Affordable Pre-Finishing of SiC for Optical Applications

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Presentation Outline

• Background
• Innovation
• Phase I Results
• Program Overview
• Summary
• Introduction to Creare
Silicon Carbide Optics

- Silicon carbide is an excellent candidate to replace beryllium in lightweight optics
- Eliminates toxicity concerns
- Lightweight, thermally stable
- Cost-effective manufacturing remains a challenge
Overall Manufacturing Process

<table>
<thead>
<tr>
<th>$R_a$</th>
<th>Moderate (~2 μm)</th>
<th>Low (~25 nm)</th>
<th>Very Low (~5 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>25 μm</td>
<td>100 nm</td>
<td>10 nm</td>
</tr>
<tr>
<td>MRR</td>
<td>N/A</td>
<td>High/Low</td>
<td>Low</td>
</tr>
<tr>
<td>Process</td>
<td>Single Step</td>
<td>Multiple Steps</td>
<td>Single Step</td>
</tr>
<tr>
<td>Cost</td>
<td>$$</td>
<td>$$$$$</td>
<td>$$</td>
</tr>
</tbody>
</table>
Pre-Finishing Process

High MRR Step
- Rapid removal
- Minimize SSD
- Accuracy 1 μm
- $R_a \sim 200$ nm

Low MRR Step
- Minimal to no SSD
- Accuracy 100 nm
- $R_a \sim 25$ nm

Transition
Our Hybrid Machining Approach

- Use single-point diamond turning (SPDT)
- High MRR Process: Spin-turning
- Low MRR Process: Ductile-regime machining (DRM)
Phase I Objectives Achieved

• Demonstrated Feasibility of Machining CVD SiC
  – Successfully machined material to near-optical quality
  – Demonstrated use of DRM for low MRR step

• Demonstrated Cost Savings
  – Completed detailed cost analysis
  – Showed that other options are as much 85% higher cost

• Developed a Plan to Scale-Up
  – Developed the hybrid approach
  – Both based on SPDT
  – Sufficient to machine optics for NASA
Phase I Technical Achievements

Setup for Low MRR Tests

Measured Cutting Forces
Phase I Technical Achievements

Mirror-Like Surface Produced in CVD SiC

Wavefront Profile (~40 nm variation)

Tool Wear After ~100 Cuts

Roughness (~45 nm $R_a$)
Program Overview

**Phase I SBIR**
- Basic Feasibility Testing
  - Functionality
  - Cost-reduction
  - Operational constraints

**Phase II SBIR**
- Prototype Development
  - Retro-fit system
  - Control system development
  - Evaluate and optimize
  - Testing and scale-up
  - Demonstration

**Phase II&III**
- Commercialization and Transition

- Prototype
- Commercial Partner
- Related Manufacturing Innovations
- A Suite of Commercial Products

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Summary

• Demonstrated feasibility and cost-effectiveness of our Hybrid Machining Approach
• Showed that DRM is viable process for the low-MRR phase
• Identified an available approach for the high-MRR process for Phase II
• Developed an overall program approach that focuses on commercialization and transition
Creare Incorporated

- “Problem Solvers”
- Contract Engineering R&D
  - Diverse Technical Expertise
  - Extensive Facilities
- Industrial & Federal Client Base
- Founded 1961
- Partnership of Engineers
- Technology Commercialization
  - Licensing
  - Spin-off Companies
  - Custom Products
  - Phase III
- Spinoffs
  - 9 companies/1900 employees
  - Revenues $400 M/year

- Crycooler for HST
- Catapult Gap-Width Measurement Device
- Anti-Corrosion Coverings
Technology Areas

- Fluid Dyn. & Heat Trans.
- Biomedical
- Cryogenics
- Software & Data Systems
- Sensors & Controls
- Manuf. Technology

Image Reconstruction
For
Virtual Colonoscopy

Automated Assembly
for Thermal Batteries

Advanced Head/Hearing Protection for Carrier Deck Crews

Turnkey High-Performance Data Acquisition and Processing System

Miniature High-Speed Turbine

Microchannel Evaporator for Microprocessor Cooling
Manufacturing Technology

- Process Development/Enhancement
- Manufacturing Support
- Coating, Joining, and Machining
- Innovative Materials

Thermal Spray of Selective Emissivity Coatings

Laser-Assisted and Ultra-Precision Machining

Indirect Cooling for High-Performance Machining

Titanium Welding Research
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