Low Cost, Lightweight, Easily Manufactured Mirror Component

x-mat®

Reimagining high performance materials

November 2016

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Team

- NASA SBIR Advisors - Phil Stahl, Ron Eng
- ZeCoat Corporation – David Sheikh
- Optical Mechanics, Inc. (OMI) – James Mulherin
- UCF – Kathleen Richardson, Cheng Li
- Semplastics

Talk Outline

- Technology Background
- NASA SBIR Phase 2 Activities
- Current Progress
- Commercial Possibilities
- New Material Developments
- Conclusions

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Who is Semplastics?

- 16 year old company focused on high performance plastics in electronics
- Recent development activities in novel high performance materials- X-MAT®
- US patents #8,961,840 and #9,434,653 issued - multiple patents pending
- Phase I NASA SBIR granted in May 2015
- Phase 2 NASA SBIR granted in April 2016

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What are the main goals of the project?

- Reduce areal costs to less than $\$250K/m^2$ for UV/Optics and less than $\$75K/m^2$ for IR systems
- Reduce the weight of mirror substrate through molding lightweighted structures using lighter X-MAT® materials (SiOC)
- Make a high performance mirror component that can meet NASA’s requirements

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Advantages of X-MAT® OC1

- Lightweight- 1.69 g/cc (SiC- 3.2 g/cc)
- High Temperature performance- capable of 1100C continuous usage
- Low Coefficient of Thermal Expansion- 0.60-1.27 x10E-6 in/in C (-150C-300C)- Similar to Quartz
- Amorphous structure provides isotropic properties
- Very Green technology- Uses 20X less energy than typical SiC manufacturing processes!!

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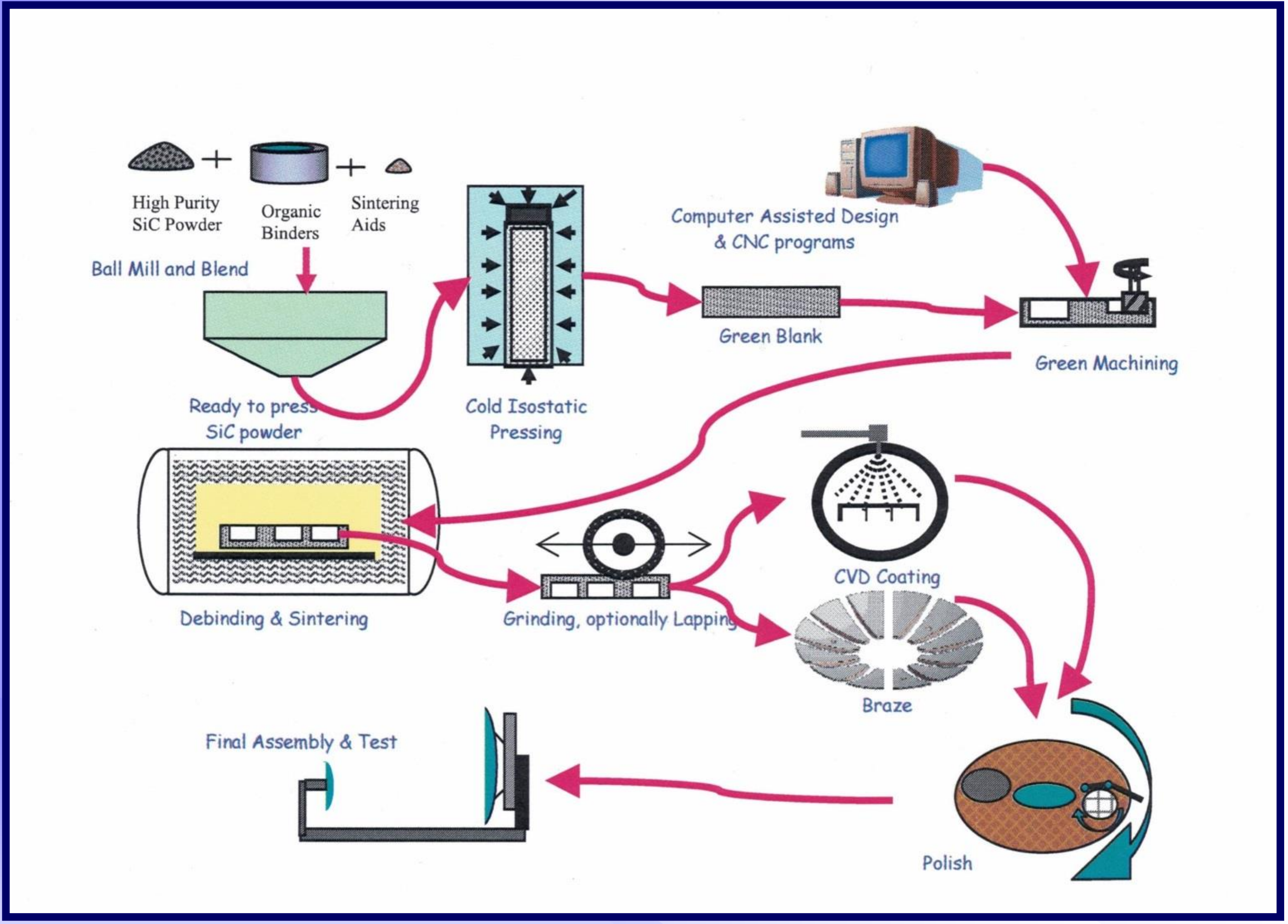
SiC Manufacturing Process*



***Overview of the production of sintered SiC Optics and optical sub-assemblies**, S. Williams, CoorsTek, Inc.; P. Deny, BOOSTEC Industries (France) [5868-04]

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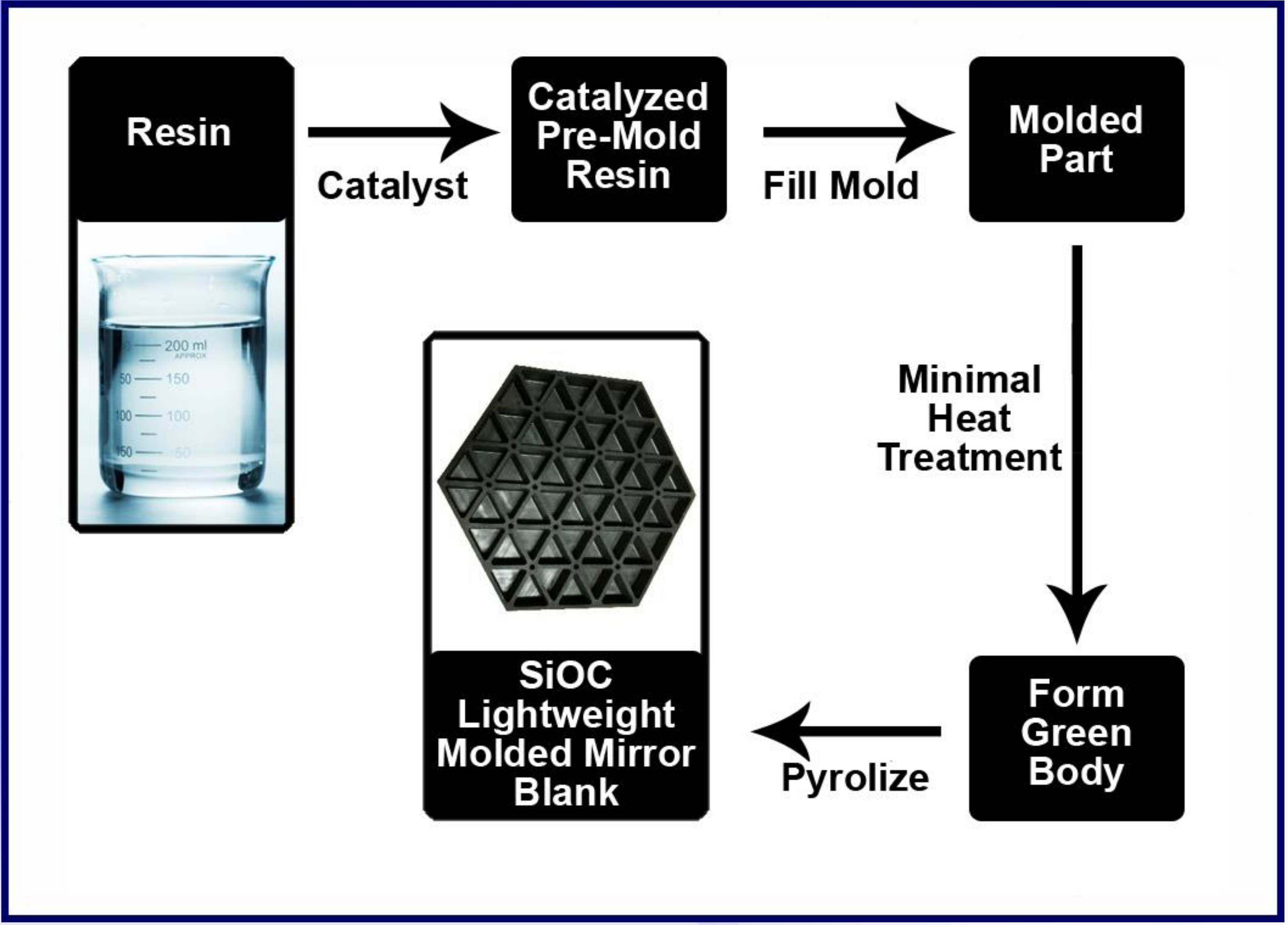
X-MAT® Mirror Blank Process



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So What is the Big Deal with X-MAT®?

- Polymer resin instead of ceramic powders
- Typical plastic processes (3D printing, molding, etc.) possible
- Shorter Manufacturing Intervals
- Chemical Bonding of the Materials rather than Sintering (Significantly Lower Energy)
- Tailored Material System Properties

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Significance/Review of Polymer-Derived Ceramics (PDCs)

- 40 year history of PDC Development activities
- Commercially Available Resins
- Current commercial usage limited to ceramic fibers, polymer coatings and thin ceramic films
- Multiple resin types and processes produce unique ceramic types and properties

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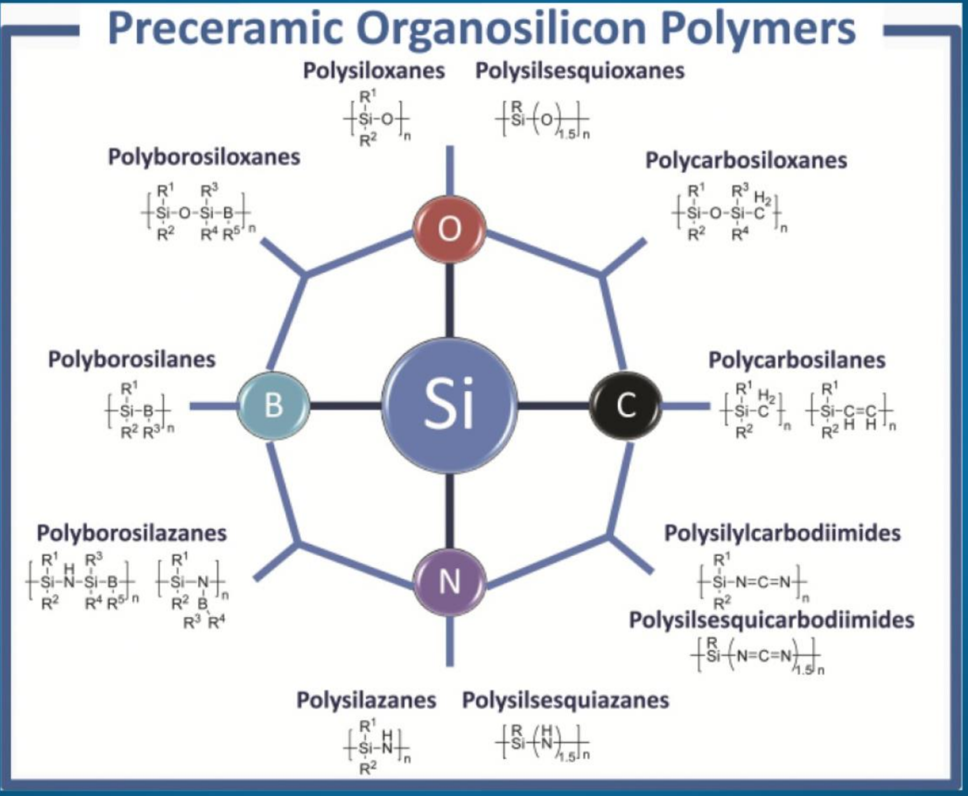
PDC Technologies



J. Am. Ceram. Soc. 93 [7] p.1807 (2010)

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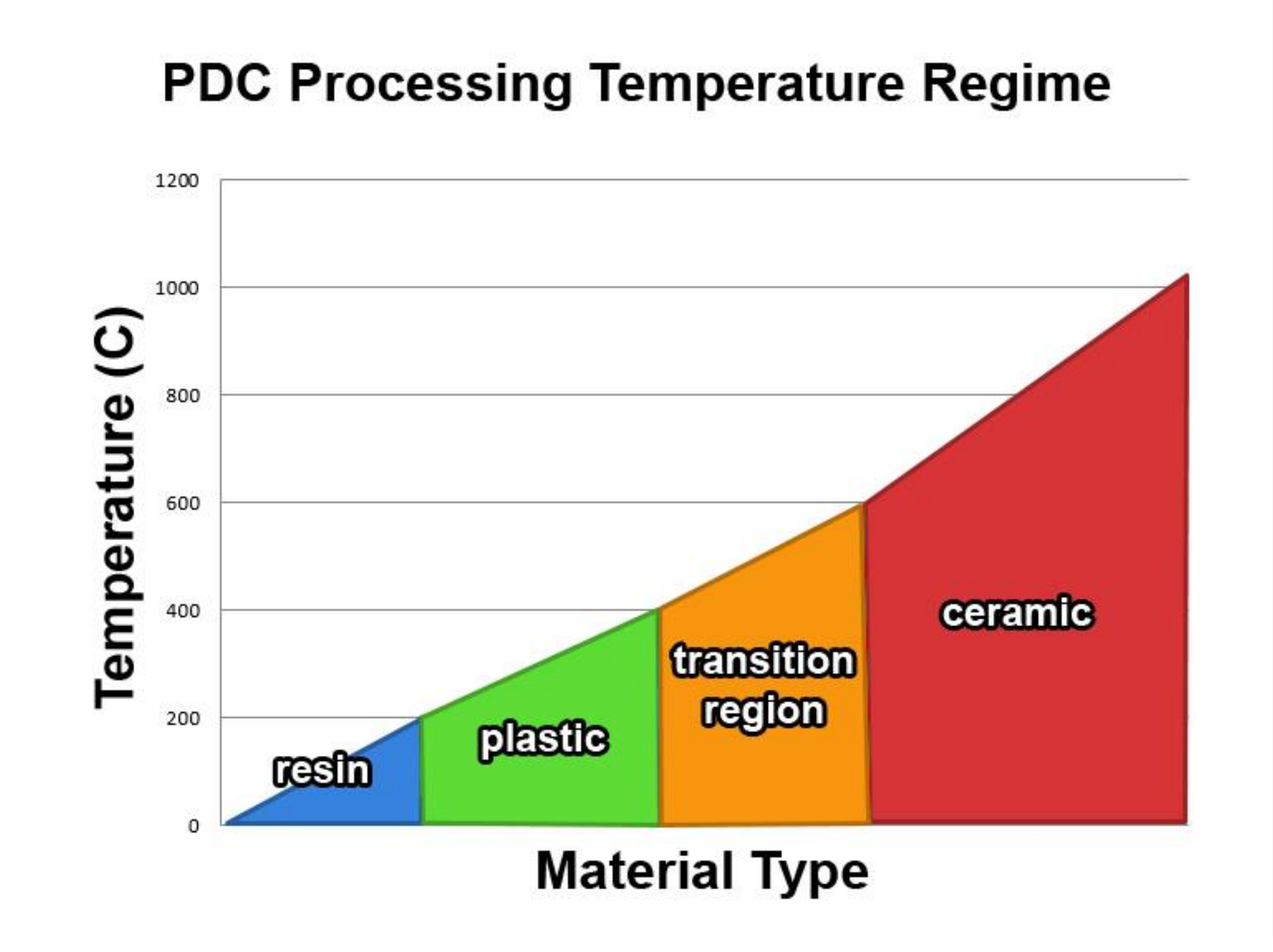
Polymer-Derived Ceramics Processing Cycle



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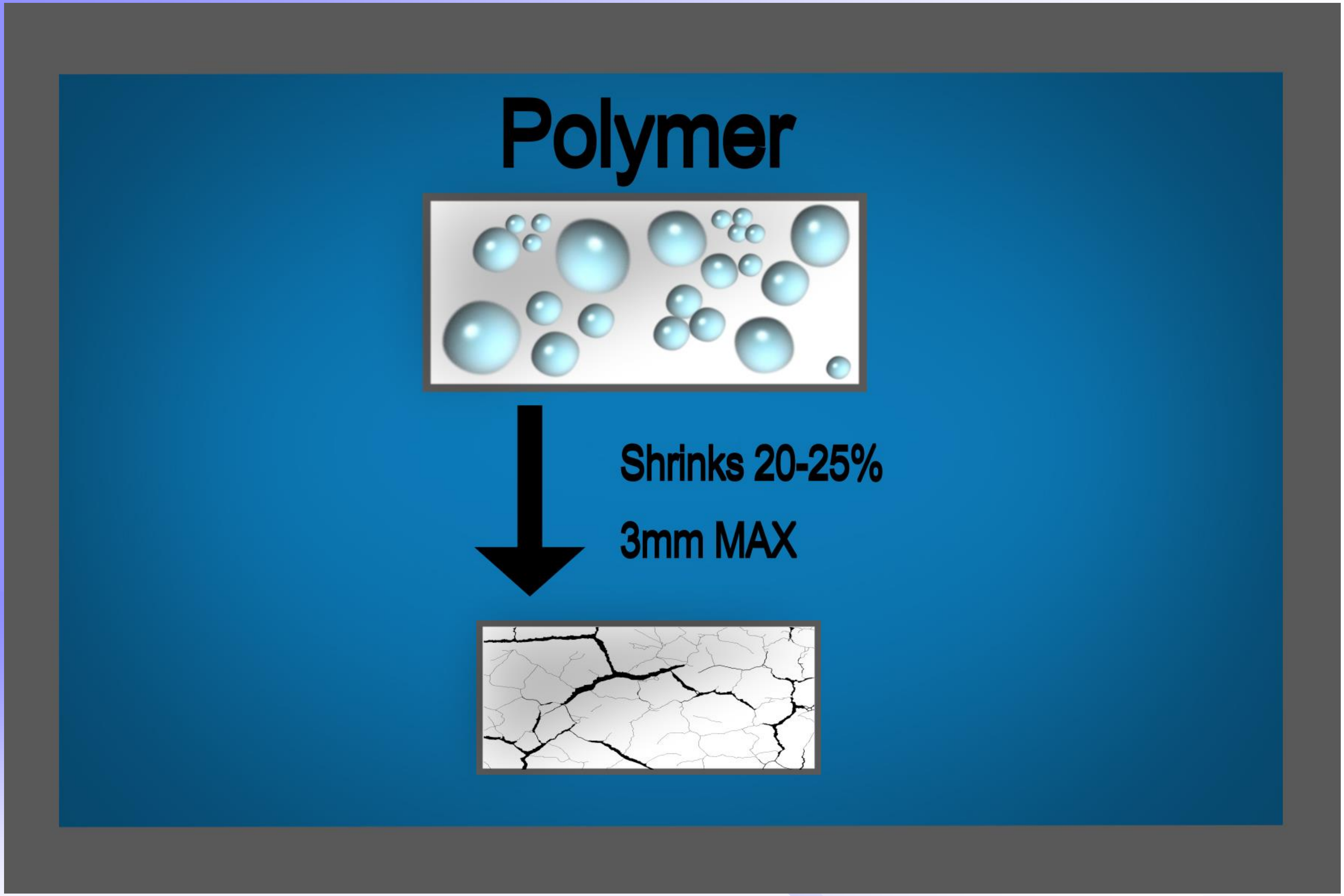
Polymer to Ceramic Processing



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Current PDC Limitations

Can only produce thin films or fibers due to cracking and degradation of films thicker than several hundred microns

" The polymer to ceramic conversion occurs with gas release which typically leads to cracks or pores which make the direct conversion of a preceramic part to a dense ceramic **virtually unachievable**, unless its dimension is typically <u>below a few hundred micrometers</u>(as in the case of fibers, coatings, or foams.) J. Am. Ceram. Soc. 93 [7] p.1811 (2010)

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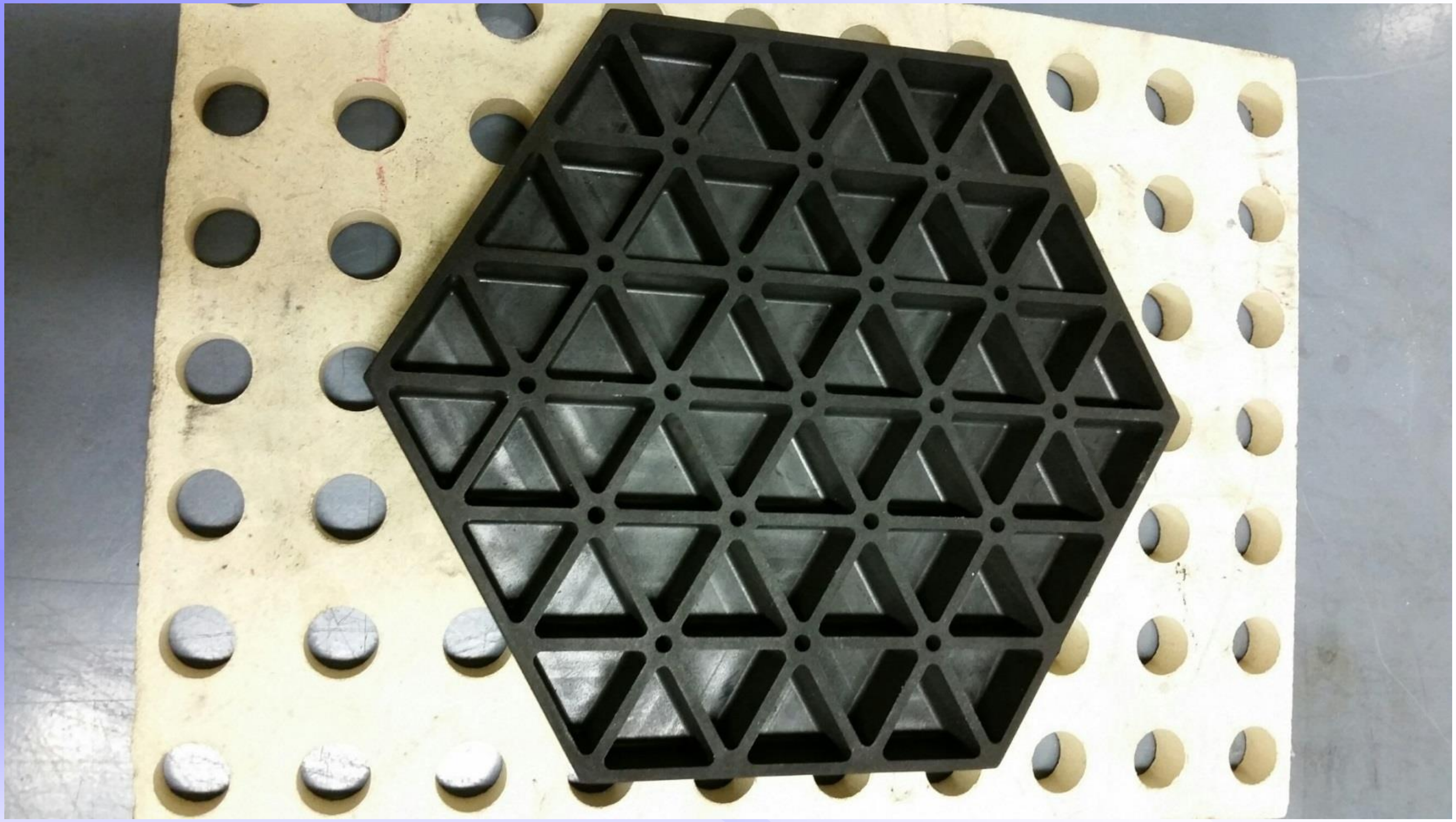
Largest Bulk PDC Ever Made (No Fibers!)



Mirror Blank Deliverable: 0.25 meters

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Properties of X-MAT® OC1

TEST	VALUE	UNITS
Fracture Toughness	.96	Mpa-m^1/2
Flexural Strength	43.5	Mpa
CTE	0.75	1E-6in/in˚C
Young’s Modulus	56	Gpa
Poisson’s Ratio	.53	-
Density	1.69	g/cc

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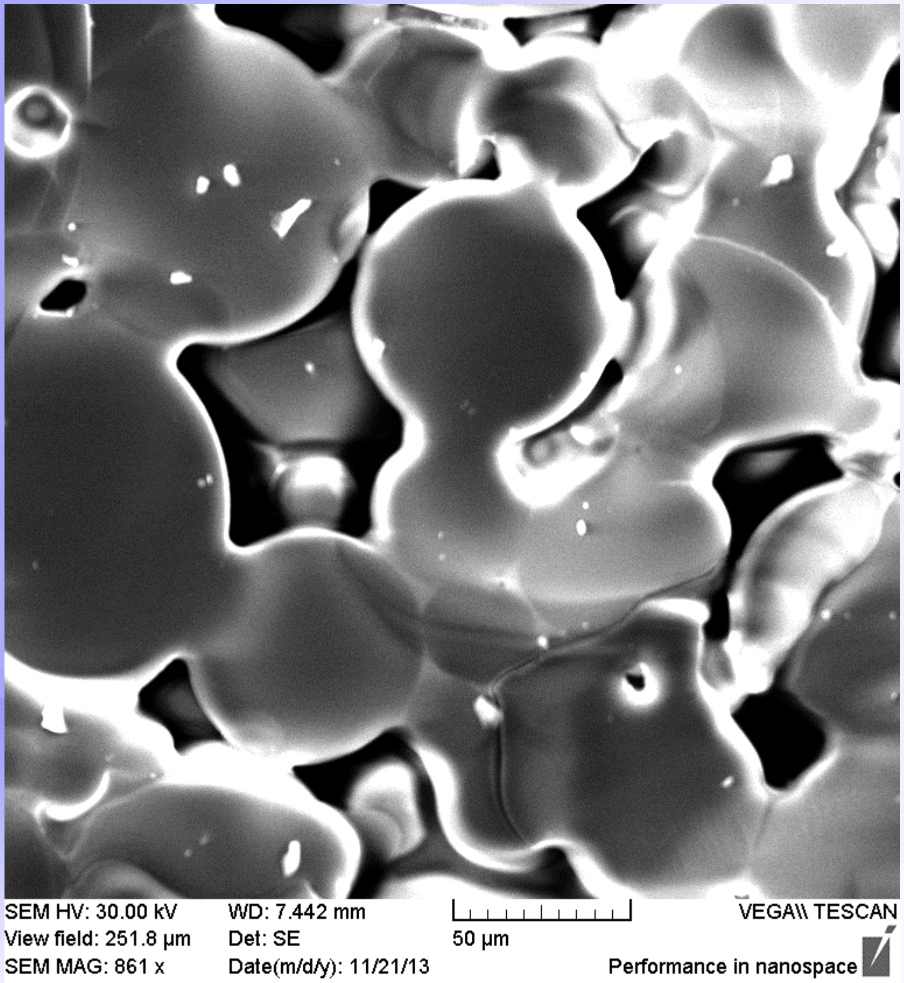
SEM of X-MAT® OC1



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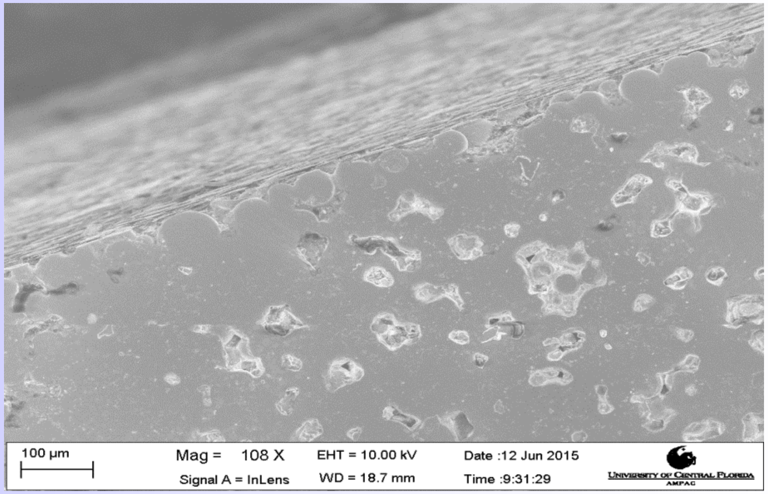
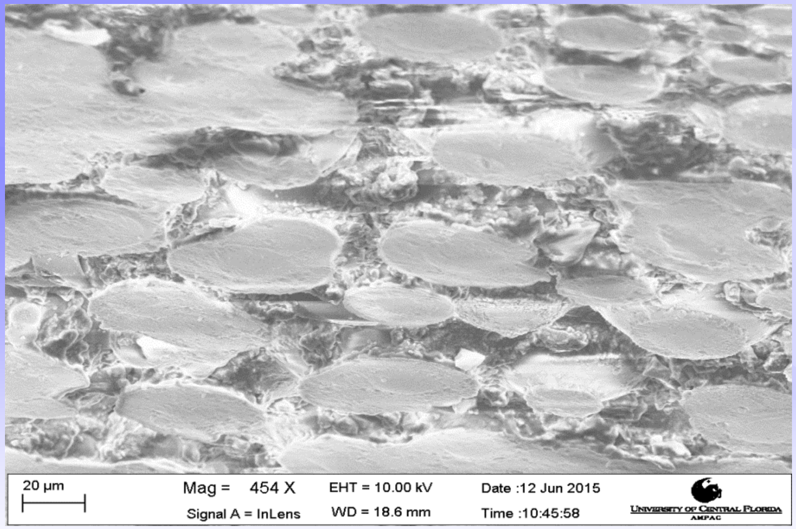
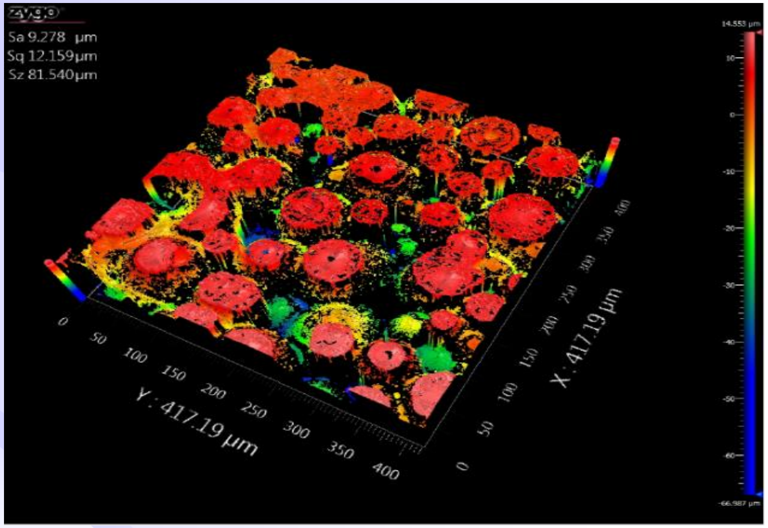
SiOC PDC Uncoated Substrate

Uncoated SiOC PDC

- Highly porous
  - ~80% dense
- Highly Rough Surface
  - RMS roughness of ~12 µm







Coated X-MAT® Sample(no metal)

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NASA SBIR Phase 2 Technical Objectives

- Demonstrate Scalability by producing an intermediate mirror(37cm[14.5”] dia.
- Implement and Characterize Two Different mirror coating systems
  - Polymer Based Coating System- Zero CTE Composite
  - Silicon cladding system using baseline process developed to coat SiC mirror substrates
- Produce one 37cm[14.5”] diameter mirror using the Polymer based coating system

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NASA SBIR Phase 2 Technical Objectives(cont.)

- Produce one 37cm[14.5”] diameter mirror using the Silicon cladding coating system
- Produce one 61cm[24.0”] diameter mirror using the Polymer based coating system
- Produce one 61cm[24.0”] diameter mirror using the Silicon cladding coating system

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Current Progress - Task 1

- Semplastics
  - Build 25 SiOC 2.5” test coupons
  - Develop and Harden Polyimide Coating Process
  - *Build 6” Mirror
  - *Test 6” Mirror with Local Amateur Astronomer
- UCF
  - Characterize and Analyze Polyimide Coating and Silicon Cladding Process on Test Coupons
  - Consult for various material concerns for this project

*Additional Activities Outside of NASA SBIR Phase 2 Proposal

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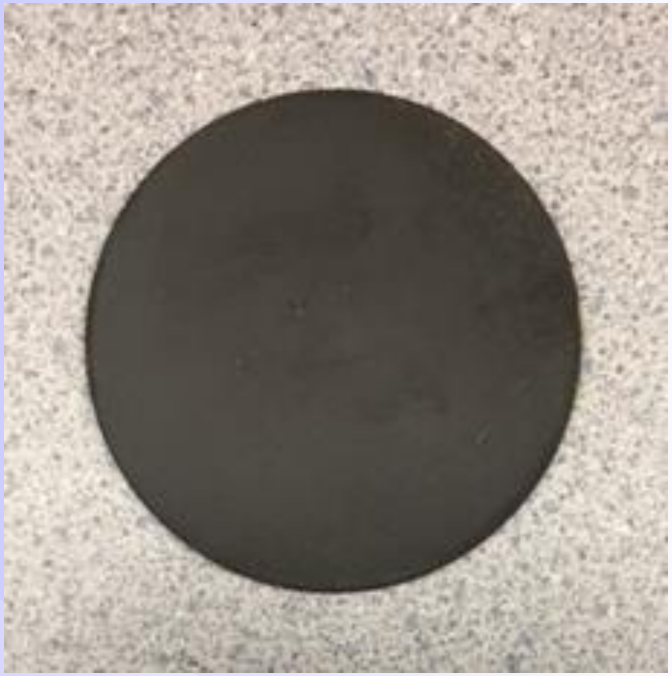
Current Progress - Task 1 (Cont.)

- ZeCoat
  - Provide Silicon Cladding services for test coupons
  - Optimize Silicon Cladding process for SiOC material
- OMI
  - Provide grinding and polishing services for test coupons
  - Develop grinding and polishing process for polyimide coating process
  - Develop grinding and polishing process for silicon cladding coating process

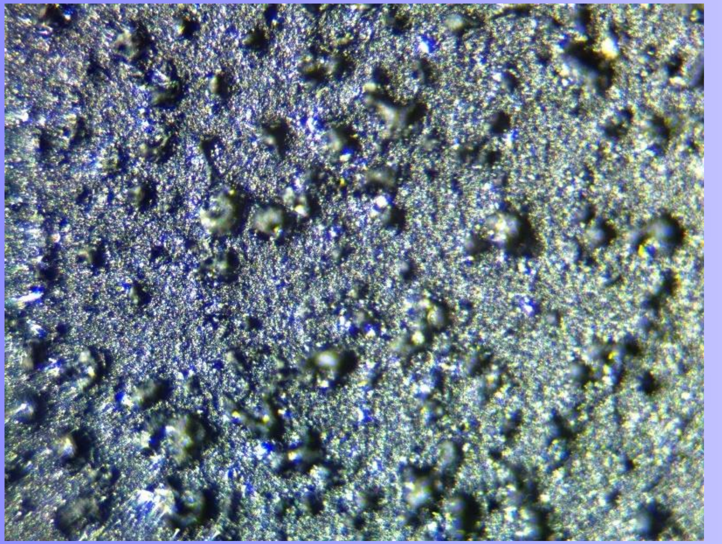
Test Disc Photos

X-MAT® Disc – No Coating

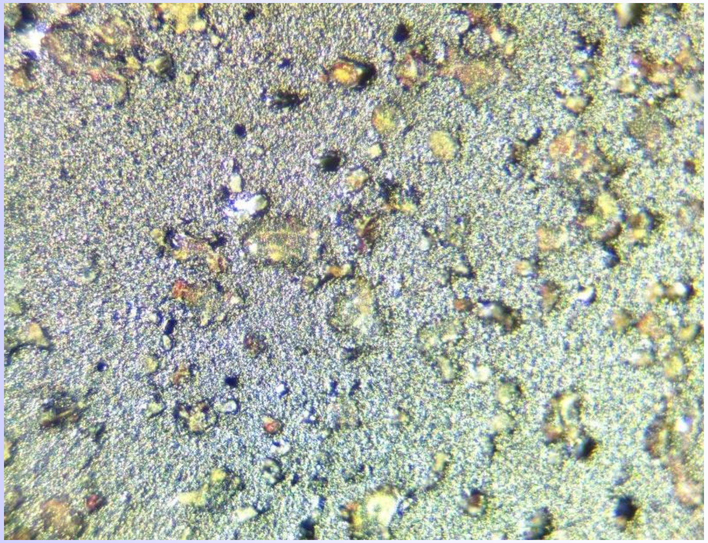


Polyimide Coated X-MAT® Disc with Sealed Pores

Test Disc Pore Photos



X-MAT® Disc –
No Coating



Polyimide Coated
X-MAT® Disc with
Sealed Pores

6-inch Disc

Uncoated ceramic mirror blank with triangular rib pattern

Uncoated ceramic mirror blank with F2 curvature ground into surface

New 36” Diameter High Temperature Furnace

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Commercial Possibilities

- Purchase X-MAT® Lightweighted blanks from Semplastics
  - Advantages
    - Lower Cost
    - Faster Turnaround – 1-2 months in production
    - Lightweighted Structures Molded-In
- License X-MAT® mirror technology from Semplastics
- Joint Development Project for Specialized Mirrors

New Material Developments

- X-MAT® Coal Core Composites
  www.x-materials.com
- Thick Bulk X-MAT® SiC structures
- X-MAT® C/C Composite Structures
- Reduced Cost Resin Formulations

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Conclusions

- NASA SBIR Phase 2 Task 1 Almost Completed
- 6” Mirror to be Tested by Amateur Astronomer in early 2017
- Continuing Advances of X-MAT® Technology in Scale, Performance, and Material System Types

Acknowledgements

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