-9 Instantaneous CTE

Theta Dialmatic II
Platinum Standard
3°C/min

AVERAGE CTE: AlSiC-9

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<th>Range (°C)</th>
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<td>30 - 100</td>
<td>7.86 +/- 0.15</td>
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<td>30 - 150</td>
<td>8.20 +/- 0.26</td>
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<td>30 - 200</td>
<td>8.58 +/- 0.31</td>
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<td>30 - 300</td>
<td>9.23 +/- 0.37</td>
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<td>100 - 150</td>
<td>8.66 +/- 0.45</td>
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03/31/99     n = 10

AlSiC-9 Selected for Waveguide CTE Requirement

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AlSiC Development Issues

- Threaded Hole Integrity
  - As-cast threaded hole torque to failure
    - 1.0 in-lb/thread - lower end of the specification.
    - Rockwell 38 F
  - Heat Treatment (532°C/8 hrs) - Forced Air Quench
    - Increased Torque to Failure to 1.6 in-lb/thread
    - Rockwell Increased to 78 F
AlSiC Summary:

- **Compatible CTE**
  - Yielding stable platform for Waveguide Application
  - Direct attachment of CuW based RF packages
  - Direct attachment of Al₂O₃ substrates

- **Low-Cost Fabrication: Geometrical Functionality**
  - Net-Shape Fabrication Avoids Costly Machining
  - Waveguide Dimensional Requirements Achieved
  - **Realized 50% Cost Savings** Compared to Machined Counterpart
AlSiC Summary:

- Compatibility with Conventional Assembly
  - Plating
  - Solder and Braze Assembly

- Product Availability
  - Product Delivered 8 Weeks After Receipt of Order

- Heat Treatment
  - 2 x increase in Rockwell Hardness
  - ~ 2 x increase in threaded hole torque to failure
Questions