



M CUBED TECHNOLOGIES, INC.
NEW MATERIALS FOR A NEW AGE

Low CTE & High Stiffness Composites with Directly Polishable Surfaces for Mirrors and Structures

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Presentation Outline

- ◆ Overview of M Cubed Technologies: Materials, Capabilities & Process.
- ◆ High Specific Stiffness Composite Development Program
 - Reaction Bonded B₄C (RBBC-751)
 - Diamond Reinforced Reaction Bonded SiC Composites
- ◆ Summary & Conclusions



M Cubed Technologies:Facilities



***Monroe, CT: 48,000 FT²
Manufacturing & Materials
Development***

***Tokyo, Japan:
Business Development
Office***



***Newark, DE: 140,000 FT²
Manufacturing & Materials
Development***



Facilities: Overview

- ◆ M Cubed Technologies – Monroe CT Site, ~ 50,000 sq.ft.
 - Design & Analysis: CAD, CAM, (ProE, ProM, ProMechanica, Virtual Gibbs, SurfCam)
 - Research & Development: Materials Development and Characterization.
 - Advanced Machining (cutting, grinding, lapping, EDM)
 - Clean room Assembly (Class 100 benches; Class 1,000 and 10,000 rooms)
 - Inspection (12” and 18” fully instrumented laser interferometers)
 - Manufacturing Focus: Precision Products (Reaction Bonded)

- ◆ M Cubed Technologies – Newark DE Site, ~ 140,000 sq.feet
 - Design & Analysis:
 - Research & Development: Materials Development and Characterization laboratories.
 - Manufacturing Focus: Metal Matrix Composites & Ceramics.(Armor & Industrial)



High Specific Stiffness Composite Development

- ◆ M Cubed Technologies developed two composite materials to complement existing materials portfolio.

| Material Family | Process | Features | Status |
|--|------------------|---|--|
| RBBC-751 (Si/SiC/B ₄ C) | Reaction Bonding | Very high specific stiffness & low density. Large size capability for precision and optical structures | Full Production Capability.. |
| RBSC (Si/SiC) + Diamond | Reaction Bonding | Ultra high specific stiffness. Very high thermal conductivity & low CTE for precision and optical structures. | Pilot line running. M Cubed technologies accepts orders on case by case basis. |

Material properties of RBBC –751 and RBSC + diamond will be discussed in the following slides.



Composite Properties:

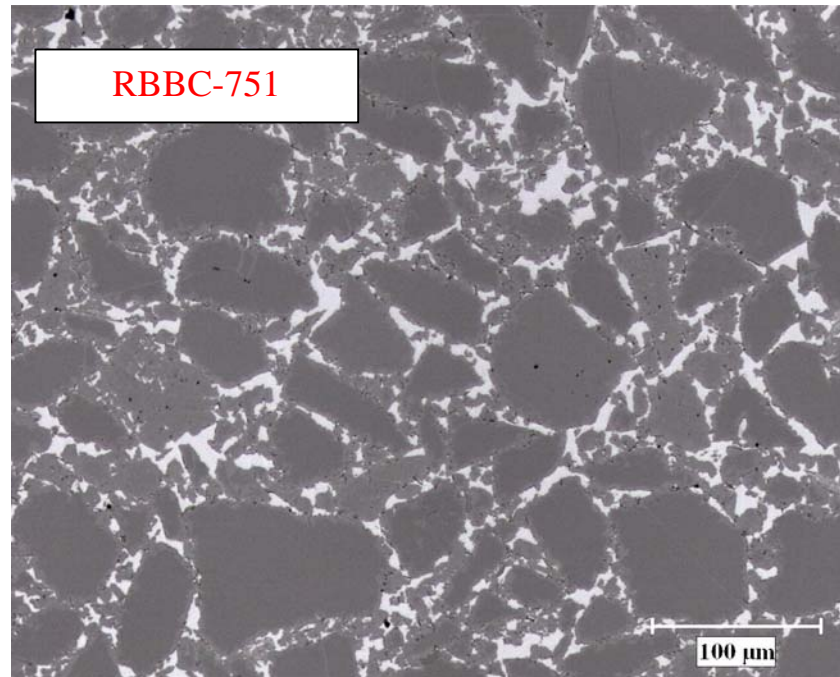
| M Cubed Grade | Density (g/cc) | Young's Modulus (GPa) | Specific Stiffness (GPa/g/cc) | Thermal Conduct. @RT (W/mk) | CTE, 20 to 100°C (ppm/K) | Thermal Stability (W/mK/ppm /K) | Flexural Strength (MPa) | Specific Strength (MPa/g/cc) | Fracture Toughness (MPa m ^{1/2}) |
|--|----------------|-----------------------|-------------------------------|-----------------------------|--------------------------|---------------------------------|-------------------------|------------------------------|--|
| Properties of Be for Comparison - Reference Data | | | | | | | | | |
| * Beryllium(S-200F) | 1.85 | 303 | 164 | 146 | 12 | 12 | 324 | 175 | 9 to 13 |
| * BeAl Alloy (#363) | 2.16 | 207 | 96 | 105 | 14 | 8 | 290 | 134 | N/A |
| * AlBeMet162 | 2.1 | 196 | 93 | 212 | 14 | 15 | 305 | 145 | 9 to 13 |
| Reaction Bonded Boron Carbide (Si/SiC/B₄C): Material has extremely high specific stiffness | | | | | | | | | |
| RBBC-751 (B₄C/Si/SiC) | 2.56 | 400 | 148 | 52 | 4.8 | 11 | 280 | 109 | 5 |
| Diamond Reinforced Reaction Bonded SiC | | | | | | | | | |
| RBSC (Si/SiC)-40 vol.% Diamond | 3.27 | 580 | 177 | 380 | 1.8 | 211 | N/A | N/A | N/A |

Material properties of RBBC –751 and RBSC + diamond compares favorable with Be and Be-alloys.



Reaction Bonded B_4C – RBBC- 751

M Cubed's RBBC - 751 Ceramics



- As a result of the high stiffness and low density of B_4C , its addition to an Si/SiC ceramic leads to a composite with very high specific stiffness.

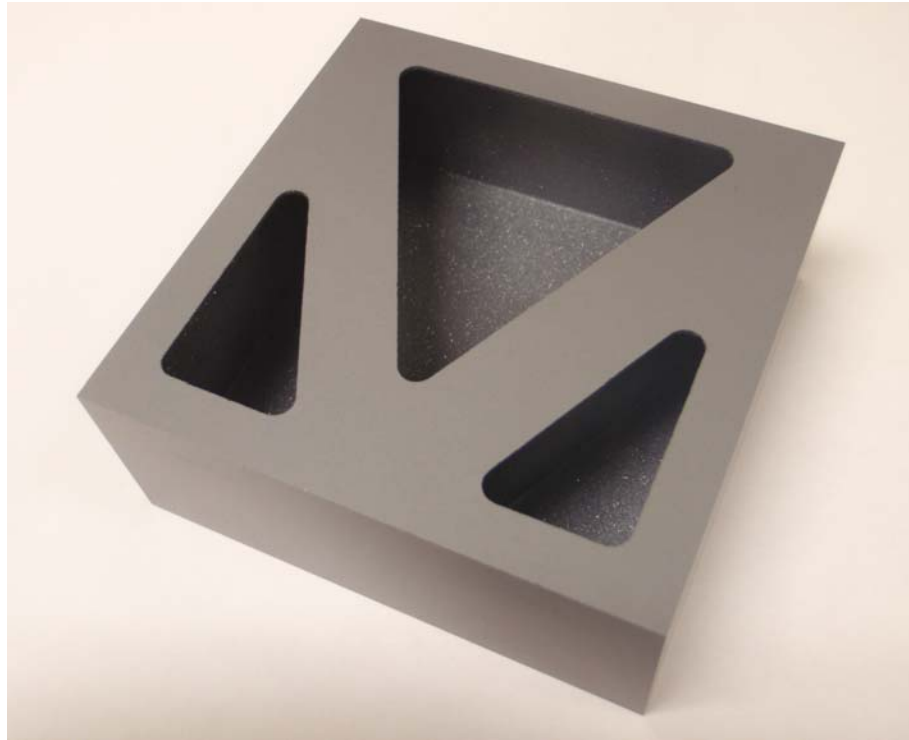


Reaction Bonded B₄C Properties – Si-SiC/B₄C

| Property | RBBC-751 |
|--|----------|
| Density (g/cc) | 2.56 |
| Young's Modulus (GPa) | 400 |
| CTE ave from 20-100°C (ppm/K) | 4.8 |
| Thermal Conductivity (W/m-K) | 50 |
| Specific Heat (J/kg-K) | 890 |
| Knoop 2 kg Hardness (kg/mm ²) | 1550 |
| Flexural Strength (MPa) | 280 |
| Fracture Toughness (MPa-m ^{1/2}) | 5.0 |



RBBC – 751: Product Examples



- A light weight box structure with a wall thickness of 1 mm.



RBSC + Diamond Materials

- ◆ Features very high thermal and mechanical stability due to high Young's modulus > 400 GPa and thermal conductivity > 400 W/mK.
- ◆ Composite is suitable for precision devices such as optical structures, stages and mirrors.

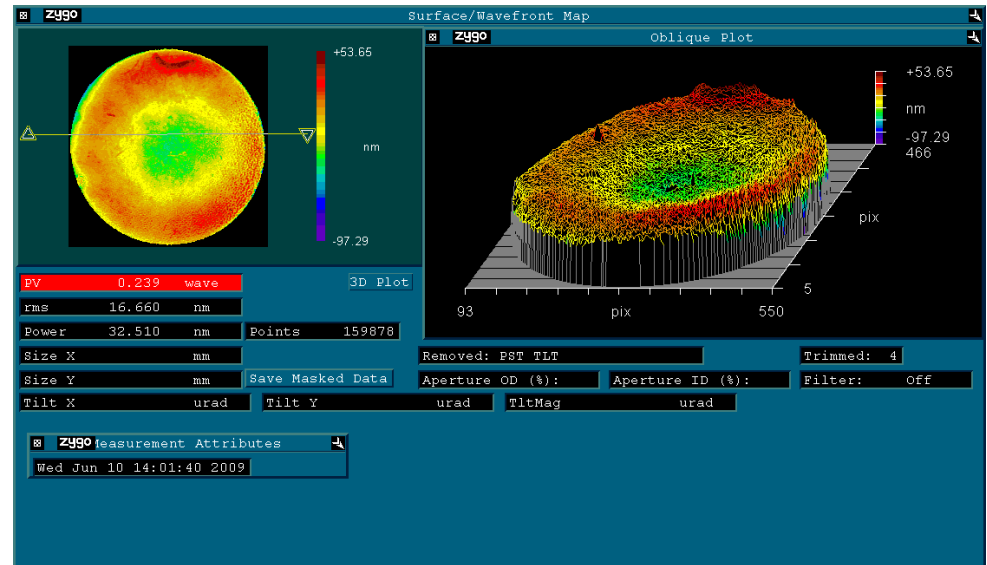
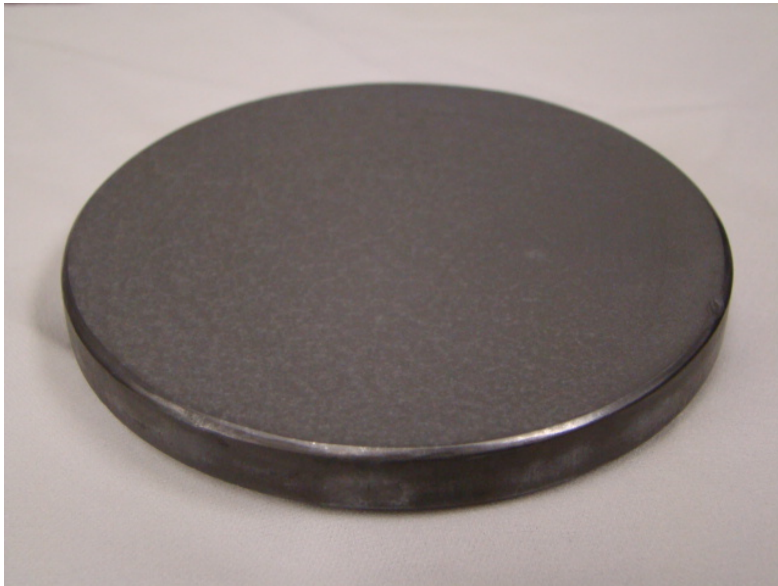


Reaction Bonding of Si/SiC + Diamond Composites

- ◆ Si/SiC and diamond composites can be manufactured using M Cubed standard reaction bonded process.
- ◆ Composites with 14 to 70 vol.% diamond have been successfully produced.

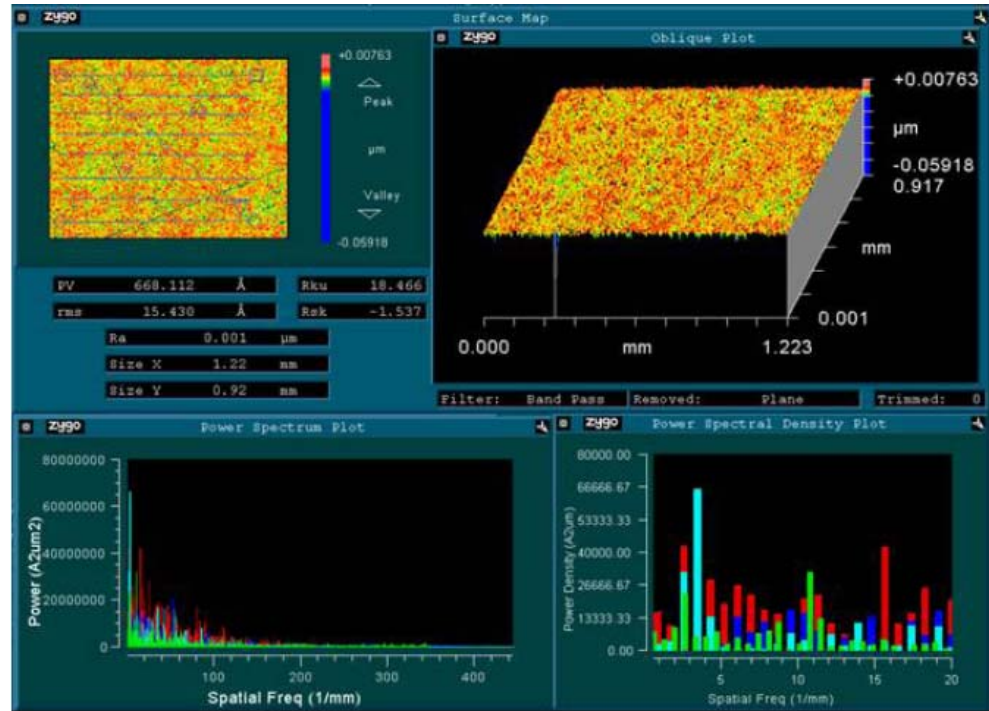
| Property | RBSC + 42% Diamond |
|---------------------------------------|-----------------------|
| Density (g/cc) | 3.27 |
| Young's Modulus (GPa) | 580 |
| CTE avg. from 20-100°C (ppm/K) | 1.8 |
| Thermal Conductivity (W/m-K) | 380 |

Product Example: Directly Polishable Surfaces on Diamond Reinforced RBBS





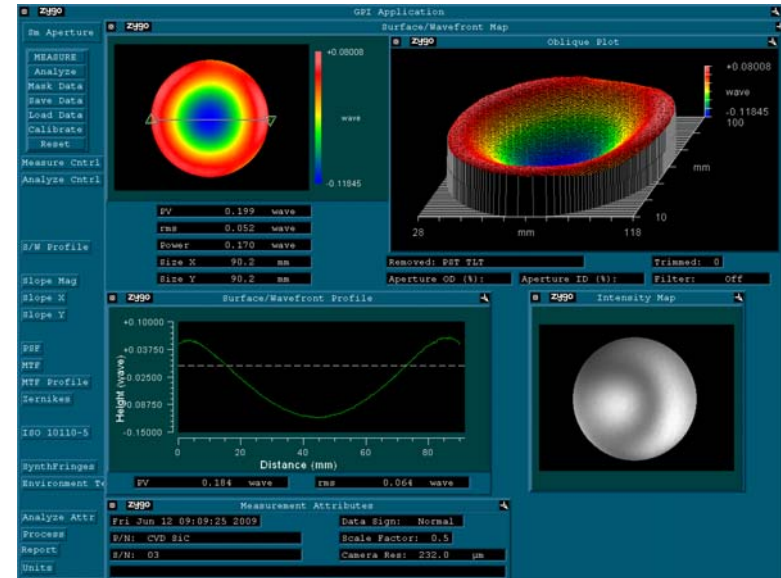
Product Example: Directly Polishable Surfaces on Diamond Reinforced RBBS



<20Å Average Surface Roughness Achieved with Conventional Grinding and Polishing

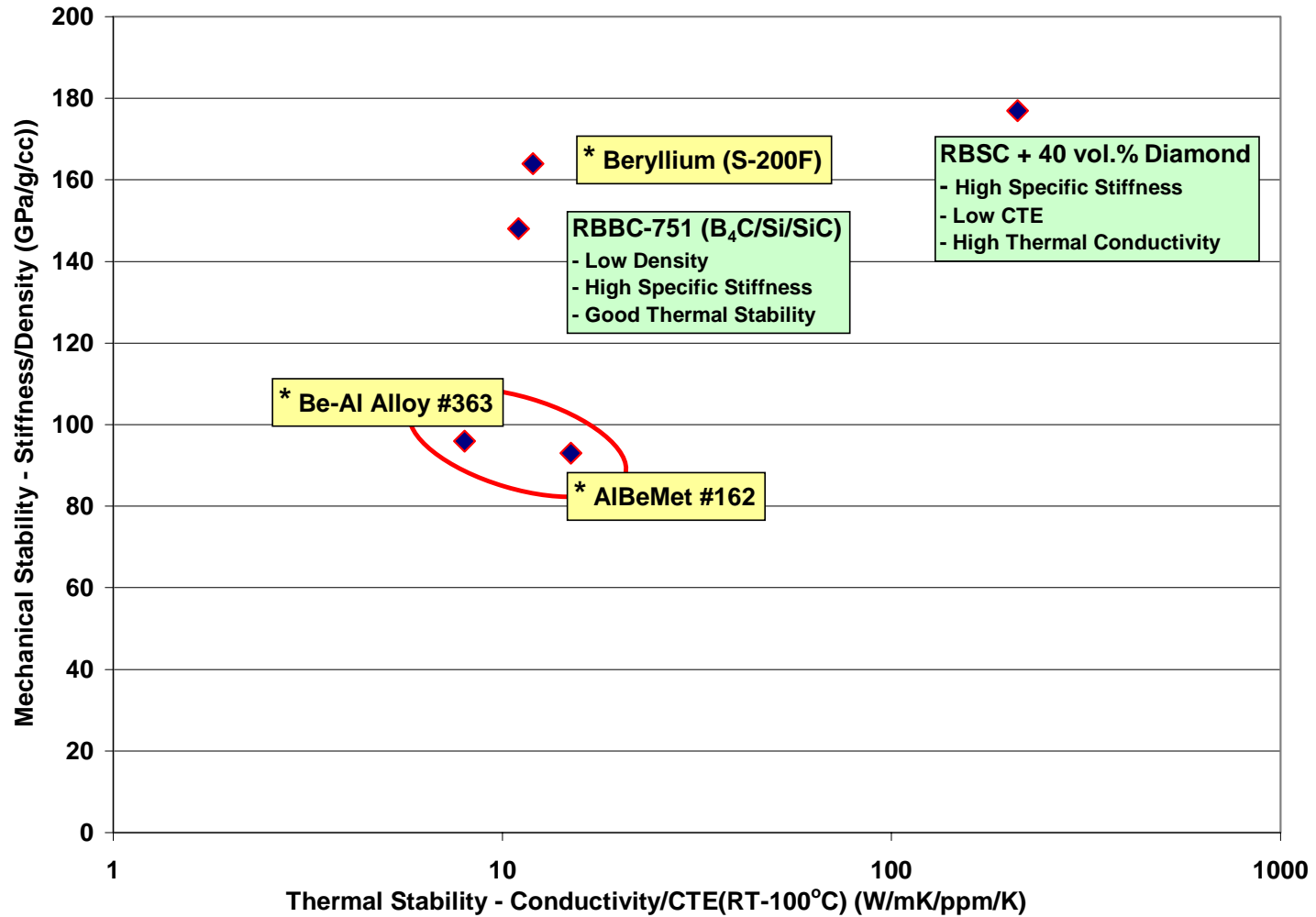


Product Example: Coated Surfaces (Si Clad or CVD SiC)





Thermal & Mechanical Stability Chart





Summary & Conclusions

- ◆ M Cubed Technologies produces very high specific stiffness composites based on reaction bonded B_4C and diamond reinforced SiC
- ◆ Diamond Reinforced Si/SiC composites combine ultra high specific stiffness with excellent thermal stability.
- ◆ M Cubed is in full production with RBBC-751 and accepts orders for Diamond reinforced Si/SiC composites case by case basis.

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