Fabrication Strategies for Light Weight Optics

Presented by Mel Ulmer[a]

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Goal:

Light weight (< 1 kg/m^2)

High quality (<1 arc sec)

For Plasma Spraying, What are we dong differently?

Spray on Electroformed shell (100 microns thick for now), then laminate by more electro-forming on back

Use Ni coated micro-spheres rather than alumina

Comparative advantages for plasma spraying:

In house patented small particle (down to sub- 1 micron); typical particle sizes used = 50-100 microns

Small sizes may be important to prevent print-through

Preliminary Results on plasma spraying

With 100 micron particles; 30 microns ones to be done in the future


ASEA


ASEA
2000

Background info re micro-spheres, Part I

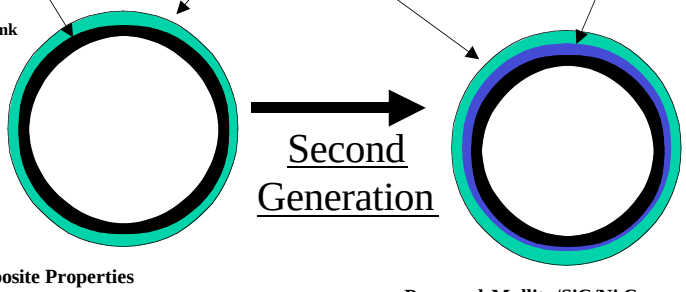
Current State-of-the-Art

Hollow Mullite Spheres

Density= .6 -.7 gm/cc
Strength= 5 -7,000 psi
size 1 micron -1000 microns
Low Thermal cionductivity =.3 W/mk

Ni Coating

SiC Coating

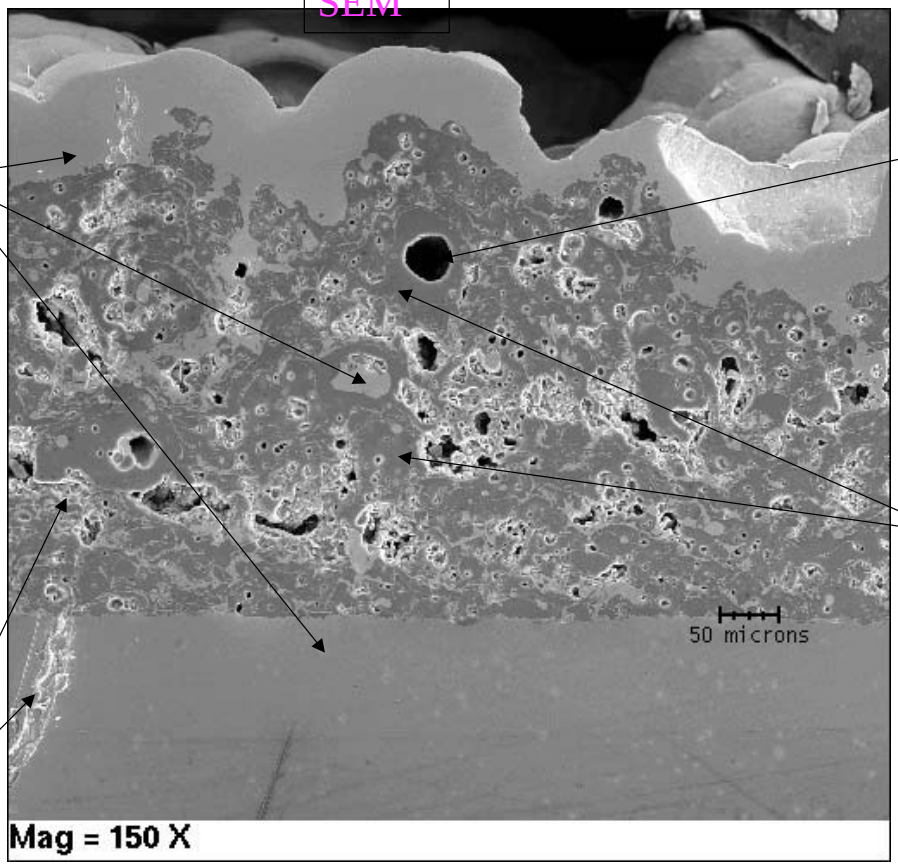


Second Generation

Mullite/Ni Cermet Composite Properties
(Dependent on Ni Content)
Plasma Sprayed Shapes (60 -70% Microspheres Retained)
- Thermal Conductivity= .7 - 5.5 W/mk
- Desnity= .8-.85 gm/cc(6% Wt Ni coating)
2.0-2.3 gm/cc (40 -50% Wt Ni Coating)
- Crush Strength = 8 -9,000 psi
- CTE= 10-15 micron/m C
- Flexure= 4-22,000 psi
- Compression= 10 -50,000 psi
- Modulus= 2 -9 MSI

Proposed Mullite/SiC/Ni Composite
Density= .9 -1.0 gm/cc
SiC= 3-6 % Wt
Ni= 6% Wt
Increased Crush strength, Increased microsphere spray retention, Inc Composite strengths with lower Metal Content, Lower CTE

SEM



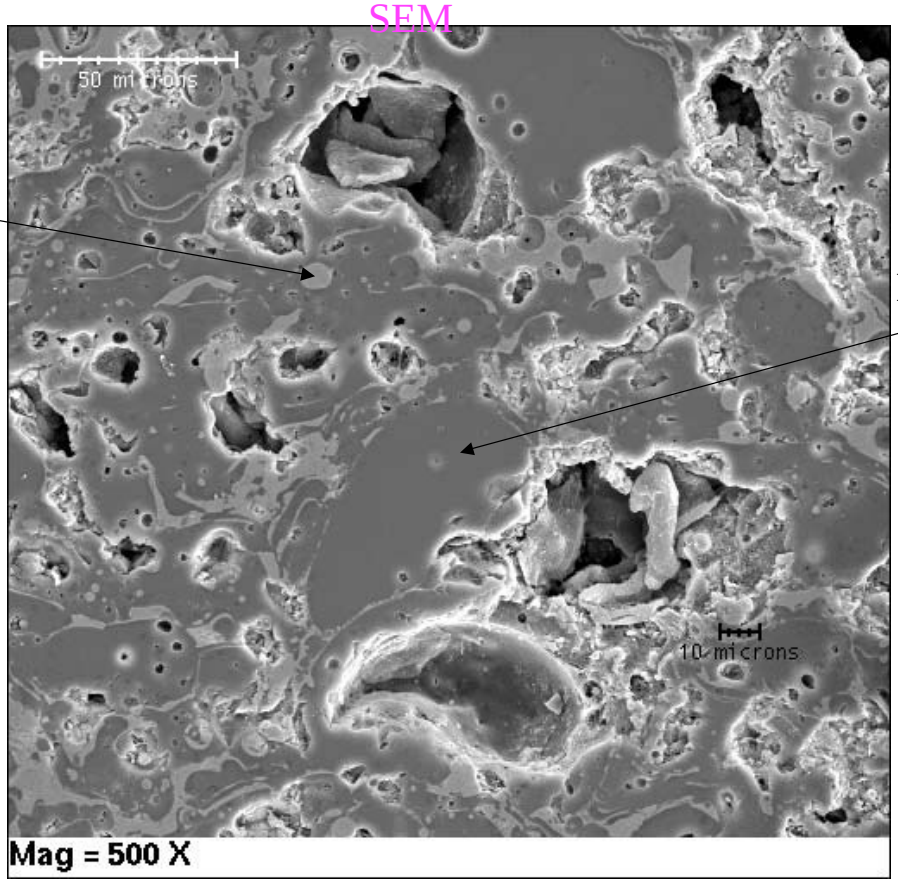
Nickel

cavity

Mullite = **3Al2O3 -2SiO2**

Gold for SEM

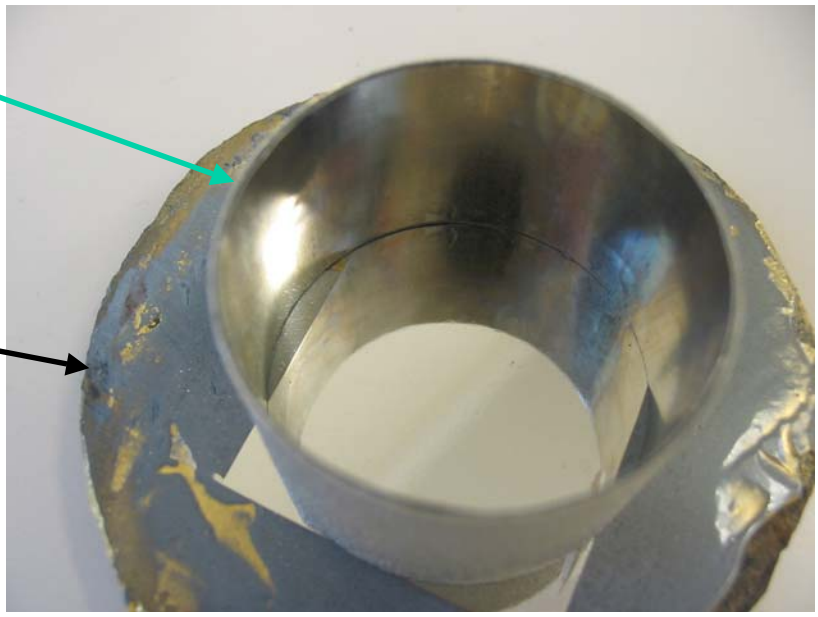
SEM



Proof of concept study for light weight X-ray and visible light optics

X-ray optics geometry; 3 cm diameter. cylinder

“hockey puck” for visible light optics; 6 cm diameter

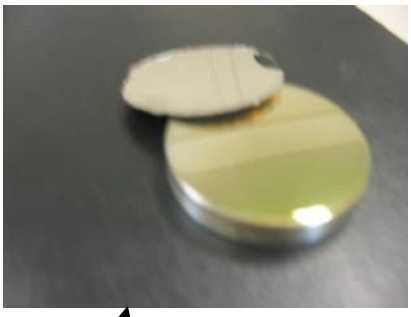


Cylinder: Density of material is 4.7 g/cm^3 and the areal density is about 2.3 kg/m^2 . The cylinder is laminate of a 100 μm thick Ni layer, a 200 μm thick layer of plasma sprayed micro-spheres, and another 100 μm thick Ni layer.

RMS deviation from master = 4 microns over 5 cm , corresponding to about 17 arcseconds

The "hockey puck" was made by a sintering process. For reasons yet TBD, we cannot directly plate this, but we can 200 μm thick versions. In order to metal plate to be able to polished, we first coated with epoxy, then evaporated gold for conductivity, and then electroplated about 100 μm Ni which we then polished. Goal is to meet NASA request of 1/100 wave figure at HeNeAr, 0.2 nm smoothness, and 15 kg/m^2

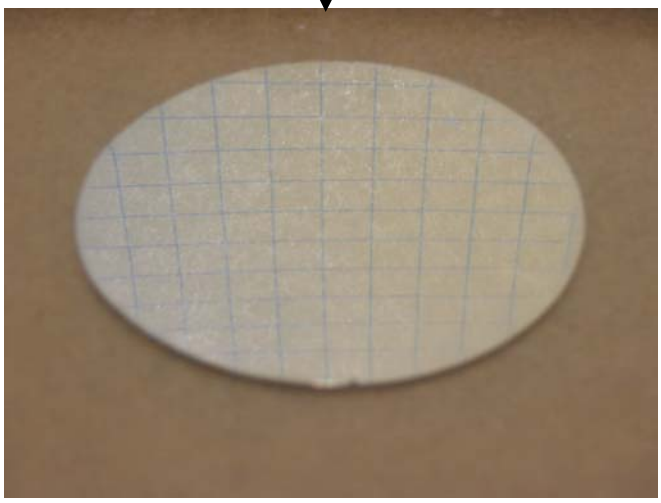
Ni/sprayed/Ni laminated 5 cm dia. flat: areal density, 2 kg/m^2; 140 μm front/back of and 120 μm of sprayed micro-spheres; 7.3 gm = 3.7 kg/m^2



Mirror and mandrel together, both 5 nm smooth

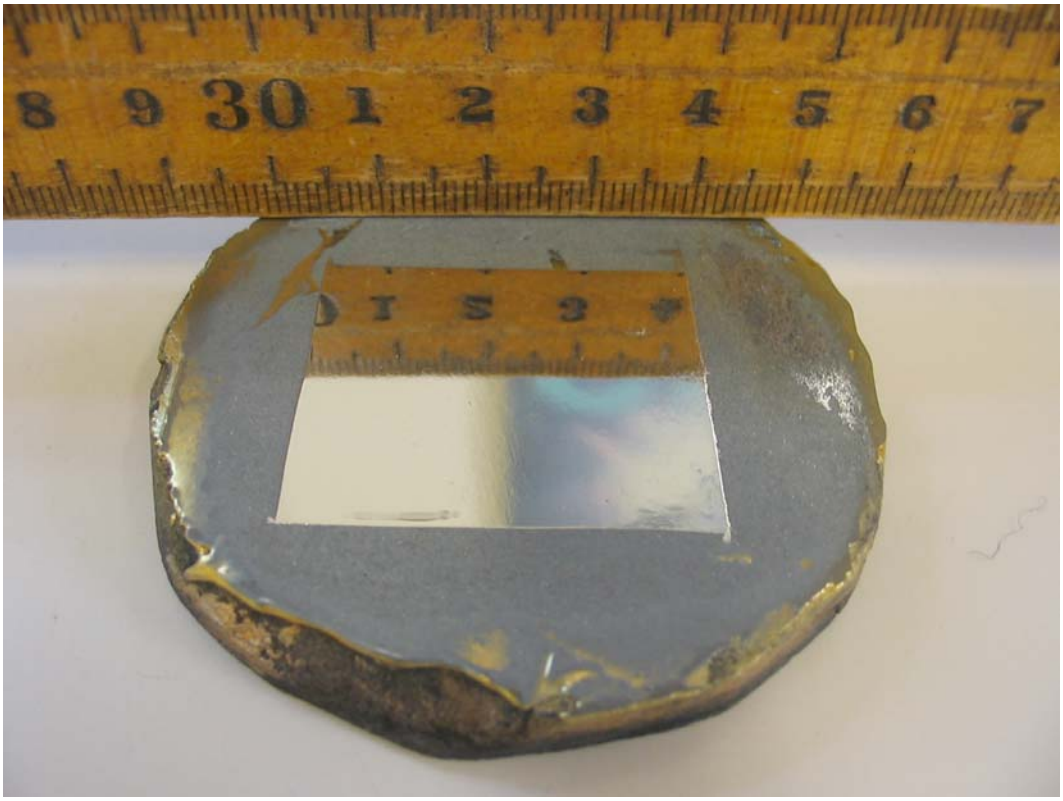
NB for cryo mirror applications, dipping in liquid N_2 had no effect

Straight line test on flat; profiler measurements show deviation from flat of 1/3 λ (600 nm); smoothness on 5 nm 10-100 μm scale; <0.2 μm over 3 mm



“Puck” w/Epoxy

- Epoxy applied to the surface of the “puck” with doctor’s blade
- Surface polished
- Gold layer (10 nm) is sputtered
- Bright Ni (100 microns) is electroplated
- Surface is polished

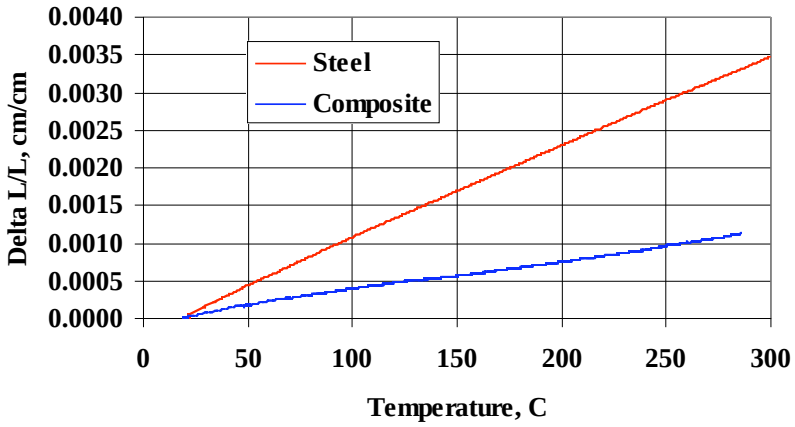


“Puck” w/plasma-sprayed Ni

- Ni (100 microns) is plasma-sprayed on the surface of the “puck”
- Surface polished
- Bright Ni (20 microns) is electroplated
- Surface is polished

Densities

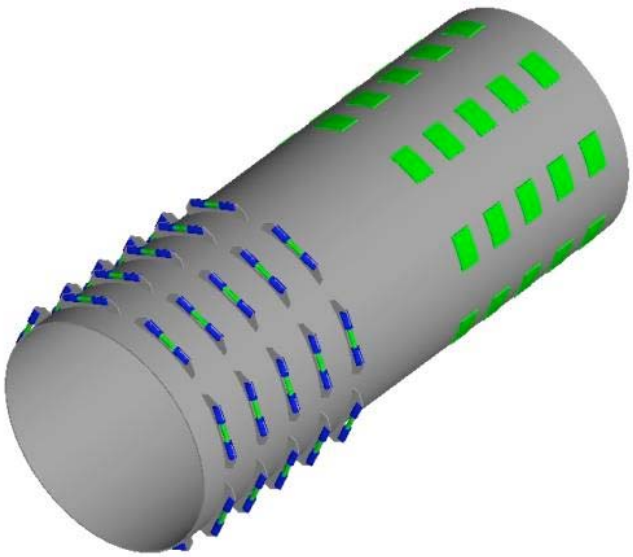
	Density, g/cm^3	Areal Density, kg/m^2	Average Thickness, mm
Cylinder (Ni-plate+plasma spray+Ni-plate)	4.72	2.31	0.5
Puck (epoxy+gold+Ni-plate)	1.89	3.96	8.0
Puck (Ni-plasma+Ni-plate)	2.18	2.60	4.5



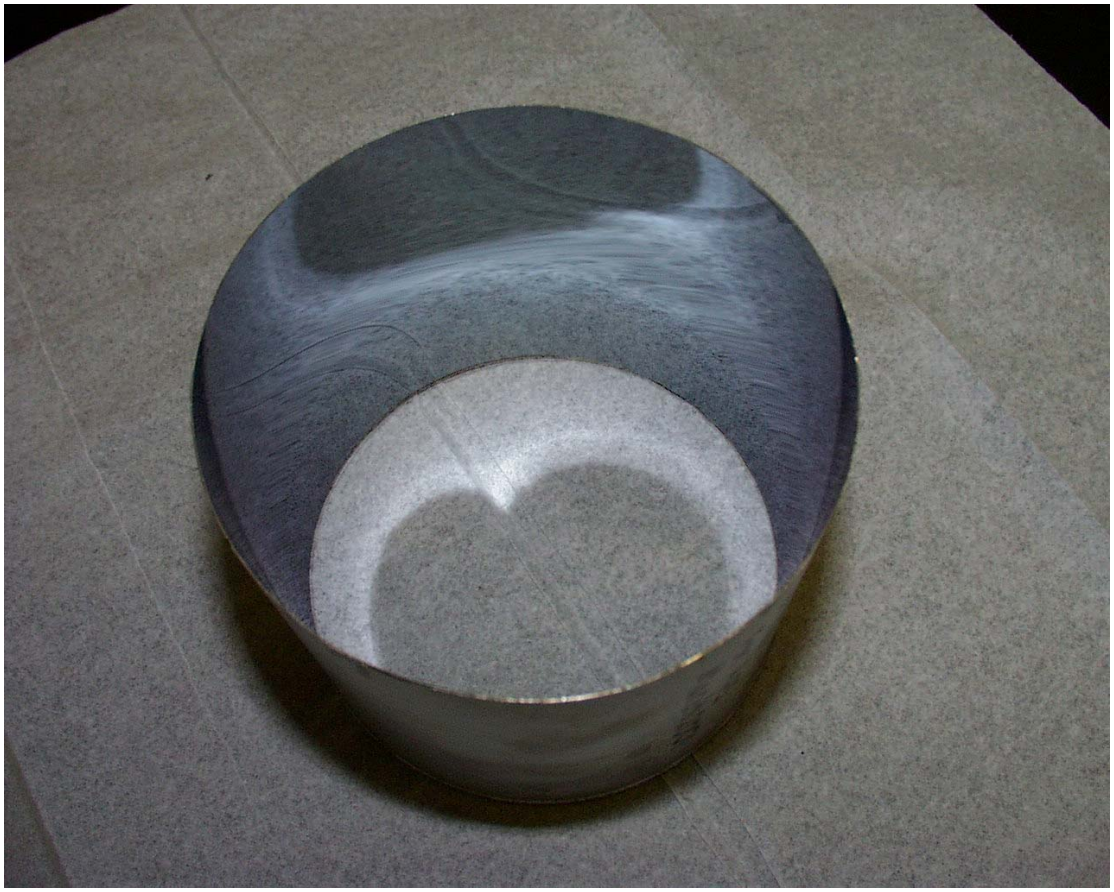
For cylinder:

CTE about 4.2*E-6 versus 2.4E-6 CVD SiC

Density = 4.7 g/cm^3 versus 3.2 g/cm^3 CVD SiC



Two Actuator Concepts



Concluding Remarks:

- Plasma spray shows promise for light weight mirrors, and actuators are fall back
- Facilities available to test with and without Actuators
- Technology Exists to Enhance High Energy Reflectivity

Funding Sources:

NASA Space Grant to Illinois

NASA STTR