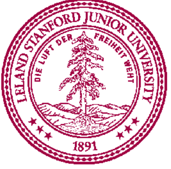
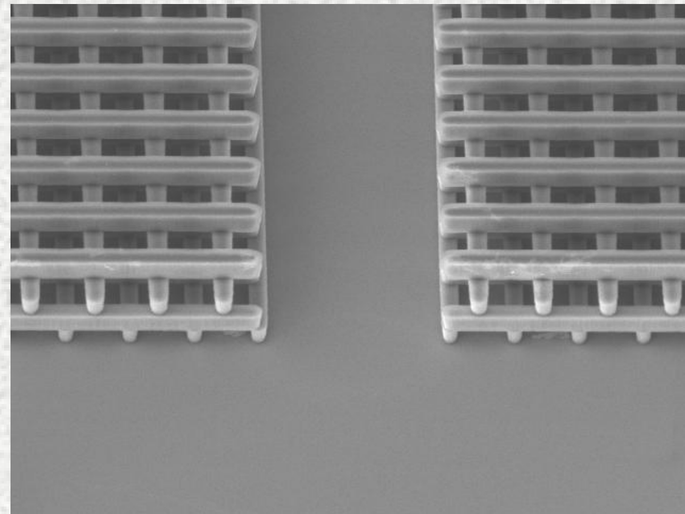


NATIONAL ACCELERATOR LABORATORY

Woodpile Structure Fabrication

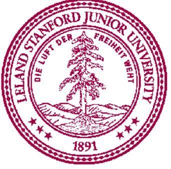


Chris McGuinness

July 8, 2009

Workshop on Novel Concepts for Linear Accelerators and Colliders

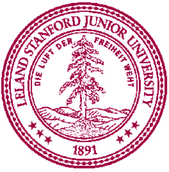
Working Group 2: Dielectric Laser Accelerators



SLAC NATIONAL ACCELERATOR LABORATORY

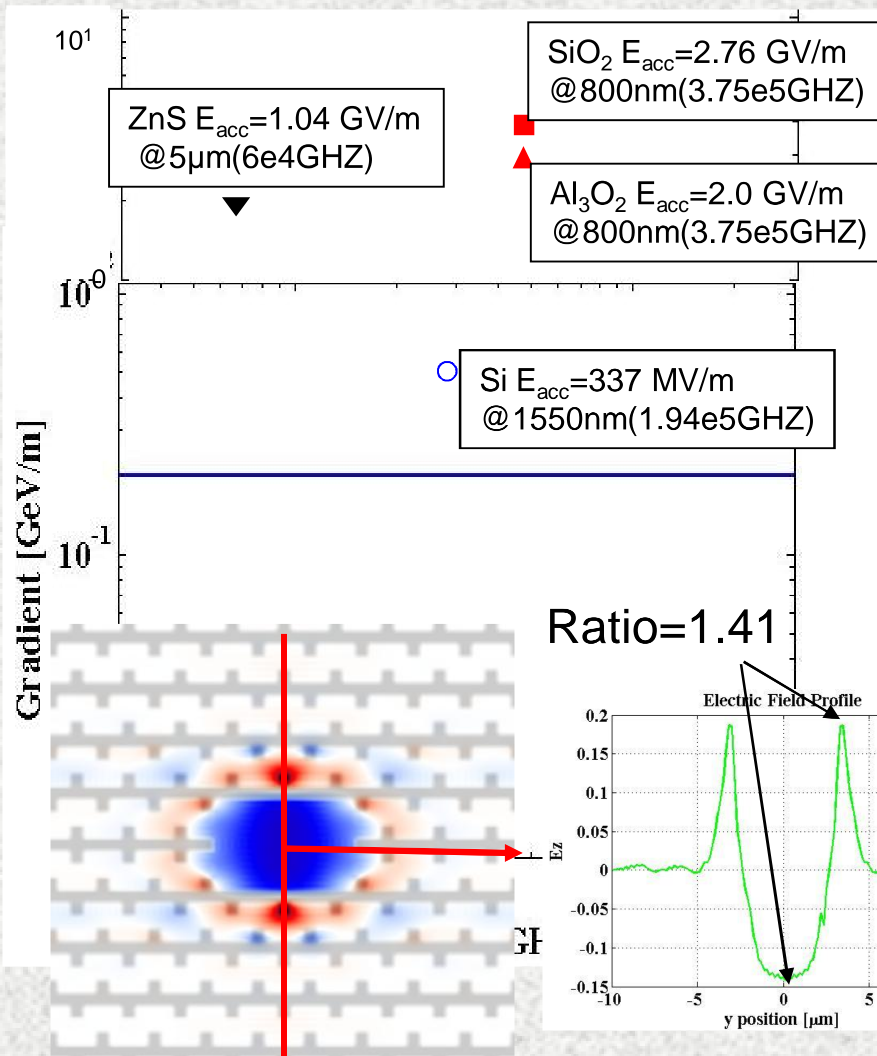
Outline

- Motivation
- Fabrication Process
- Fabrication Parameters
- Layer Adhesion
- Future Plans

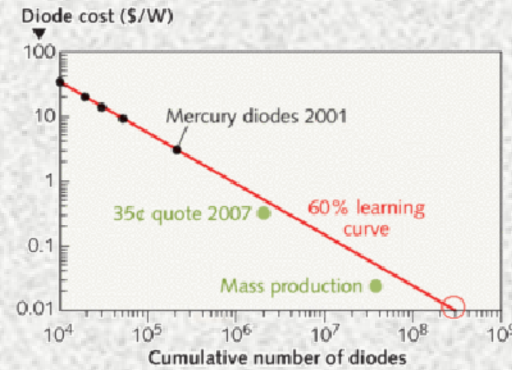


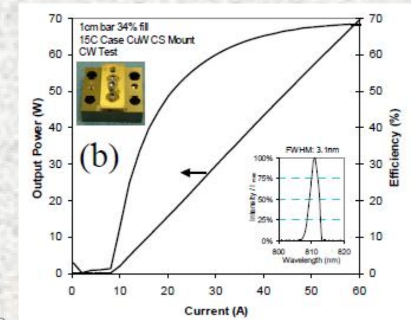
Motivations

Gradient

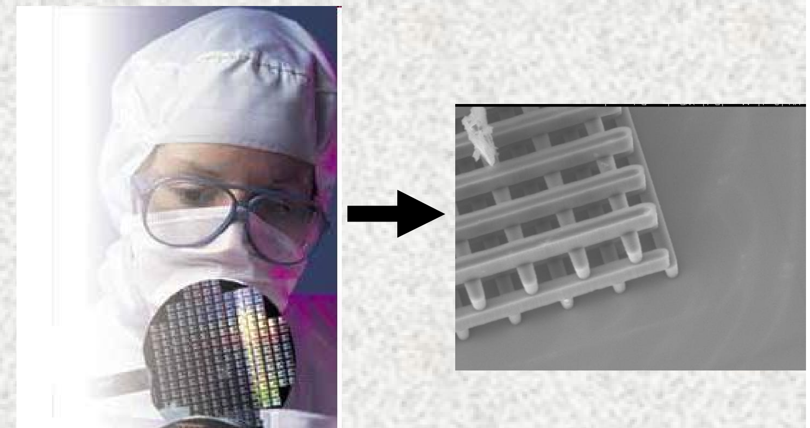


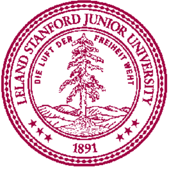
Sources



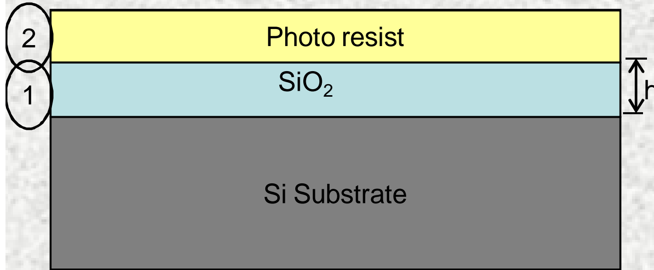


Fabrication



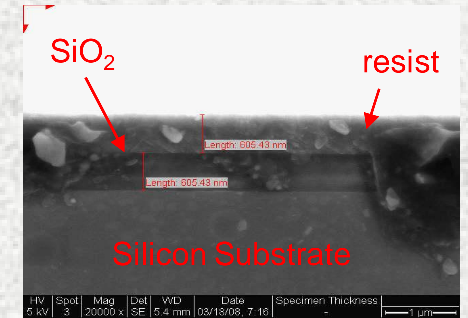


Fabrication Process

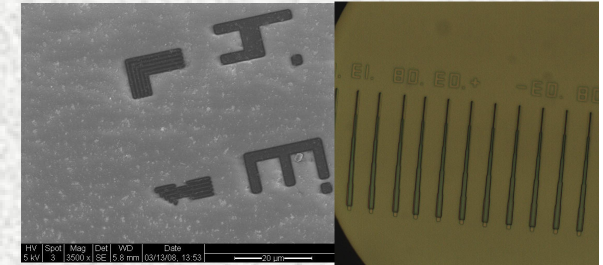


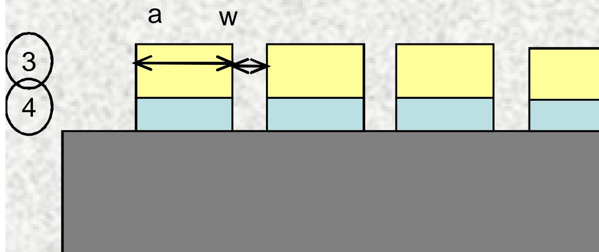
Step 1: SiO_2 Deposition - LPCVD

- Uniformity = 1-2%
- Controllability = 7%



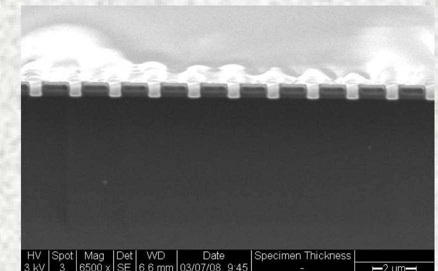
Step 2: Resist Coat



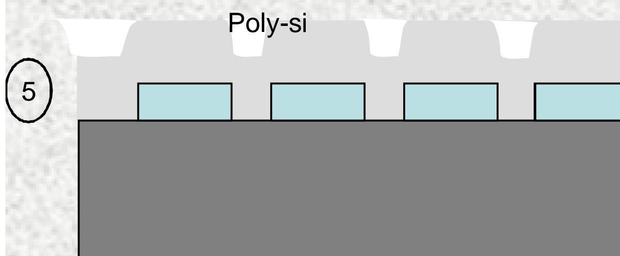


Step 3: Optical Lithography

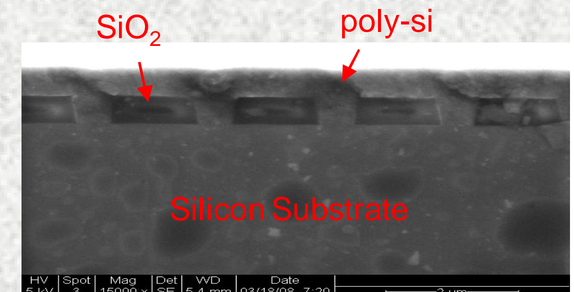
- Minimum feature size 450nm
- Alignment 3σ=60nm

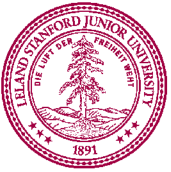


Step 4: Plasma etch SiO_2



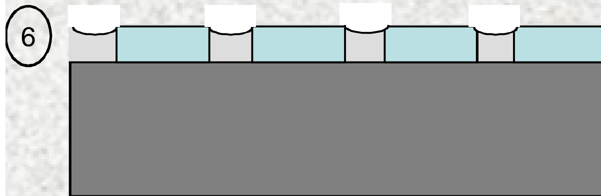
Step 5: Poly-si Deposition



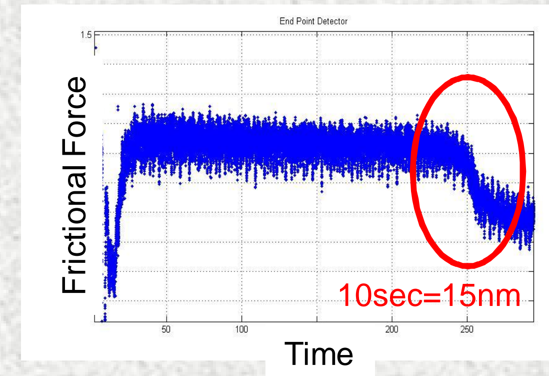


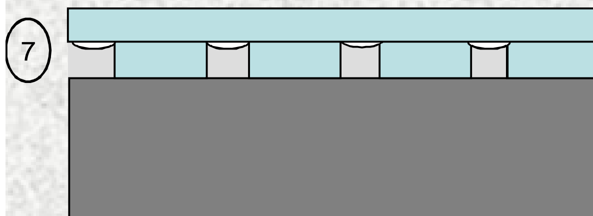
Fabrication Process

SLAC
NATIONAL ACCELERATOR LABORATORY

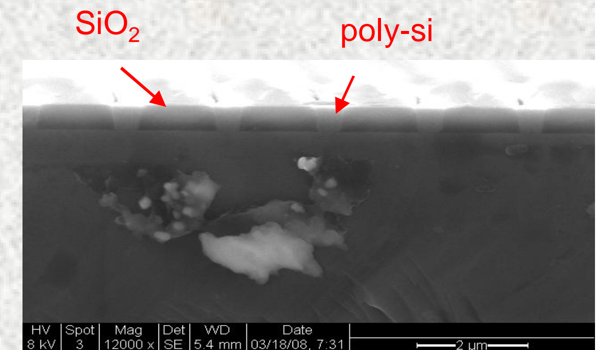


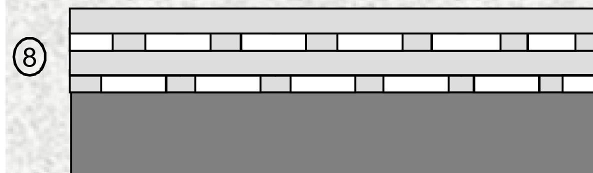
Step 6: Chemical Mechanical Polish



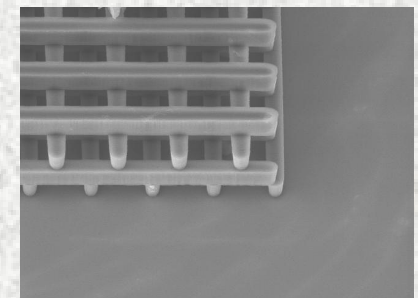


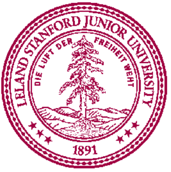
Step 7: Repeat process for remaining layers





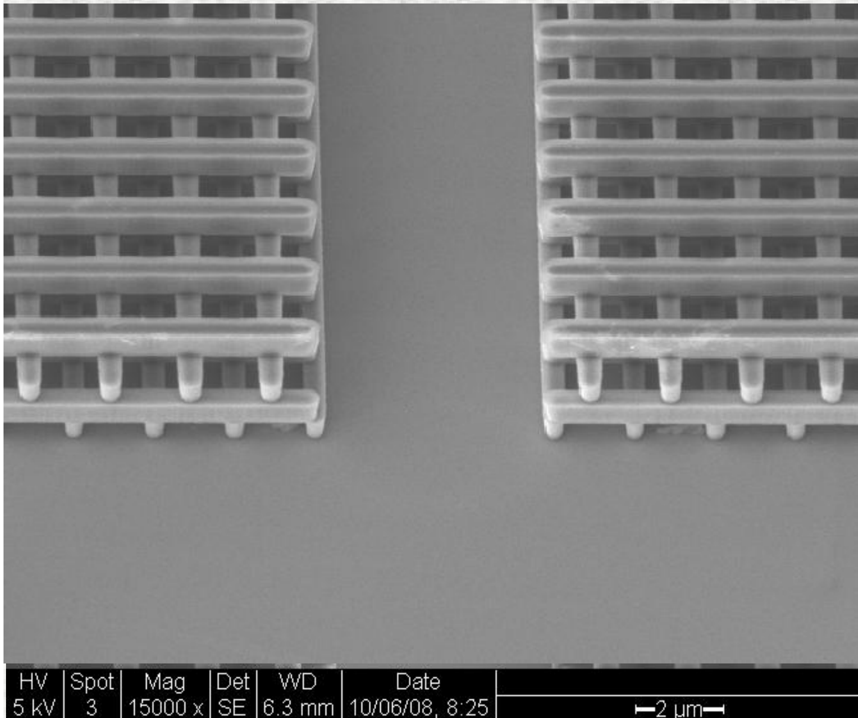
Final Step: HF Vapor Etch

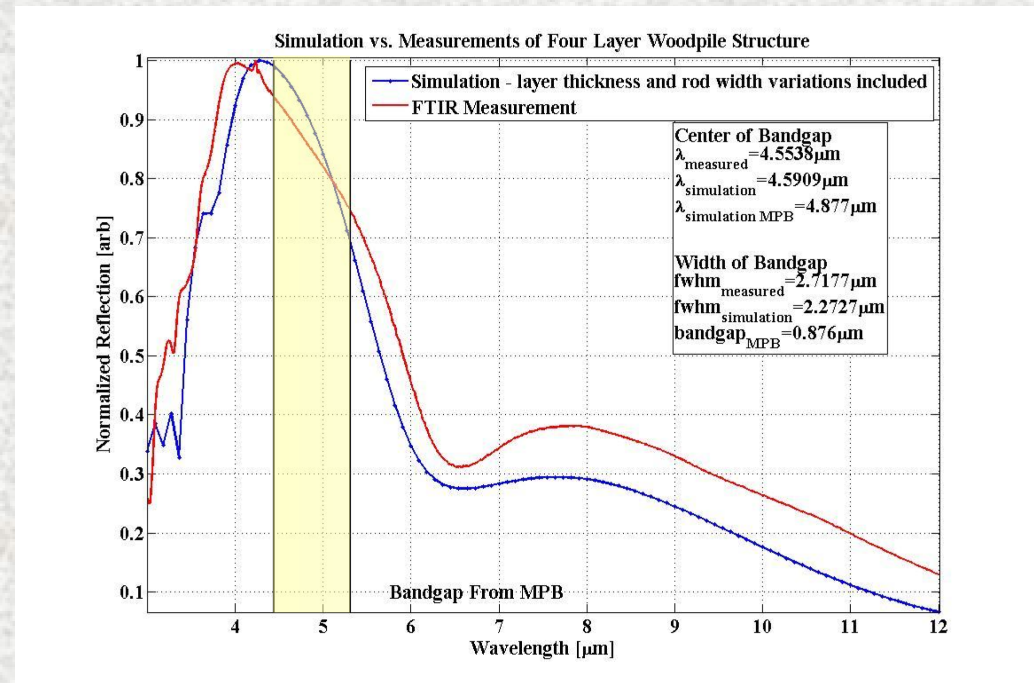


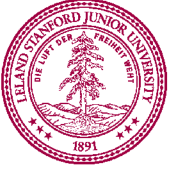


SLAC
NATIONAL ACCELERATOR LABORATORY

Four Layer Test Structure

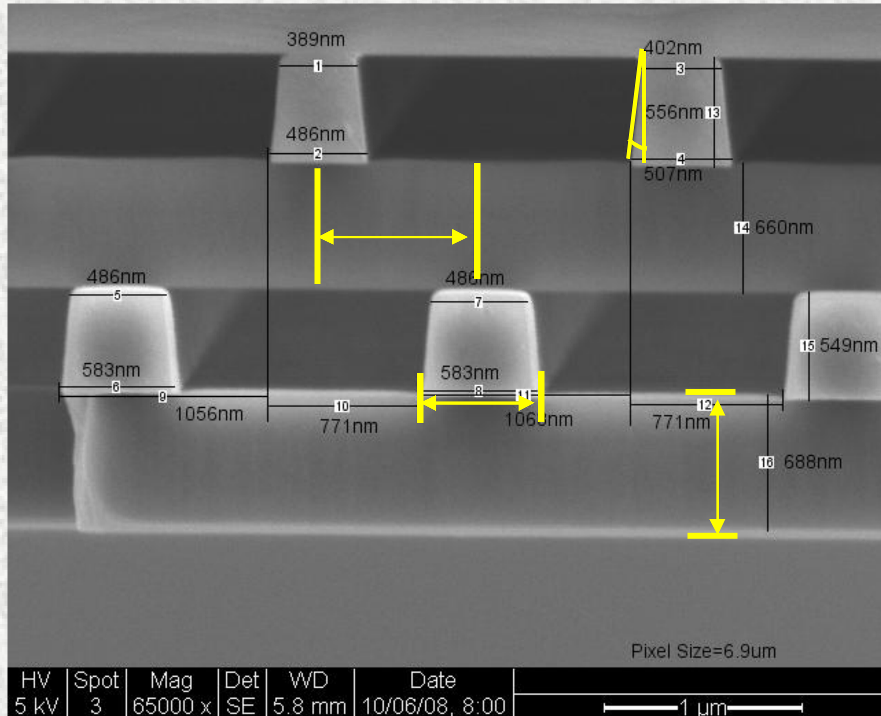


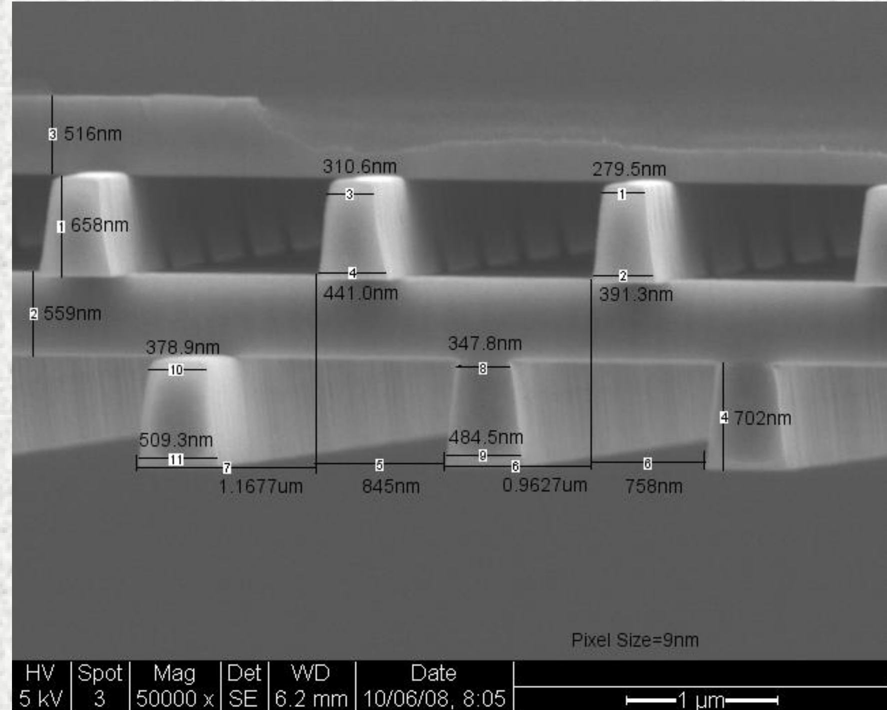




SLAC
NATIONAL ACCELERATOR LABORATORY

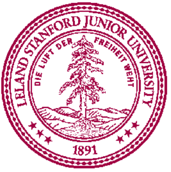
Fabrication Deviations





Parameter Summary

	Target	Measured
Rod Width	500nm	498nm ± 74nm
Tapper Angle	0º	10.4º ± 0.6º
Layer Thickness	632nm	611nm ± 73nm
Alignment Offset	<80nm	138nm

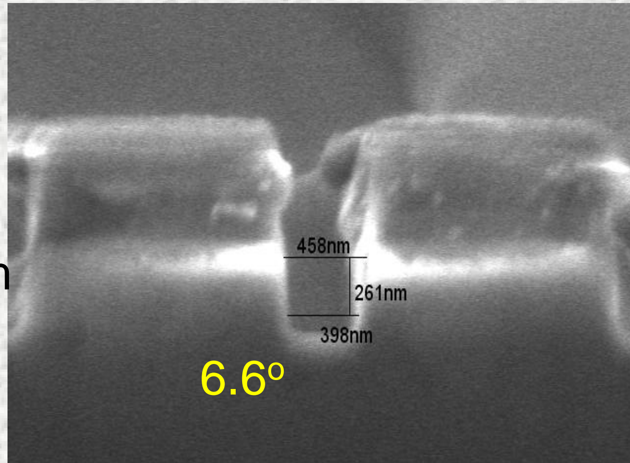


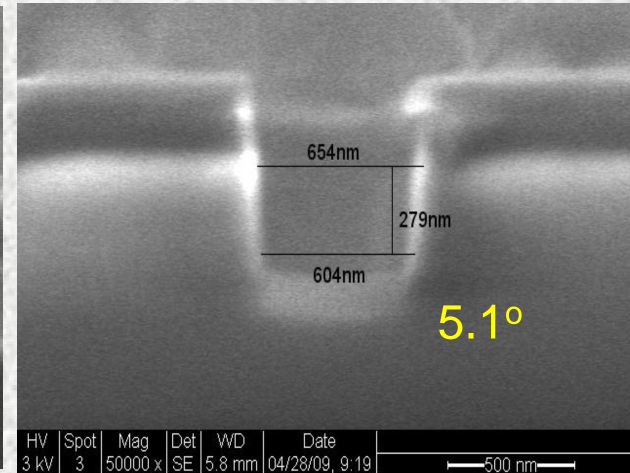
SLAC NATIONAL ACCELERATOR LABORATORY

Tapper Angle

AMT 8100 - Hexode Plasma Etcher

CHF_3 85 sccm
O_2 6 sccm

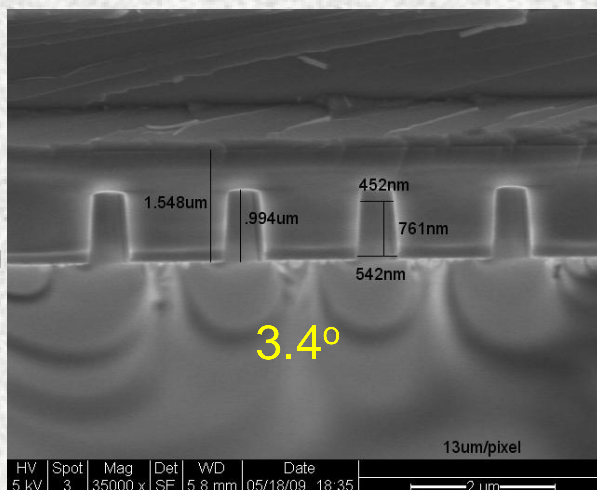


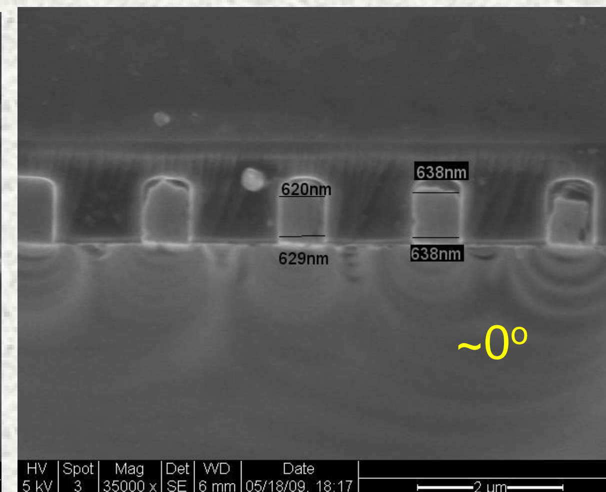


CHF_3 50 sccm
O_2 30 sccm

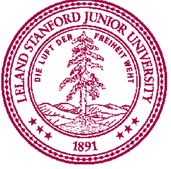
P5000 -Magnetically Enhanced RIE

CF_4 50 sccm
CH_3F 20 sccm
Ar 100 sccm

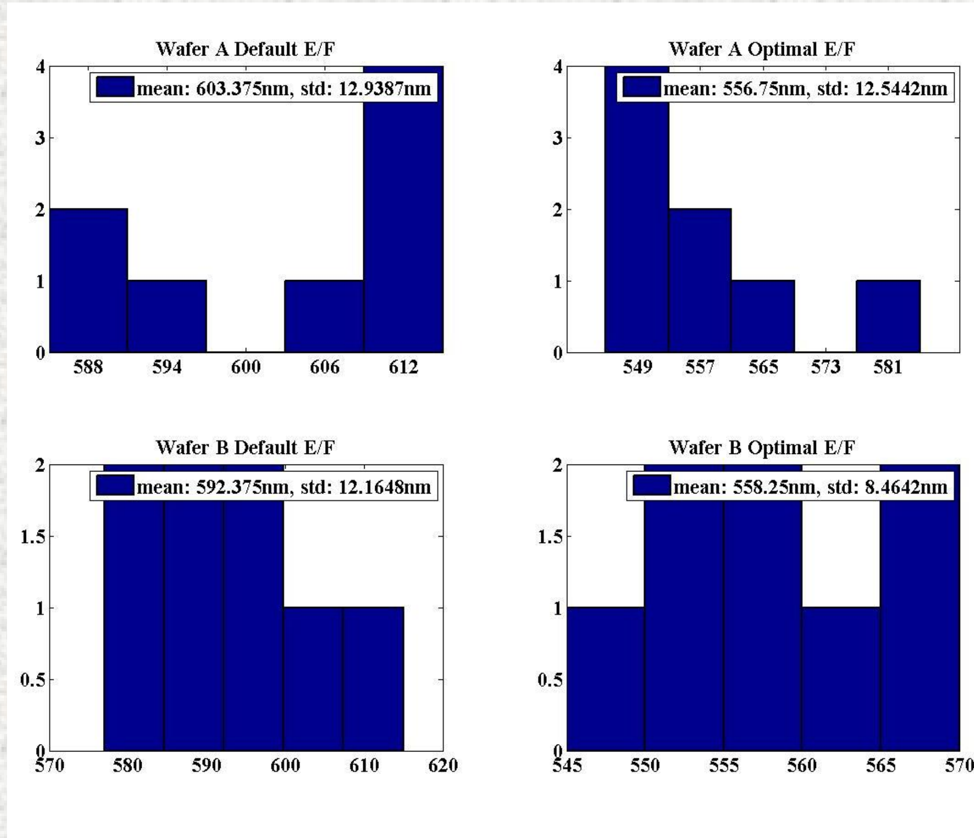


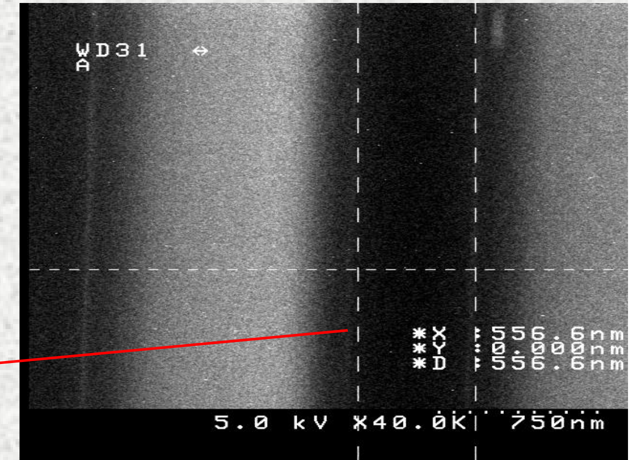


CF_4 50 sccm
CH_3F 25 sccm
Ar 120 sccm

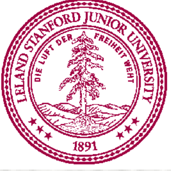


Rod Width





Measurement Resolution ~25nm



SLAC NATIONAL ACCELERATOR LABORATORY

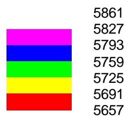
Layer Thickness

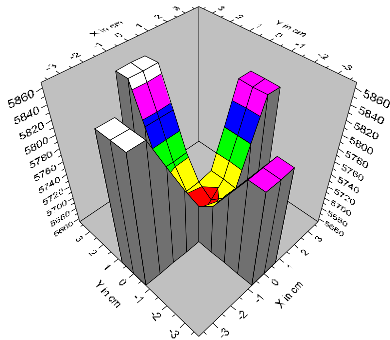
Deposition – LPCVD TEOS

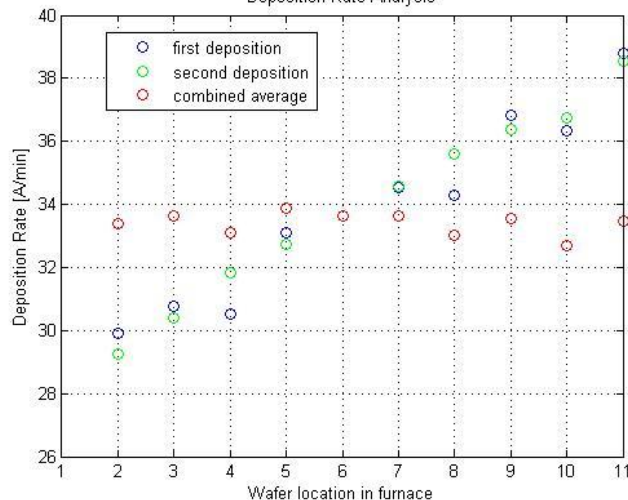
- Uniformity = 1-2%
- Controllability = 7%

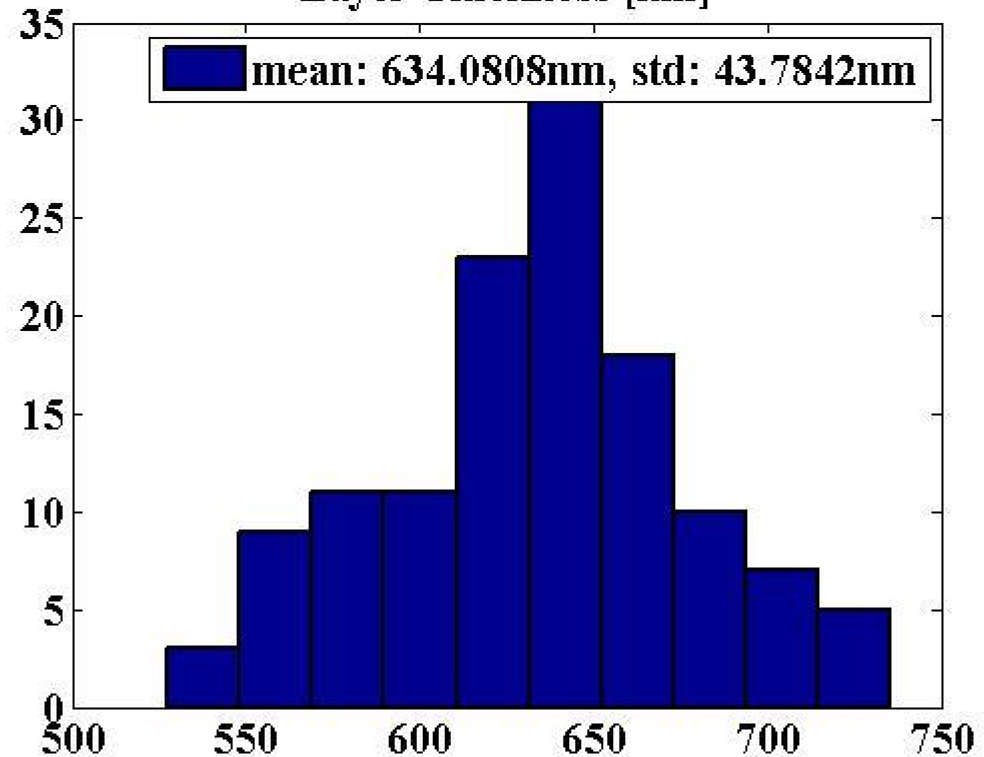
Oxide thick

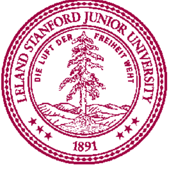
Mean = 5769.0
Min = 5656.6
Max = 5861.2
Std Dev = 68.524
Uniformity = 1.1878 %





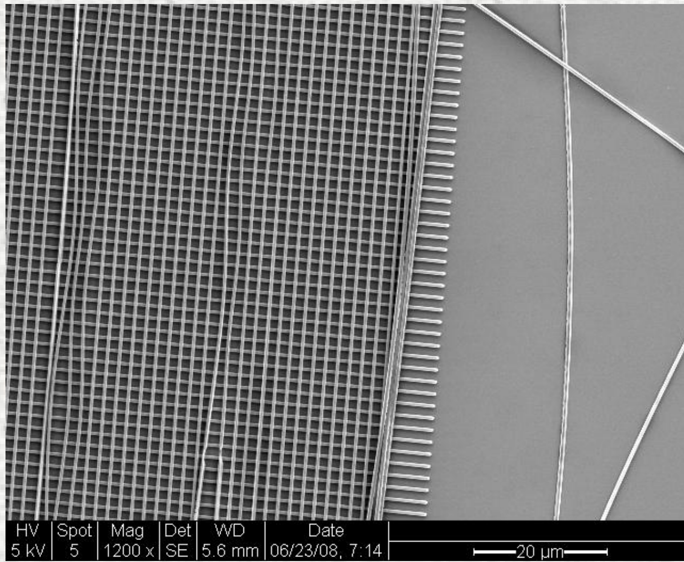


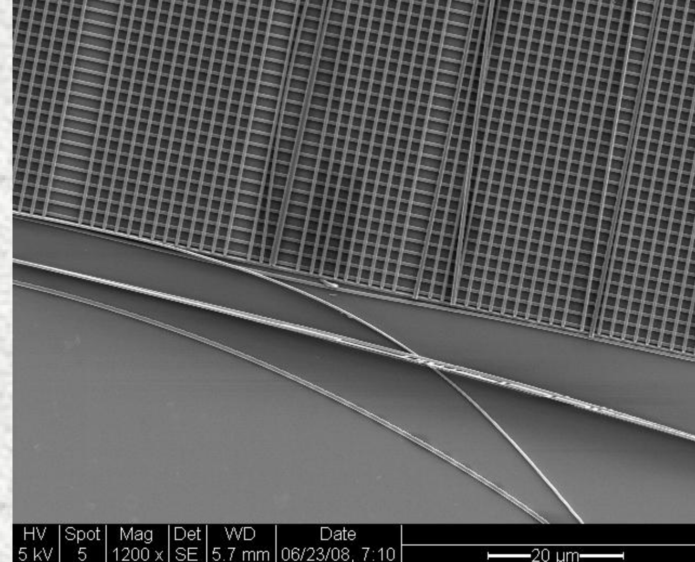


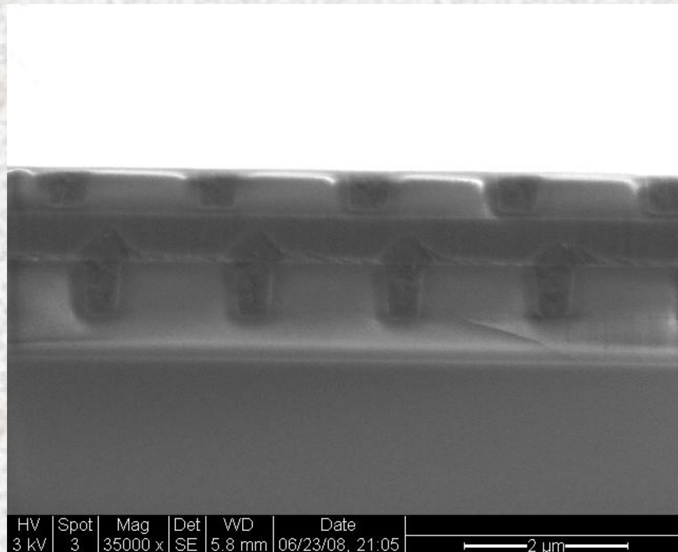


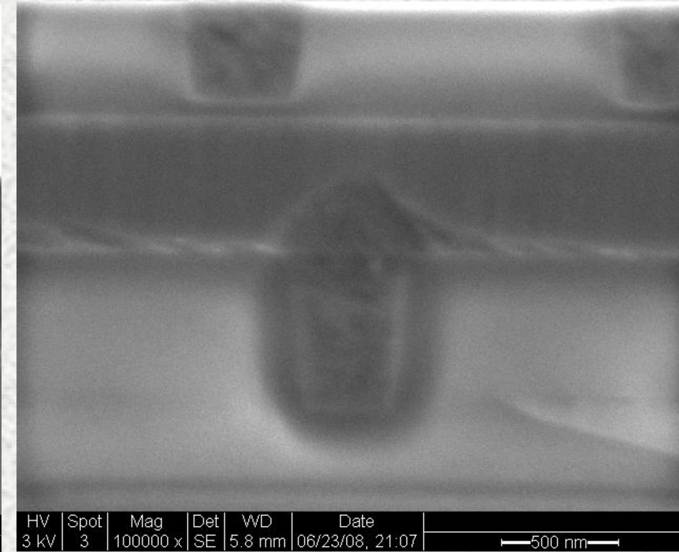
SLAC
NATIONAL ACCELERATOR LABORATORY

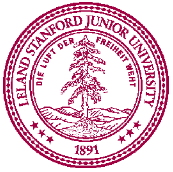
Layer Adhesion





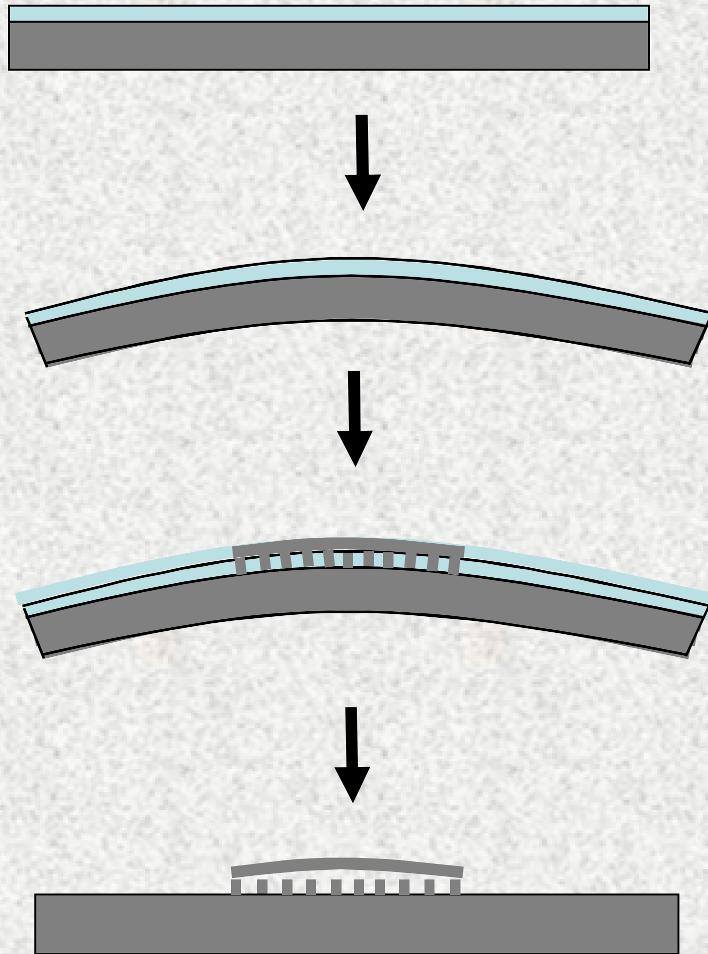


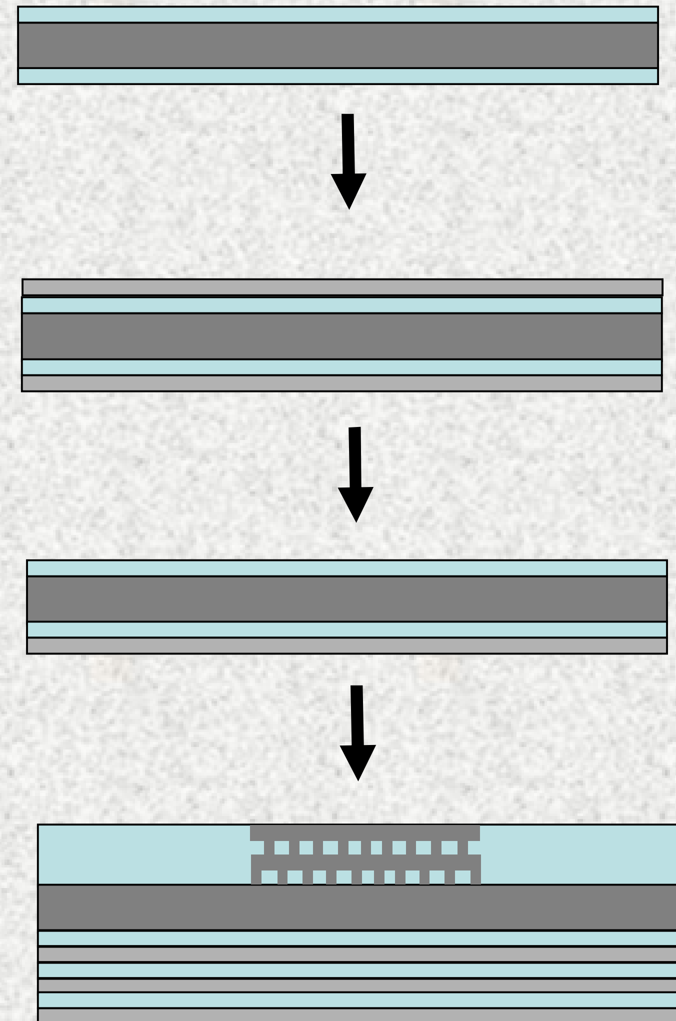




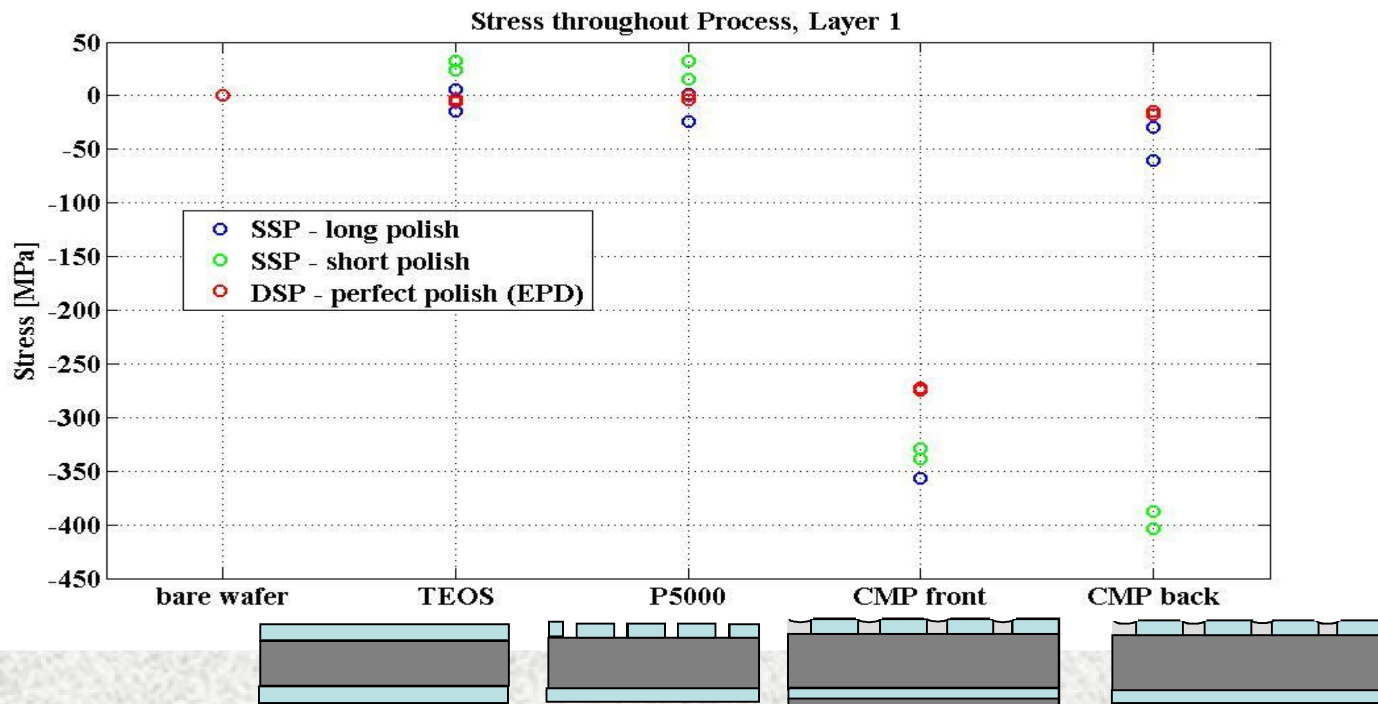
SLAC
NATIONAL ACCELERATOR LABORATORY

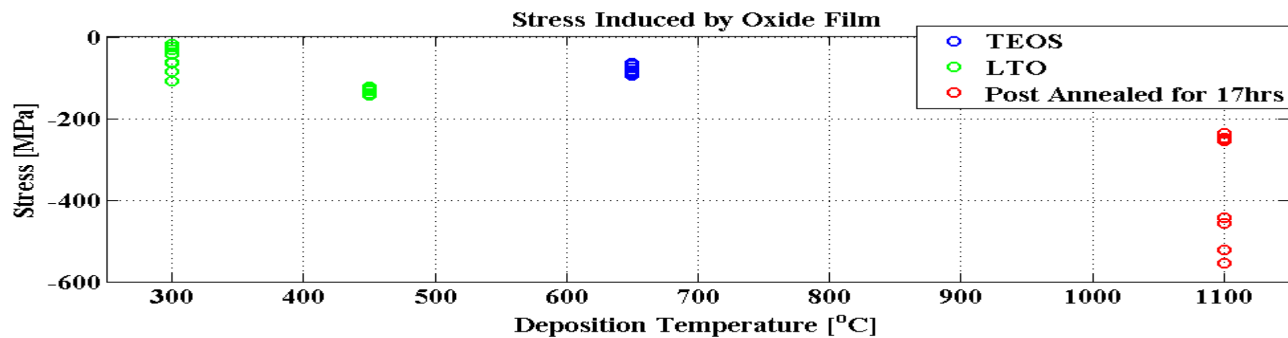
Stress

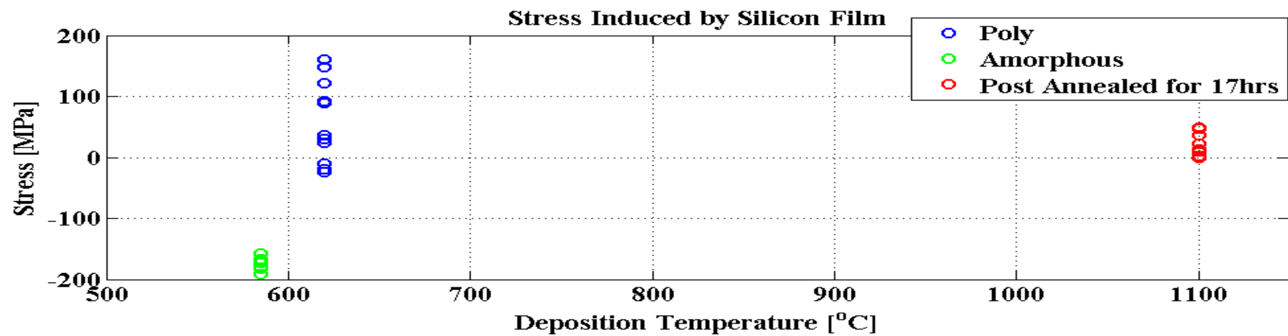


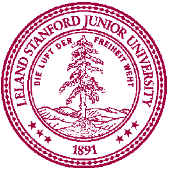


SLAC
NAL ACCELERATOR LABORATORY


Stress throughout Process, Layer 1
Stress [MPa]
SSP - long polish
SSP - short polish
DSP - perfect polish (EPD)
bare wafer
TEOS
P5000
CMP front
CMP back


Stress Induced by Oxide Film
Stress [MPa]
TEOS
LTO
Post Annealed for 17hrs
Deposition Temperature [°C]


Stress Induced by Silicon Film
Stress [MPa]
Poly
Amorphous
Post Annealed for 17hrs
Deposition Temperature [°C]

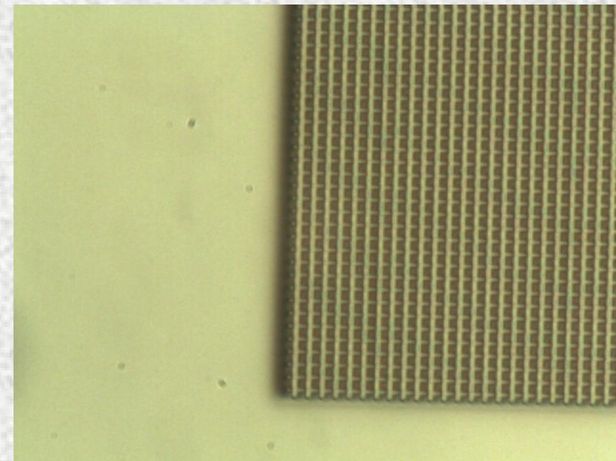


Annealed Wafer HF Vapor Etch

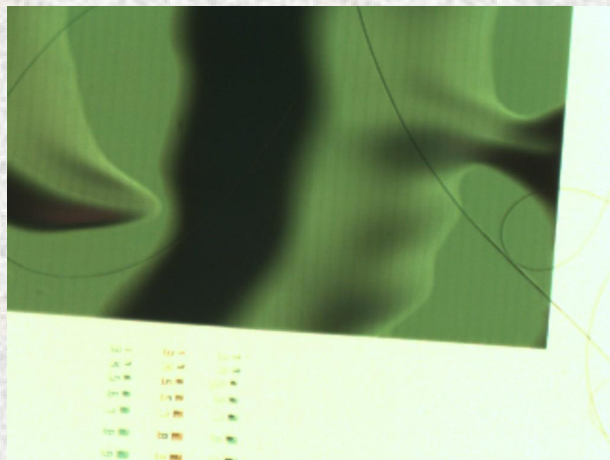
SLAC NATIONAL ACCELERATOR LABORATORY

Not Annealed, Buffered HF Etch

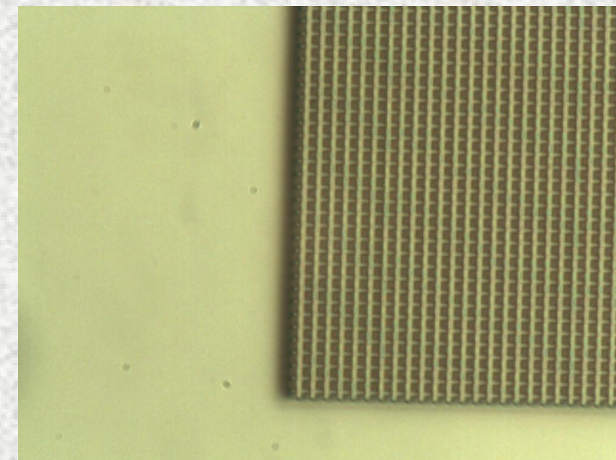
Annealed, Buffered HF Etch

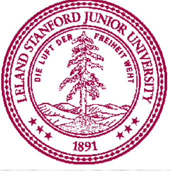


Not Annealed, Vapor HF Etched

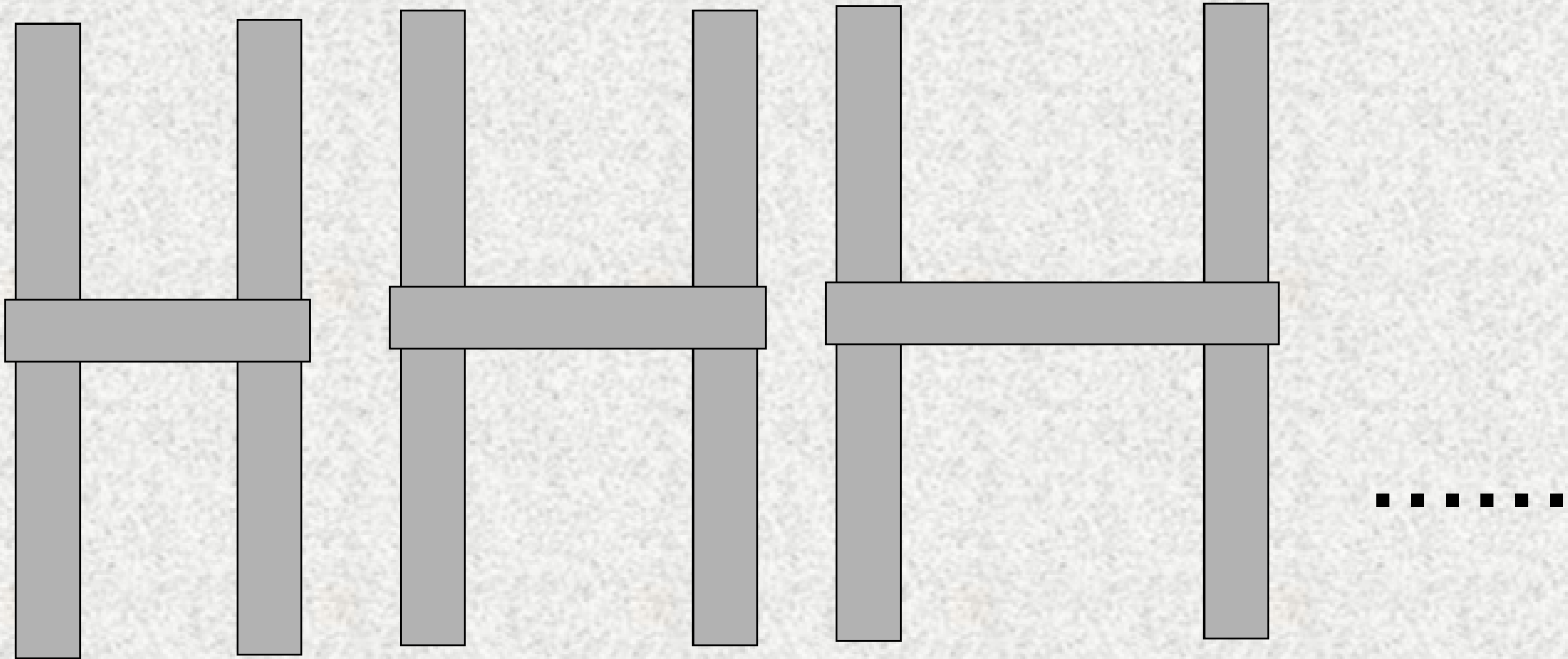


Annealed, Vapor HF Etch

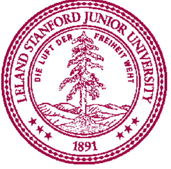




Measure Adhesion Strength



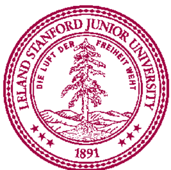
……



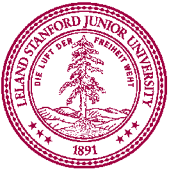
SLAC NATIONAL ACCELERATOR LABORATORY

Future Direction

- Complete 15 layer structure
- Optical measurements
  - Spectroscopy
  - Coupling
  - Mode excitation
- Beam measurements
  - Wakefield modes
- Simulations
  - Consider fabrication variations
  - Couplers

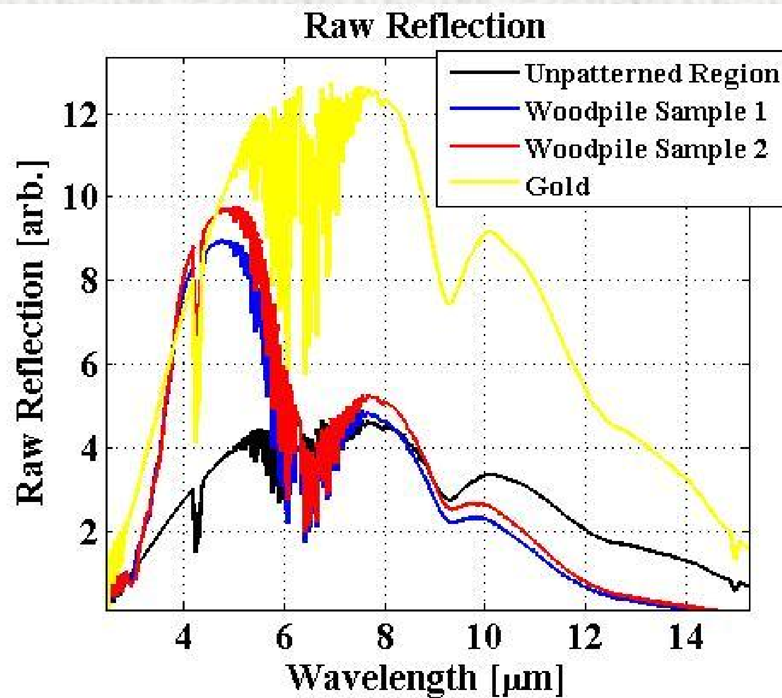


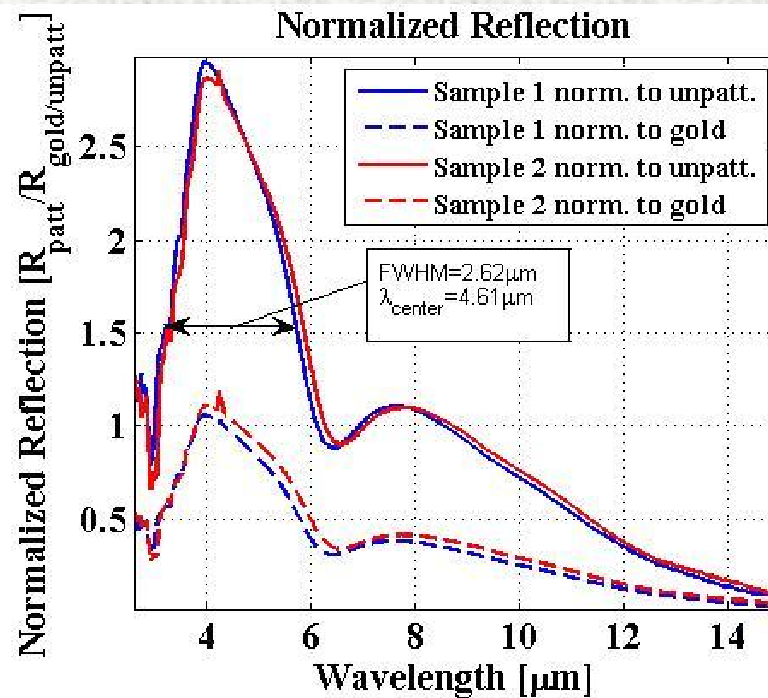
THE END

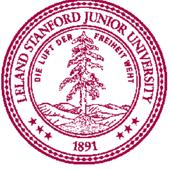


SLAC NATIONAL ACCELERATOR LABORATORY

FTIR Spectroscopy Measurements



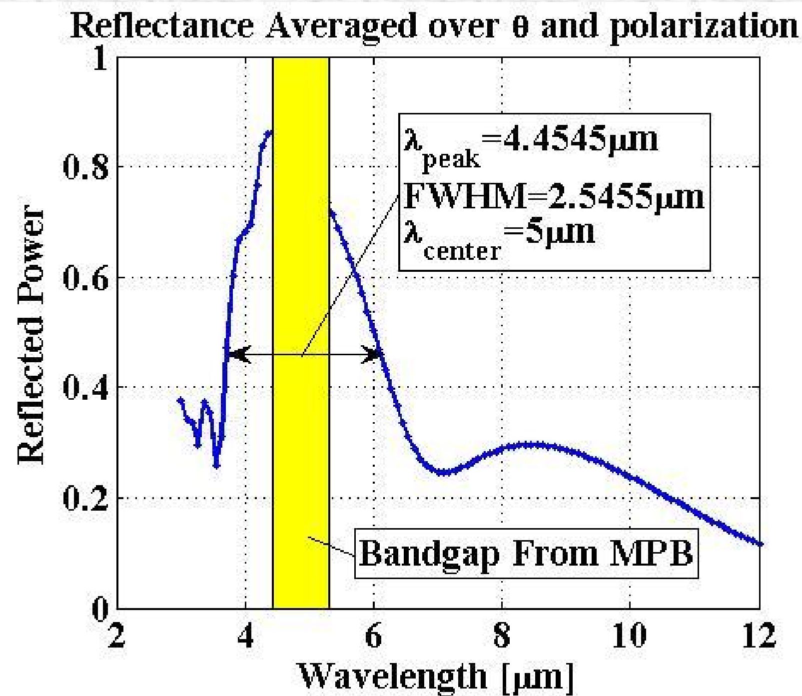


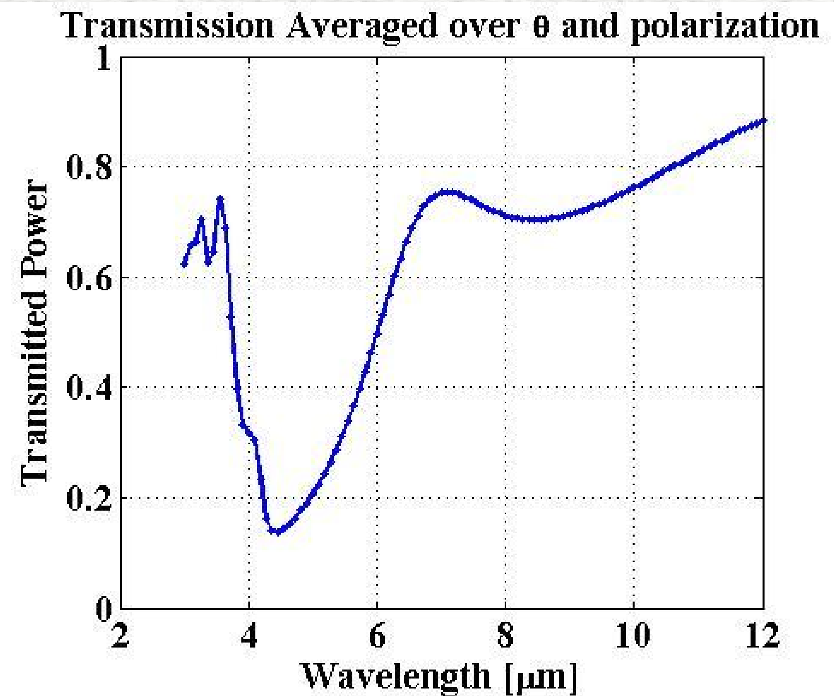


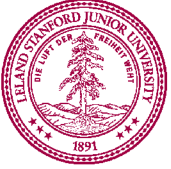
Finite Thickness Simulation

Reflection/Transmission

(averaged over S&P polarizations, and polar angle θ, φ=0)



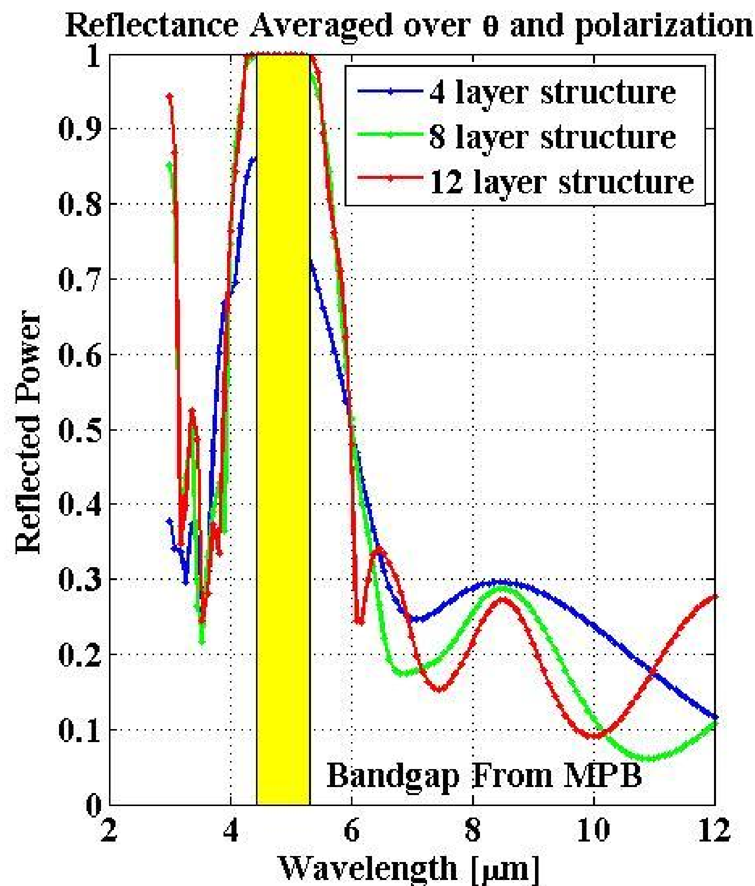


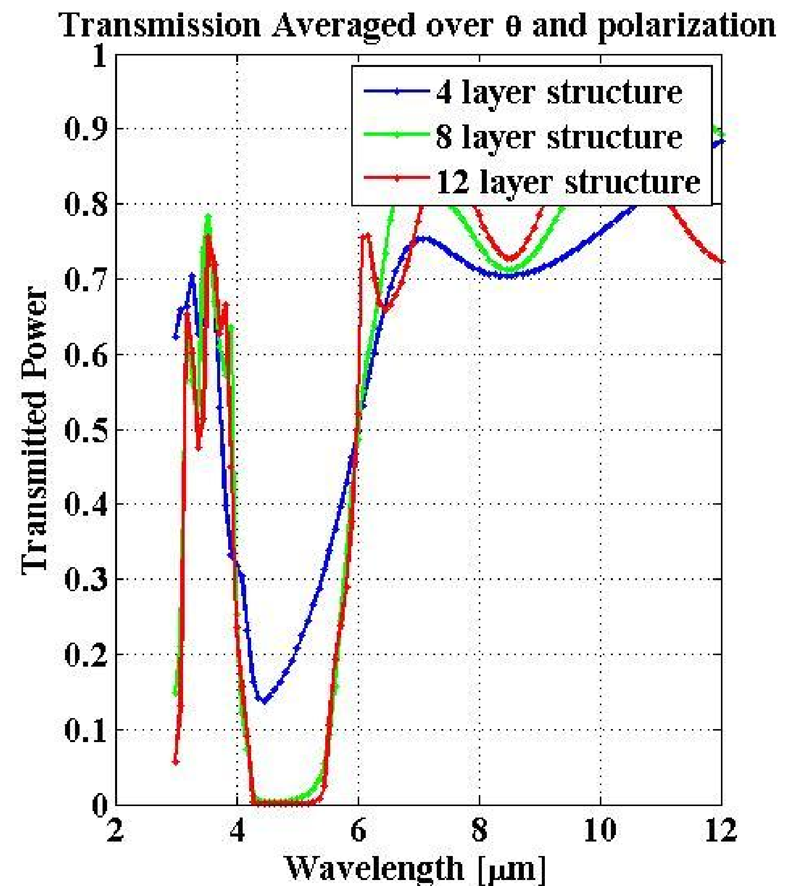


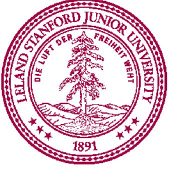
Simulation

Reflection/Transmission

(averaged over S&P polarizations, and polar angle θ, φ=0)







SLAC
NATIONAL ACCELERATOR LABORATORY

Simulation vs. Measurement

Simulation vs. Measurements of Four Layer Woodpile Structure

Simulation - target structure dimensions
FTIR Measurement

Center of Bandgap
$\lambda_{measured}$=4.5538μm
$\lambda_{simulation}$=5μm
$\lambda_{simulation\ MPB}$=4.877μm

Width of Bandgap
$fwhm_{measured}$=2.7177μm
$fwhm_{simulation}$=2.5455μm
$bandgap_{MPB}$=0.876μm

Bandgap from MPB

Normalized Reflection [arb]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2

3 4 5 6 7 8 9 10 11
Bandgap From MPB
Wavelength [μm]