THE AFFORDABLE PRE-FINISHING OF SILICON CARBIDE FOR OPTICAL APPLICATIONS

Period of Performance: **FEBRUARY 23, 2009–FEBRUARY 11, 2012**

Contract No. NNX09CA66C

PROJECT SUMMARY

Purpose of the Research. The work described here was performed under the SBIR Phase II project titled "The Affordable Pre-Finishing of Silicon Carbide for Optical Applications," performed under Contract No. NNX09CA66C. Jay C. Rozzi, Ph.D., was the Project Director, John R. Gagne was Project Engineer, and Peter Blake was the Technical Officer at NASA Goddard Space Flight Center. The overall objective was to develop an affordable pre-finishing machining process for super-hard ceramics for optical applications. Large aperture, lightweight, optical mirror technologies are critical for the future of lightweight telescopes and their attendant missions to explore the planets in our solar system and beyond. Chemical vapor deposition (CVD) coated silicon carbide (SiC) has been shown to be a viable alternative for lightweight mirrors due to its thermal stability; however, cost-effective manufacturing techniques to pre-finish this material have not been sufficiently developed. In addition, silicon optics are of significant interest for space-based mirror applications.

Description of the Research Carried Out, Our approach for this project was to develop a hybrid machining process for Si or SiC. This process is based on two unique and deterministic processing steps that both utilize a single-point diamond turning (SPDT) machine. In the first step, a high material removal rate (MRR) process is used to machine the part within several microns (<5 μm) of the final geometry. In the second step, a low MRR process is used to machine the part to a pre-finish quality, preparing the surface for final optical finishing. This step is based on a ductile regime machining (DRM) process that we developed during our Phase I project.

Research Results. Our hybrid machining process is based on a single-crystal spin turner that we integrated onto a precision diamond-turning machine. We machined trial silicon and silicon carbide parts to optimize the cutting conditions, evaluate the machined part quality and tool wear characteristics, and produce a silicon demonstration article for NASA review. For silicon carbide, we found that even with the spin-turning methodology, significant tool wear prevents cost effective high MRR machining of this material. Since spin-turner wear rate for SiC was a function of the volume of material removed, not the material removal rate, slowing down the process does not alleviate the problem. However, we were able to develop a viable methodology for spin-turner-based pre-finishing of silicon that consists of two steps. In the first high-MRR step relatively slow spin rate of the spin turner is used to remove material to achieve good geometrical tolerances during uninterrupted cutting. In the second step, the spin tuner is used with a high spin rate (relative to the work piece rotation) to produce a surface quality suitable for subsequent finishing operations. During our testing, we removed 1000 mm^3 of silicon without incurring any spin turner tool wear.