

Goals and Potential Impact if Successful

- Real-Time, in situ monitoring of the evolution of topography on the sub-micron and nanoscale during both top-down and bottom-up fabrication process
- Real-Time feedback & feedforward control of micro/nanofab processes for high precision manufacturing
- Improved understanding of chemistry and physics of fabrication processes
- Potential applications of optical remote sensing for non-semiconductor problems (biological/chemical)
- Sensing and feedback control are needed for evolutionary improvements in current top-down manufacturing and should prove valuable in new nanofabrication processes

Approach and/or Accomplishments

Monitoring: Some of the 1st demonstrations of critical dimension/topography extraction from gratings using spectroscopic ellipsometry and reflectometry

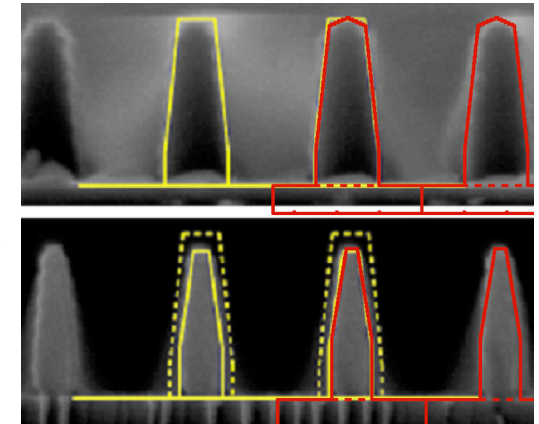
- The 1st real-time, in situ “movies” of topography evolution in reactive ion etch systems

• Also developed a unique RF plasma spectroscopy tool

Control: The 1st and only examples of real-time endpoint detection based on critical dimensions – etching to target CD

- A factor of 3 improvement in etch depth reproducibility using SISO control of plasma density on an industrially standard process and improved the physiochemical understanding of the dynamics of the Cl_2/Si etch process

- 350nm Photoresist Lines on SiO_2/Si Before Trim-back + Overlaid Profiles Extracted with Nondestructive in situ Optical Measurement (top figure)
- Similar Photoresist lines reactively ion etch to a bottom dimension of 200nm under automated control



Start: CD $296.7 \pm 9.1 \text{ nm}$

Trimmed: CD $189.1 \pm 29.3 \text{ nm}$

Bottlenecks and Open Research Questions

- Optical topography extraction methods work to sub-100nm scales but are becoming challenged due to wavelength limitations – development of instruments in the EUV range is needed
- Experimental data on the optical properties of materials in nanometer regime is limited at best
- Optical topography extraction for non-period structures has barely been explored due to both computational and measurement problems. This limits current industrial use and possible uses in the nano regime.
- Applications of real-time control in micro-scale manufacturing are limited due to sensing and detailed process understanding issues