GRESEARCH & DEVELOPMENT

Affordable Pre-Finishing of SiC for Optical Applications

> Mirror Technology Days 2008 Albuquerque, NM

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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



R _a	Moderate (~2 μm)	Low (~25 nm)	Very Low (~5 nm)
Accuracy	25 μm	100 nm	10 nm
MRR	N/A	High/Low	Low
Process	Single Step	Multiple Steps	Single Step
Cost	\$\$	\$\$\$\$	\$\$



Pre-Finishing Process





Our Hybrid Machining Approach

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



Spin Turner for High MRR Step



Stress-Strain Curve Strain Demonstrating Low-MRR DRM Process

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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



Tool Wear After ~100 Cuts



Wavefront Profile (~40 nm variation)



 $Roughness(~45 nm R_a)$

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Program Overview





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

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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 compaines/1900 employees
 - Revenues \$400 M/year



Crycooler for HST



Catapult Gap-Width Measurement Device





Anti-Corrosion Coverings



DEVELOPMENT **Sreare**

Technology Areas

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



Automated Assembly for Thermal Batteries

> Advanced Head/Hearing Protection for Carrier Deck Crews





Image Reconstruction For Virtual Colonoscopy

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Turnkey High-Performance Data Acquisition and Processing System



Microchannel Evaporator for Microprocessor Cooling

Miniature High-Speed Turbine







Manufacturing Technology

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



Thermal Spray of Selective Emissivity Coatings

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Laser-Assisted and Ultra-Precision Machining



Indirect Cooling for High-Performance Machining



Titanium Welding Research

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