



CVD - 7 Polysilicon Furnace Undoped Poly Process

Poly Process

Temperature ^a	SiH ₄ Flow	Pressure mtorr	# Wafers ^b	Wafer Size (in) ^c	Deposition Time (min)
620, 625, 627	75	250	1-6	2-6	Variable

Slide Outline

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- a) Temperature of zones L, C, and S fixed
- b) LPCVD Furnace can accommodate up to 50 whole 2 to 6" wafers. Slot numbers are 1-50 with 1 being towards the chase and 50 towards the cleanroom; Small batches are run with one 25 sample boat in the boat 2 position furthest towards the cleanroom ; Lot sizes over 6 wafers will have slightly lower growth rates then those reported here
- c) Samples smaller than 2" can be accommodated using the special small sample boat; see tool owner for more information
- d) All data from closed boat



Optical Properties

Wavelength, nm	Refractive Index, n^a	Absorption Coefficient, k^b	Transmission	Optical Model ^c
630	3.93	0.05	TBD	general oscillator

- a, b) Taken from the optical constants vs wavelength curve; Woollam WVASE 32; 400-800nm 5nm steps; 55,65,75°
c) Click on link for detailed description of model



Growth Rate and Uniformity: Avg. from all Poly runs to-date

Growth Rate ^a (nm/min)	Std. Uniformity ^b	Max/min Uniformity ^c	Linear or non- linear w/time
10.6 ± 0.3	0.7 %	na	linear

- a) Thickness data averaged from four runs and 5 different wafers
 - Data from Woollam Spectroscopic ellipsometer
- b) $(1 \text{ sigma} / \text{mean}) \times 100$ averaged over 13 different wafers from 5 separate depositions
- c) $((\text{Max} - \text{Min}) / \text{mean}) \times 100$ averaged over 13 different wafers from 5 separate depositions



Roughness, Stress, Etch, and Density

Stress ^a , MPa	Etch Rate KOH ^b	RMS Roughness, R _q nm ^c	Grain Size, nm	Density g/ cm ³
-230 ± 10 (compressive)	204 nm/min	<u>2.5</u>	<u>50 ± 15</u>	not measured

- a) Measured on FLX-2320-S Thin Film Stress (MET-1) at room temperature using 6" USA ring; averaged over 4 samples
- b) Stock KOH solution (30%) at 78 °C
- c) Measured on SPM-5, Veeco NanoMan AFM, tapping mode, standard tip or Optical profiler



Electrical Data – MIS Devices on Probe Station

Electrical Parameter	As-Deposited	Annealed ^d
Leakage Current Density (A/cm ² at 2MV/cm) ^a	TBD	
Breakdown Field (MV/cm)		
ϵ (10 kHz)		
ϵ (100 kHz)		
ϵ (1 MHz)		
V_{FB} (@100kHz)		
Q_{eff} (@100kHz)		
N_{eff} (e10)		
Q_m		
N_m (e10)		

[More data
here](#)

- a) Measured using probe station connected to Agilent 4156c and B1500 analyzers; created using the liftoff technique
- Aluminum pad sizes of 0.00533 cm²; backside contact sputtered gold
 - All values listed derived from averages of at least three measurements per sample
- b) 2 Wafer batch on 08/28/2013; 58 min deposition time; 6" p-type prime wafers, HF cleaned; 329nm
- c) Wafer annealed at 425C in forming gas for 4 hours with contact pads present
- d) V_{FB} , Q_{eff} , N_{eff} , Q_m , N_m calculation method on [Parameter Extraction Method](#) slide



Film Composition and Contaminants

VPD-ICPMS

Al ^a	Ca	Cr	Cu	Fe	Mg	Ni	K	Na	Ti	Zn
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XPS^b

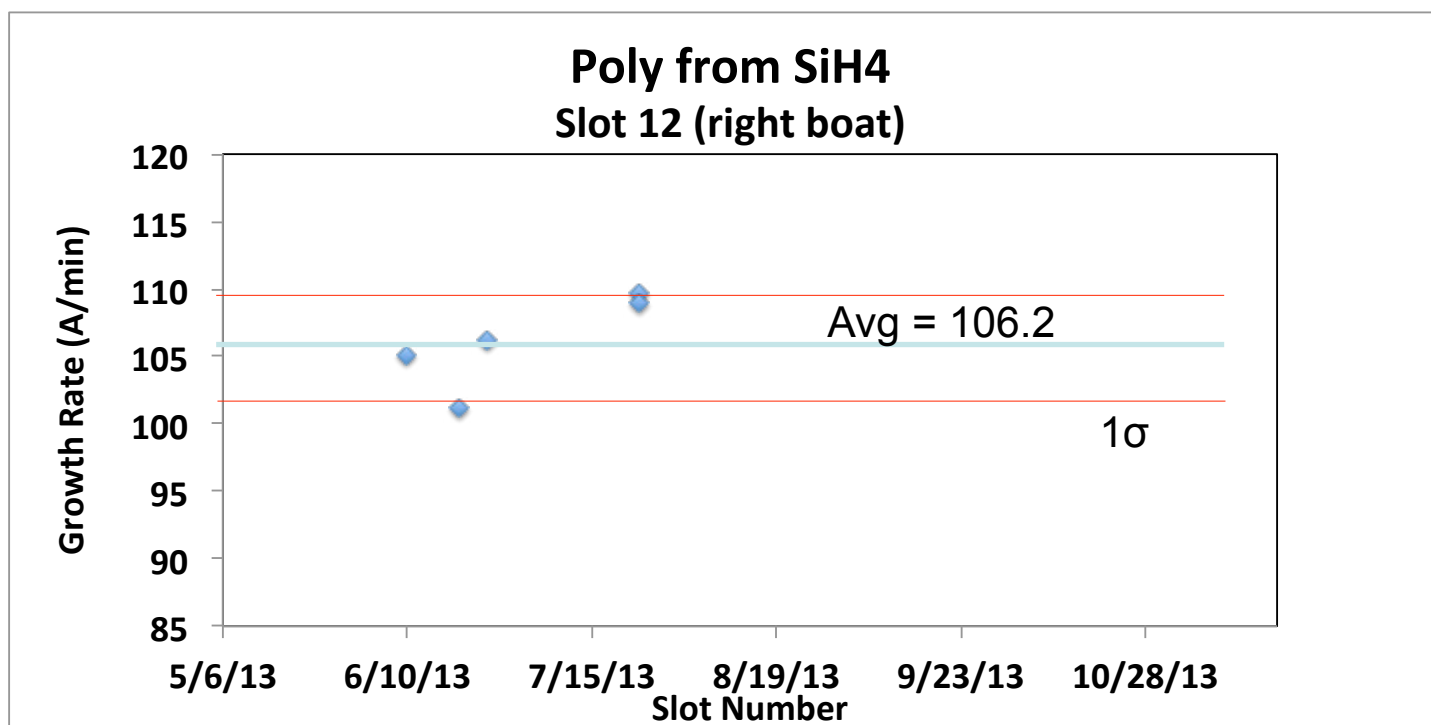
Si	C	O
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95	2.5	2.5
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- a) Surface trace metal analysis by VPD-ICPMS; 7mm edge exclusion; values in ppm (by weight)
- b) Measured on XPS (09/19/2013), after 100s sputter (depth profile) using survey results



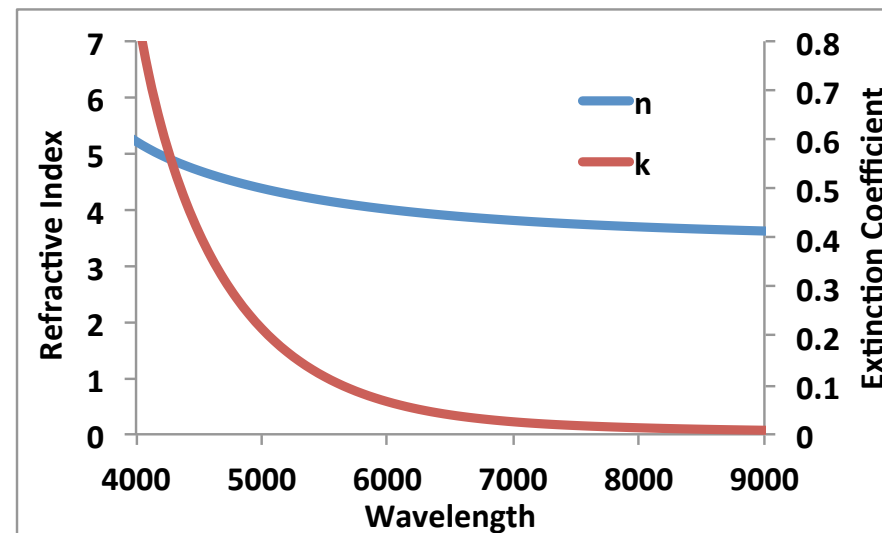
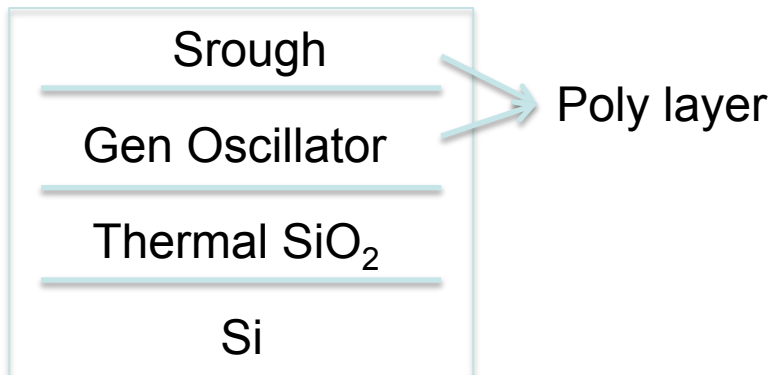
Baseline Statistics



- a) Various Poly growth times from slot 12 second boat (right most)
- b) Blue line = running average = 10.6nm/min
- c) Red lines = 1 sigma above and below avg



Optical Model



Thermal SiO ₂	Srough	Spectroscopic Ellipsometer Model	Ideal or non-ideal	Position Pole #1 (eV)	Position Pole #2 (eV)	Magnitude Pole #1	Magnitude Pole #2	Offset	Egap
104 nm	2.4 nm	General Oscillator	non-ideal	15.61	0.001	404.5	0.375	-0.8099	1.45

- Woollam WVASE 32; 300-1000nm 3 nm steps; 55,65,75°

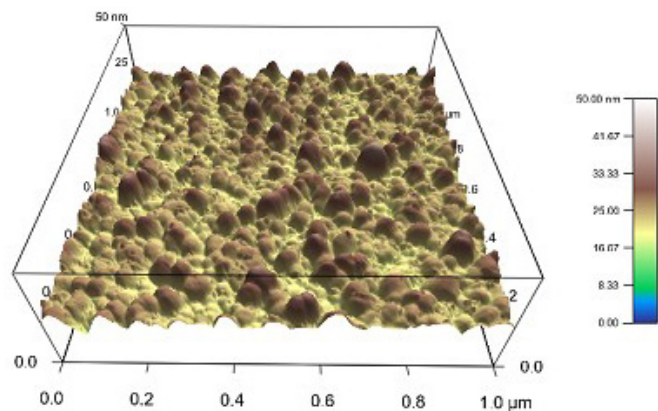
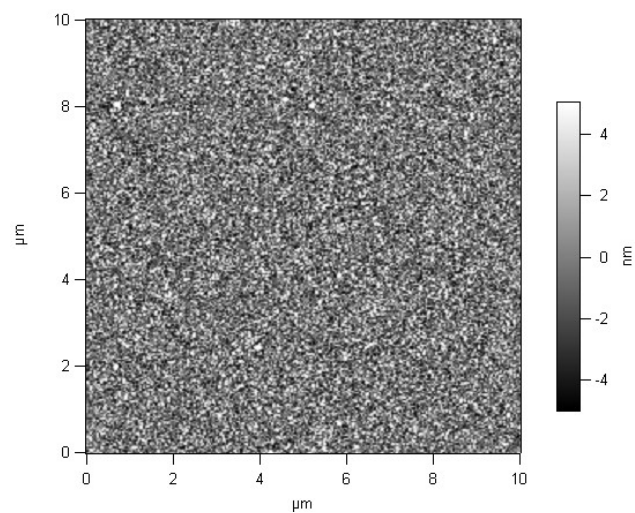


Wafer-to-Wafer Uniformity (within batch)

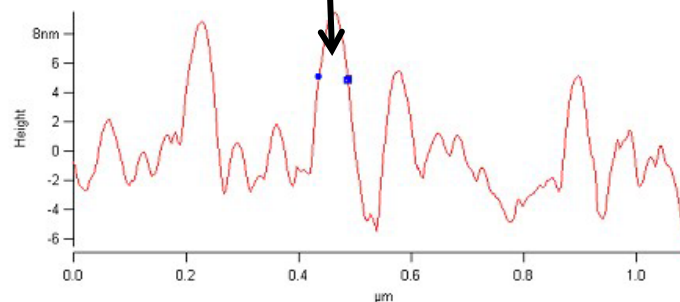
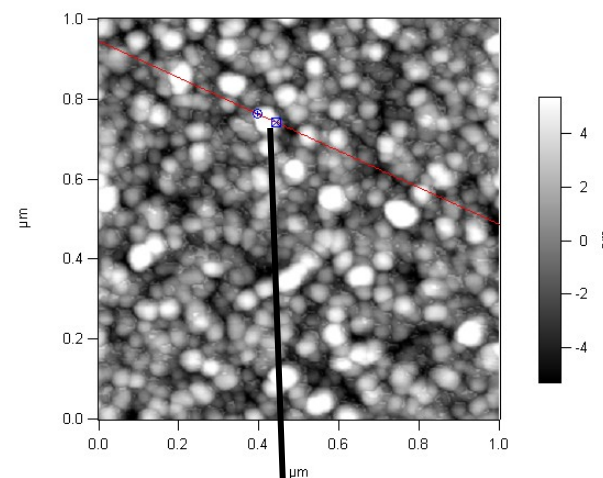
Coming Spring 2014



AFM Data Set “Typical Run”



RMS: 2.5 nm
Adev: 1.9 nm



Grain Size
Dx: 50.0 nm +- 15nm

- a) **Sample:** 10min deposition Poly recipe
- slot 12
 - 6” wafer, 2 wafer lot
 - Thickness = 109nm

12/20/13

P. de Rouffignac

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XRR Data





Expanded Probe Station Data

100 kHz CV Curves

IV Curves

To be provided later



Parameter Extraction Method

ϵ_r	vacuum permittivity	C_{FB}	flat band capacitance
d	film thickness in meters	λ	Debye length (cm)
A	gate area (m ²)	ϵ_s	permittivity of Si (F/cm) $11.7 \cdot \epsilon_0$
C_{ox}	Oxide capacitance	A	gate area (cm ²)
ϵ_0	8.854×10^{-14} F/cm	kT	thermal energy @ RT ($293K \cdot 1.3806e-23$ J/K)
W_{MS}	metal semiconductor work function	q	electron charge (coulombs)
V_{FB}	Forward flat band voltage	N_D (N _{bulk})	Bulk doping concentration (cm ⁻³)
Q_{eff}	effective dielectric charge (coul/cm ²)	N_i	Intrinsic carrier concentration (cm ⁻³)
N_{eff}	effective charge concentration #/cm ²	<i>Dopetype</i>	+1 ptype / -1 ntype'
		N_m	mobile charge concentration

Eq. 1

$$C_{FB} = \frac{C_{ox} \epsilon_s A / \lambda}{C_{ox} + \epsilon_s A / \lambda}$$

Eq. 2

$$\lambda = \left(\frac{\epsilon_s kT}{q^2 N} \right)$$

Eq. 3

$$W_{ms} = -0.61 - \frac{kT}{q} \ln \left(\frac{N_{BULK}}{N_i} \right) (dopetype)$$

Eq. 4

$$Q_{eff} = \frac{C_{ox} (W_{ms} - V_{FB})}{A}$$

Eq. 5

$$N_{eff} = \frac{Q_{eff}}{q}$$

Eq. 6

$$Q_m = -\frac{C_{ox} \Delta V_{FB}}{A}$$

Eq. 7

$$N_m = \frac{Q_m}{q}$$

- The flat band capacitance is calculated in order to extract the flat band voltage, V_{FB} , from the experimental C-V curves.
 - Equations 1 and 2
- The forward V_{FB} is then used to determine the effective charge in the dielectric, Q_{eff} .
 - Equations 3 and 4
- Equation 5 extracts the density (#/cm²) of effective charges from Q_{eff} and the charge of an electron, q .
- The effective mobile charge, Q_m , in the dielectric is determined using the change in V_{FB} between the forward and backward CV curves using equation 6.
- The mobile charge density is determined using equation 7.