UNIVERSITY OF CALIFORNIA

BERKELEY

Marvell Nanofabrication Laboratory

SiO_2 Characterization

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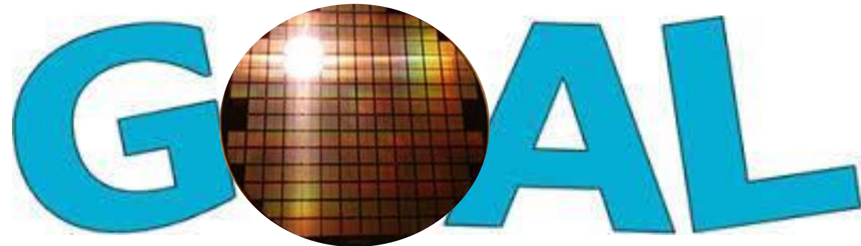
Overview

- Project Background & Objective
- Plan
- Process
- Results
- Conclusions
- Acknowledgements

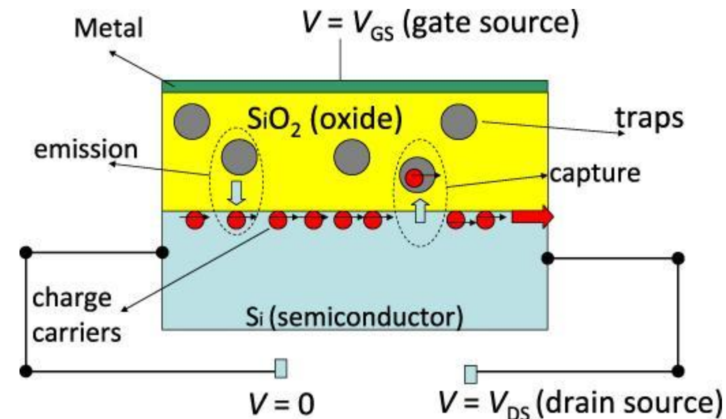
Project Objective

- compare 1 μm of:
  - Thermal
  - Low Temp
  - High Temp
  - PQECR
  - Oxford2
- properties:
  - index of refraction
  - oxide charge
  - stress
  - surface roughness
- make an oxide in Oxford2 comparable to thermal oxide

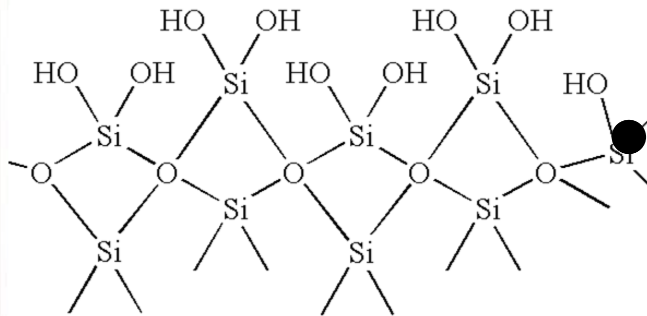


Project Background

- SiO_2: part of metal oxide semiconductor
  - basis of transistors in all electronics
- many other uses in the lab
  - etch mask
  - dielectric layer
  - barrier layer
  - optical properties



Project Background

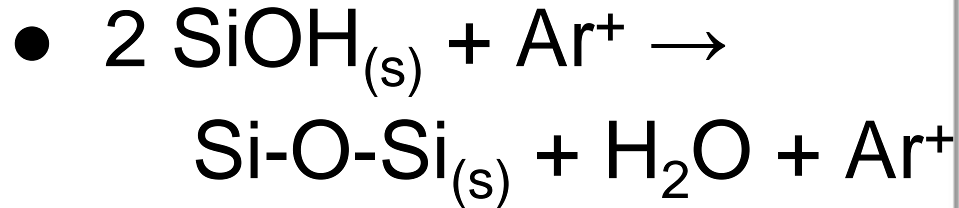


HYDROXIDE TERMINATED SiO_2 FILM

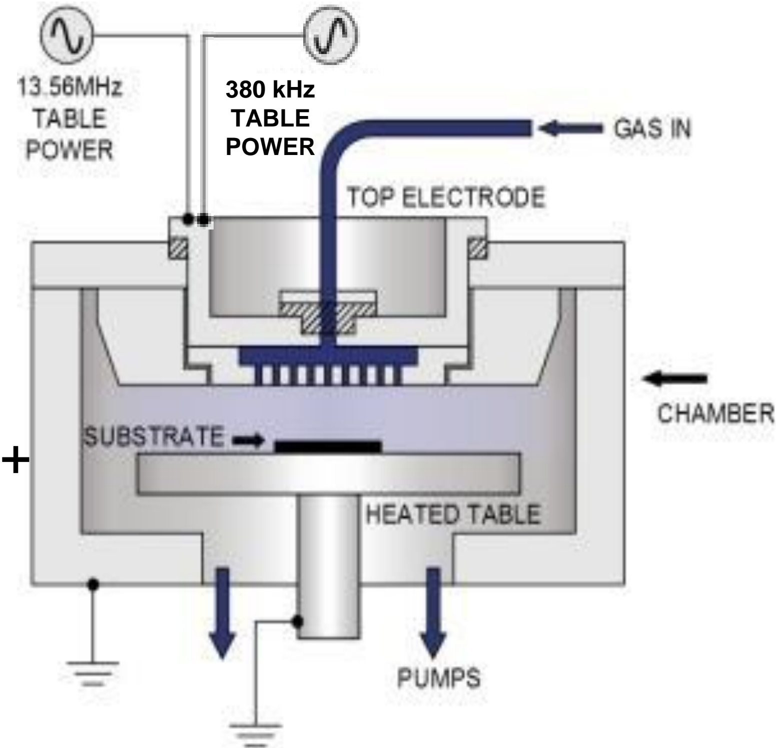
- Best quality oxide: Tystar furnace
  - ~1050 °C
- Oxford2
  - 350 °C
  - OH impurities
  - high and low frequency
  - “hammer” the film with large ions moving in LF conduction current

Project Background

- HF: 13.56 MHz
- LF: 380 kHz



- $2\ SiOH_{(s)} + Ar^{+} \rightarrow$
  $Si\text{-}O\text{-}Si_{(s)} + H_2O + Ar^{+}$



The Plan: General

- deposit/grow 1 μm of oxide on [tool]
- measure on
  - ellipsometer (index)
  - SCA (oxide charge)
  - flexus (stress)
  - wyko (surface roughness)
  - msink8 (etch rate)

The Plan: Oxford2

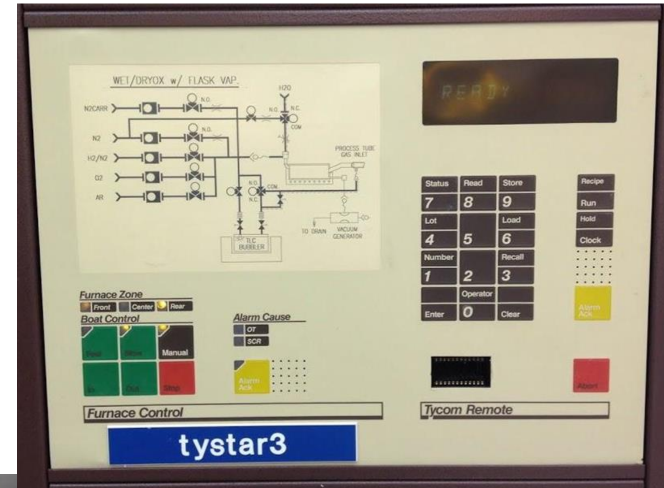
- deposit standard oxide1.rec
- adjust HF and LF pulse times
- deposit 1 μm
- measure
- adjust HF and LF accordingly
    - based on index

Process: Cleaning the Wafers

- msink6
  - 10 min piranha
  - 4 cycle water
  - 1 min 10:1 HF
  - 4 cycle water
  - spin dry

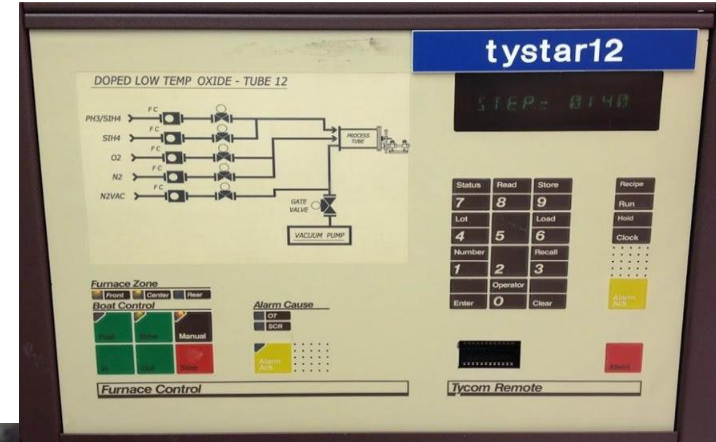
Process: Thermal Oxide

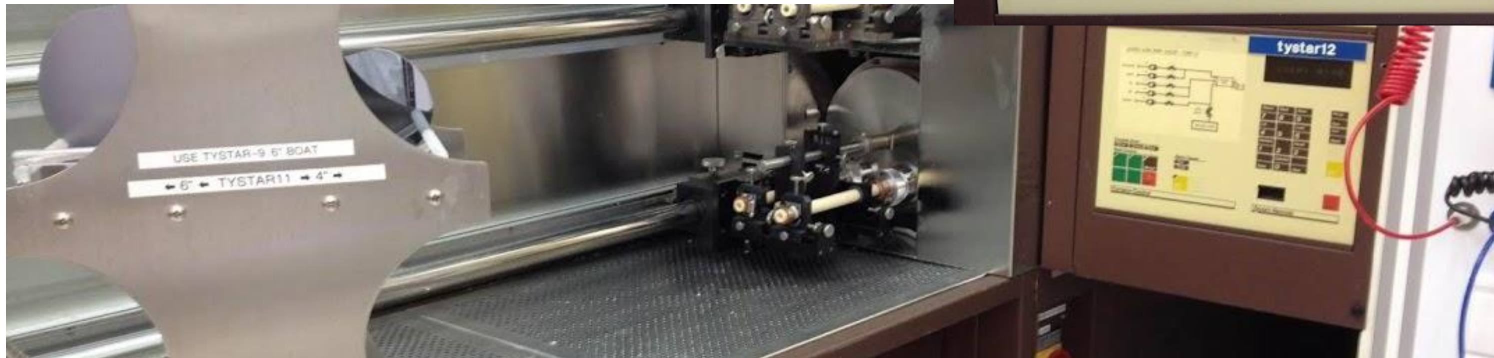
- tystar 3
  - 3 hrs 5 min 43 sec
  - 3WETOXA
  - 1050 °C, 760 Torr



Process: Low Temp Oxide

- tystar 12
  - 1 hr 28 min 53 sec
  - 12SULTON
  - 450 °C, 300 mTorr



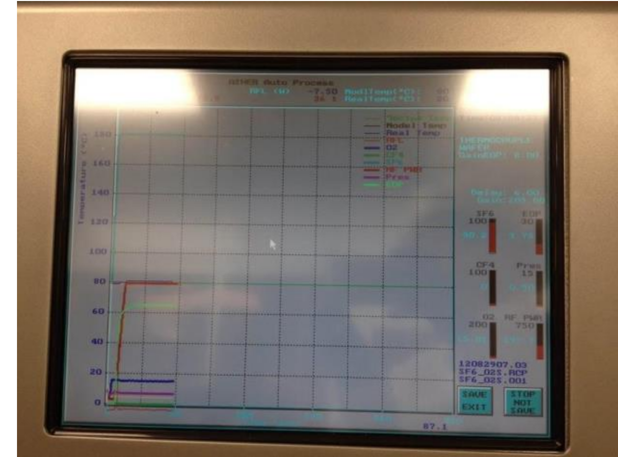


Process: High Temp Oxide

- tystar17
  - 4 hrs
  - HTOSTDA
  - 920 °C, 400 mTorr

Process: Back Etch

- Matrix Etch
- ~ 25 minutes
- SF_6 and O_2



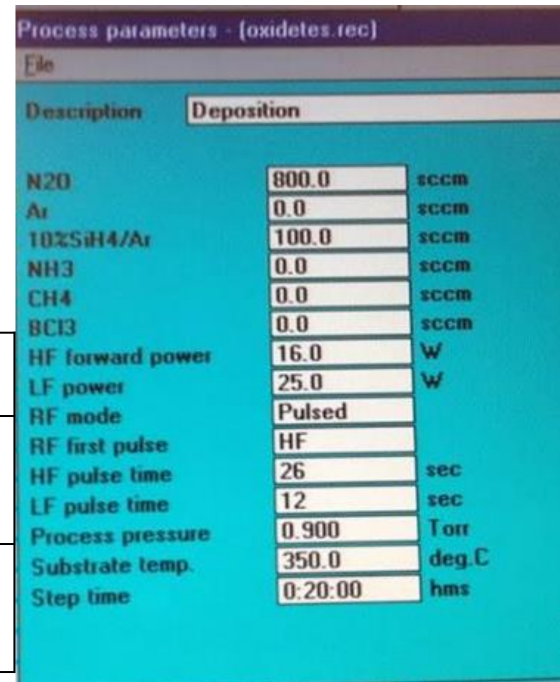
Process: PQECR Oxide

- PQECR
  - 15 min 17 sec
  - Gas Flows:
    - O_2: 36.20 sccm
    - SiH_4: 138.49 sccm
    - Ar: 127.66 sccm
  - 19 °C, 34.35 mTorr

Process: Oxford2 Oxide

- 20 min
- 350 °C, 0.9 Torr
- HF: 16 W (25 W actual)
- LF: 25 W (~30 W actual)

	trial 1	trial 2	trial 3	trial 4	trial 5	trial 6	trial 7
HF Pulse Time (sec)	26	26	26	26	18	21	52
LF Pulse Time (sec)	6	12	18	13	8	10	24



Process: Measurements

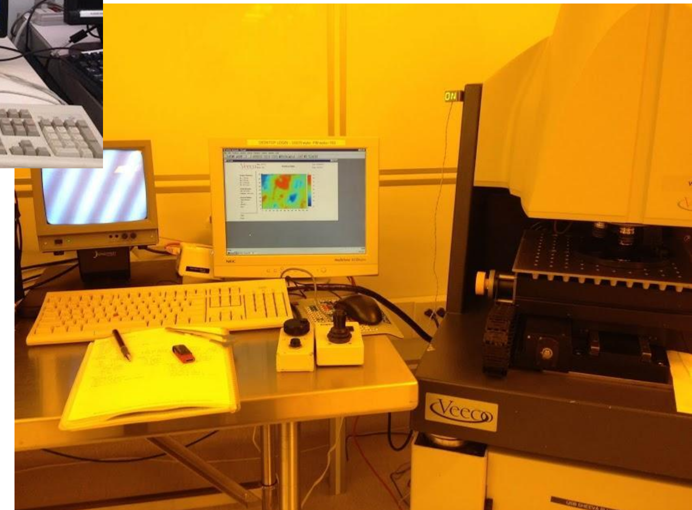
- nanoduv: approx. thickness & index
- ellips: more accurate thickness & index

Process: Measurements

- flexus: wafer stress

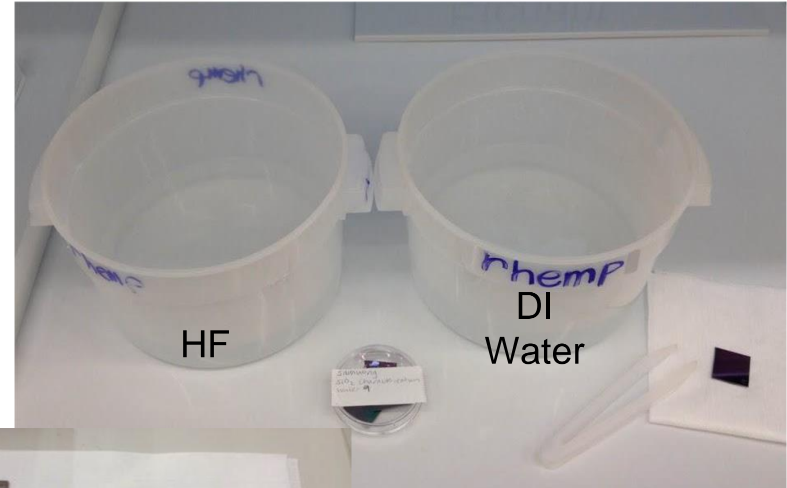
- SCA: oxide charge

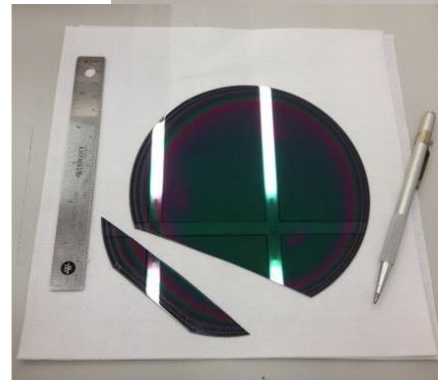
- wyko: surface roughness



Process: Measurements

- chemical etch
  - slice wafers
  - 5:1 BHF for 5 sec
  - water for 5 sec
  - N_2 dry
  - measure thickness
  - repeat

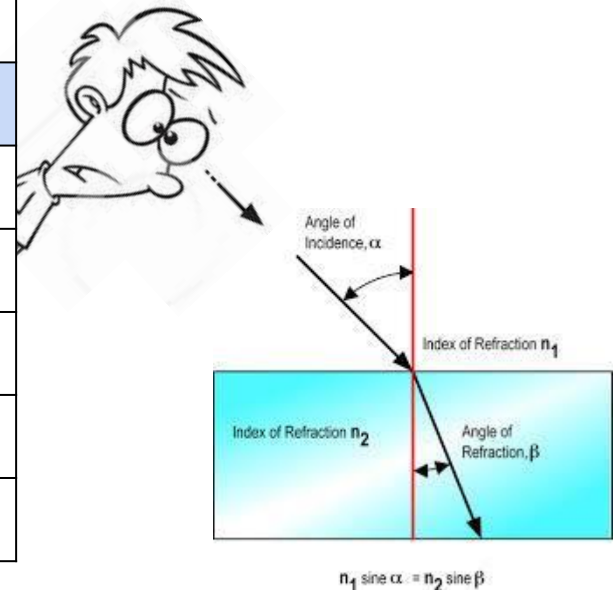




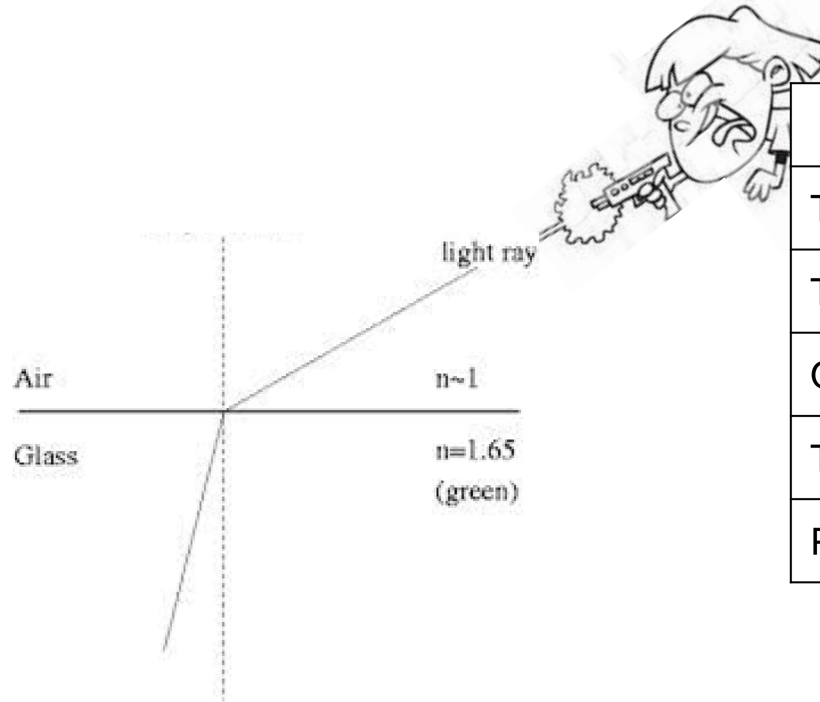
Results: Index of Refraction (Oxford2)

High Frequency Pulse (sec)	Low Frequency Pulse (sec)	Index
26	6	1.42
26	12	1.46
26	18	1.48
26	13	1.47
18	8	-
21	10	-
52	24	-

- Oxide1.rec: 1.32
- Thermal: 1.46



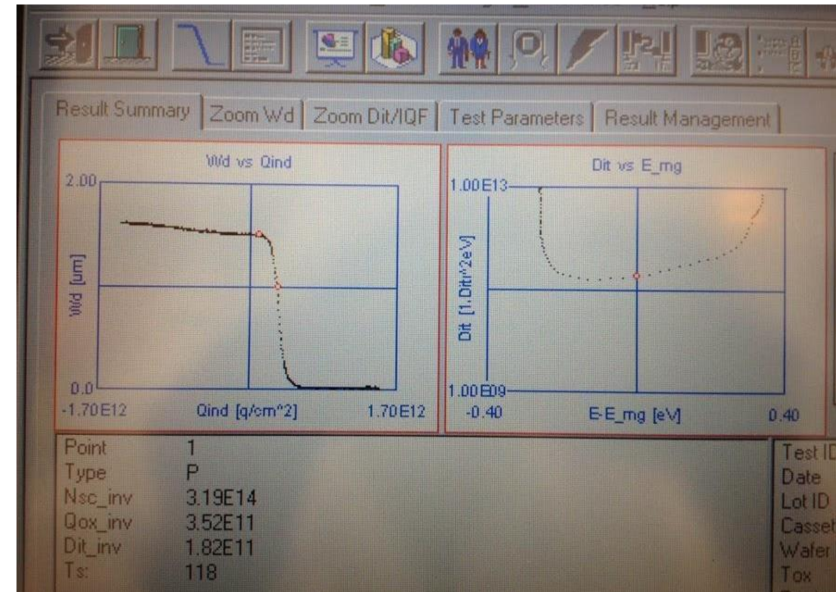
Results: Index of Refraction



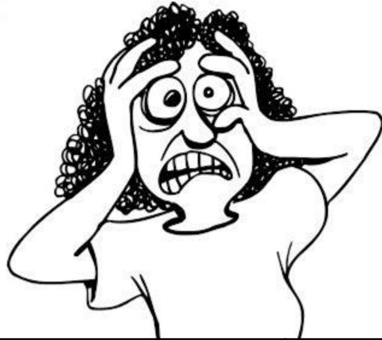
	Index
Tystar 3 (thermal)	1.46
Tystar 17 (HTO)	1.46
Oxford2 (Best HiLo Rec)	1.46
Tystar 12 (LTO)	1.45
PQECR	1.43

Results: Oxide Charge

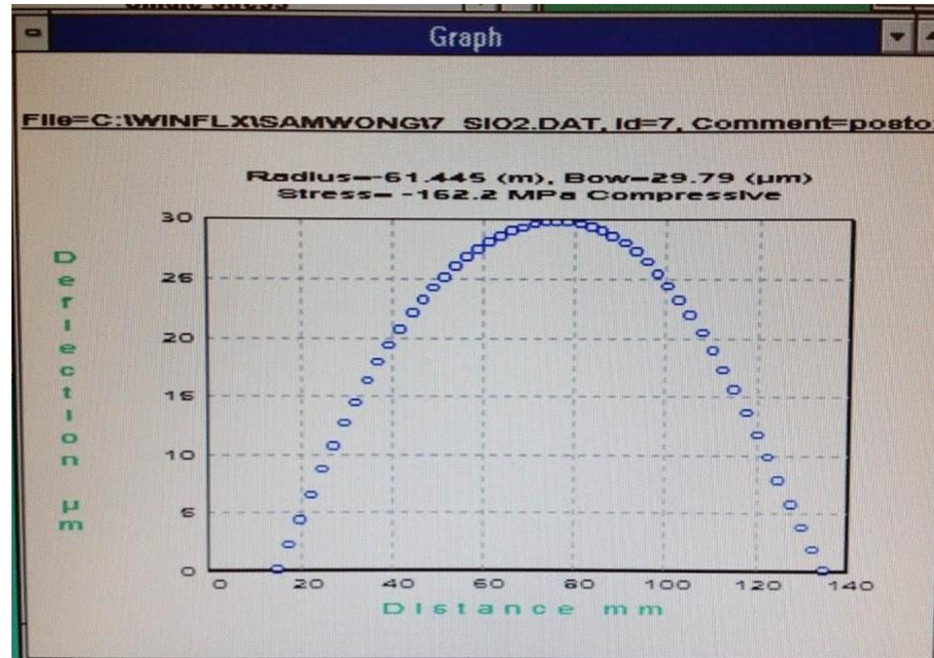
	Charge (q/cm²)
Tystar 3 (thermal)	-2.37E10
Tystar 17 (HTO)	-7.41E10
Tystar 12 (LTO)	3.75E11
Oxford2 (Best HiLo Rec)	1.09E12
PQECR	1.99E12



Results: Stress

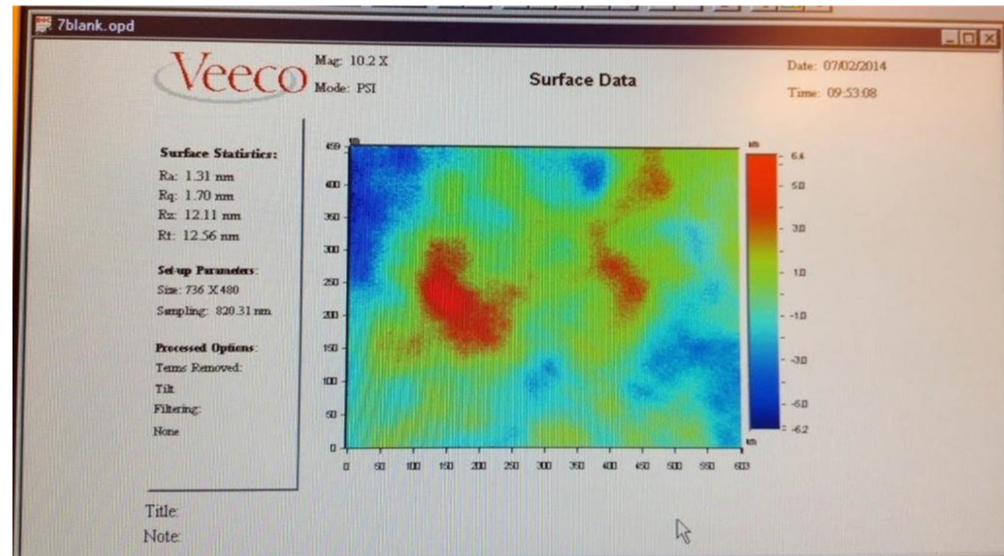


	Stress (MPa)
PQECR	<10
Tystar 12 (LTO)	-85
Tystar 17 (HTO)	-110
Oxford2 (Best HiLo Rec)	-162
Tystar 3 (Thermal)	-258



Results: Surface Roughness

	Average Roughness (nm)
Bare Si Wafer	1.03
Tystar 17 (HTO)	1.24
Tystar 12 (LTO)	1.40
Oxford2 (Best HiLo Rec)	1.44
Tystar 3 (Thermal)	2.88
PQECR	3.41

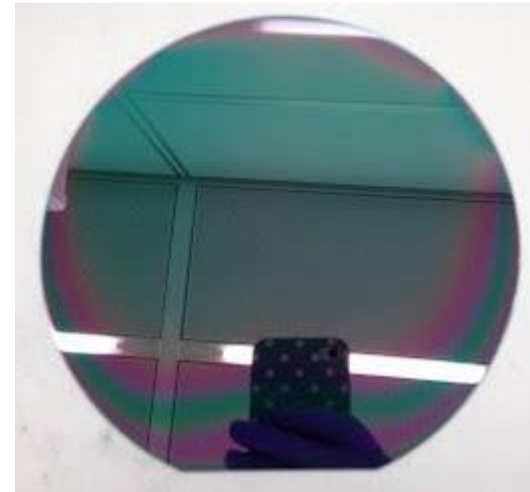


Conclusions: Oxford2

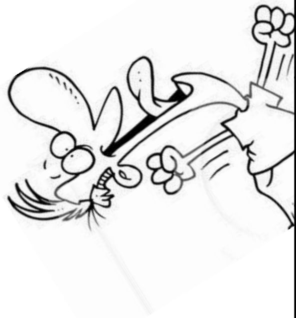
Best recipe:

HF Power	16 Watts (Actual 25 W)
LF Power	25 Watts
HF Pulse	26 secs
LF Pulse	12 secs
Time	20 mins

- index: 1.46
- boundaries



Conclusions: General



Property	Best Tool	2nd	3rd	4th	5th
Index of Refraction	tystar3	tystar17	Oxford2	tystar12	PQECR
Oxide Charge	tystar3	tystar17	tystar12	Oxford2	PQECR
Surface Roughness	tystar17	tystar12	Oxford2	tystar3	PQECR
Etch Rate	tystar3	tystar17	tystar12	Oxford2	PQECR

- Stress: “best tool” dependent on need

Acknowledgements

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