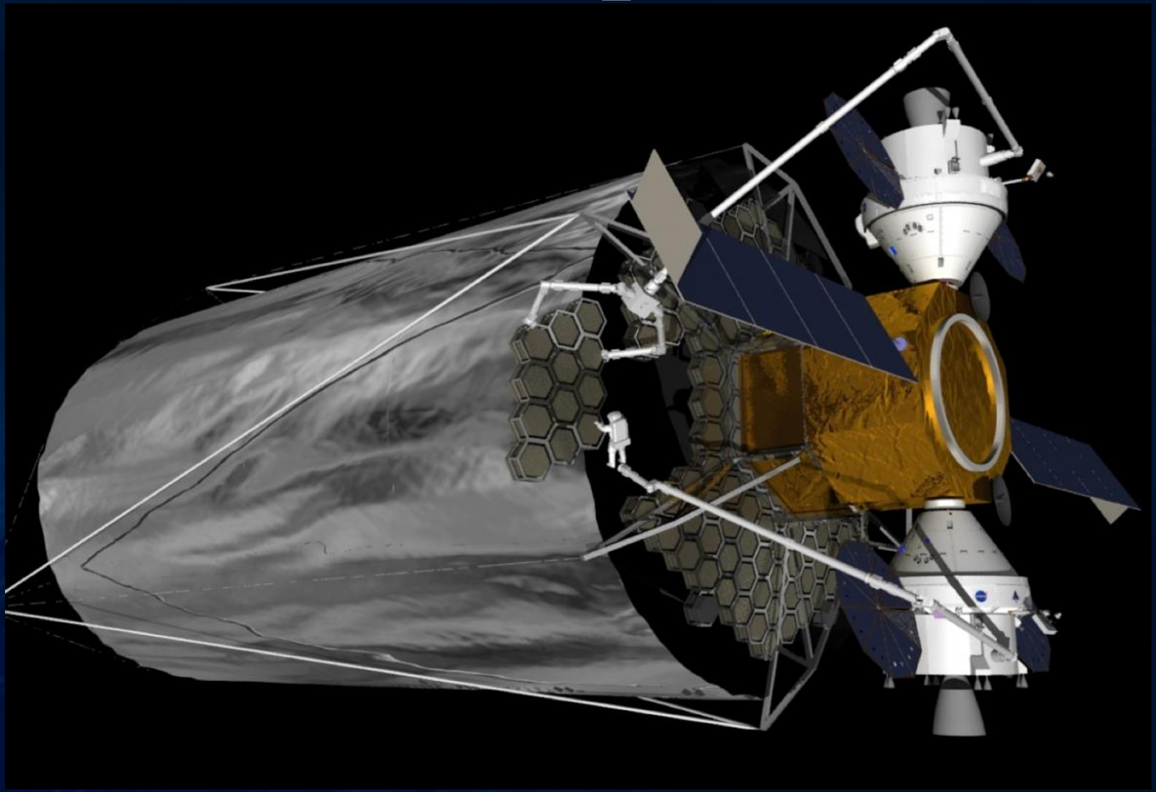
Matching NiP on Be-38Al for Low Temp Mirrors / SBIR Phase II



NASA MIRROR TECHNOLOGY DAYS
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THE PEREGRINE FALCON CORPORATION

CURRENT SOA

Current state of the art materials for precision structures/optical substrates include:

- **ULE** – heavy & long lead time
- **SiC** – heavy & long lead time
- **Beryllium** – lightweight / high cost*
- **Composites** – lightweight / high cost

***JWST Beryllium Optics cost: $6 M/m^2$**

The Candidate Material System will Provide…

- Large Monolithic Mirrors.
- Low Temperature Operation.
- High Stiffness/Stable.
- Durability / Robustness
- Budget Friendly Cost: 4x less than JWST

DEVELOPMENT: Be-38Al NEAR MATCHING CTE TO ELECTROLESS NICKEL

LOW COST APPROACH TO OPTICS WHILE MAINTAINING OVER 80% OF THE PERFORMANCE OF BERYLLIUM

- Be-38Al
- Electroless Nickel – Phosphorous (NiP)
- Single Point Diamond Turn

- Use Liquid Interface Diffusion (LID) Bonding for joining to create large substrates/structures/Section Moduli.

COMPARISON CHART (Ambient Temperature)

Property	Be-38Al AMS 7911	Beryllium	ULE	SiC
Density (g/cc)	2.10	1.85	2.21	2.89
Thermal Conductivity (W/mK)	210	216	1.3	155
CTE (ppm/°C)	13.9	11.4	< 1	2.4
Modulus of Elasticity (GPA)	192	303	68	330
Ductility (%)	2	2	Very Low	Very Low
Yield Strength (MPA)	192	241	< 50	NA
PEL (MPA)	17.3	30	NA	NA
Specific Heat (J/kg°K)	1506	1925	767	670
Specific Stiffness	**91**	164	30	114
Machinability (1 easy)	**2.5***	6	8	10

Ductile

Large Sections

Producibility

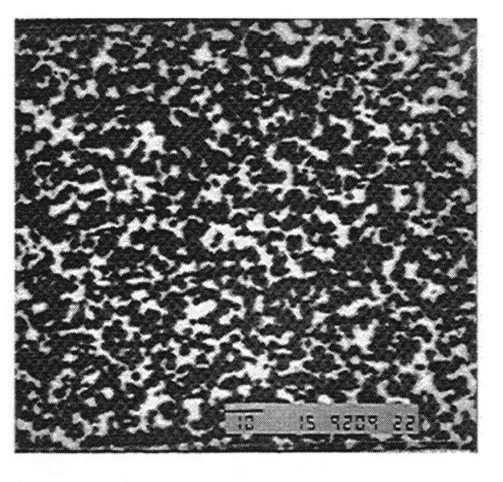
* Aluminum = 1

Be-38Al

(Highly Characterized Material – Re-Introduced in Early 1990's)

Low cost substitute for beryllium.

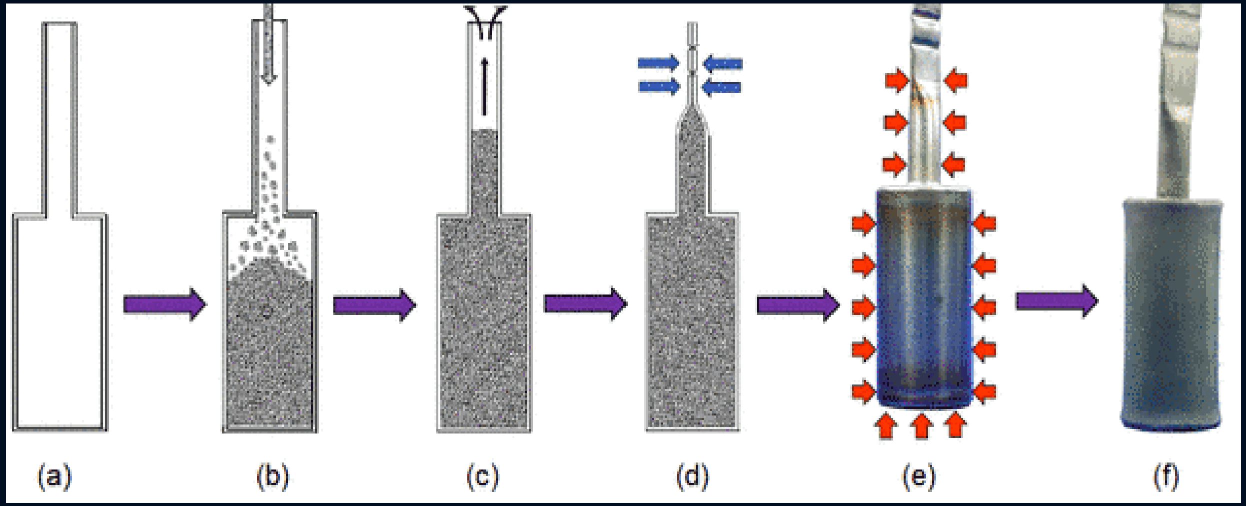
(Density 1.85 gm/cc Be; 2.1 gm/cc Be-38Al)



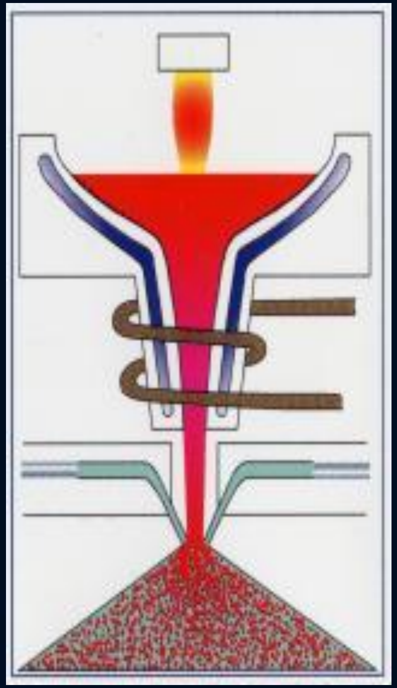
Beryllium is a brittle material, like other optical materials, which requires heavier wall thicknesses than what most designs specify.

Be-38Al has improved toughness allowing thinner wall sections to be fabricated, resulting in a substrate weight similar to beryllium.

Be-38Al

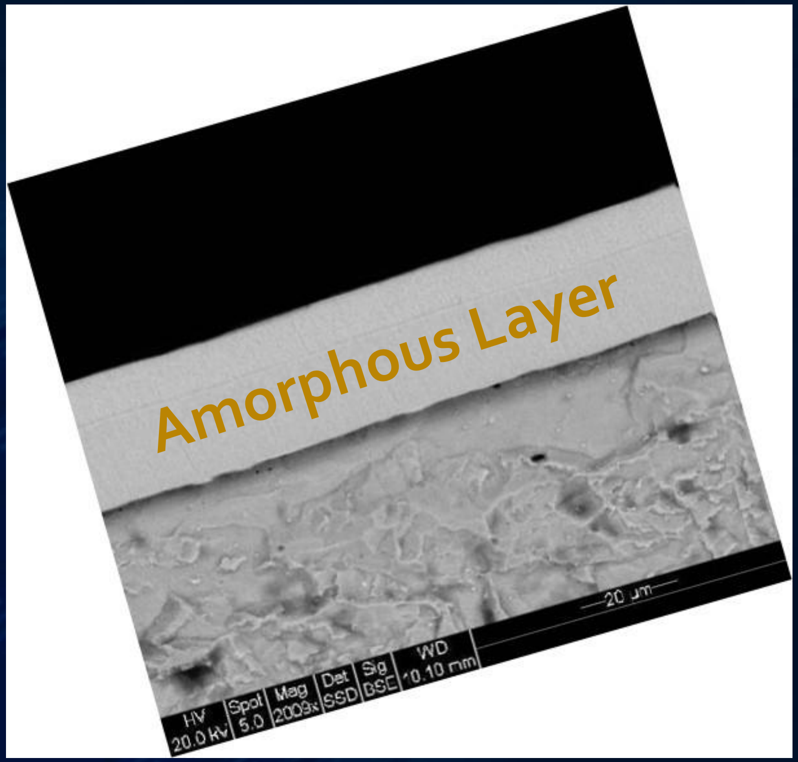


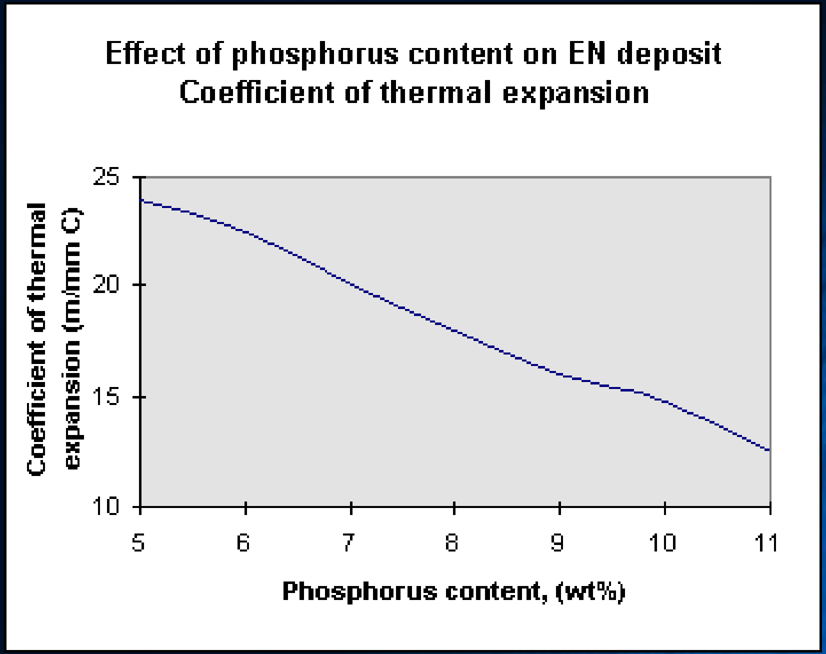
- 62% Be and 38% Al by weight; commercially pure materials as they are combined.
- < 2% Solution (Composite)
- Powder Metal made by gas atomization.
- Material follows the rule of mixtures for its properties.
- Hot Isostatically Pressed (HIP'd).

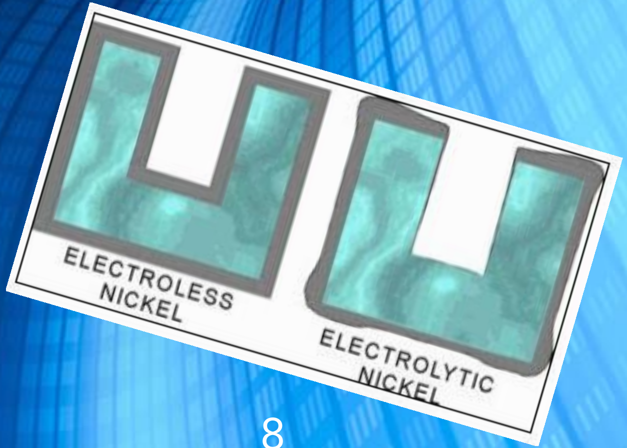


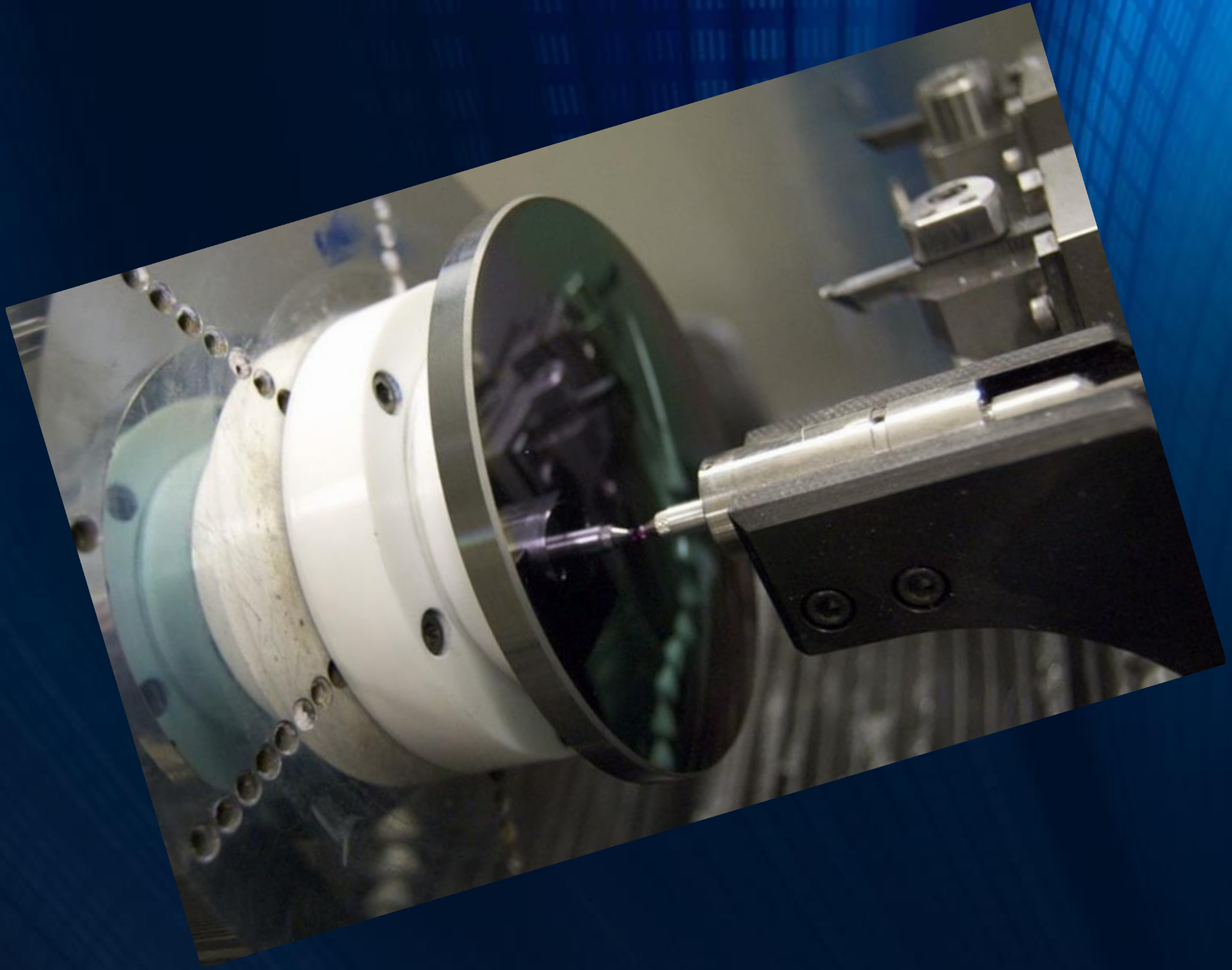
Electroless Nickel
(A Highly Characterized Process – Developed in 1942)

- An autocatalytic process that uniformly deposits and replicates the receiving surface.
- It is amorphous layer, leading to the term "metal glass."
- Highly machinable.









Single Point Diamond Turning of Amorphous NiP

Turned to the edge

Be-38Al / NiP⁺ / SPDT

CHEMISTRY

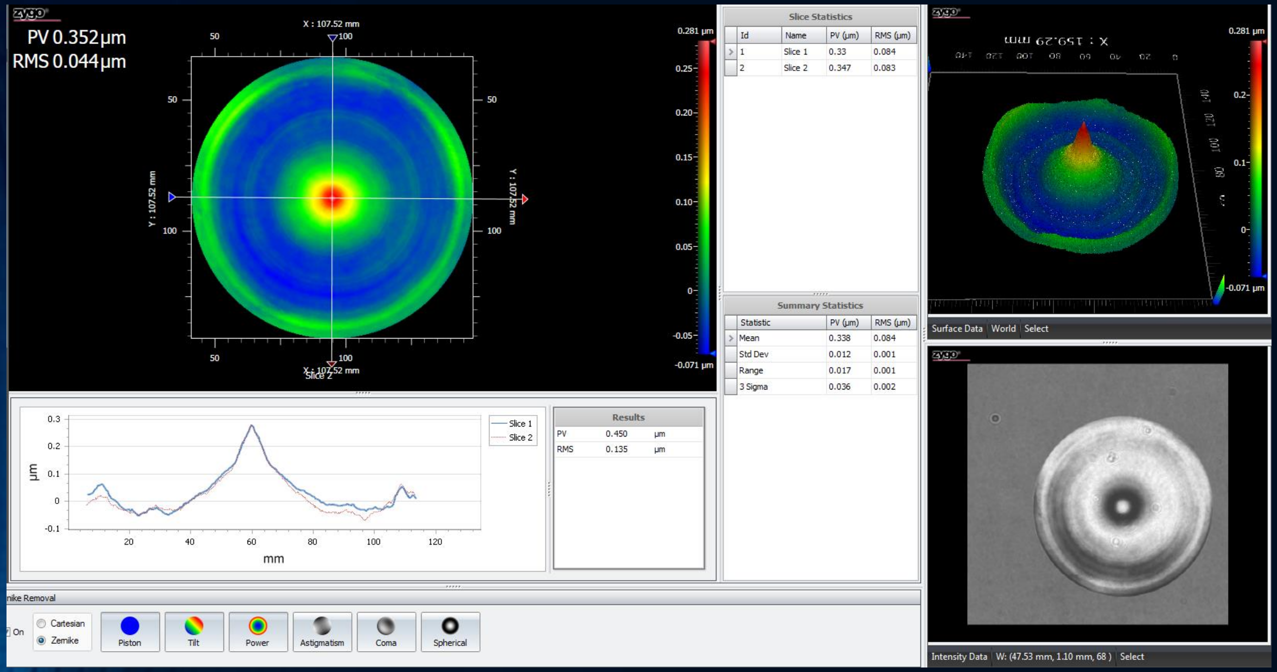
Screen NiP %P Range → Refine Range → Define a Working Range

MATCH CTE OF Be-38Al & NICKEL ACROSS A DEFINED OPERATING TEMPERATURE RANGE (Goal Cryogenic)

THICKNESS

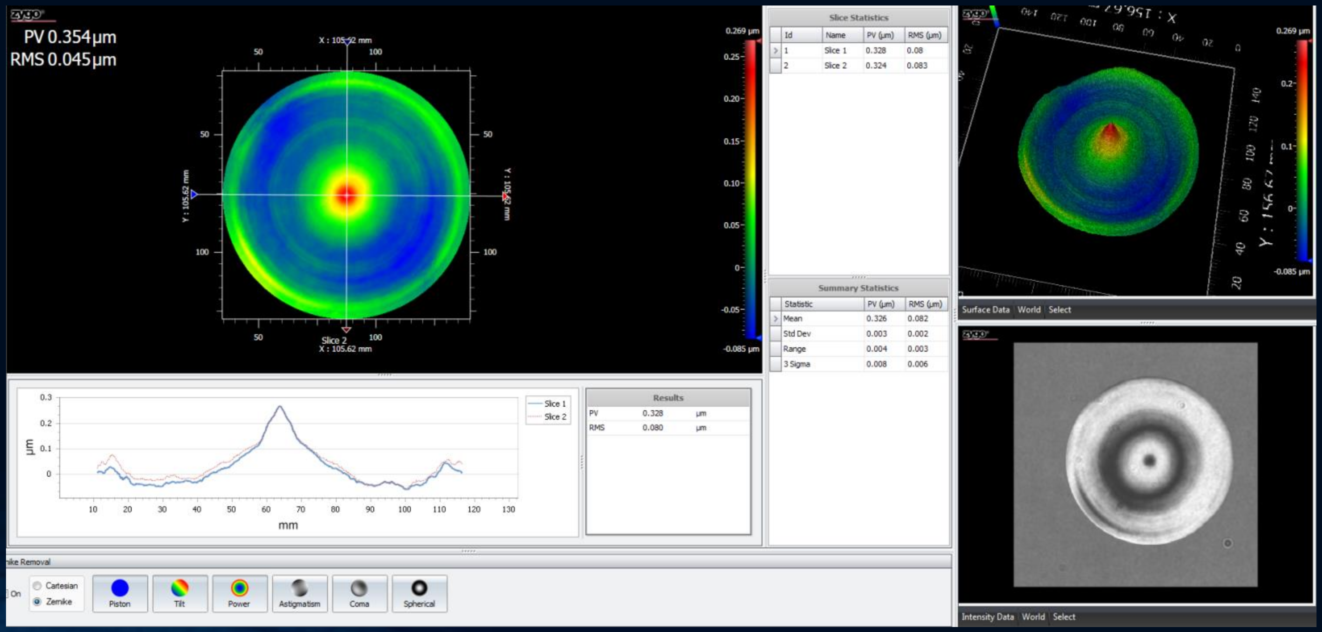
Screen NiP Thk Range → Understand Effect of Thickness on Performance over Temperature Range

Be-38Al / NiP+ / SPDT



Pre-Cryo Cycling Measurements

Post-Cryo Cycling Measurements



No Discernible Change after Cryo Temperature Cycling

Be-38Al Current Efforts of Focus

Electroless Nickel Plating Coupons with Varied P%

Coupon	+/- P%
A*	-0.60
B*	-0.46
C*	-0.20
D*	-0.15
E*	-0.00
F*	+0.15
G*	+0.55

* From Phase I "sweet spot"

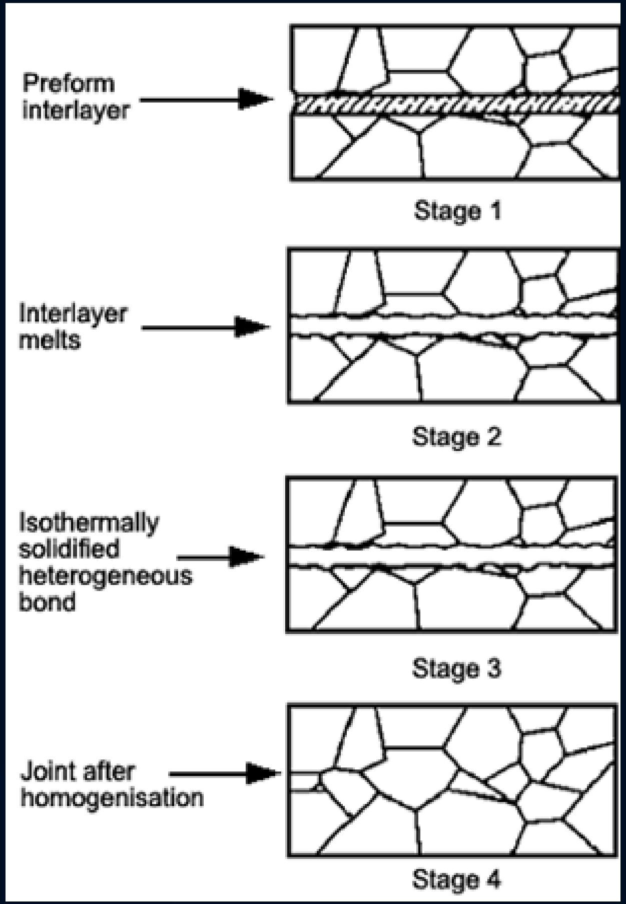
1. Dial in phosphorous percentage of electroless nickel to match Be-38Al.
2. Two campaigns of coupons underway; the first group finishing up in SPDT and the second group ready to NiP plate.

DEVELOPMENT:
LID Bonding Be-38Al

Large Optics;
8 M Diameter

(LIQUID INTERFACE DIFFUSION BONDING)

- LID bonding relies upon temperature and pressure .
- The detail parts are stress relieved before metallurgical joining.
- A stabilization process follows to relieve any induced stress through the joining process.
- Process is step-able.



DEVELOPMENT: LID BONDING

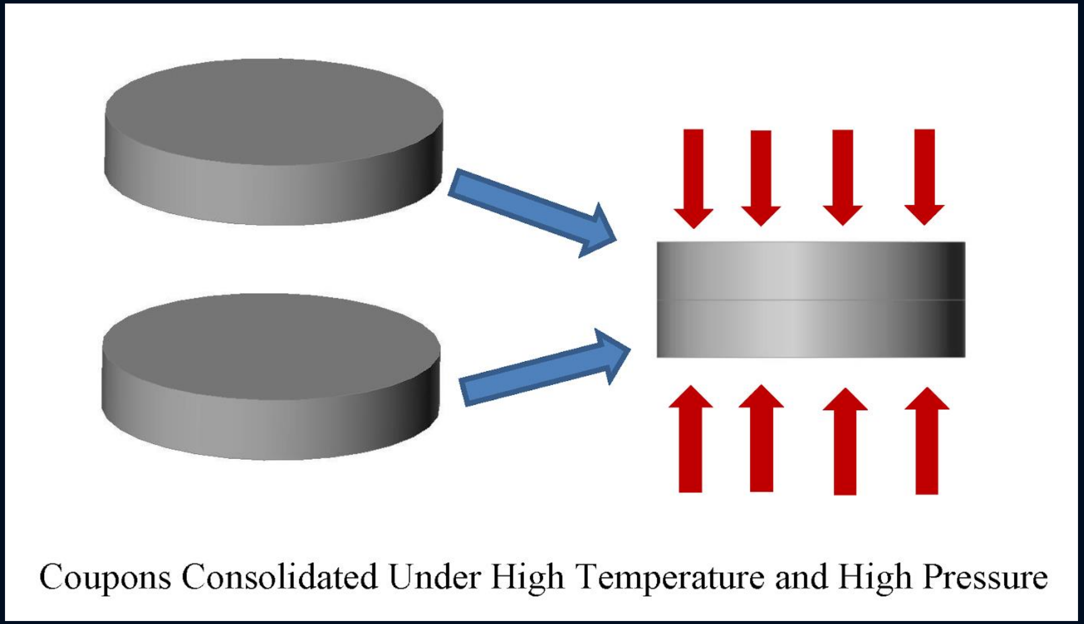
SCREEN BEST LID AGENTS

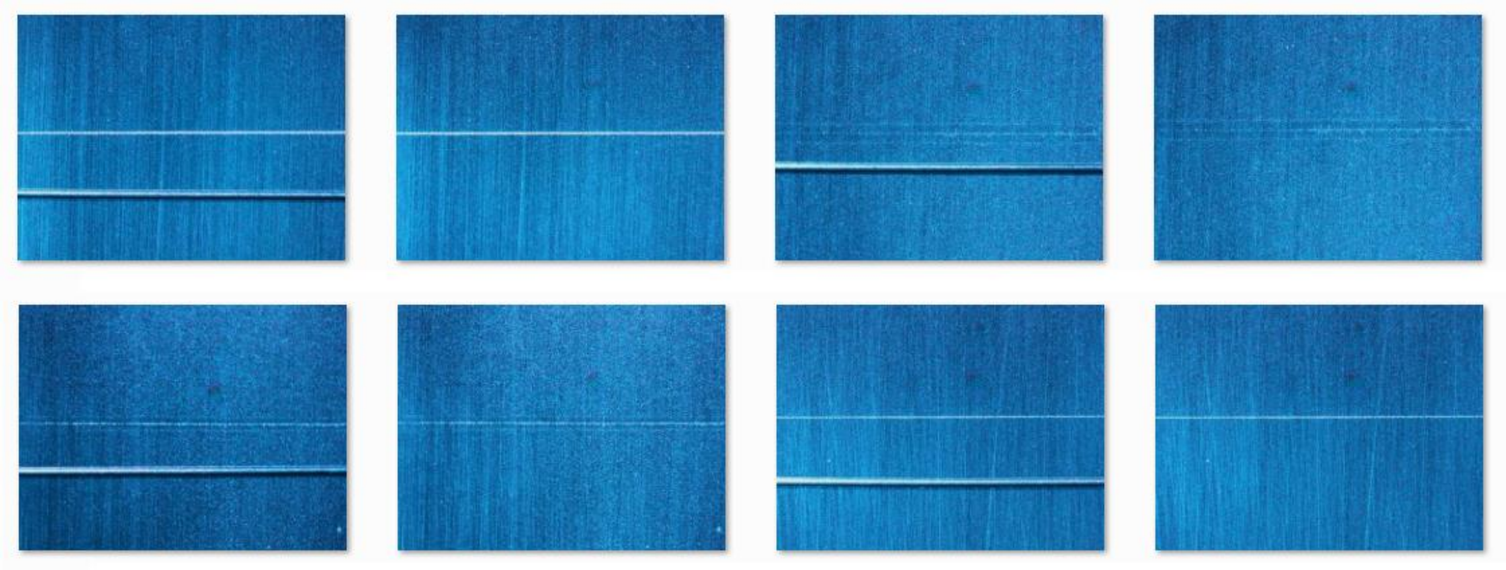
→ DOWN SELECT SINGLE AGENT AND OPTIMIZE PROCESS

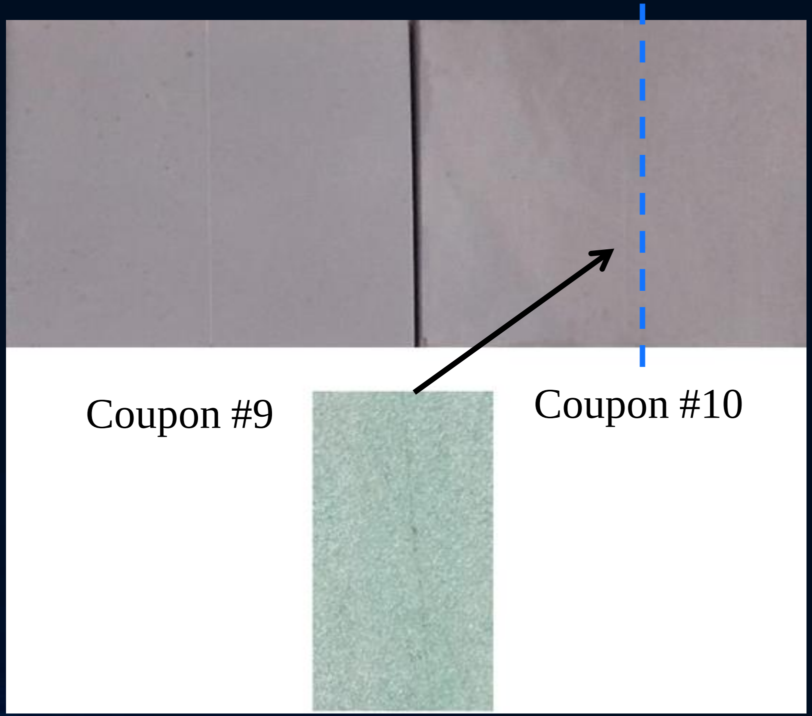
→ EVALUATE MECHANICAL PROPERTIES

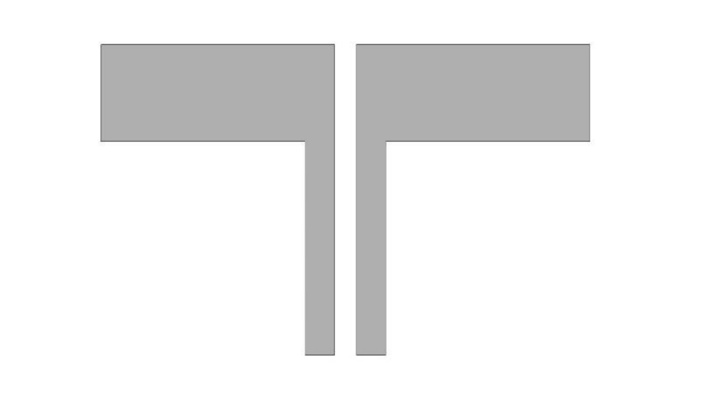
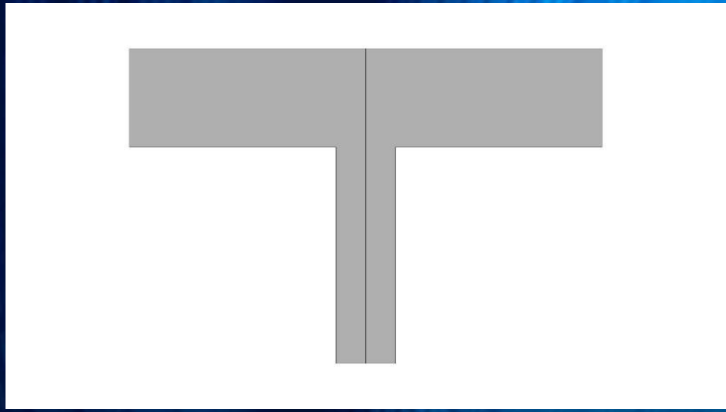
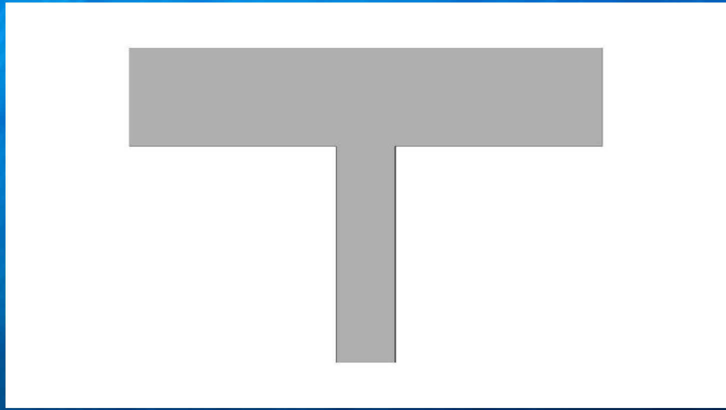
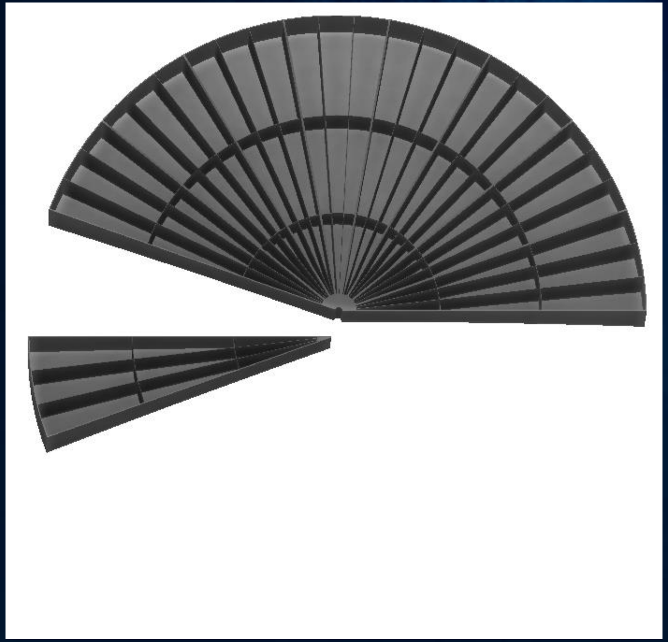
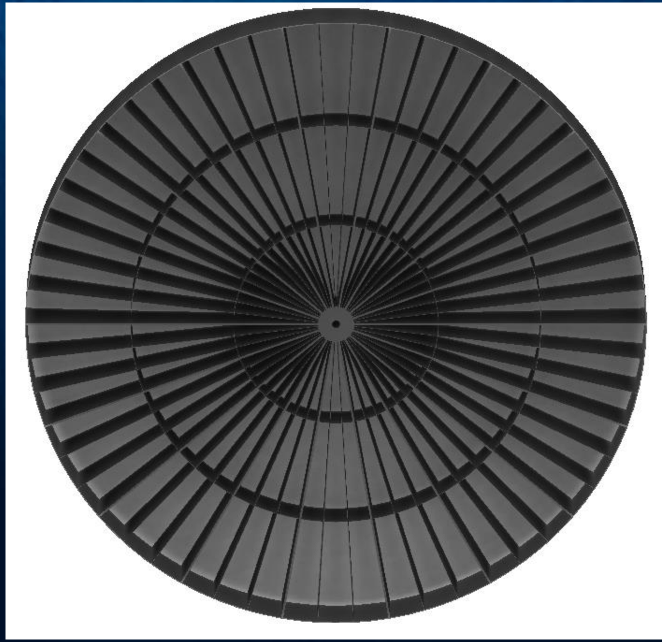
Not Only Provides the ability to build large structures but also closed backed structures.

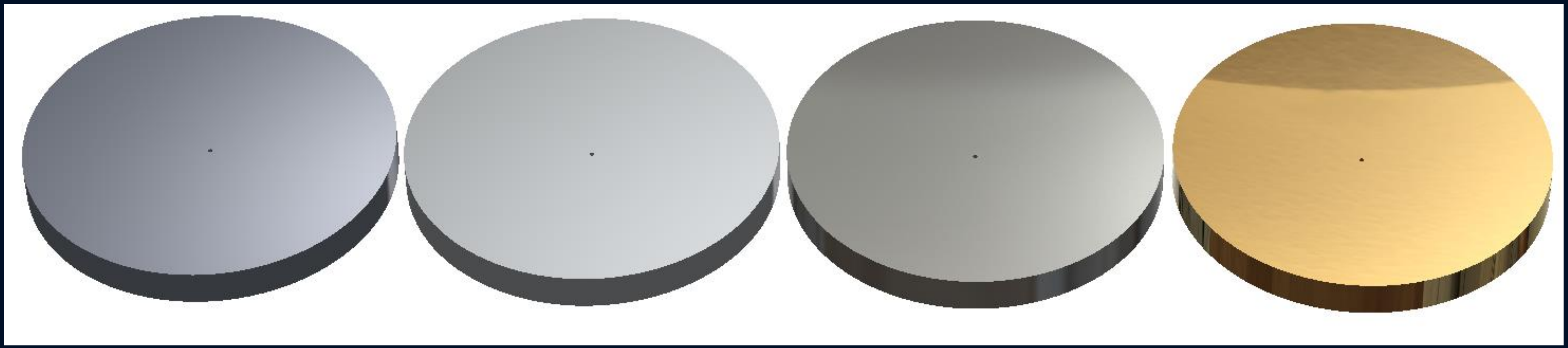
Liquid Interface Diffusion Bond Screening









Advantages (Producibility):

The Be-38Al/NiP/SPDT system provides the following advantages:

- Large Mirrors at a cost < 1.5M/m^2 (and make large structures).
- Low Temperature Operation.
- Thick substrates can be produced (Aspect ratios < 10 to 1; Large section modulus).
- Low density, high stiffness and ductility allows for thin sections (Lightweight substrates to survive launch).
- NiP provides an amorphous optical surface (for SPDT).
- SPDT to the edge uses entire optical surface and eliminates stray light (More efficient).
- Robust; it's durable and repairable (You can manage a schedule).
- Provides the option for an athermal system.