UNIVERSITY OF ROCHESTER

CENTER FOR OPTICS MANUFACTURING

16 September 2004

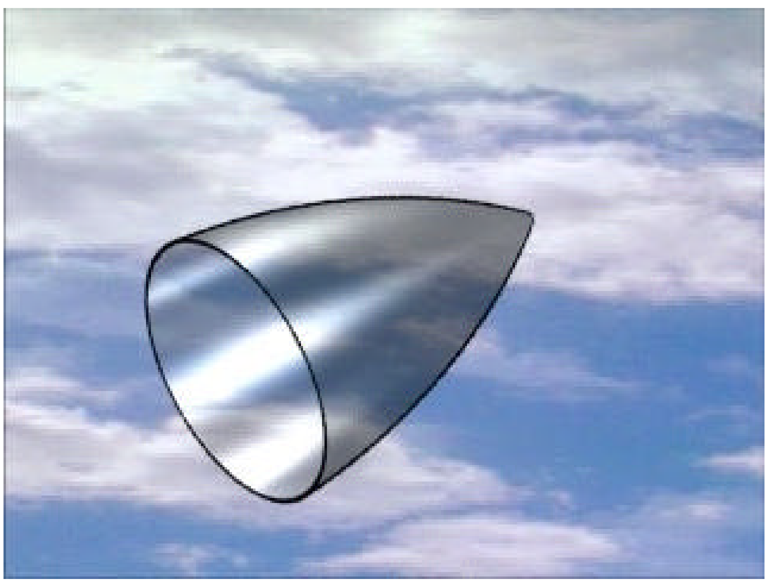
TECHNOLOGY DEMONSTRATION BRIEF

CONFORMAL OGIVE ALON™ DOME FABRICATION

Keywords:

Conformal, freeform, optics, ogive, ALONä , domes, near-net-shape castings, infrared transmitting ceramics

This brief will describe a successful project at the Center for Optics Manufacturing (COM) to demonstrate a conformal optics manufacturing process to deterministically microgrind a freeform ogive missile dome of ALONä ceramic from a near-net-shape cast blank. The dome is 6.45 inches tall and 4.7 inches wide at the base. The concave surface was an off axis sphere, and the convex surface was an asphere. Both surfaces transitioned to a sphere at their apex.



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Fabrication Processes:

A near net shape molded dome of ALONä was provided in an oversized condition. The dome's shapes were then deterministically contour microground with toric shaped grinding wheels on the convex surface, and ball shaped grinding wheels on the concave surface. For added stiffness and positional accuracy during grinding, COM leveraged and applied the technology the Moore Nanotech 500FG multi-axis freeform machining platform developed in the DARPA Precision Conformal Optics Technology program.

The following presents the steps used to fabricate the dome.

- The dome blank was received molded oversized to the final shape, per Figure 1

Figure 1: ALON dome as near net shape

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- The first step was to block the blank into a conforming fixture using UV adhesive for processing the concave surface (see figure 2). The first grinding step was to grind a flat on the base, and bring the dome to the correct height.

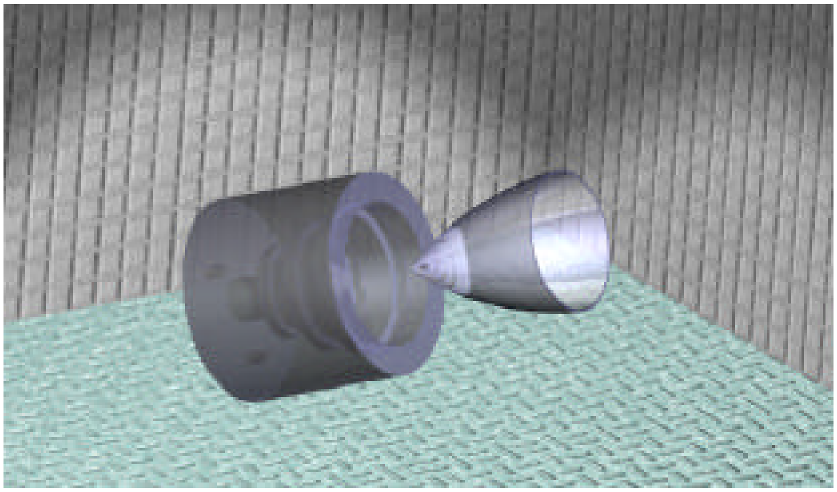

Figure 2: Computer model of ALON dome and fixture for concave side processing.

- The second step was to grind (FG500) the concave surface using ball tools. The surface would be referenced to the flat base that was ground in the previous step. To accomplish this task, a series of different size ball tools were used to reduce tool wear during the grinding cycle, and to maximize grinding efficiency.

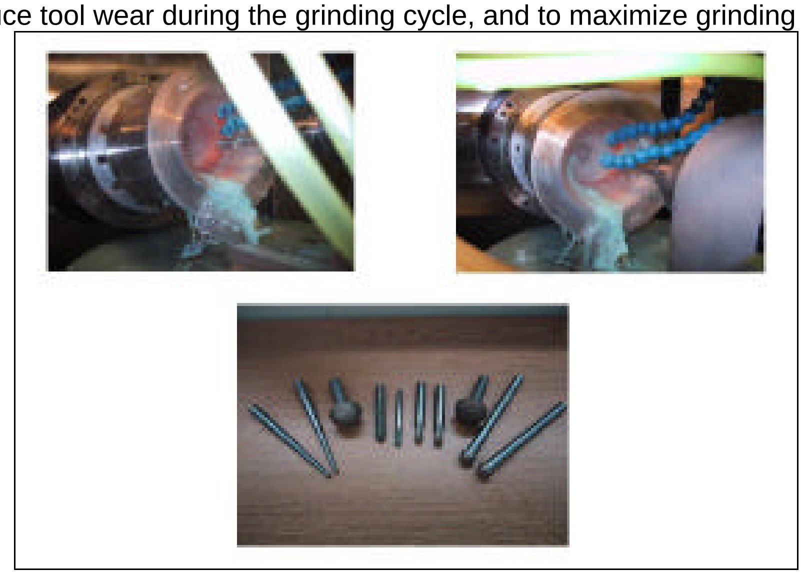

Figure 3: Examples of ball tools grinding ALON dome, and various ball tool configurations.

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- The final step for the concave surface was to develop a hybrid conventional polishing process it before deblocking. A tool was designed and made by a rapid prototype machine located at COM's facility. The tool was made with a shorter radius to accommodate the thickness of double-sided foam tape, and a polyurethane pad with a diamond slurry worked the best to remove the sub-surface damage and "shine" the surface. Figure 4 shows this process.

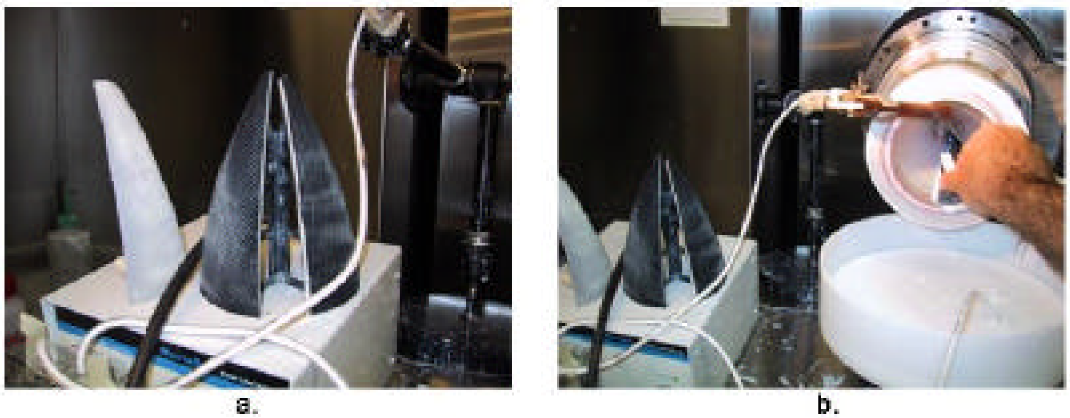

Figure 4: a.) Polishing tools with various polyurethane pads attached. b.) Polishing tool was hand held during polishing operation.

- Once the concave side was complete, the dome was deblocked and inverted to grind the convex surface. The fixture for the convex surface held the dome by the concave curve with the adhesive, and was referenced by optical contact with the base to try and obtain the best tilt accuracy. Figure 5 shows this process.

Figure 5: Blocking fixture for the convex surface processing, and dome mounted to fixture.

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- The dome's convex surface was then ground to final shape with two torrid shaped contour grinding wheels using a 3-axis motion (X, Z and B). Figure 6 depicts this process on the Moore FG500 freeform machine platform.

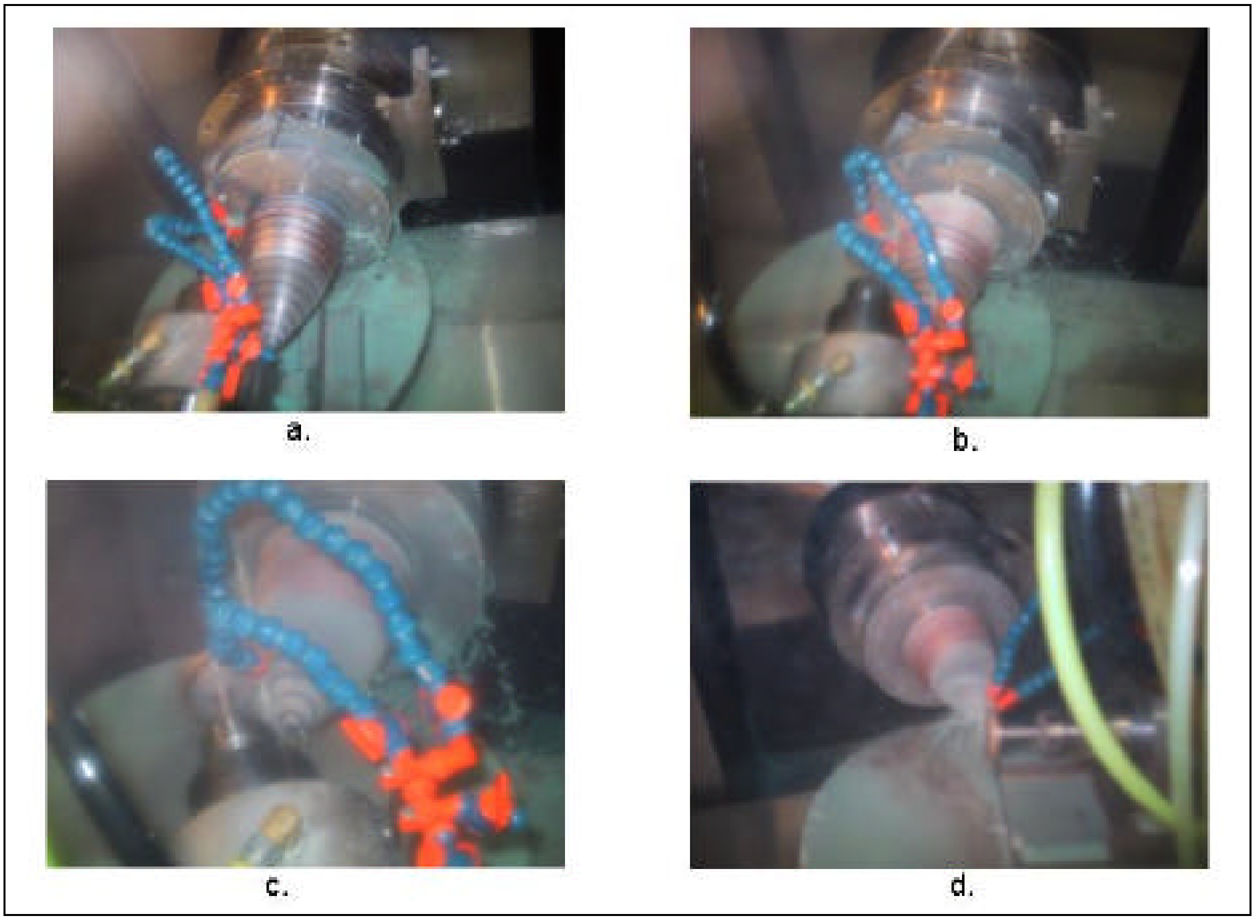

Figure 6: Progression of grinding wheel for contour grinding the convex surface of the ALON dome.

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- Once the convex surface of the dome was ground to final specifications, it was hand polished to remove the residual sub-surface damage. The dome was left blocked on its fixture, and placed on a single spindle polisher. There, the same process was used as described in step 3. Figure 7 shows the finalized dome.

Figure 7: Finished ALON dome on mounting fixture.

Current Development Efforts (2004):

COM's next focus has been to follow the successful grinding effort and to explore, develop and refine affordable and deterministic finishing/polishing processes for these conformal ogive shapes and the diverse range of IR ceramics such as ALONä , Spinel, Zinc Sulfide and/or nanograined alumina. These materials have relevance to DoD joint services and programs in the areas of transparent armor and missile systems.

A new compliant sub-aperture optical finishing technique is being investigated for the removal of mid-spatial frequency artifacts and smoothing of hard polycrystalline infrared ceramics for aspheric applications and conformal shaped optics. The Ultra-Form concept was developed by OptiPro Systems, Ontario, NY, and is a joint process development effort with the Center for Optics Manufacturing (COM).

[Optipro Systems, Ontatio, NY has been involved with deterministic processing programs since the inception of COM and was one of the first companies to commercialize the revolutionary Opticamâ series of optical grinding platforms. Optipro has also provided significant in-kind support to this new effort in equipment, metrology and engineering support.]

Developmental Superfine Platform (In-kind loan from Optipro Systems)

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The Ultra-Form tool is a pressurized, elastomeric bladder in the shape of a toroid. Finishing pads are attached to the periphery, allowing the use of a wide variety of pad materials and abrasive selections.

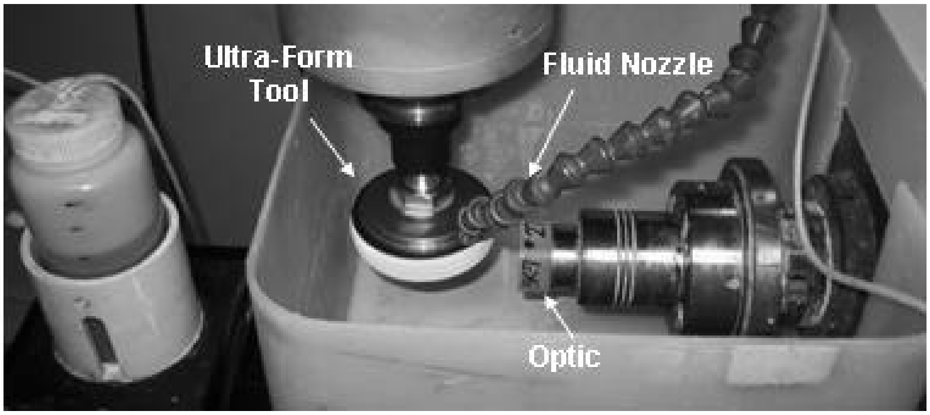
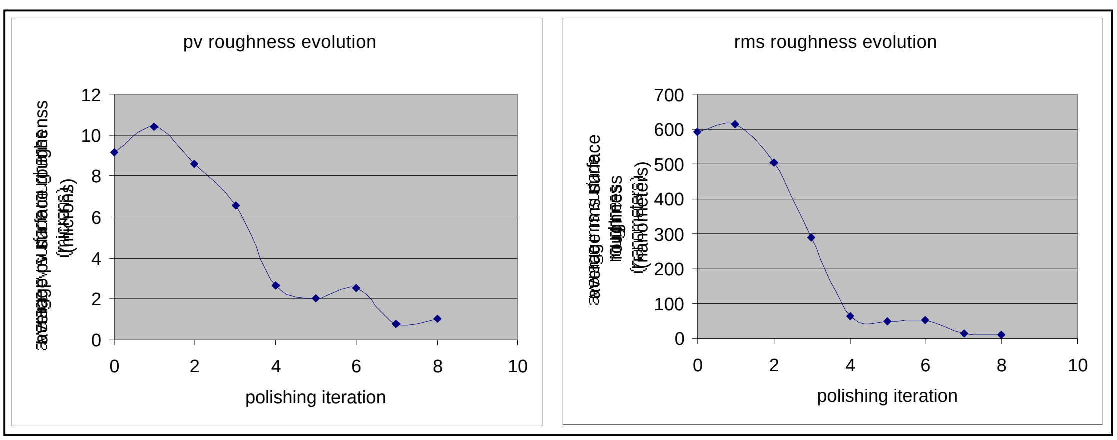


Figure 1: Ultra-Form process

Initial development emphasis has been placed on demonstrating the reduction of surface roughness, removal of mid-spatial artifacts and understanding the material removal function and associated parameters.

For ALON™ (from Surmet Corporation), which is a hard polycrystalline ceramic material, a diamond developmental pad was found that performed extremely well. With this pad we were able to remove sub-surface damage from ALON™, reduce the rms surface roughness below 10 nanometers and not induce any grain highlighting.



Roughness evolution of ALON™ using the Ultra-Form tool. Measurements are an average of 5 data points taken across the surface on a Zygo NewView 5000.

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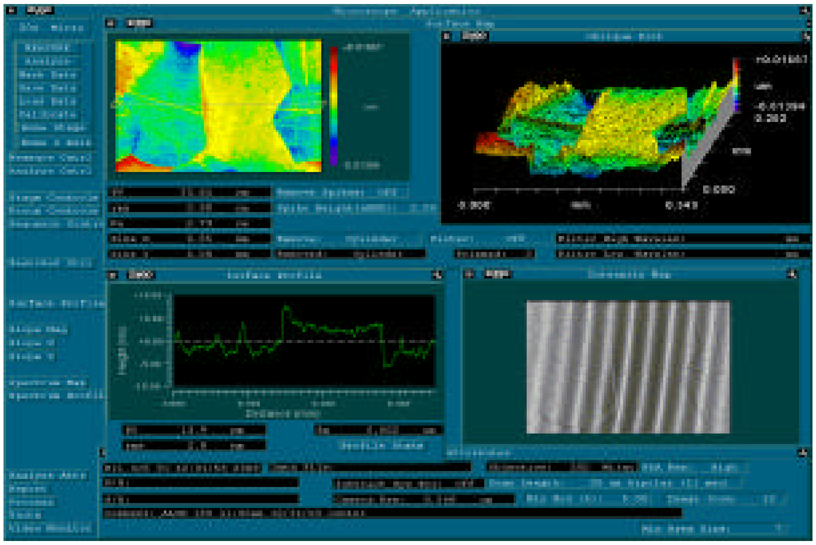
Promising ALON Results on Optipro CpX125 with 3M diamond pad



COM is currently conducting experimentation and materials process development for:

- ALONä (Surmet, previously Raytheon),
- Spinel (Surmet and Technology Assessment and Transfer)
- Nano-grained alumina (CeraNova)

Future Frontiers and Peril in 2005

COM's future objectives remain directed to developing and implementing affordable processes for the manufacture of precision optical shapes with an emphasis on emerging IR ceramics.

These efforts involve leveraging a core competency of material science and the relationship to fabrication, finishing solutions employing new and novel approaches such as the above Ultra-Form process and Jet-Magnetorheological finishing.

Support is essential to continue these efforts with our industrial partners and leverage COM's assets of fabrication expertise and the resources of the University of Rochester.

The future of COM is in jeopardy and will close in early 2005 without further support and funding for these efforts. Information regarding COM is attached.

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Overview of the Center for Optics Manufacturing

The University of Rochester's Center for Optics Manufacturing (COM), established in 1990, is a nationally supported, award-winning university-industry-DoD research and development alliance that is modernizing precision optics manufacturing technology. The Army has funded COM, a DoD Center of Excellence for Optics, on a yearly basis since its inception. Part of the Army's Manufacturing Science and Technology (ManTech) program, COM is an important element of the DoD strategy to develop and acquire affordable equipment for the warfighter, and to do so with dramatically reduced cycle time using commercial processes. COM fulfills this objective by systematically identifying and attacking manufacturing cost drivers and technology shortfalls that prevent the application of advanced optical shapes in next-generation optical systems. COM's resources are its skilled staff, a large pool of University faculty and students, and industrial collaborators in small and large companies throughout the US.

Awards and Accomplishments

- DoD Manufacturing Technology Achievement Award in both 1992 and 2000
- Photonics Circle of Excellence Award in 1993 and 2000
- Laser Focus Commercial Technology Award in 1993 and 2000
- R&D 100 Award in 2001 for breakthrough optics manufacturing technology developments
- Over 150 COM-developed machines in commercial use on factory floors throughout the US

Facilities and Research Programs

COM occupies 10,000 ft^2 at the Center for Optoelectronics and Imaging on the University's South Campus. Experimental and commercial CNC precision grinding and polishing machines are located in an open "shop floor" area. Here, teams study the manufacturing processes for finishing spheres, aspherics and conformal optics from an array of glasses, crystals and polycrystalline materials. Fundamental to this research is the development of scientific rule-based methods for the achievement of low subsurface damage in rapid grinding to shape, followed by rapid polishing to sub-nanometer roughness levels with surface figure errors at or below 0.1 micron. Optics metrology is carried out in a separate area equipped with an array of state-of-the-art instruments for evaluating surface form and roughness. A third lab is devoted to slurry fluid chemistry issues in the Magnetorheological Finishing (MRF) process that was invented at COM in the mid-1990's. COM's current emphasis is on process improvements for the manufacture of optics from hard, polycrystalline ceramics that offer multi-spectral imaging capability to viewing systems in tanks and aircraft.