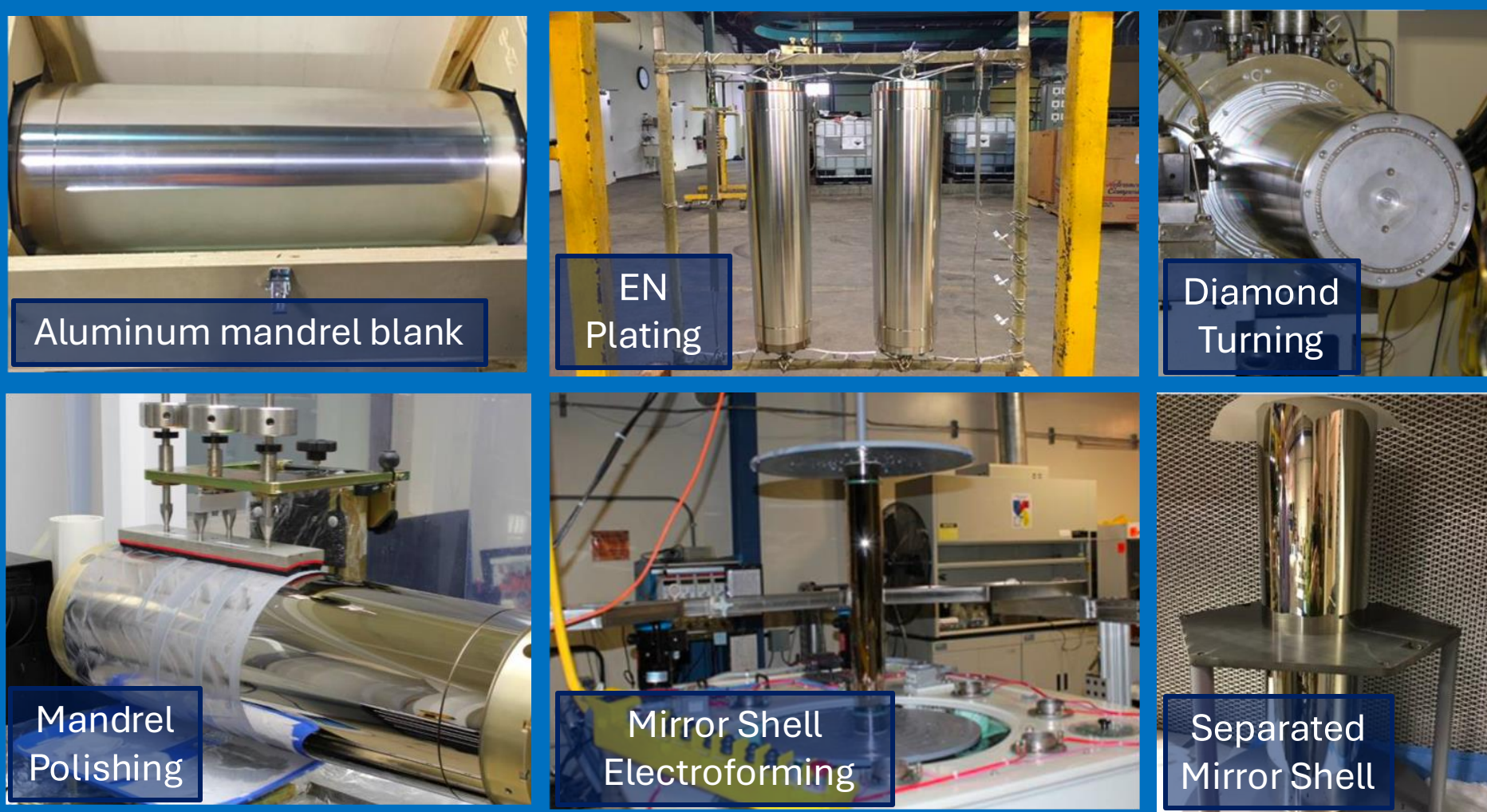


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## Introduction

The X-ray group at NASA Marshall Space Flight Center is developing replicated full-shell X-ray optics for future mission concepts with a goal of achieving sub-arcsecond angular resolution. One of the electroforming fabrication processes that may contribute significantly to resolution degradation of the mirror shell is the shell separation from the mandrel. Traditionally, a passivation layer has been used between the mandrel and the NiCo shell, resulting in the required medium angular resolution mirror shells. However, as resolution requirements become more stringent, improvements to this process must be investigated. To this end, we present the application of gold release layers for full-shell optics designed to improve the optic fabrication process and reduce azimuthal errors. MSFC sputtered gold coatings are first optimized and characterized via X-ray reflectometry (XRR) measurements, atomic force microscopy (AFM), optical profilometry, and adhesion testing. Initial replication studies conducted on flat coupons made of the mandrel surface material are presented along with a comparison to other replicants fabricated using both passivation and evaporated Au layers. To validate the Au release layer for grazing incidence geometries, sputtered gold coatings were deposited onto a mandrel from which a full-shell optic was replicated. We report on the X-ray performance of this optic and compare the results to that of an identical optic fabricated with a passivation layer.

## Full Shell Fabrication



As MSFC continues to move toward fabrication of sub-arcsecond x-ray optics, figure errors induced via the shell release step begin to dominate

## Shell Separation:

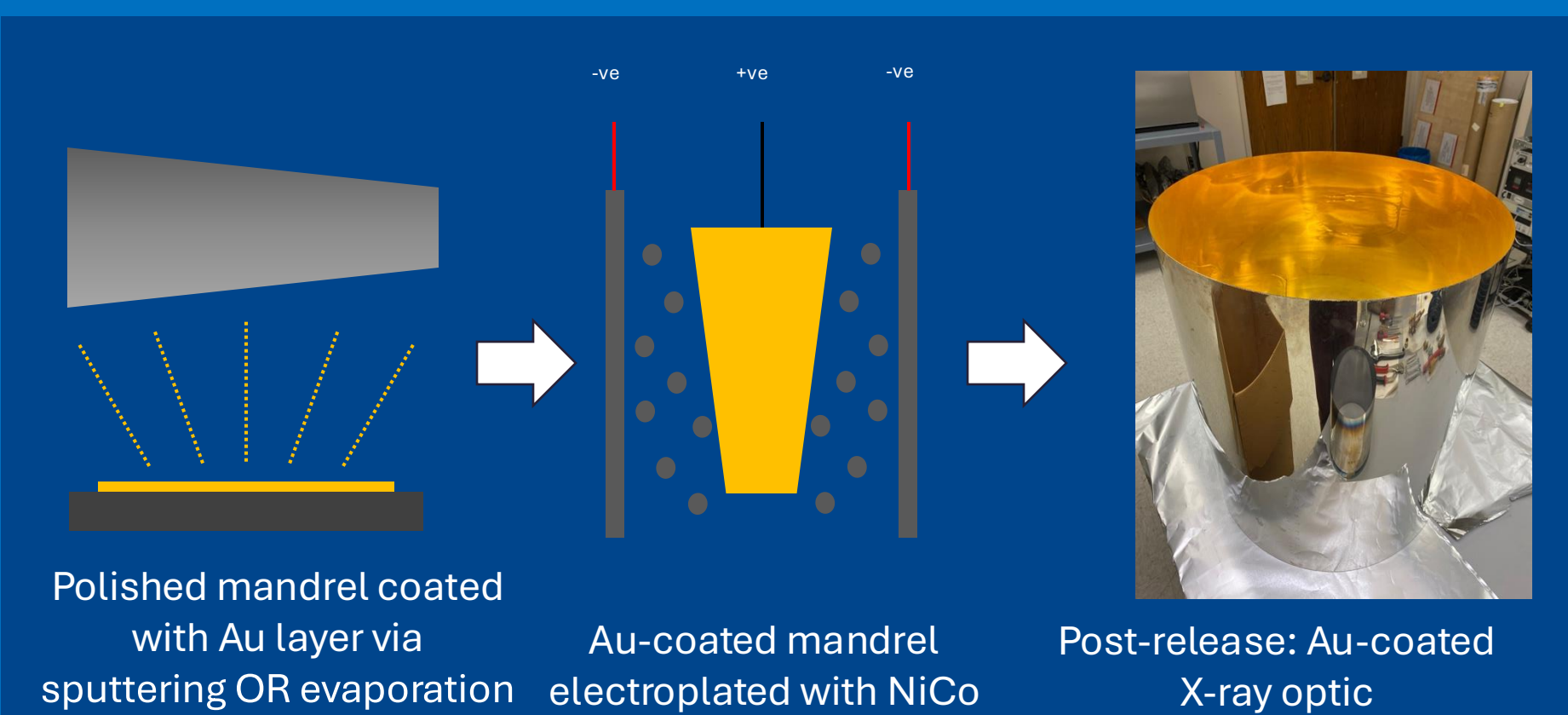
Traditional Process: Passivation layer – Potassium dichromate

- Method: Oxide layer grown onto NiP mandrel in passivation bath
- Pros: Sufficient release of moderate resolution optics, layer can be grown quickly at room temp/pressure
- Cons: Unable to characterize oxide layer, still results in non-uniform release

New Process: Gold thin film – 500Å

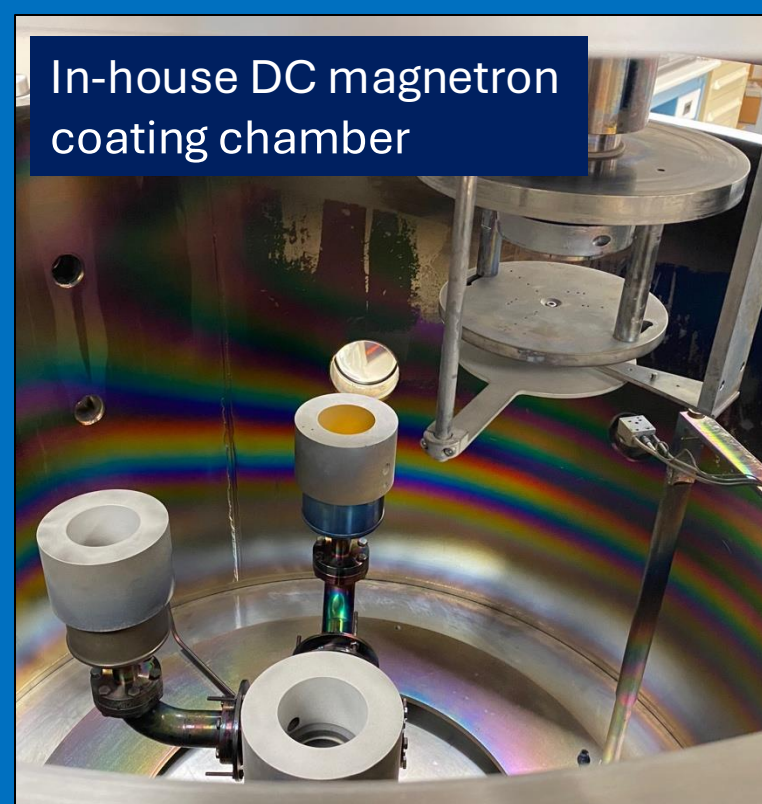
- Method: Sputter thin gold layer on NiP mandrel in vacuum chamber
- Pros: Low adhesion to mandrel, doubles as reflective coating, can be well-characterized
- Cons: Longer duty cycle, must optimize parameters

## Sputtered Au coatings



## Au coatings at MSFC:

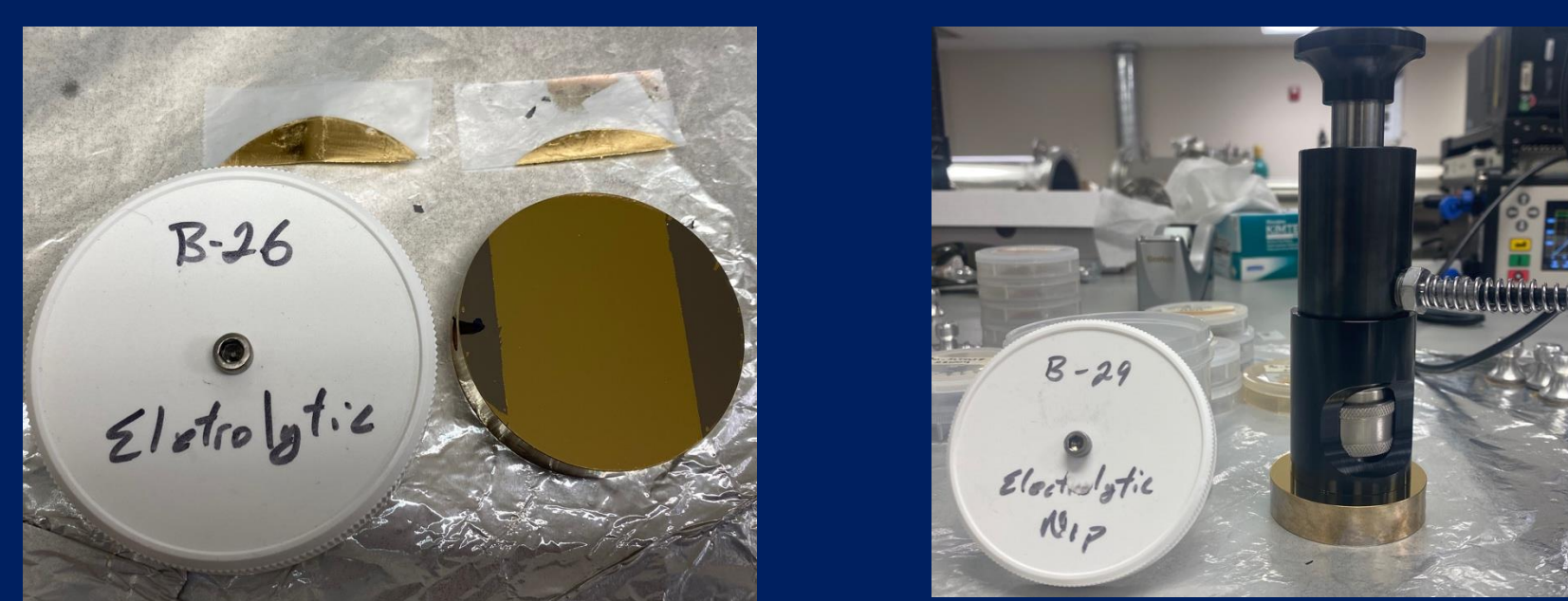
- Utilize existing DC magnetron coating chamber for initial testing
- Coat flat coupons for proof of concept
- Retrofit with small rotary fixture to coat small-scale mandrel for geometrically correct configuration



## Au Layer Optimization

### Optimizing the Sputtering Process for Au Release – NiP Coupons

- DC magnetron sputtering typically results in high-adhesion, low roughness, high density coatings
- Process optimization is needed to reduce adhesion while maintaining low roughness and near-bulk density (> 90%)
- Deposit ~500Å Au coatings with differing process parameters onto NiP coupons which mimic the mandrel surface and compare adhesion results from tape + pull tests



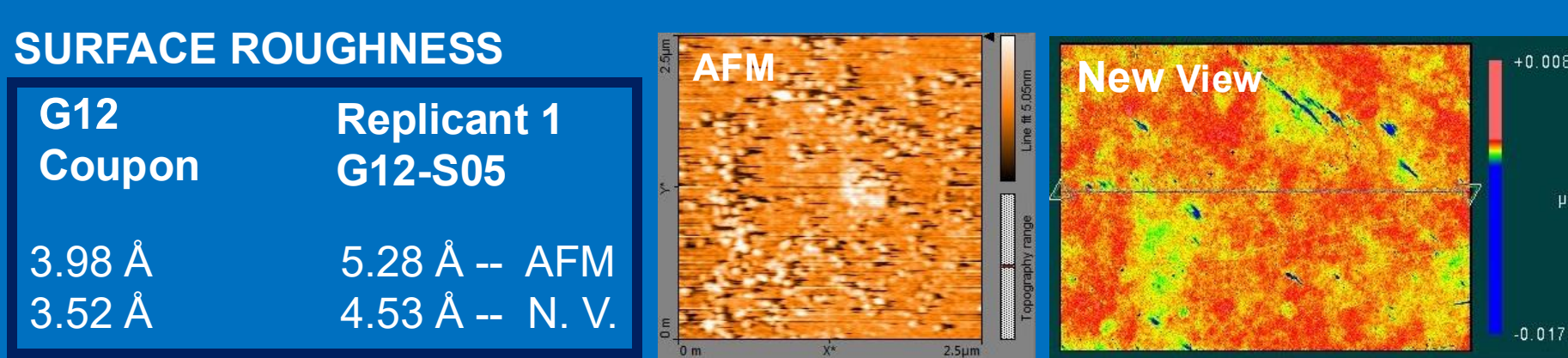
ID	h (Å)	σ (Å)	ρ (g/cm <sup>3</sup> )	Cathode P (W)	Ar Gas (mTorr)	Pull Test (psi)	Tape Test
B26	507.78	7.69	19.30	150	17	~25	✓
B29	540.68	8.62	18.89	50	3	No release	✗

Optimal Process Parameters: 150 W, 15 mTorr

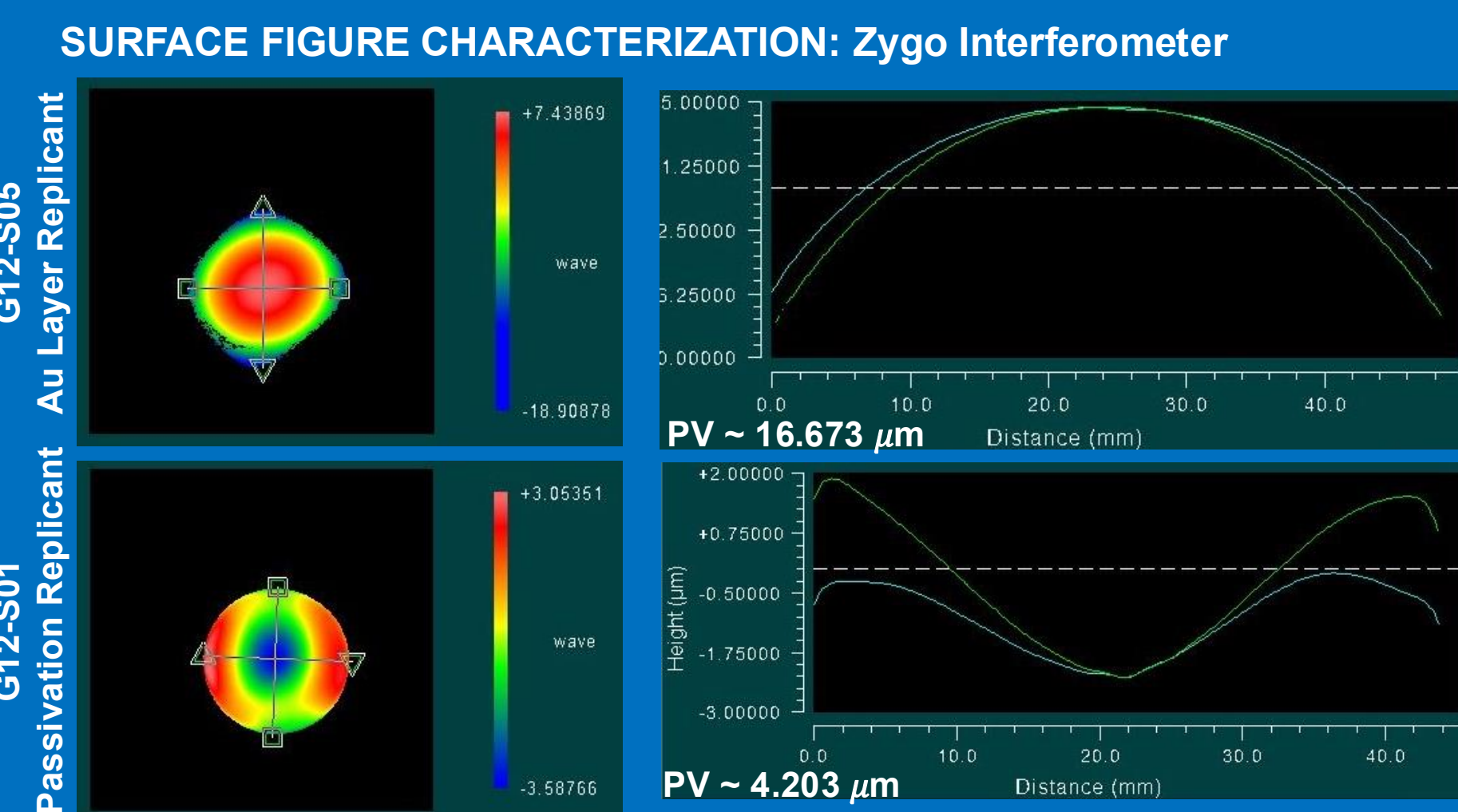
### NiP Coupon Replicant Release Tests - Method

- Deposit 500 Å of Au on NiP coupon (no passivation)
- Electroplate 500 μm of NiCo at 13 ASF, +0.4 ksi
- Perform release via temperature differential
- Repeat coupon plating with passivation layer and compare results

### Au Replicant Test 1 - Results



### Replicant Comparison – Au vs. Dichromate



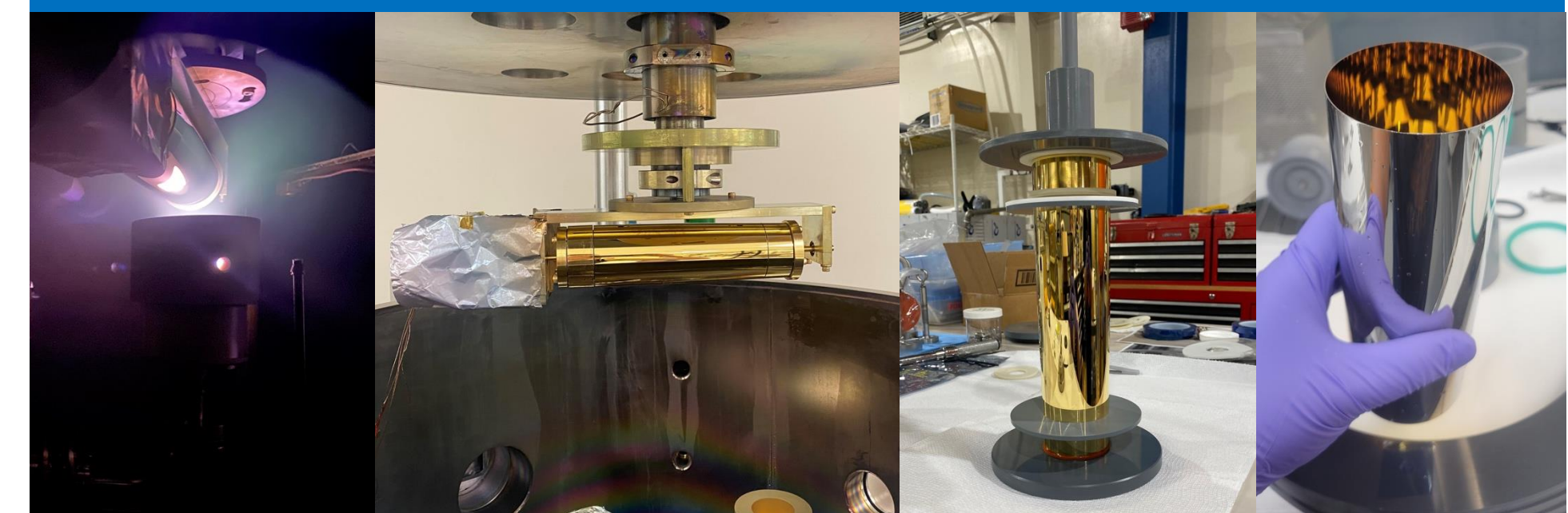
### CONCLUSIONS:

- G12-S01 demonstrates edge flaring, indicative of possible micro yielding during release
- G12-S05 (with Au layer) has opposite, convex shape – indicating opposite stress (compressive) and minimal pulling at edges

## Full Shell Release with Au

### Au Sputtered coatings on 62mm Mandrel

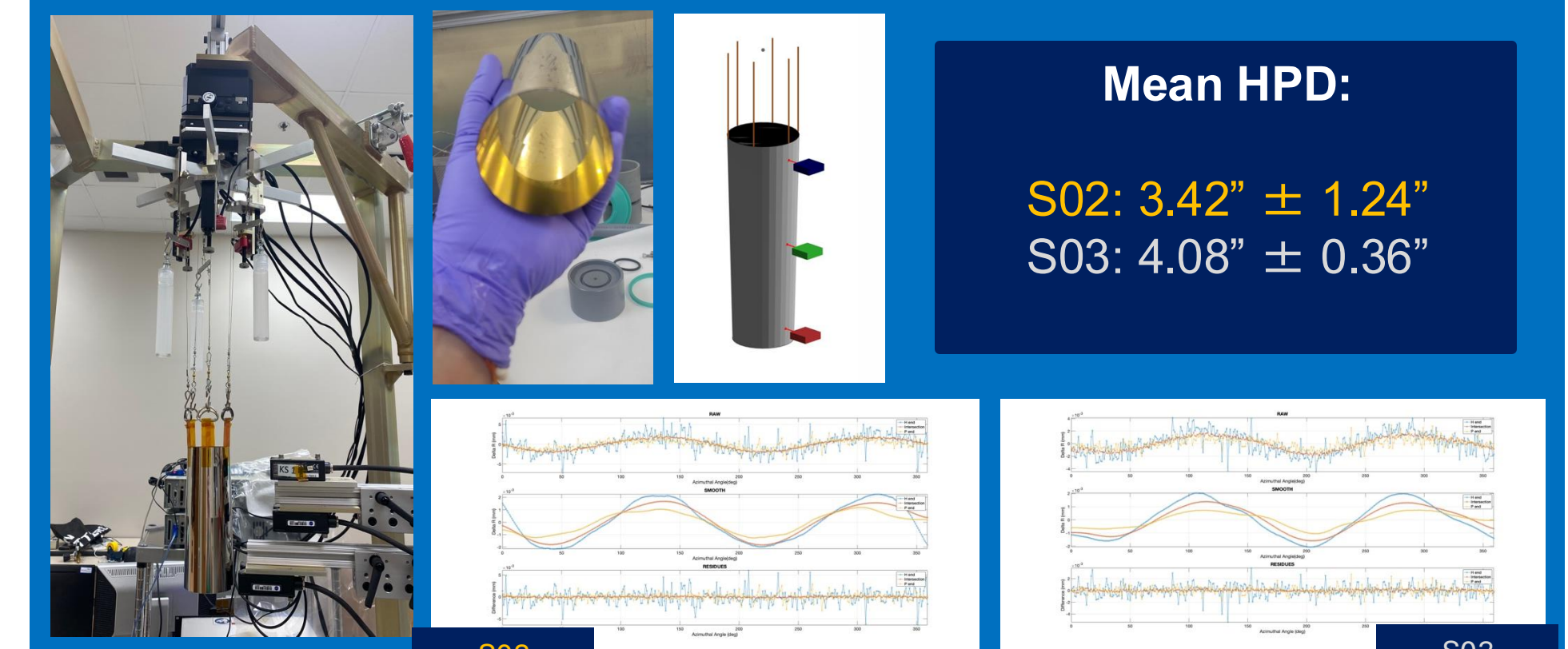
- Retrofitted small multilayer DC magnetron sputtering chamber for 62mm mandrel with custom rotary fixture
- Ensured minimum thickness of 500Å achieved across full length of mandrel
- Utilized optimized gold coating parameters from test flat optimization



The figure error of full shell optics is dominated by circularity or out-of-roundness errors – most of which occur during shell release. Measuring circularity is a key metric for comparing the effectiveness of the Au release layer method with dichromate.

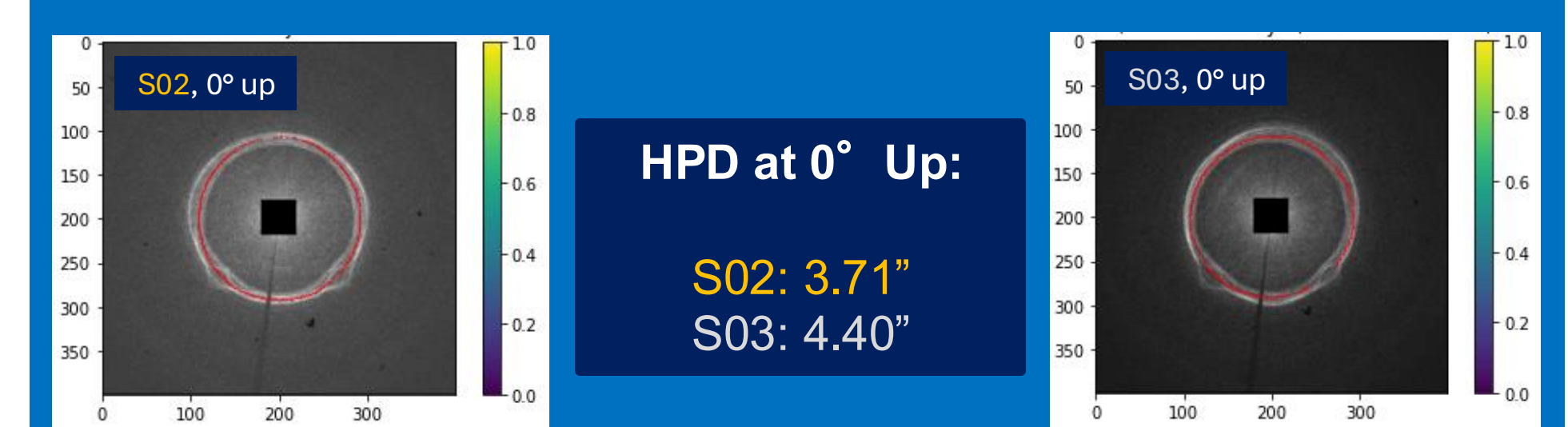
### Circularity Measurement – Alignment Station

- Custom alignment stage setup: displacement sensors measure relative position of shell in the azimuthal direction at 3 distinct axial positions
- DDR metric is calculated and translated into an HPD
- This HPD value is compared between shells: S02 (Au) and S03 (dichromate)



### Circularity Measurement – X-ray Testing

- X-ray testing offers more repeatable measure of shell circularity (Mo Tube, 10 keV, 1mA)
- Measured S02 and S03 at defocus of 40mm – derived HPD from shell circularity



## Conclusions + Future Work

- X-ray measurements at other angles will help constrain the HPD derived from circularity
- Smoother mandrel will enable in-focus HPD comparison
- Promising results – continue to pursue with larger, higher quality mandrels

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