Phase-Sensitive EUV Imaging Reflectometry for Depth-Dependent Composition Determination

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2021 EUVL Workshop
Shrinking Size and Increasing Complexity Requires Advancement in Nanoscale Metrology

Subtle details can significantly affect performance of next-generation systems:

- Layer Thicknesses
- Surface/Interface Roughness
- Dopant Profiles

Our technique uses coherent EUV light generated from a tabletop HHG setup:

- High spatial resolution at diffraction limit
- Penetrates layers for buried layers imaging
- Elemental Specificity

Ultramicroscopy 158, 98 (2015)  
Nano Letters 16, 5444 (2016)
2. Obtain complex reflectance curves for different areas of the sample.


1. Take multiple images of the sample at many incidence angles using ptychography.

EUV Imaging Reflectometry
Spatially resolved reflectometry using computational imaging
Enhanced Sensitivity by Measuring Amplitude and Phase of Reflectivity

Ptychography (Coherent Diffractive Imaging)
Computational imaging technique that can retrieve the complex reflectivity of the sample

Ptychography

Image both amplitude and phase shift

Material Composition

Surface topography

Tabletop
Spatially resolved
Non-destructive
Enhanced sensitivity from measuring complex reflectivity
Demonstration on a Semiconductor Sample

Pixel size at 30 nm: 64 nm × 172 nm (can be further improved with higher NA or 13 nm light)
Structure height & layer thickness sensitivity: ~0.3 nm averaged across an area
Sensitivity to parameters can be further increased by taking more images, using multiple wavelengths
Future Directions: Apply Technique to A Wide Range of Materials and Systems

<table>
<thead>
<tr>
<th>Josephson Junction</th>
<th>Phase Change Materials</th>
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<tbody>
<tr>
<td><strong>What?</strong></td>
<td>Next generation memory material – records on/off by changing between crystalline and amorphous state</td>
</tr>
<tr>
<td>Superconducting quantum computing component made by lithography</td>
<td><strong>Why?</strong> Measure density and distribution of two states</td>
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<tr>
<td><strong>Why?</strong> Measure fabrication quality, detect defects</td>
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Measure fabrication quality, defects, density, layer thicknesses of new generation devices and materials at improved speed and sensitivity

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<th>Low-k Materials</th>
<th>Diamond</th>
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<td><strong>What?</strong> Low dielectric constant ($k$) materials for next-generation computer chips</td>
<td><strong>What?</strong> Ideal for validating heat-transport theories (because it has a long phonon mean free path)</td>
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<td><strong>Why?</strong> Measure density change due to strain from other fabricated layers</td>
<td><strong>Why?</strong> Carbon changes its property drastically depending on its atomic configuration – measure density, contamination</td>
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Summary: Phase-Sensitive EUV Reflectometry

1. Spatially-resolved reflectometry using computational imaging
2. Measures depth-dependent composition in a non-destructive way
3. Phase shift upon reflection gives enhanced sensitivity

Acknowledgements
- Current and Former Students: Michael Tanksalvala, Christina Porter, Nicholas Jenkins, Zhe Zhang, Matthew Jacobs, Bin Wang, Robert Karl Jr., Charles Bevis, Peter Johnsen, Joshua Knobloch, Brendan McBennett
- Advisors: Prof. Margaret Murnane, Prof. Henry Kapteyn
- Postdocs and Scientists: Chen-Ting Liao, Michael Gerrity, Sadegh Yazdi
- Collaborators: KM Labs, Interuniversity Microelectronics Centre (Imec), University of California Los Angeles, University of California Berkeley
- Funding sources: NSF STC STROBE, DARPA, Gordon and Betty Moore Foundation

References

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