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Sandia National Laboratories

Dimensional Fidelity of Replica Casting Compounds

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Overview

- Background on Replica Compounds

- Creation of Replicas

- Taylor Hobson Talysurf Coherence Correlation Interferometer (CCI)

- Measurement Concerns

- Uncertainty Analysis

- Results

- Conclusion

*Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately describe the experimental procedure. Such identification does not imply recommendation or endorsement by the authors, Sandia National Laboratories, or NCSL International, nor does it imply that the materials or equipment identified are the only or best available for the purpose.

Introduction

- Difficulty arises when wanting to measure features on a part or assembly that is inaccessible with measuring equipment.

- This work discusses the use of replica casting compounds to create a negative impression of the feature of interest and measuring the replica.

- The results of this work are used to assign a Type B uncertainty associated with the replication process.

Replica Compounds

o Replica compounds are a type of silicon rubber

o Can be used to characterize typically inaccessible components

o This study used ReproRubber® brand replica compounds

  o Polyvinyl Siloxane (PVS)

    o Quick-setting Putty

      o Blue PVS

    o Medium Body
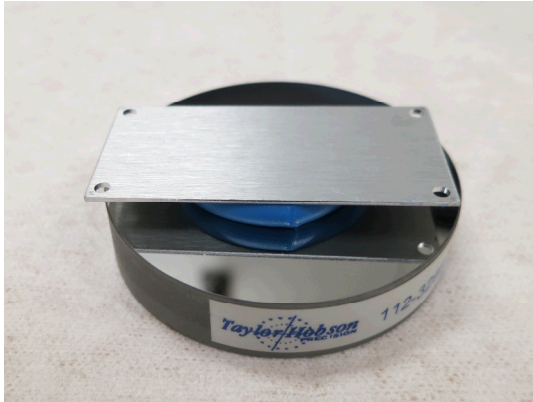
      o Orange PVS

    o Thin Pour

      o Green PVS

Measurement Standard

- Taylor Hobson step height standard
  - Type A depth measurement standard
  - Average step height of 4925 nm +/- 51 nm (k=2)
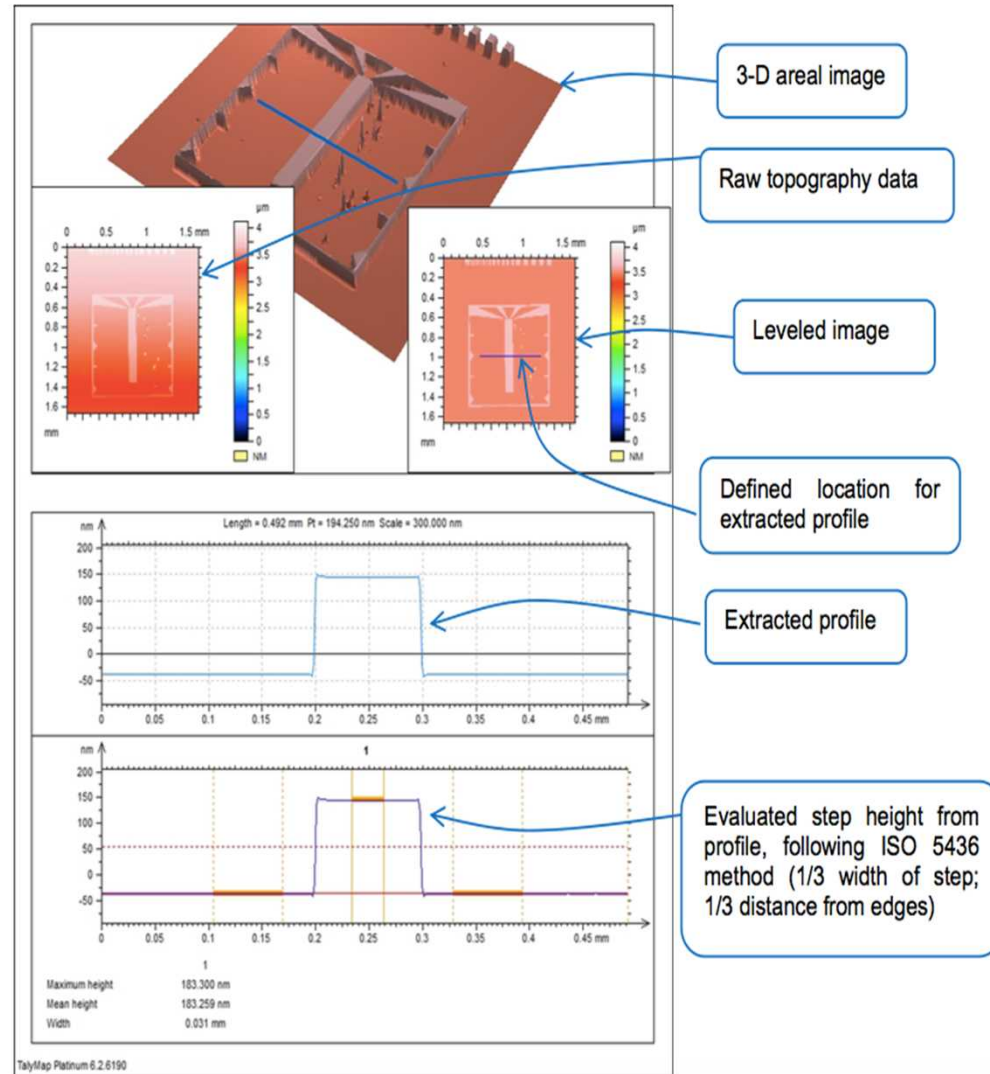 - Three wide grooves with a flat bottom

Grooves

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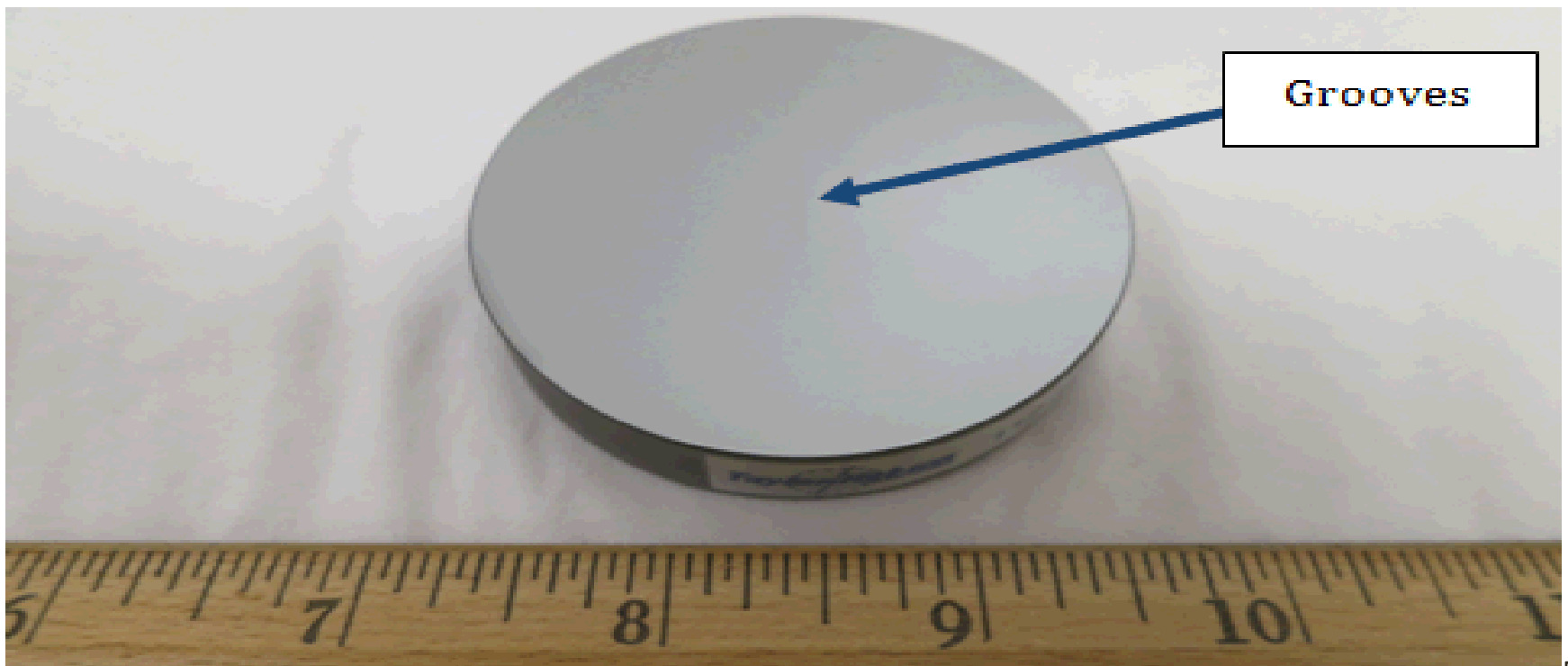
Creating the Replicas

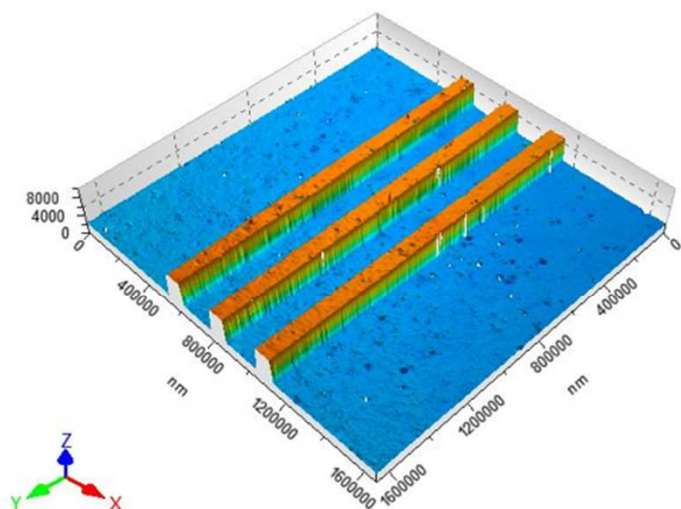| Casting Material	Viscosity	Advantages	Disadvantages
Quick-setting Putty (Blue PVS)	High Viscosity paste. Will not flow.	Easy to use on all applications.	May not replicate smaller surface artifacts; air bubbles in the mixture are a common issue and could mask an area of interest.
Medium Body (Orange PVS)	Low viscosity paste.	Can be used on internal and external applications.	Somewhat runny so some external artifacts may be hard to replicate.
Thin Pour (Green PVS)	Low viscosity liquid. Runny paste.	Minimal to no air bubbles.	Must be used in a contained area.

- White light interferometer

- Scans for Fringes

  - Fringes are visible when the wavelengths path to the reference mirror and to the surface are nearly equal due to the light source being short coherence.

Measurement Results

3D Areal Image

Blue PVS

Maximum height	4920.790 nm
Mean height	4859.519 nm
Width	25980.933 nm

Orange PVS

Maximum height	4950.610 nm
Mean height	4938.591 nm
Width	27604.741 nm

Green PVS

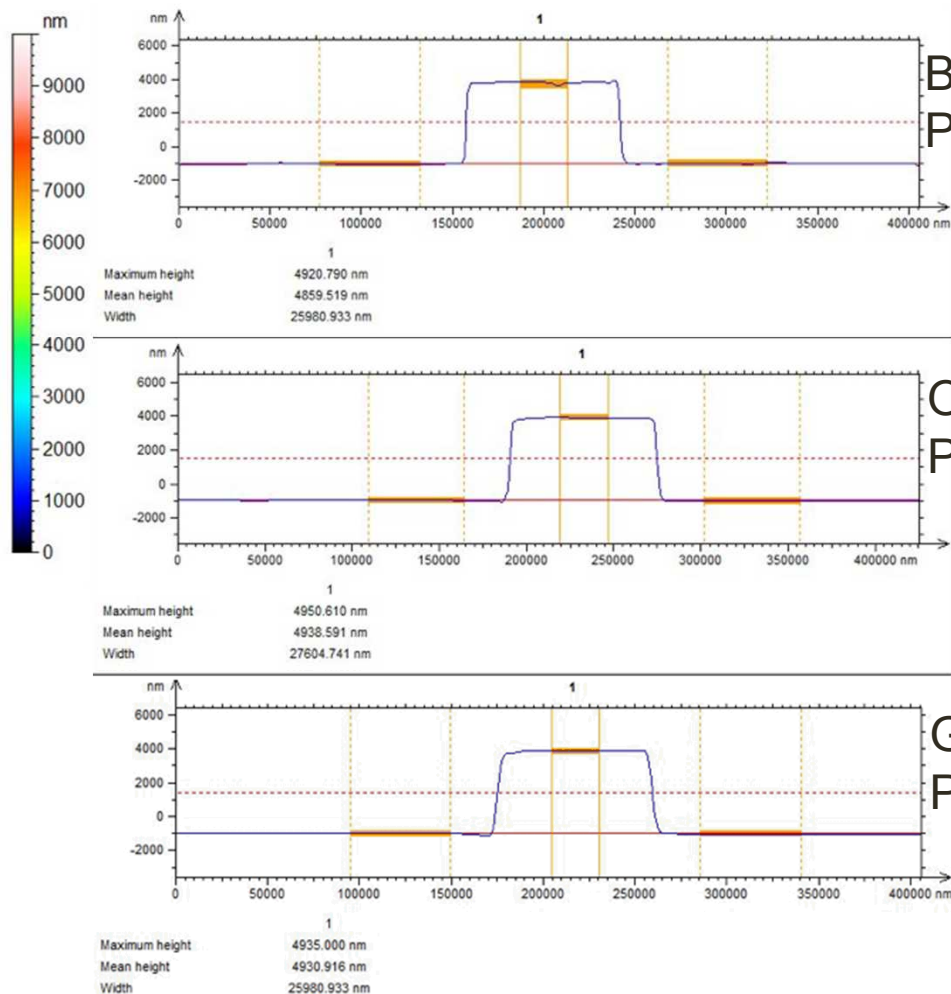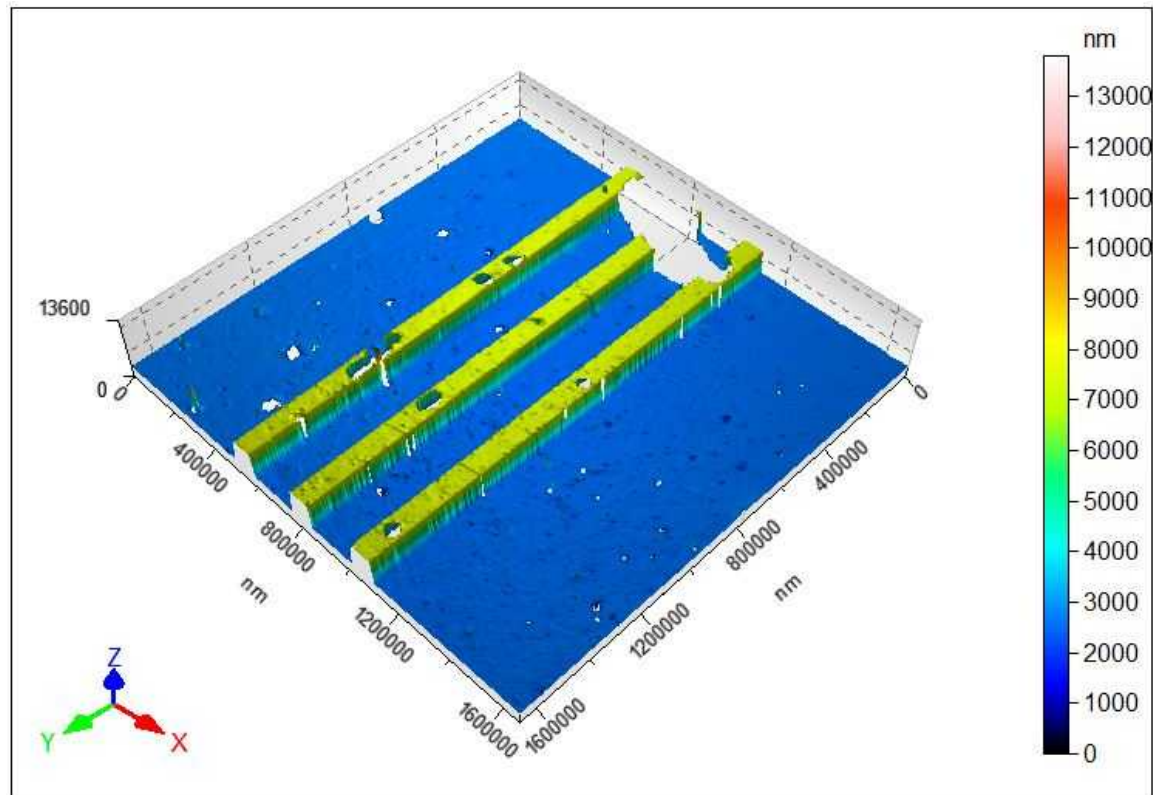|	
Maximum height	4935.000 nm
Mean height	4930.916 nm
Width	25980.933 nm

Affect of Air Bubbles

- Air bubbles can cause large defects in the replica
  - Could be either smaller or larger than area of interest
  - Any areas with noticeable air bubbles were ignored

Uncertainty Analysis

- Time of test uncertainties (k=2) were calculated
- Following the ISO GUM method for uncorrelated input quantities

Blue	Measurement Results After 24 Hours				Measurement Results After 1 Week		
	Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)		Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)
Groove							
Left	4959.6	37.5	90.4	Left	4934.6	41.5	97.0
Center	4939.2	21.7	90.4	Center	4928.2	32.6	97.0
Right	4944.9	34.4	90.4	Right	4934.2	24.7	97.0
Orange	Measurement Results After 24 Hours				Measurement Results After 1 Week		
	Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)		Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)
Groove							
Left	4939.6	4.7	51.2	Left	4928.1	4.2	50.8
Center	4926.3	7.2	51.2	Center	4904.9	7.6	50.8
Right	4930.7	5.1	51.2	Right	4915.6	9.0	50.8
Green	Measurement Results After 24 Hours				Measurement Results After 1 Week		
	Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)		Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)
Groove							
Left	4952.1	16.4	60.3	Left	4913.4	12.0	55.4
Center	4939.3	15.1	60.3	Center	4899.8	12.7	55.4
Right	4942.0	17.5	60.3	Right	4903.0	11.1	55.4

Taylor Hobson Step Standard

|	Measurement Results Before Applying Replica Putty's				Measurement Results Applying Putty and Cleaning		
	Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)		Step Height (nm)	Standard Deviation (nm)	Time of Test Uncertainty (k=2)
Groove							
Left	4944.3	5.9	52.5	Left	4942.4	3.7	50.5
Center	4933.1	6.4	52.5	Center	4931.4	4.2	50.5
Right	4934.9	5.8	52.5	Right	4936.5	3.4	50.5

$$SF = \frac{CV}{MV}$$

$$y = SF \times m$$

Where, CV is the certified reference standard, MV is the current measured value of the standard and SF is the scale factor. The calibrated measured value of the test is y and the measured value of the unit under test is m.
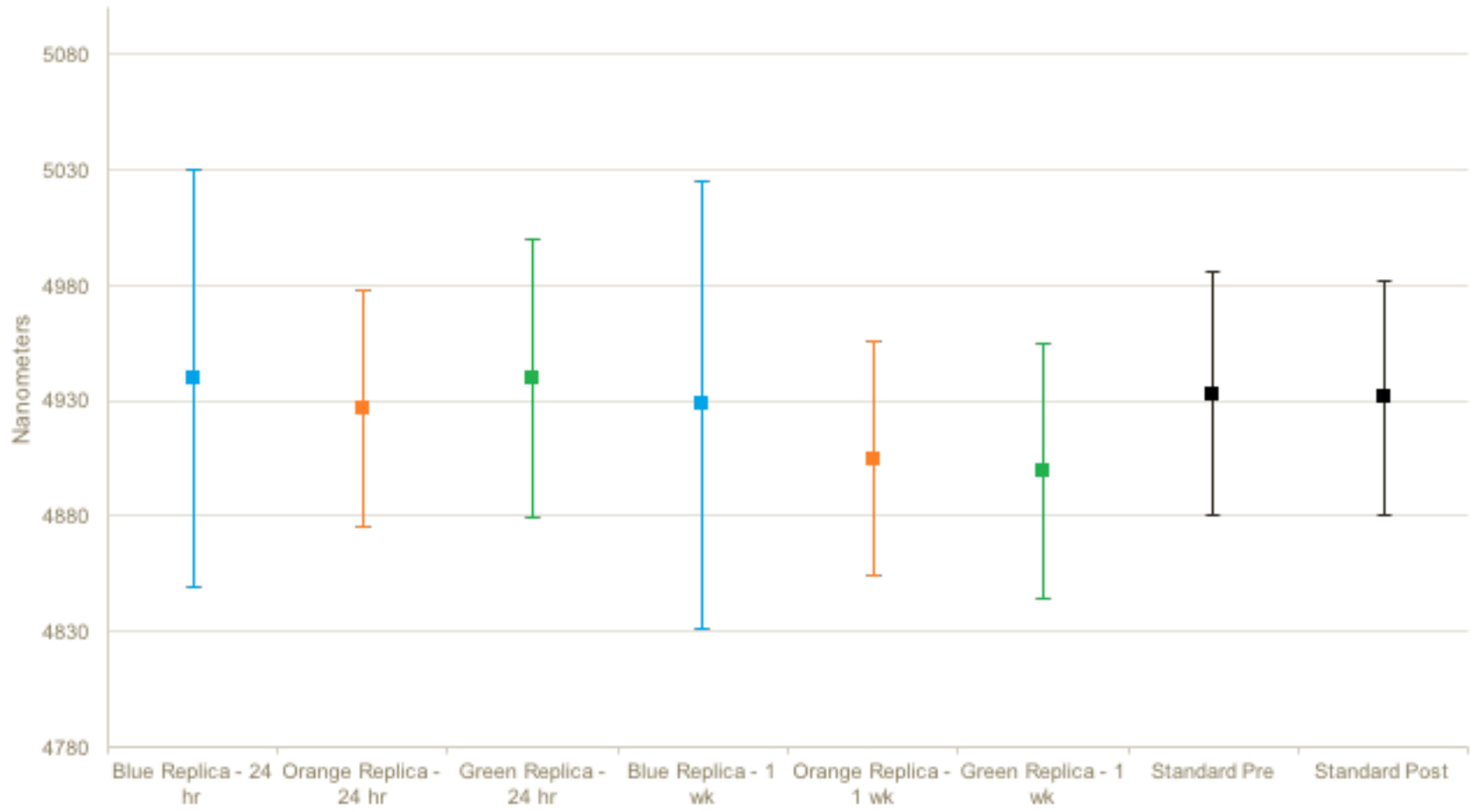
Measurement Results: Left Groove

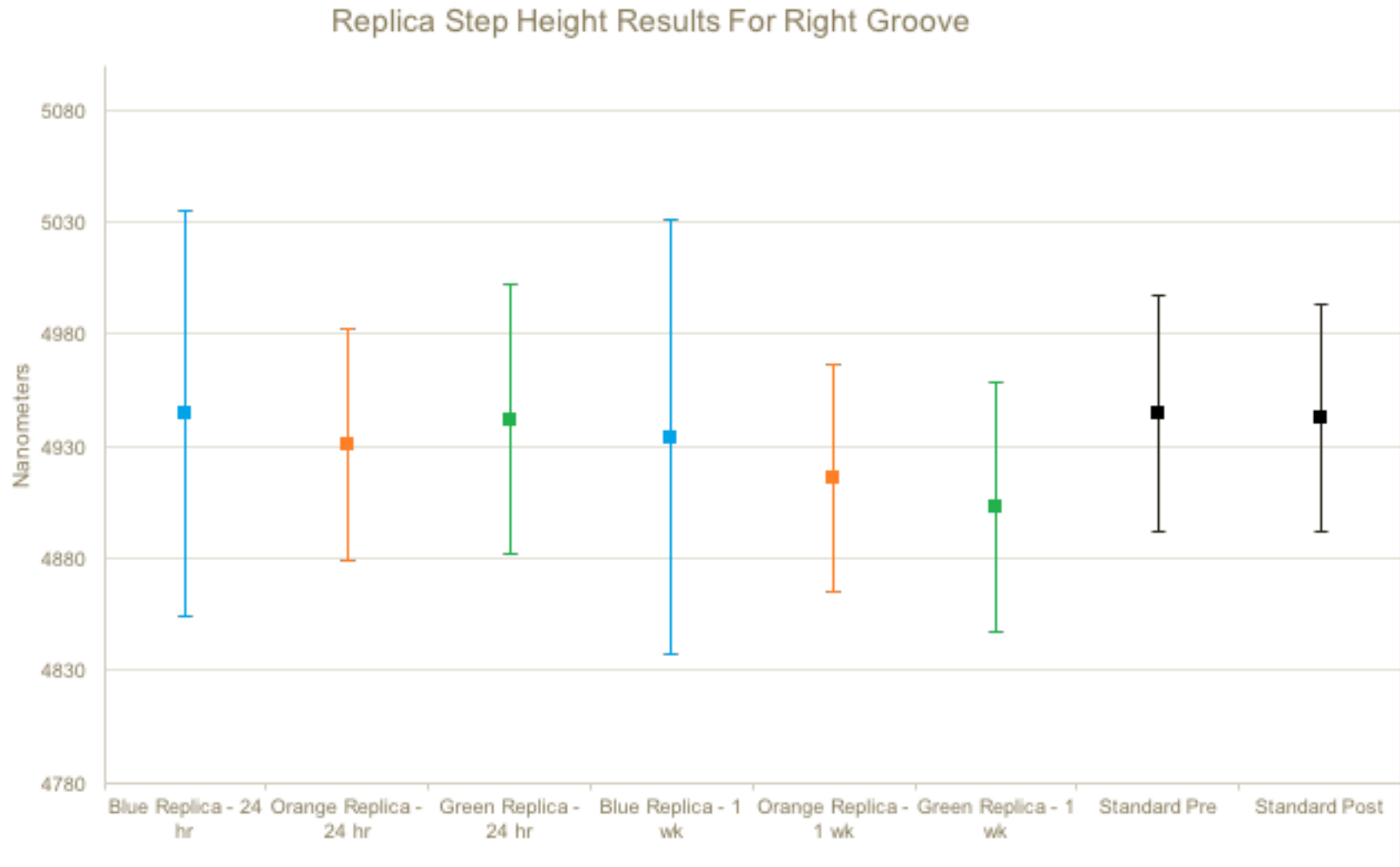Replica Step Height Results For Left Groove
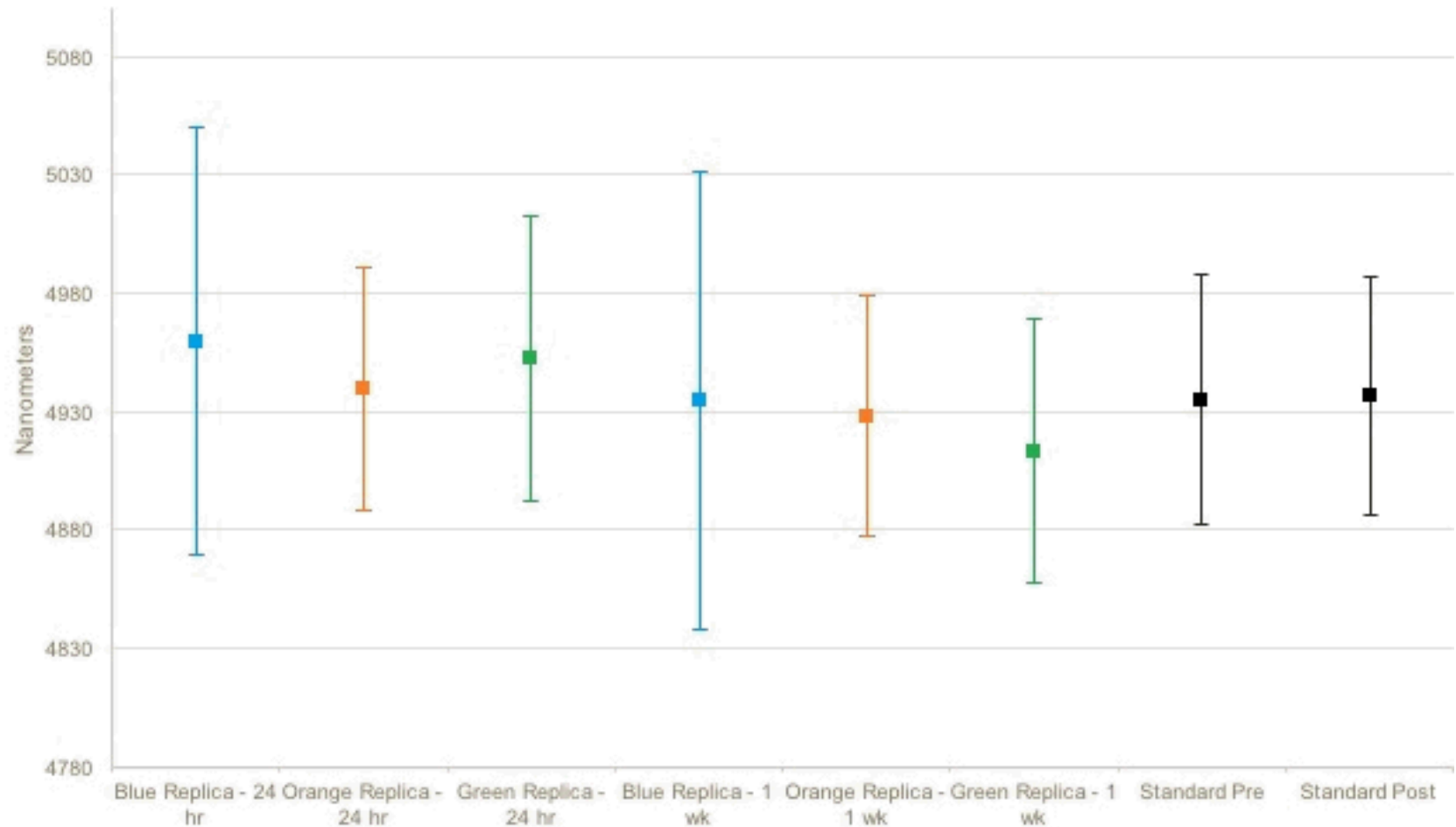
Measurement Results: Center Groove

Replica Step Height Results For Center Groove

Measurement Results: Right Groove

Replica Step Height Results For Right Groove

Shrinkage Over Time

Manufacturers Specification	Blue Replica	Orange Replica	Green Replica
Shrinkage 24 hr. (%)	0.5	0.3	0.5
Shrinkage 1 wk. (%)	0.5	0.4	0.5

Measurement Results	Blue Replica	Orange Replica	Green Replica
Average Depth (nm) - 24 hr.	4949.2	4929.3	4941.7
Average Depth (nm) - 1 wk.	4924.2	4917.8	4903.1
Difference (nm)	-25.0	-11.5	-38.6
Percent Difference (%)	-0.5	-0.2	-0.8

- Correction factor for shrinkage
  - Shrinkage for temperatures from 40 to 120 ° C can be described by a 1st order polynomial

Future Work
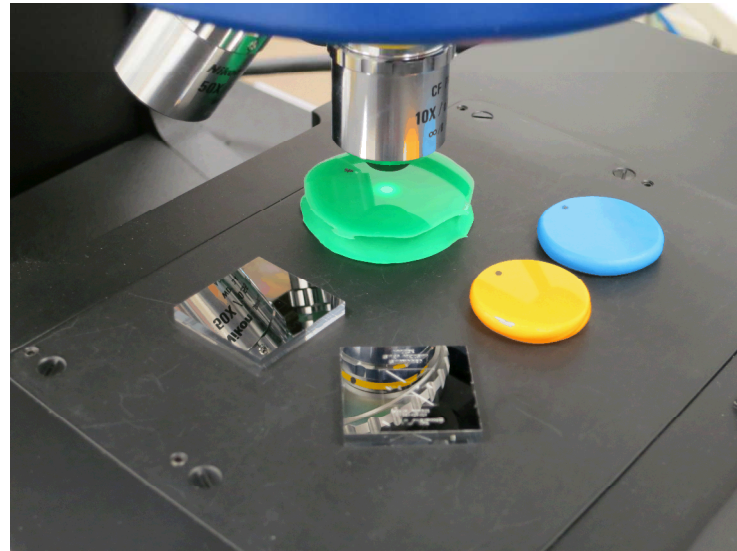
- Characterize a curved surface
  - Created a reference point
  - Measured +/- 5 mm, which equates to 30° of the sphere
  - Currently comparing measurements to determine the accuracy of replication

Conclusion

- Impressions were made of a 3-channel step height standard

- These measurements quantified the fidelity and accuracy of the replica casting compounds to measure depth anomalies.

- These ReproRubber® brand replica compounds are a suitable technique to reproduce surface imperfections that cannot be directly measured by a contact or non-contact surface characterization tool.

  - Although it is recommended to take special care when mixing the base and catalyst material to minimize air bubbles. Additionally, one should minimize the wait time to analyze the replica components to reduce shrinkage as much as possible.

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Acknowledgements

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Questions?