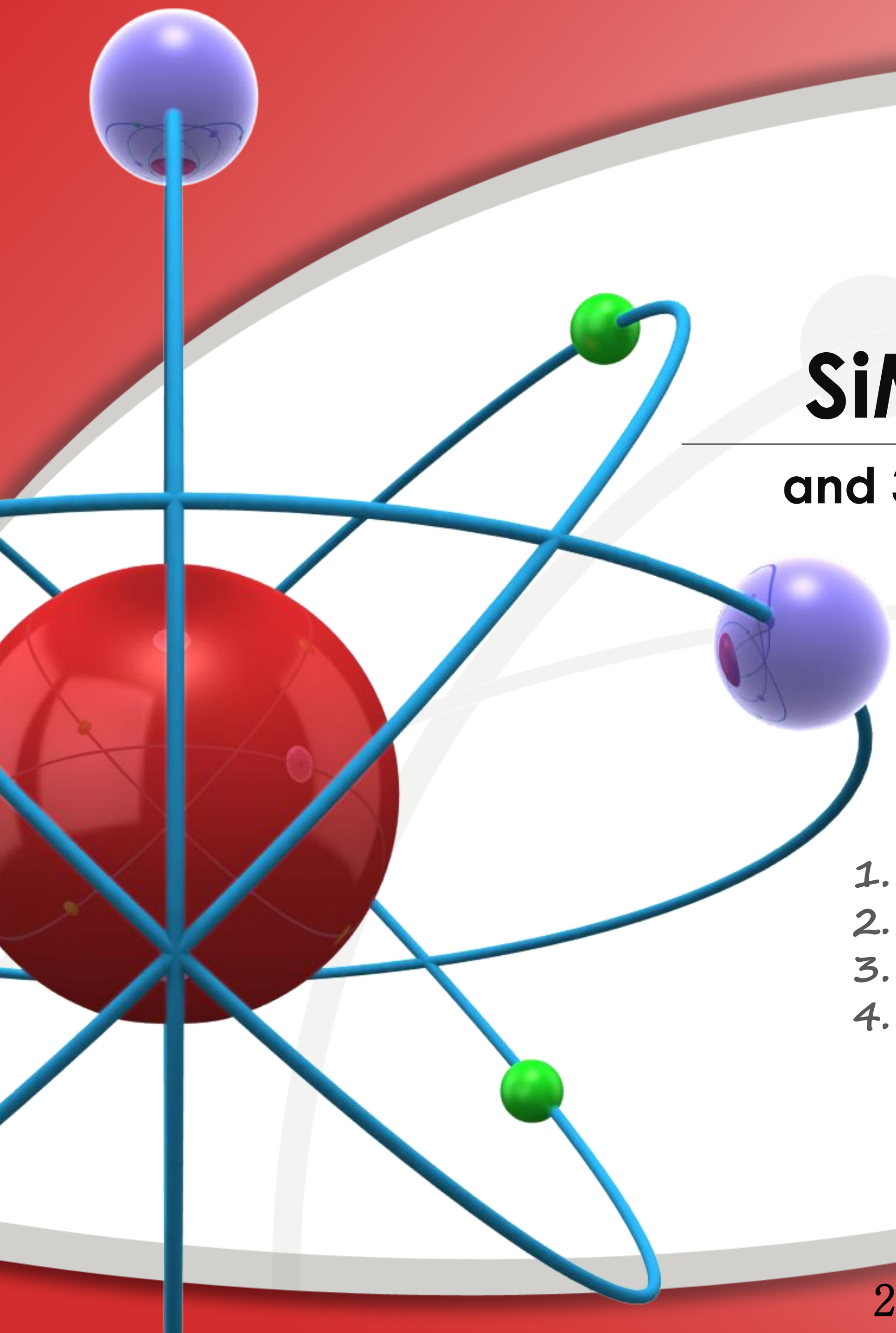


SiMS Measurements

and 3D Simulation on variant stuctures

V. Gkougkousis[1]
A. Lounis[1,2], N. Dinu[1], A. Bassalat[1,2],
C. Nellist[1,2], S. Dumitriu[1,4]

1. Laboratoire de L'accélérateur Linéaire
2. Université Paris-SUD XI
3. CERN
4. CEA

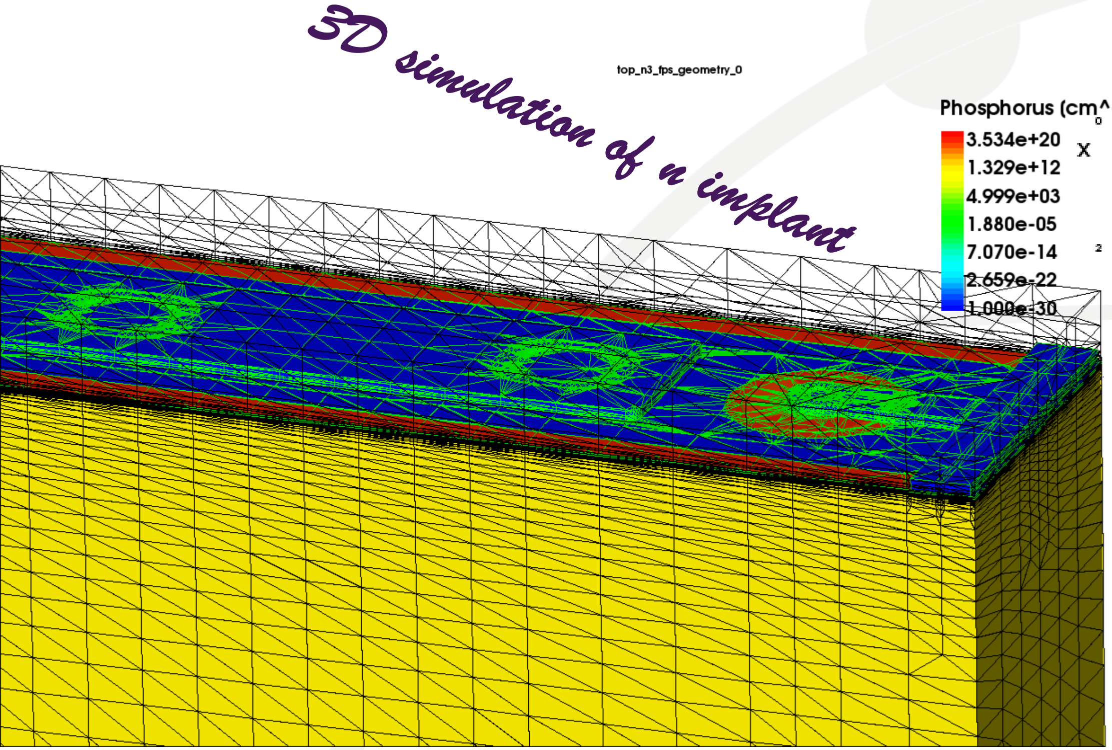
24th RD50 Workshop, Bucharest– 12/6/2014

Overview

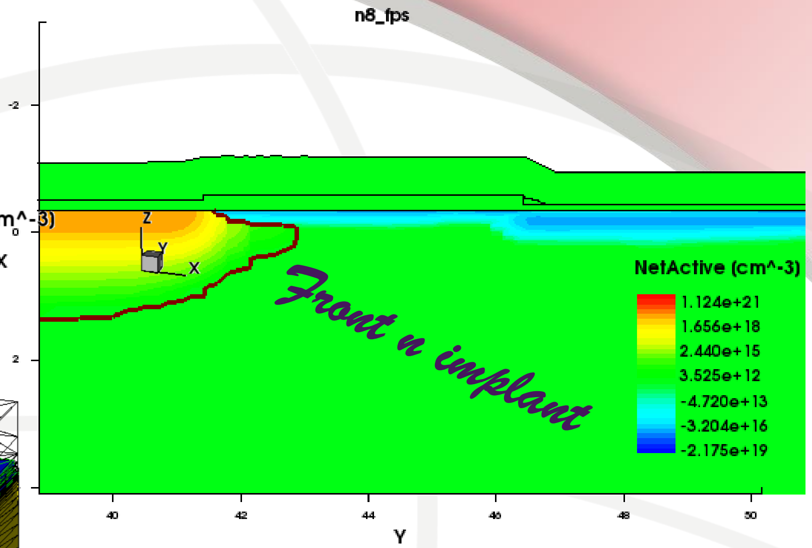
Introduction	3D profile simulations of CiS structures
SiMS measurements	Procedure and sample preparation Equipment and team, preprocessing
Callibration wafers	CiS and Advacam uniformly doped wafers
Simulation vs SiMS	N implanted wafers Doping profiles simulation
CiS Structures	Varied bias rail structures Ivs and Simulations
Conclusions - Plans	Testing, Production and plans for VTT wafers

•3D Simulation

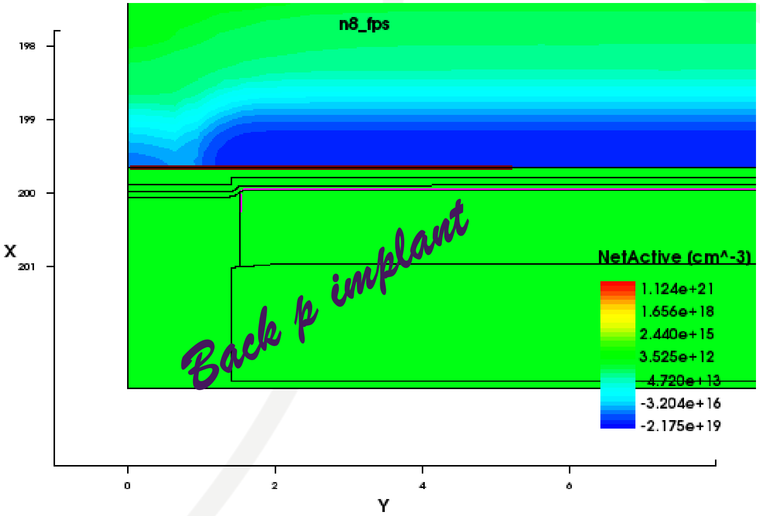
CiS IBL Doping Profiles



3D simulation of n implant



Front n implant

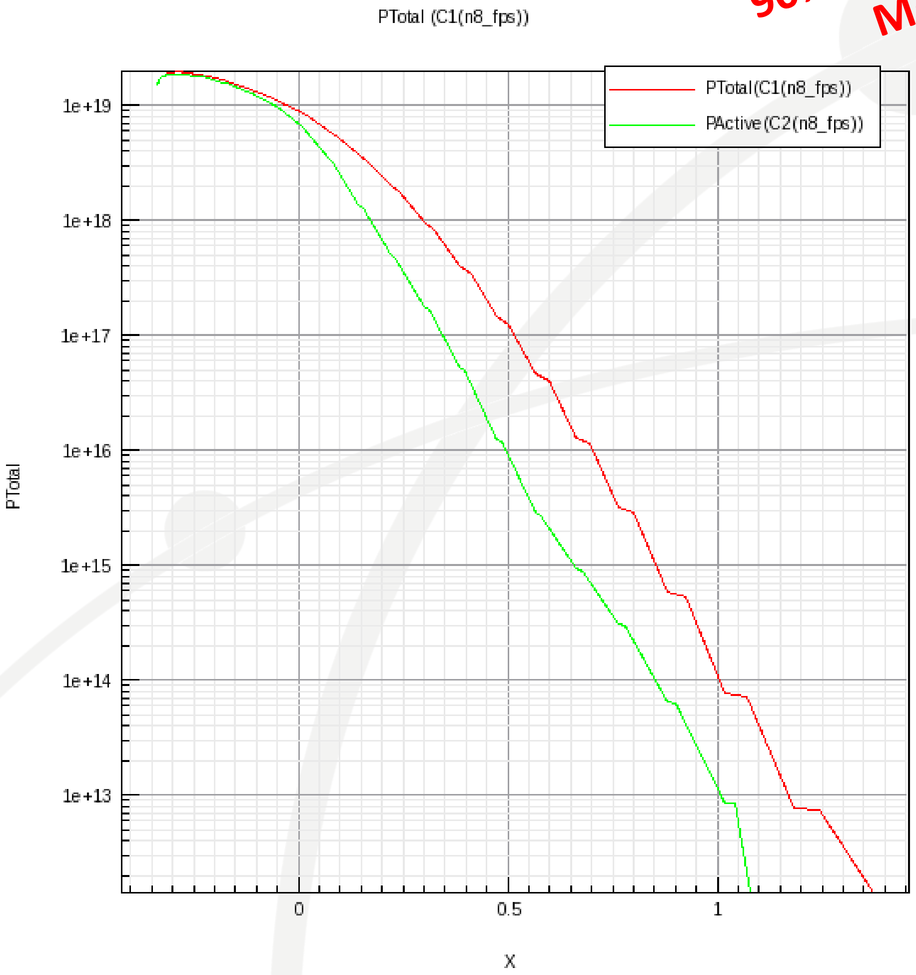


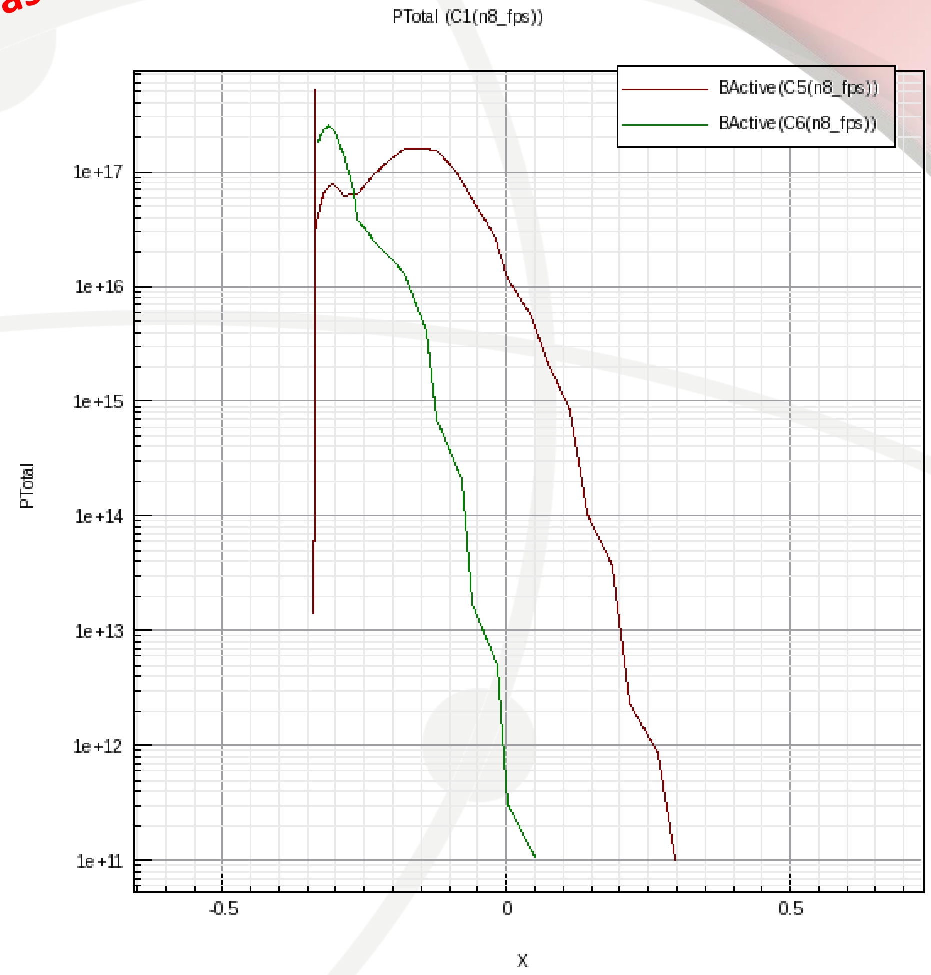
Back p implant

•3D Simulation

Doping Profiles

90% agreement with SiMS Measurements

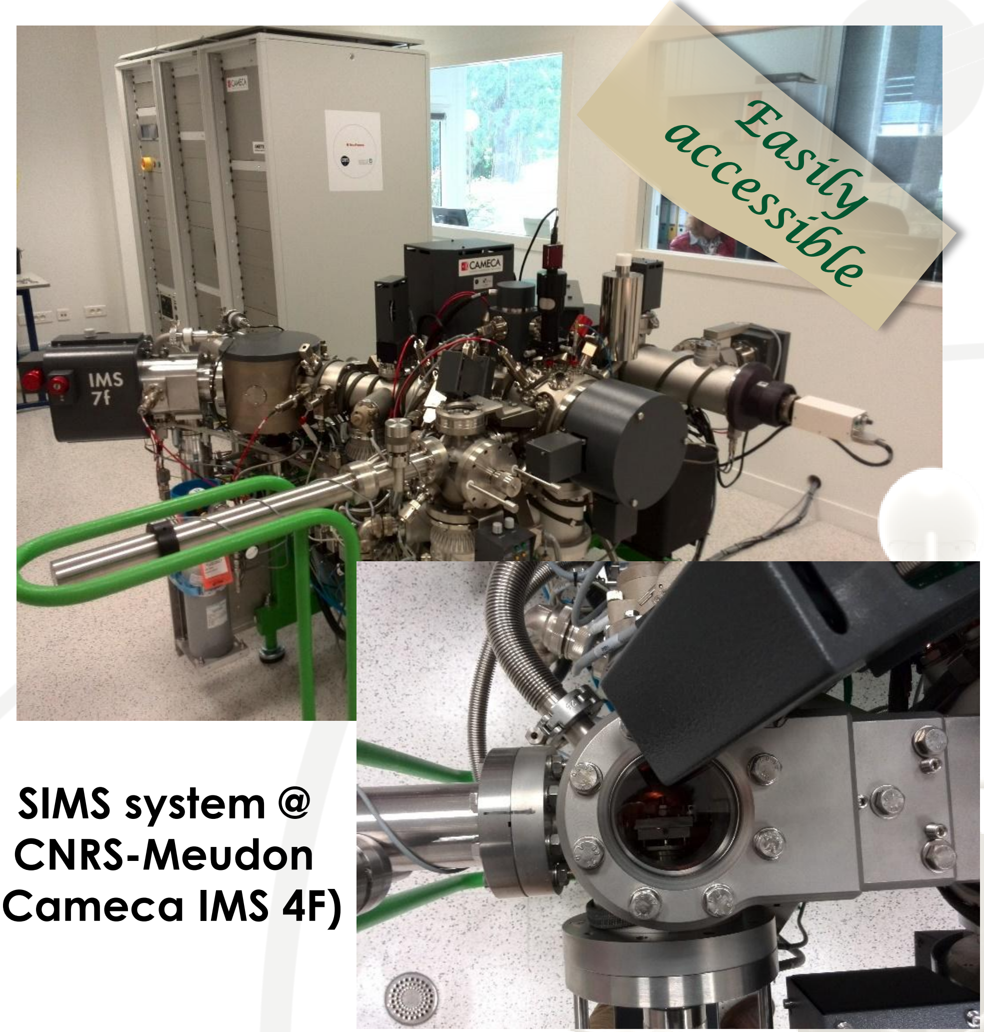




•Doping profile measurements

SiMS Method @ Versailles

(slide by N. Dinu)


Easily accessible

SIMS system @ CNRS-Meudon (Cameca IMS 4F)

- ✓ Analytical technique to *characterize the impurities in the surface and near surface (~30μm) region*
- ✓ Relies on sputtering of a *primary energetic ion beam (0.5-20 keV)* on sample surface and analysis of produced ionized secondary particles by mass spectrometry
- ✓ Good detection sensitivity for many elements: *it can detect dopant densities as low as 10^{14} cm^{-3}*
- ✓ Allows multielement detection, *has a depth resolution of 1 to 5 nm* and can give a lateral surface characterization on a scale of several microns
- ✓ Destructive method, since the act of the removing material by sputtering leaves a crater in a sample
- ✓ It determines the *total dopant density profile*

•Doping profile measurements

Sample preparation

Sample preparation

- Sample preparation
  - Wafer Dicing (Uniformly doped wafers of 4" and 6", not thinned)
  - Chemical oxide etching
  - Diamond powder surface polishing
  - Bevel cutting with 2° angle
- Future plans
  - Through-oxide measurements under way
  - Investigation of oxide layer thickness with respect to etching rates and time

Sample preparation and measurements

- Nicoleta Dinu
- Sorin Dumitriu
- Francois Jomard

•Doping profile measurements

CiS and VTT wafers

N in N

N in N, CiS production, <100> orientation														
Oxide thickness	100 nm							200 nm						
P implantation doses	10^{13} cm^{-2}		10^{14} cm^{-2}		10^{15} cm^{-2}		10^{16} cm^{-2}	10^{13} cm^{-2}		10^{14} cm^{-2}		10^{15} cm^{-2}		10^{16} cm^{-2}
Implantation energy (keV)	130	240	130	240	130	240	130	130	240	130	240	130	430	130
Annealing	4hours, 975 °C													

- ✓ $\rho = 0.25\ \Omega/\text{cm}$ ($3 \times 10^{16}/\text{cm}^3$) 380µm thickness
- ✓ $\rho = 4\ \text{k}\Omega/\text{cm}$ ($1{,}1 \times 10^{12}/\text{cm}^3$) 525µm thickness

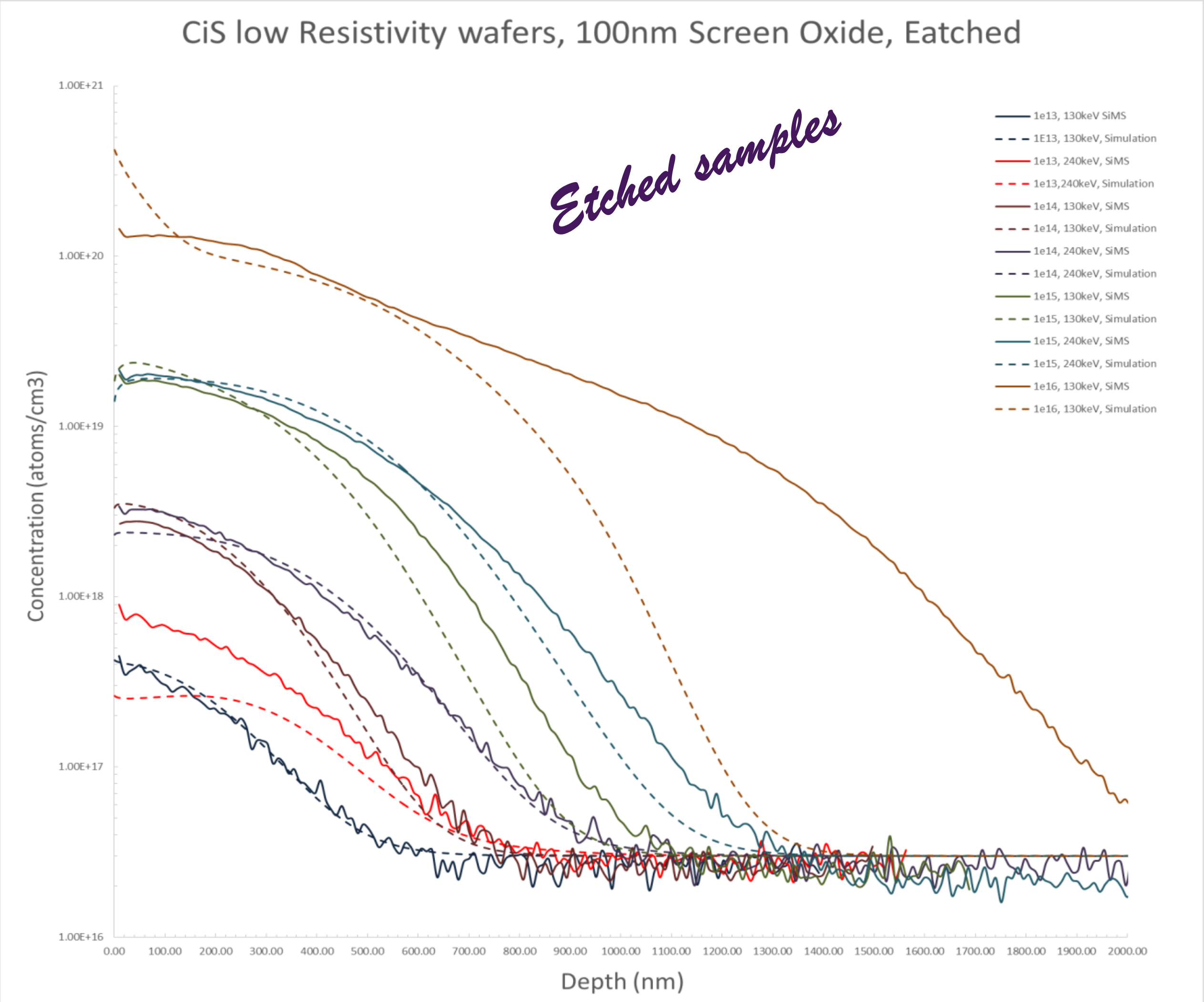
N in P

N in P, VTT production, <100> orientation, thickness of 675 µm or less,																
Oxide thickness	100 nm								200 nm							
P implantation doses	10^{13} cm^{-2}		10^{14} cm^{-2}		10^{15} cm^{-2}		10^{16} cm^{-2}		10^{13} cm^{-2}		10^{14} cm^{-2}		10^{15} cm^{-2}		10^{6} cm^{-2}	
Implantation energy (keV)	130	250	130	250	130	250	130	250	130	250	130	250	130	250	130	250
Annealing	3hours, 1000 °C (1h annealing + 1h wer oxidation +1h dry oxidation)															

- ✓ $\rho > 4\ \text{k}\Omega/\text{cm}$ (1.1×10^{12}) - 525µm thickness
- ✓ $\rho = 0.2 - 0..25\ \Omega/\text{cm}$ ($2.5 - 3 \times 10^{16}$) – 675µm thickness

•Doping profile measurements

ρ = 0.25 Ω/cm (3 x10^{16}/cm^3) 380μm thickness (n in n)



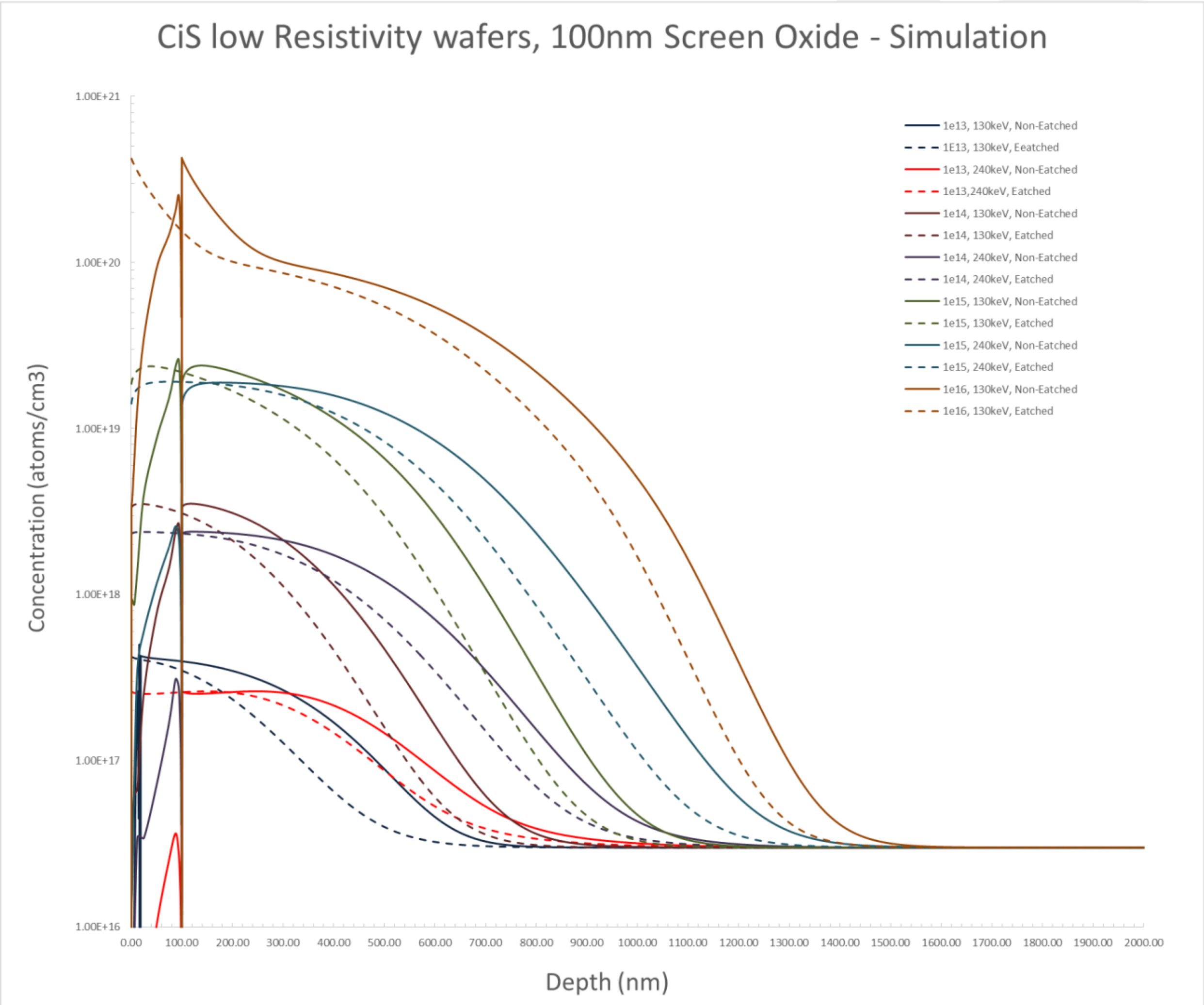
Etched samples

1. **Synopsys MC Crystal TRIM full cascade simulator**
2. **Final oxide layer etching step implemented**
3. **Normal thermal annealing for implant activation**

- Overall good agreement for low doses
- Pronounced deviations of depth concentration for high doses
- Surface dose agreement for all samples
- Evidence of important surface effects for high dose wafers

•Simulated doping profiles

ρ = 0.25 Ω/cm (3 x10^{16}/cm^3) 380μm thickness (n in n)



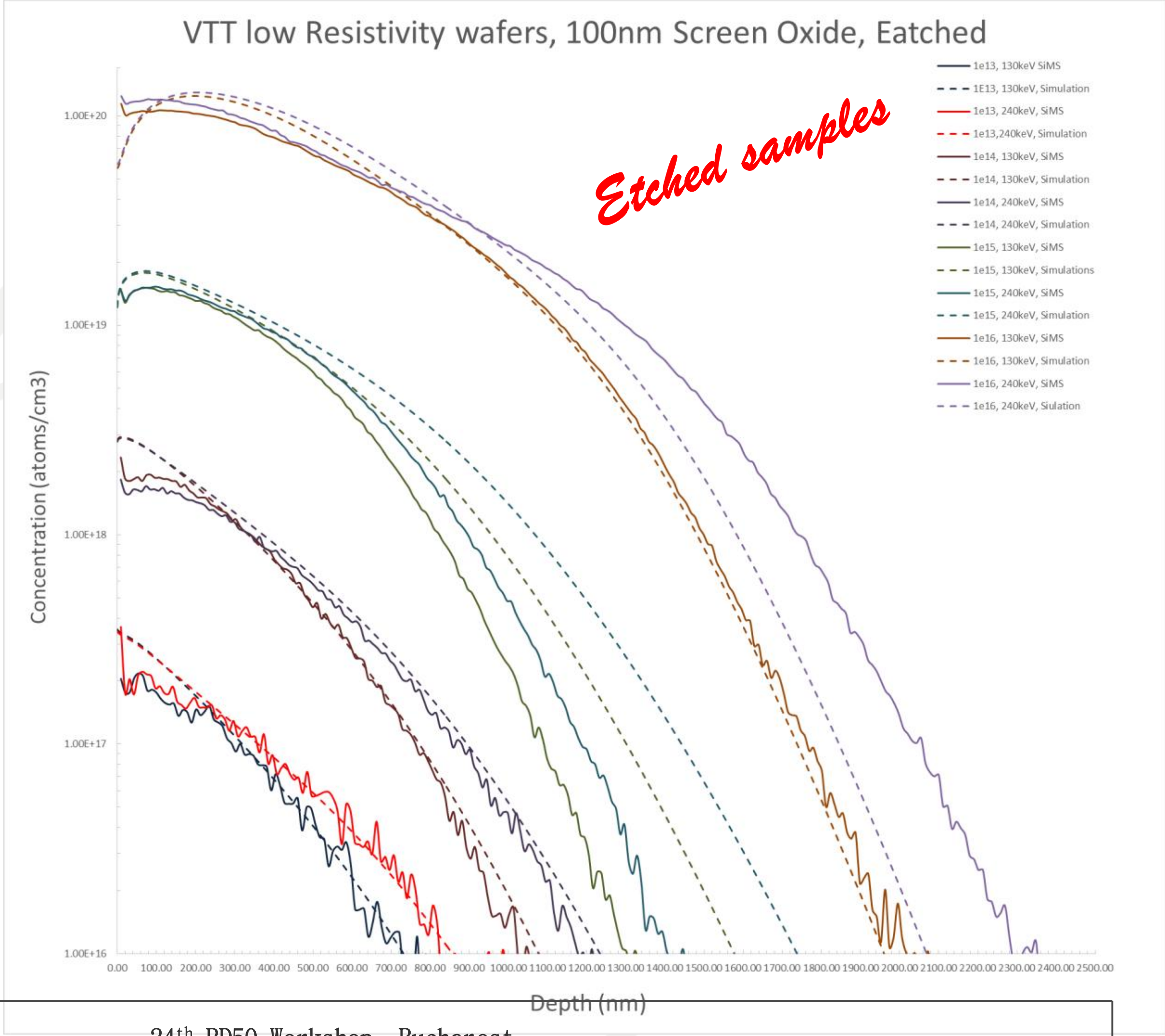
Etched and Non-etched simulations

- Investigation of the deposited implant on the oxide layer
- Measurements through the silicon oxide under way
- Simulations show a 300nm displacement with no modification of the dopant concentration distribution
- Provide insight for disagreement between simulation – SiMS and the quantity of implant trapped at the oxide layer
- High Resistivity wafer measurements under way, simulations show no variation of profile distribution

•Doping profile measurements

ρ = 0.25 Ω/cm (3 x10^{16}/cm^3) 675µm thickness (n in p)

- ☐ Simulations have been displaced towards 0 to compensate for oxide growth
- ☐ Advacam uses annealing through oxidation
- ☐ Dry + wet oxidation that really ‘eats-up’ dopant
- ☐ Oxide removed for SiMS
- ☐ Simulated oxide diffusion and complete oxidation



•Doping profile Simulations

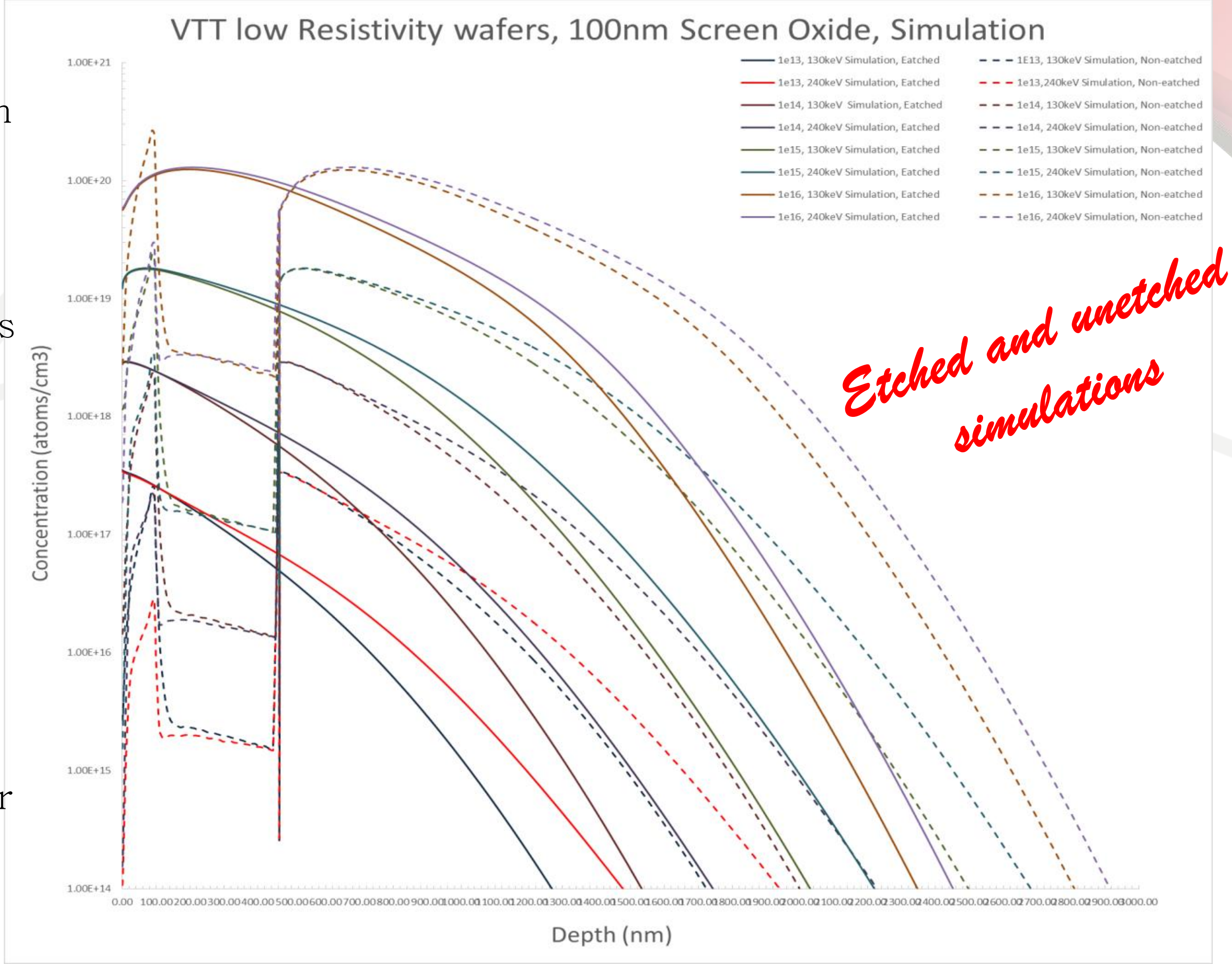
ρ = 0.25 Ω/cm (3 x10^{16}/cm^3) 675μm thickness (n in p)

Remarks

- Overall good agreement on the low and intermediate doses
- Disagreement on the profile distribution for the higher- intermediate doses but almost perfect agreement for one of the highest ones
- Deviation trend between simulation – SiMS exhibits contradicting behavior

Wafer – annealing uniformity??

- No difference expected for etched – non-etched samples

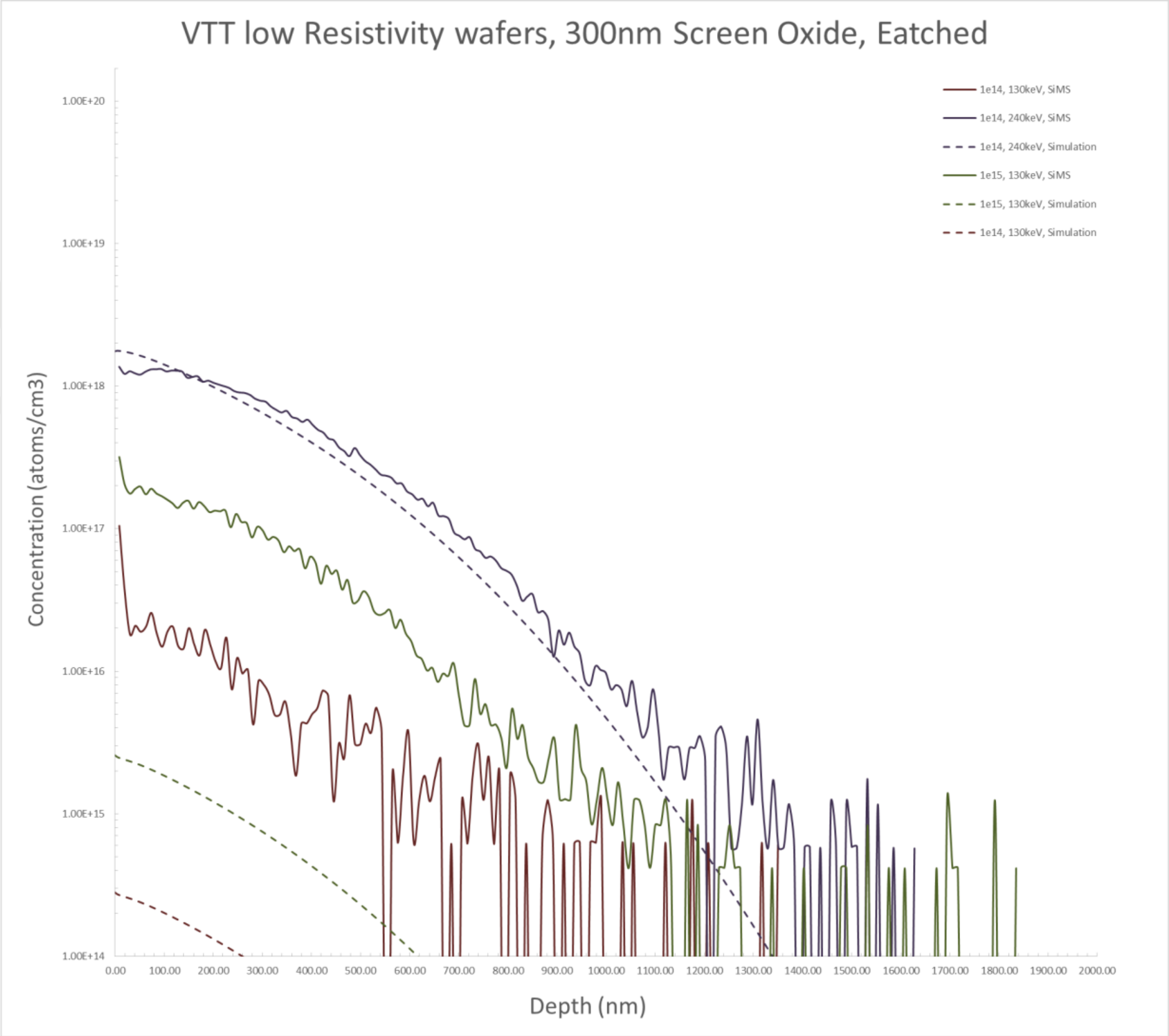


Etched and unetched simulations

•Doping profile measurements

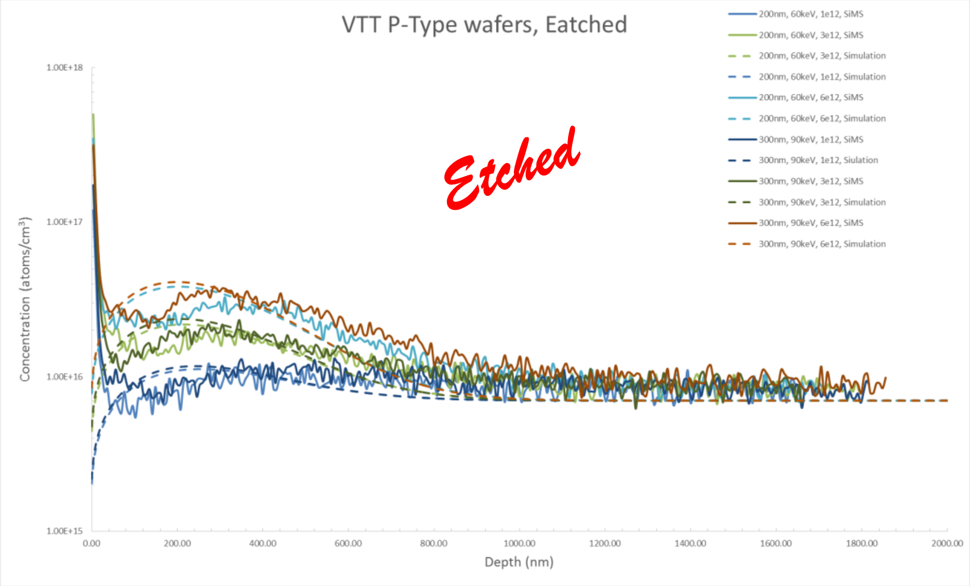
ρ = 0.25 Ω/cm (3 x10^{16}/cm^3) 675μm thickness (n in p)

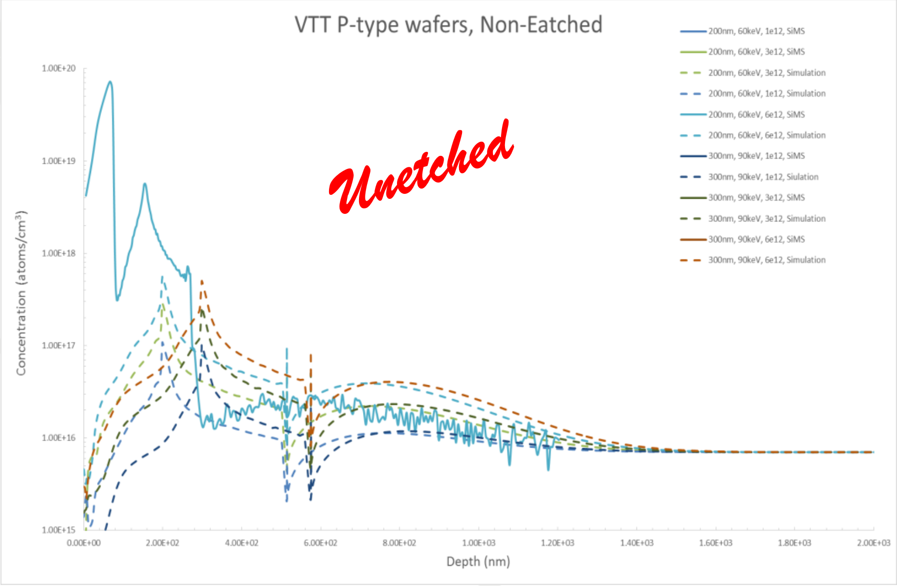
- 300nm screen oxide used
- Same parameters as in the 100 nm screen oxide case
- Lower dose in the limits of measurements
- More pronounced deviations between SiMS and simulations with good agreement for the high dose



•Doping profile measurements

ADVACAM p spray Calibration Wafers





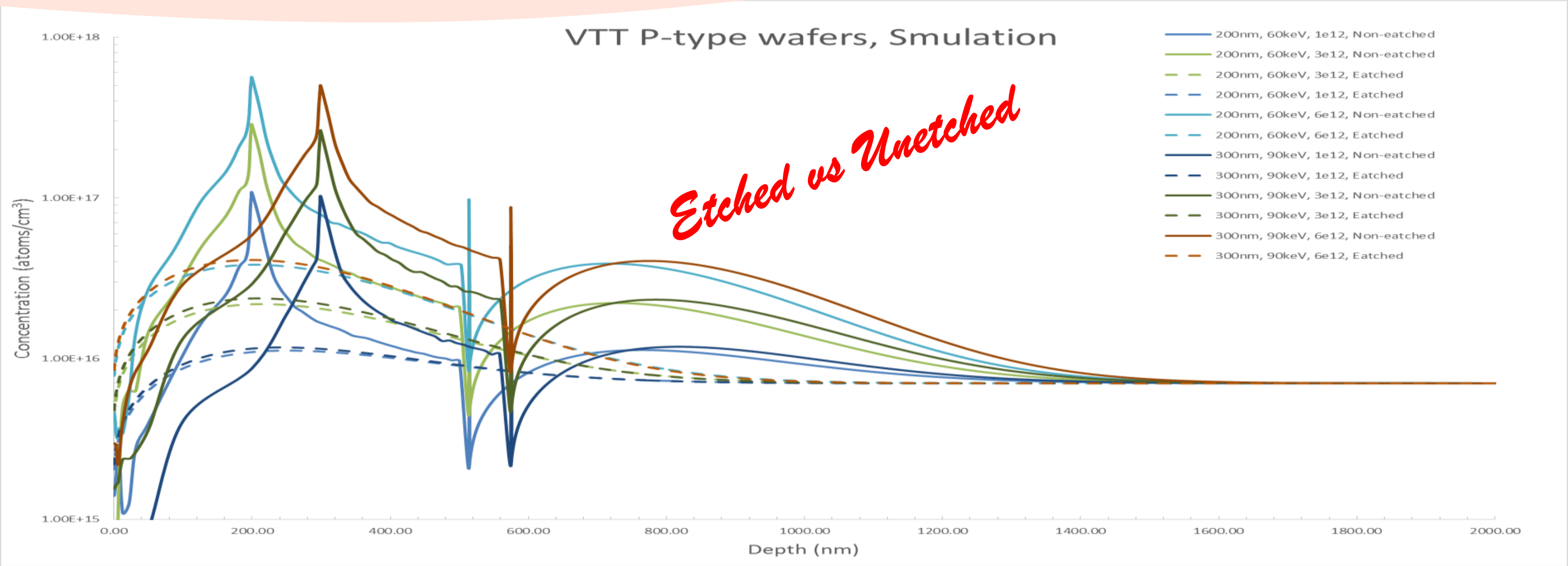
N in P, VTT production, <100> orientation						
Oxide thickness	200nm			300nm		
P implantation doses	$1X10^{12}$ cm^{-2}	$3X10^{12}$ cm^{-2}	$6X10^{12}$ cm^{-2}	$1X10^{12}$ cm^{-2}	$3X10^{12}$ cm^{-2}	$6X10^{12}$ cm^{-2}
Implantation energy	60 KeV			90 KeV		
Annealing	3hours, 1000 °C					

✓ ρ = 2 Ω/cm (7 x 10^{15}) – 380μm thickness

•Doping profile Simulations

ADVACAM p spray Calibration Wafers

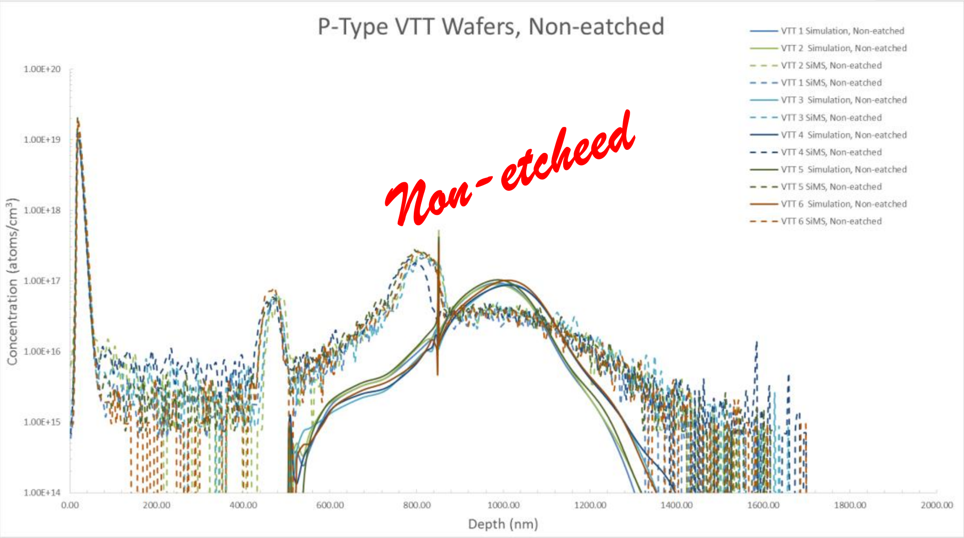
- ✓ p-Spray was performed on low resistivity wafers, at the limit of measurement accuracy
- ✓ 200nm displacement between simulated and measured profile
- ✓ Through oxide measurements exhibit same behavior
- ✓ Quantitavely good agreement, displacement issue needs further investigation

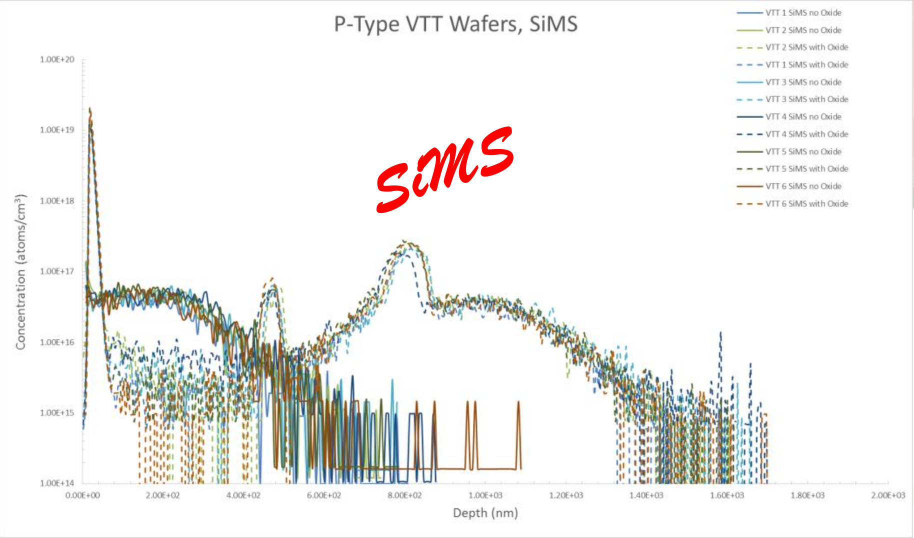


Etched vs Unetched

•Doping profile measurements

VTT p spray Calibration Wafers





N in P, VTT production, <100> orientation						
Oxide thickness	355nm					
P implantation doses	$1.8X10^{12}$ cm^{-2}				$2X10^{12}$ cm^{-2}	
Implantation energy	140 KeV		150 keV		90 KeV	
Annealing	150min, 900 °C	60min, 950 °C	150min, 900 °C	60min, 950 °C	150min, 900 °C	60min, 950 °C

- ✓ ρ = 4 kΩ/cm (1.1 x 10^{12}) – 525μm thickness

•Simulated doping profiles

Conclusions

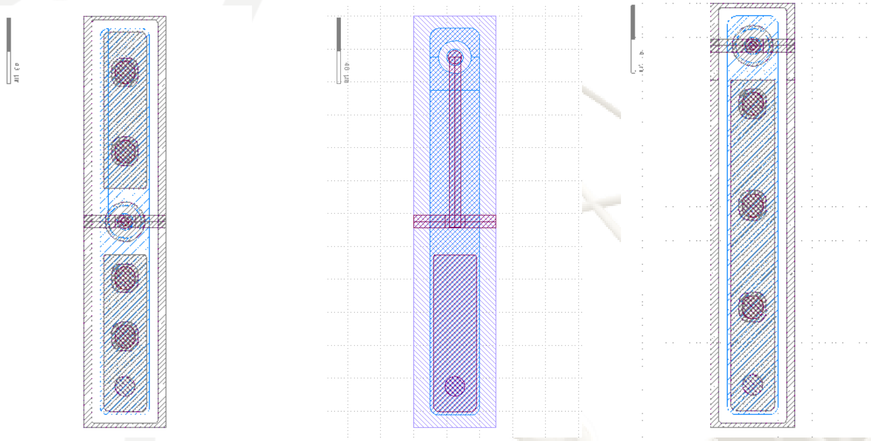
- ✓ In CiS wafers the simulated implant depth is much less than the SiMS measured one. Effect significantly remarkable in high dose
- ✓ In VTT P-Spray wafers there is a displacement of the simulated curves to compensate for the oxide growth which is later etched. Displacement is in the order of 200nm
- ✓ VTT n-implanted wafers present same implant depth divergence as VTT wafers with a less effect. More detailed information needed in terms of oxide growth recopies and temperatures
- ✓ 300 nm VTT wafers have very low doses, not well simulated

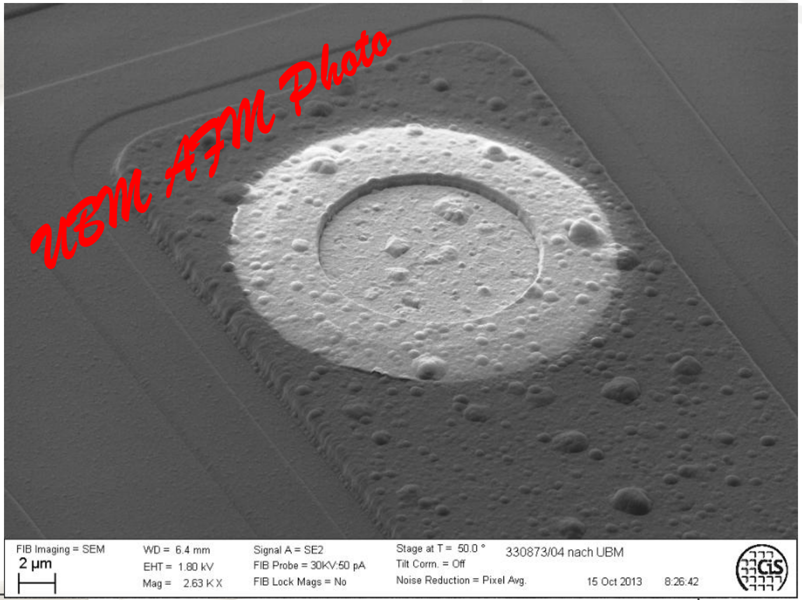
•CiS Collaboration Structures

Varied Bias rail geometry structures

- ☐ FEI4 compatible structures with classic IBL geometry
- ☐ Bias rail position varies between different columns of the matrix
- ☐ Metallization is removed in certain regions
- ☐ Bias dot moved from pixel edge towards center
- ☐ Several geometries in a single matrix
- ☐ Two standard matrices from same production and wafer were also acquired for reference
- ☐ Diced structures with NI-Ag UBMS

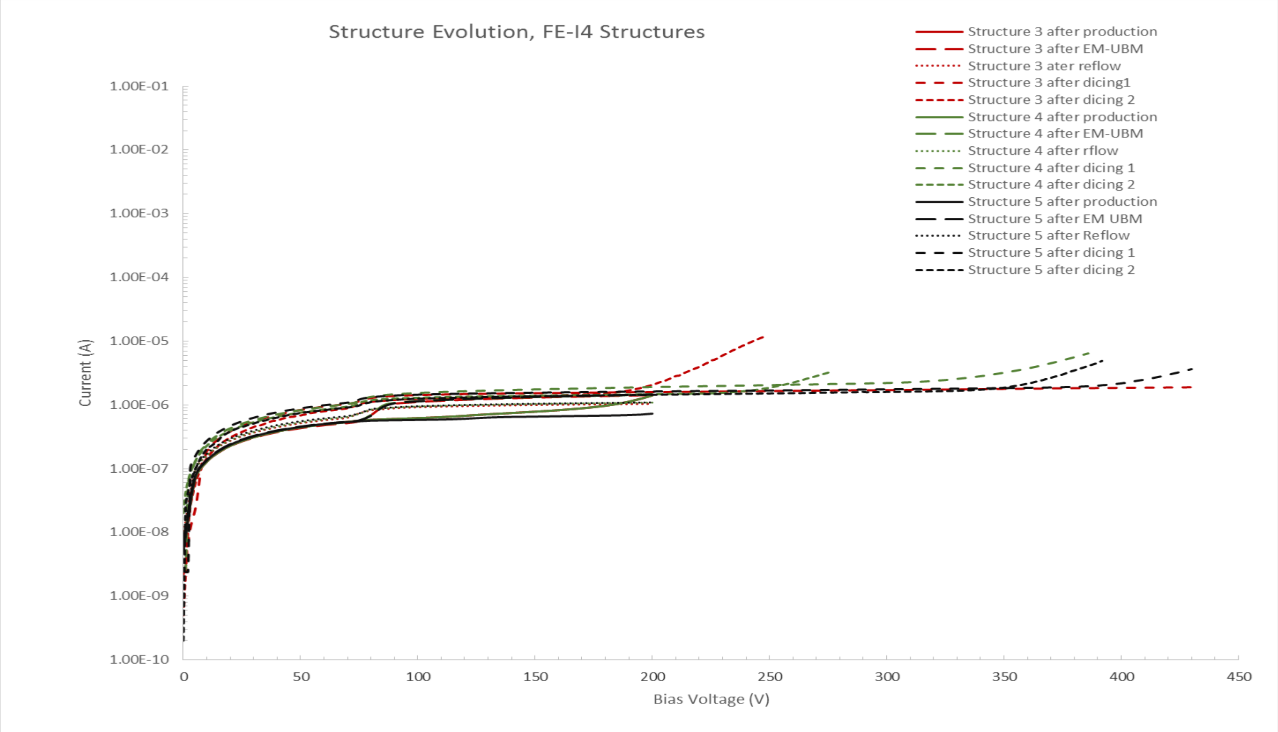
40nm Au
200nm Ni
40nm Ti
Size: 21-22μm





•CiS Collaboration Structures

IV curves – Breakdown Voltages

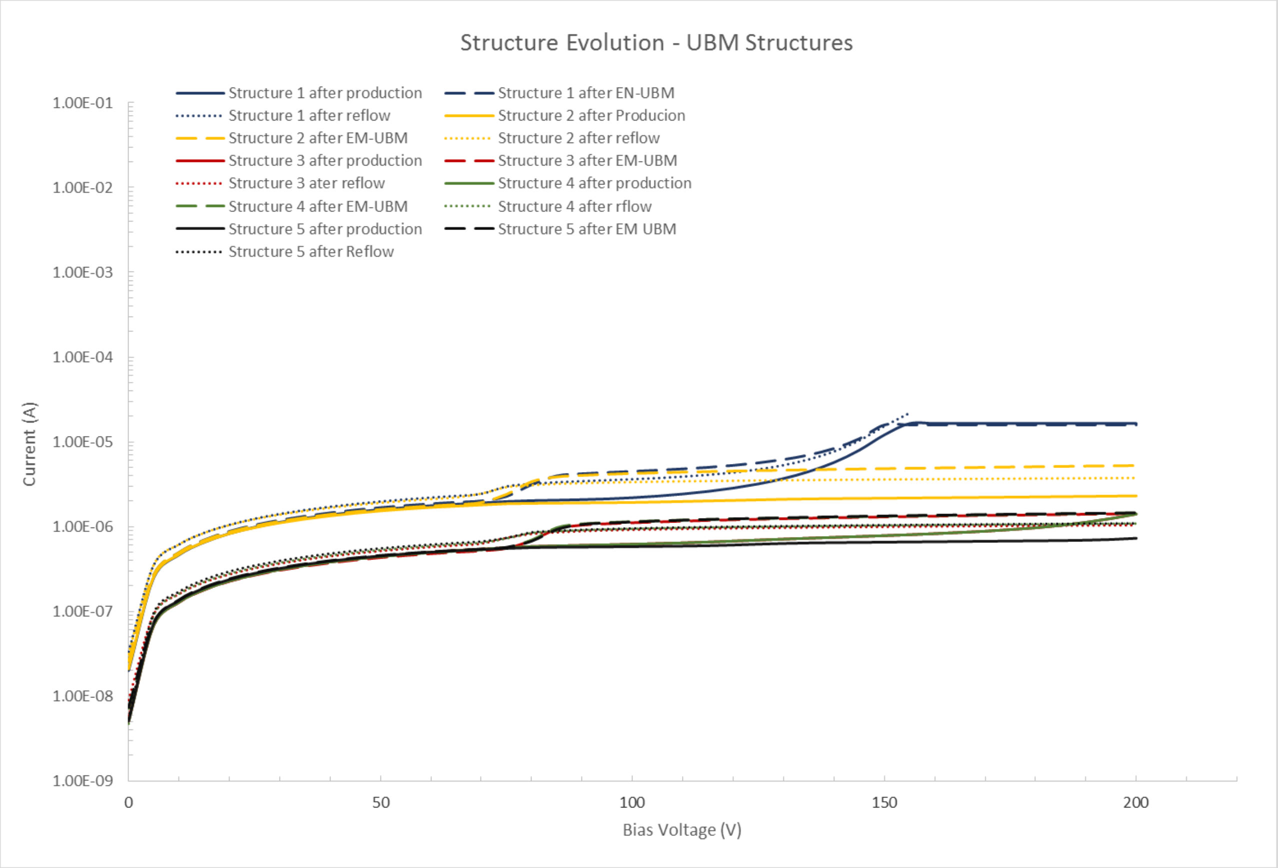


10 minutes reflow at 180°C

- ✓ Breakdown Voltages in order of 430 V for standard structures, decreased to around 250V 11 days afterwards
- ✓ Higher Breakdown voltages for modified structures
- ✓ UBMs already integrated
- ✓ Diced and thermal treated structures

•CiS Collaboration Structures

IV curves – Breakdown Voltages



- ✓ After production structures exhibit normal behavior
- ✓ After UBM deposition leakage current increases and an subnormal bump appears in the IVs
- ✓ Reflow compensates for the bump and decreases leakage but still present

Further Reflow effect??

•Futer Plans

Simulations – Tests - Bounding

- ☐ Investigate evolution of dopping profiles after irradiation and compare SiMS measurements in irradiated samples with simulation
- ☐ Investigate surface and calibration effects for the SiMS measurements
- ☐ Validate SiMS for VTT and complete simulation input for new production
- ☐ Irradiate variant bias rail geometry structures and test efficacy before and after irradiation

THANK YOU FOR YOUR ATTENTION!!