IC™ Optic Material for Precision CNC Optical Polishing

In collaboration with Blue Ridge Optics and OptiPro

APOMA Workshop 2018

Smarter. Faster. More Reliable

Outline

- Introduction
  - Fast and high volume CNC production of precision optics will be manufactured in rigorous, predictive, process-controlled environments
- Problem addressed
  - Current polishing pads used in CNC production of precision optics are reaching their limits with respect to consistency and dependability
- Material solution
  - IC Optic is made from the same controlled variation-free material that transformed semiconductor manufacturing
- Case studies
  - IC Optic Puck provides unparalleled consistency and versatility to production of precision optics

Introduction

- Precision spherical optic production utilizes CNC machines to generate and finish parts
  - Generation is performed with diamond matrix cup wheels
  - Polishing is performed with rigid form tools to which a foil is applied

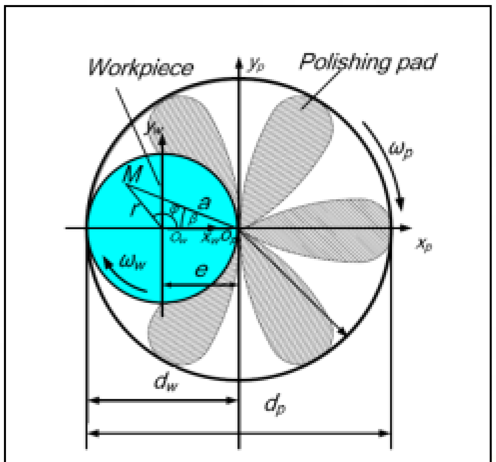


Figure 2 Kinematic

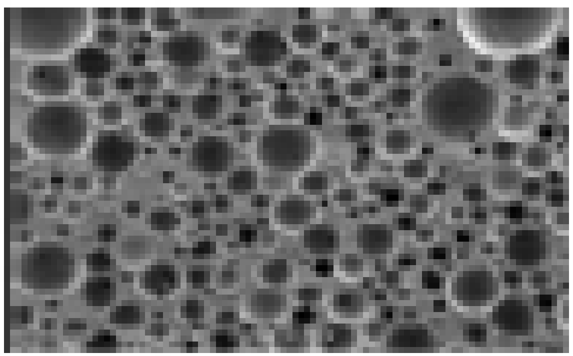
- “Synchrospeed” polishing is able to polish entire spherical optic in a uniform manner through the use of a “petal” shaped polishing pad or foil mounted on tool

Introduction

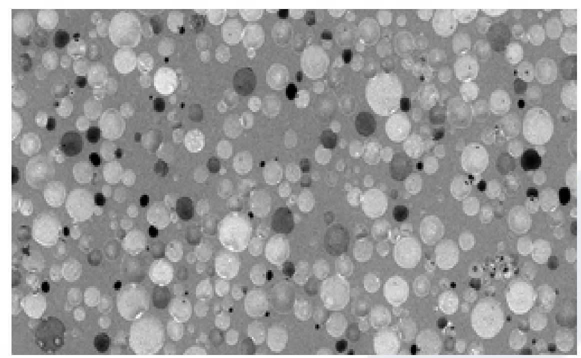
- The finishing or polishing process improves surface quality and figure to target specifications
- Polishing pads, typically in the form of urethane elastomers, are applied to rigid form tools made of steel or aluminum or some other material
- Many form tools required for diverse optic portfolio production

Current Polishing Tools & Pads Have Limitations

Process	Current State	Ideal State	Solution Dependency
Pad performance	Break-in required	One truing operation	Material properties
Pad lifetime	Frequent pad swaps	No pad swaps	Material properties
Limited pad rigidity	Thin pads	Rigid bulk material	Material properties
Performance variation	Inconsistent material	Consistent material	Material properties
Different parts	Many form tools	One tool platform	Material properties
Prototyping	Long lead time	Generate on the fly	Material properties



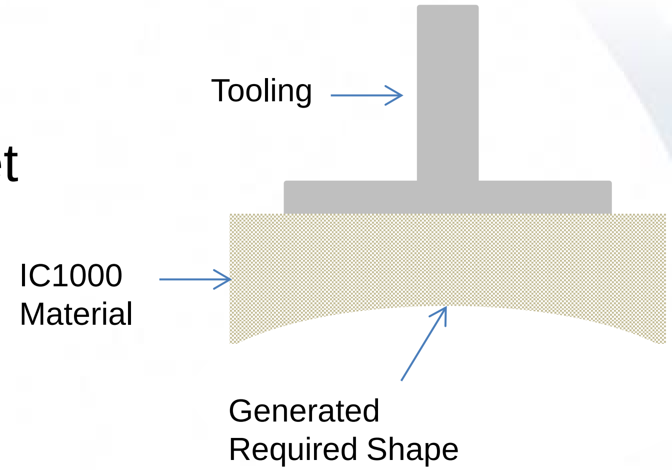
Traditional PU Pads
Low density
Low hardness
Inconsistent porosity



IC Optic Material
High density
High hardness
Consistent porosity

IC1000 New Material Configuration – IC Optic Puck

- Distribute IC1000 material to the advanced optical fabrication market in a new configurable format – IC Optic Puck
- Deliver the IC Optic Puck to CNC applications to improve consistency in final polishing operations
- Eliminate the need for an optical house to maintain dozens or hundreds of rigid form tools
- Enable rapid prototyping or short runs of custom optics



IC Optic Puck

- The new material format of IC Optic can be generated into complex three-dimensional shapes not achievable by conventional petal pads, particularly for operations involving steep radii.
- This three-dimensional form used in conjunction with CNC or spindle polishing tools can be dressed, re-generated, or modified to different figures during its lifetime.
- Furthermore, the need for an optical house to maintain dozens or hundreds of rigid form tools can be reduced or eliminated through the use of the new IC Optic puck material format.



Format Descriptions

- Traditional petal pads/foils
  - Cut pad mounted on rigid form tool

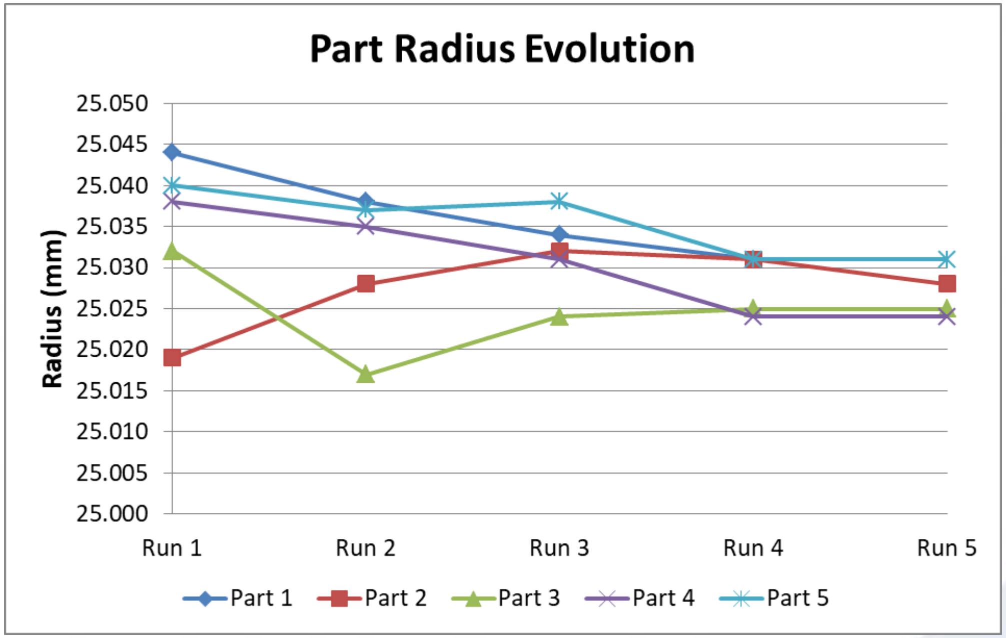
- Full surface
  - IC Optic with no machined features for slurry transport

- Grooved
  - Machined features in the IC Optic material to assist slurry flow

- Petal 3D machined
  - IC Optic material machined to similar shape as Traditional petal pads

IC Optic Initial Tests at Blue Ridge Optics

- IC Optic Puck cut with grooves to polish 25 mm radius optic
- 5 test parts generated to same thickness and radius
- Each part polished in 5 min intervals for 5 polishing cycles



All parts within 0.2 % of target radius

All parts within 0.05 % of each other

Subsequent qualification of IC Optic Puck has shown that > 100 parts can be produced without reconditioning polishing tool

IC Optic Initial Tests at OptiPro

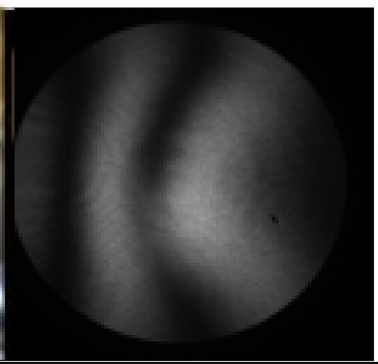
Part: 38mm BK7 CC Sphere

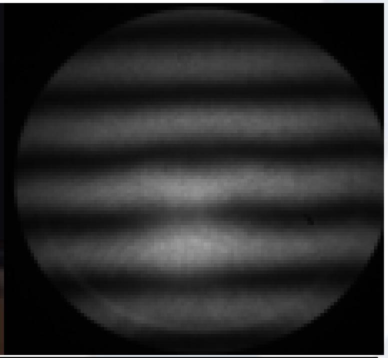
Slurry: Ultra-Sol 5010

Tool: OptiPro Pro80P

Tool: 38mm CX on 78mm ø tool

	Spec	PU Petal pad	IC Optic
Radius (mm)	- 38.00	- 37.335	**- 38.001**
PV (fr)	NA	0.279	**0.137**
RMS (fr)	NA	0.056	**0.026**
Ra (Å)	NA	29.8	**26.8**

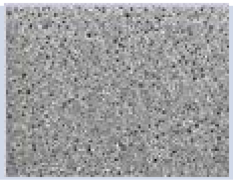
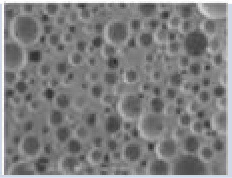
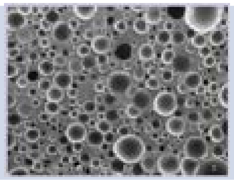
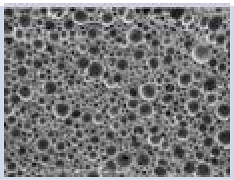


Later tests have incorporated a 3 mm center hole and vertical grooves to improve slurry delivery and flow resulting in process time reduction and improved performance

Low irregularity and form maintained throughout polishing test

Material Performance Experiment

We believe that the density, hardness and consistent pore structure contribute to the stability and performance when polishing with IC Optic Pucks.

		IC Optic	Traditional PU*	Exterion™ Non-Filled	Exterion™ Filled	Non-Porous
Pad Surface						
Property	**Units**	**Value**				
Density	g/cm^3	0.80	~0.52	0.43	0.42	NA
Hardness	Shore D	≥ 60	~32	45	46	74
Compressibility	%	1.7	~3.0	NA	NA	NA
Pore Median Diameter	µm	40	~120	100	60	NA
Filled (Ceria)		No	No	No	Yes	No

*Traditional PU material lacks rigidity to be used in bulk tool tests

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Material Performance - Wear Test

- IC Optic material and PU material were subjected to a wear test

Part: 4 x 1” pad material

Pad: 12” 180 grit AlOx paper

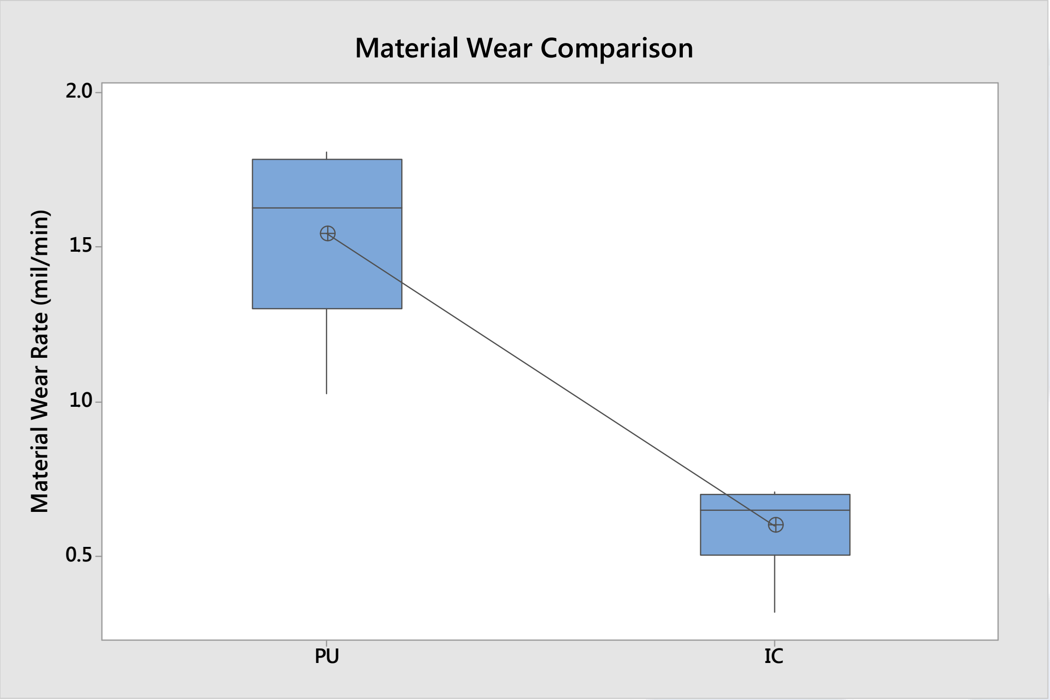
Tool: Lapmaster 12c

Test: 15 min PU, 30 min IC

Platen: 20 rpm

Coolant: Water

Repeats: n=6 for each pad



IC Optic material exhibits ~ 3 x lower wear compared to legacy urethane polishing pad

Material Performance – Polishing Tests

250 mm Radius

Material: Fused Silica

Slurry: Ultra-Sol Optiq

Tool: Satisloh SPS-125

Process Parameters	
Workpiece (rpm)	411
Tool (rpm)	210
Polishing Pressure (bar)	0.70
Oscillation Stroke (mm)	2.00
Oscillation Speed (mm/min)	20

- Different configurations of the IC Optic will be tested
  - Full surface
  - Grooved
  - Petal 3D machined
- Different material properties
  - IC Optic vs. softer traditional urethane
  - IC Optic with and without consistent pore structure

IC Optic Puck Surface Configuration Experiment

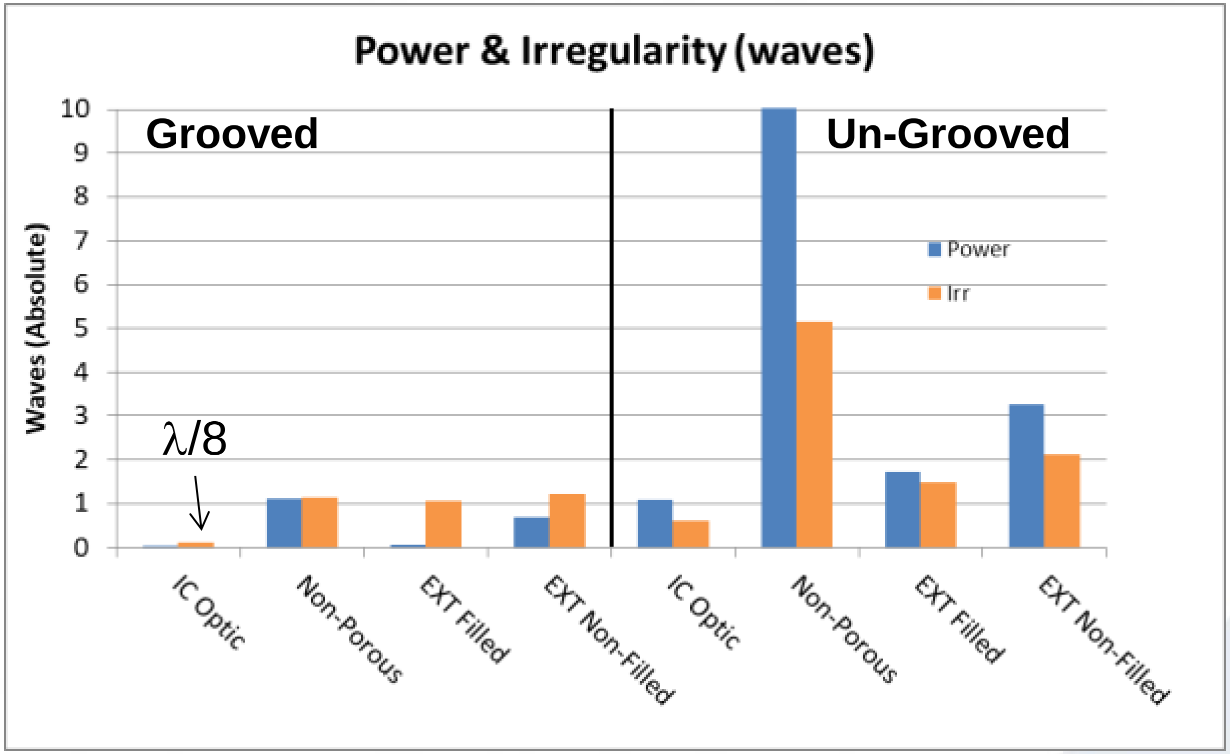
- Initial tests compared three different IC Optic Puck configurations

Material	Surface	Time (min)	Radius (mm)	Power (waves)	Irregularity (waves)	Ra (Å)
IC Optic	Full	20	248.55	-1.077	0.598	4.4
IC Optic	Grooved	20	250.52	-0.037	0.125	4.5
IC Optic	Petal	20	249.23	0.163	0.299	4.5

Both grooved and the petal shapes provided improved performance vs. full surface for conditions tested

Material Performance – Polishing Tests

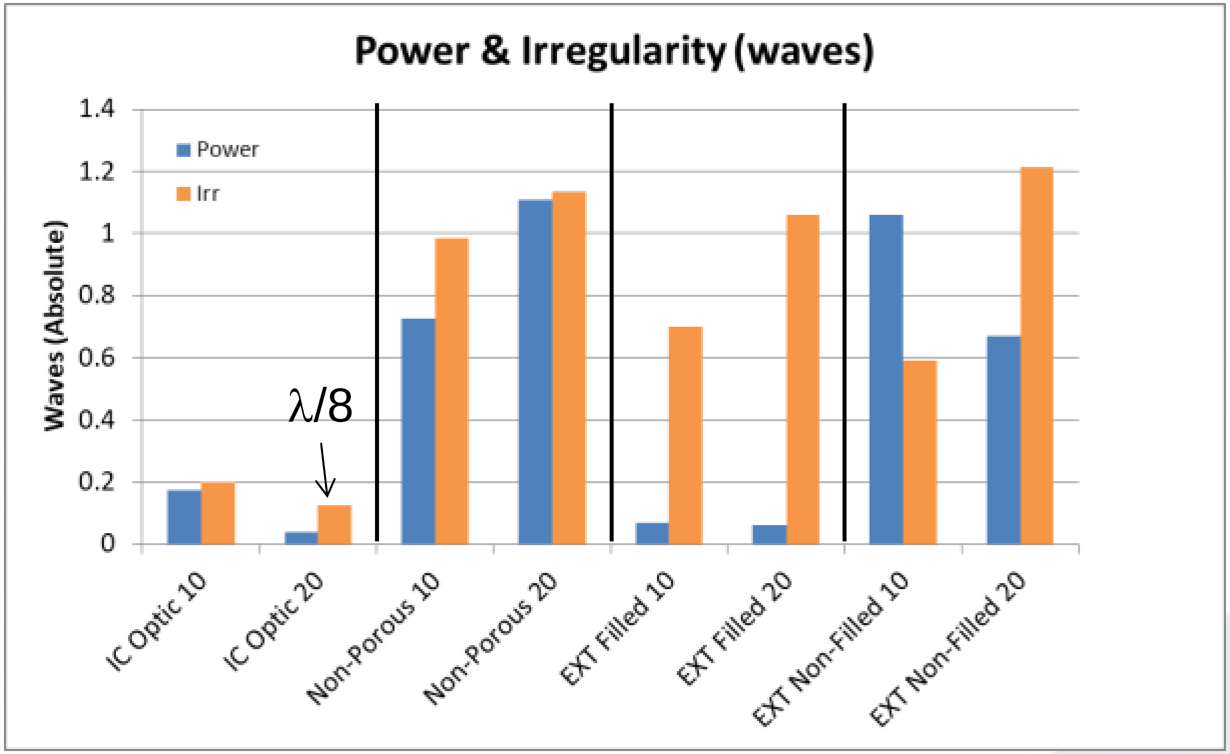
Experiment extended to other materials using the same process



Grooved configuration, consistent pore structure, and rigidity of IC Optic Puck contribute to improved polishing performance

Material Performance – Polishing Tests

Experiment to study extended polishing times without reconditioning polishing tool (grooved tools)



IC Optic maintains performance during extended runs compared to other materials tested

- Summary
  - IC Optic Puck material properties contribute to performance
    - Increased density
    - Increased hardness
    - Consistent porosity
  - IC Optic Puck can be generated into complex 3D shapes
    - Easy machining allows for easy shaping and conditioning
    - Generation of complex patterns or slurry channels possible
    - No need to generate form tool for prototyping or production runs
  - IC Optic Puck provides stable polishing tool performance
    - Consistent, predictive performance run-to-run
    - Low wear rates vs. traditional materials in bulk form
    - Consistent and tightly controlled pore structure

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Thank You

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  - https://vimeo.com/eminess