Characterization of an In-Situ Metrology Setup for the APS Modular Deposition System

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The Advanced Photon Source

- The Advanced Photon Source (APS) is a premier national research facility that provides high energy x-ray beams to over 5,000 scientists from around the world.

- The future APS Upgrade Project will deliver x-ray beam with an emittance a factor of ~50 smaller and coherent flux 2 to 3 orders of magnitude larger compared to the APS today.

- Higher energy x-ray beams will require higher quality mirrors with <1 nm figure error and <0.15 nm surface roughness.

Image courtesy of “APS Welcome” webpage: https://www1.aps.anl.gov/About/Welcome
Advanced Photon Source (APS) Modular Deposition System (MDS)

- APS/XSD Optics Group commissioned an advanced modular deposition system (MDS) to develop advanced thin film optics including:
  - Single and multilayer mirrors
  - 3-D thin film optics
  - Focusing mirrors
- The system is equipped with and in-situ metrology and an ion beam figuring system.

In-situ interferometry

1cm DC Ion Mill with vertical motion for IBF

10cm RFICP mill

Image courtesy of Ray Conley – “Directors Review” presentation
Mirror Figure Correction Using In-situ Ion Beam Figuring and In-situ Metrology

Ion beam gun moves across the optic at a certain erosion rate

Example mirror figure correction courtesy ZEISS

Basic Work Flow Diagram

In-Situ Metrology

Obtain Figure Error

Figure Error OK?

Ion Beam Figuring

Finish
Project Aim

Normally, x-ray mirror metrology uses the following setup with a transmission flat (TF) and surface under test (SUT):

FizCam2000  TF  Surface Under Test (SUT): Rectangular Mirror

In-situ metrology introduces vacuum chamber window (VCW) in the setup:

FizCam2000  VCW  TF  Surface Under Test (SUT): Rectangular Mirror

Vacuum Chamber

• The aim of the present work is to evaluate the effect of the VCW when measuring the SUT
Experimental Setup

- Basic setup to simulate the effect of the vacuum chamber window
- Preliminary tests to study the effect of the vacuum port were carried out in the APS metrology laboratory. Measurements were performed both in vacuum using a test chamber and at atmospheric pressure. The present work focuses on measurements at atmospheric pressure using the setup.
Measurements

- Types of measurements:
  - Stationary measurements (with/without VCW) taken to gauge stability of the system
  - VCW tilt measurements to observe the effect of tilting the VCW

Stationary measurements above show environmental factors contributing to noise
Results and Discussion

Measurement 1 With VCW (RMS = 20.55 nm)

Minus

Measurement 2 Without VCW (RMS = 20.52 nm)

Equals

Difference Subtraction Profile (RMS = 1.7 nm)

High RMS value most likely due to system’s systematic errors
Results and Discussion (cont’d)

The RMS values versus window tilt angle

<table>
<thead>
<tr>
<th>Tilt</th>
<th>RMS (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.81°</td>
<td>3.088</td>
</tr>
<tr>
<td>1.44°</td>
<td>3.405</td>
</tr>
<tr>
<td>1.08°</td>
<td>3.052</td>
</tr>
<tr>
<td>0.72°</td>
<td>3.128</td>
</tr>
<tr>
<td>0.36°</td>
<td>3.229</td>
</tr>
<tr>
<td>0°</td>
<td>3.095</td>
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</tbody>
</table>

The RMS values versus difference of profiles

<table>
<thead>
<tr>
<th>Line Subtraction #</th>
<th>RMS (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0° - 1.81°</td>
<td>0.676</td>
</tr>
<tr>
<td>0° - 1.44°</td>
<td>0.888</td>
</tr>
<tr>
<td>0° - 1.08°</td>
<td>0.784</td>
</tr>
<tr>
<td>0° - 0.72°</td>
<td>0.808</td>
</tr>
<tr>
<td>0° - 0.36°</td>
<td>0.678</td>
</tr>
</tbody>
</table>

- Overall, there is negligible difference in tilt angles (all RMS are <1nm)
Conclusion and Future Plans

- The measurements show that the VCW has negligible effect on the measurement of the SUT.
- Further experimenting will need to be conducted to verify this finding. Due to the limited amount of time for this project, the work could not be completed.
- Future tests will be conducted in the MDS actual vacuum chamber to obtain more representative results. The reference flat will then mounted inside the vacuum chamber using in-house designed gimbal.
- Noticeable differences between the vacuum and atmospheric environments include the deformation of the vacuum chamber window (becomes curved) when the air is pumped out.
Acknowledgements

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Questions?