3D TCAD SIMULATION AND DOPING PROFILE MEASUREMENTS OF PLANAR PIXEL SENSORS

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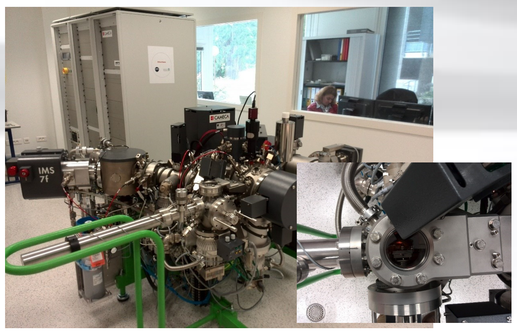
SSRM and Simulations Calibration

Uniformly doped wafers:

1) Controlled parameters
   - Implantation dose and energy
   - Screen oxide thickness and annealing
2) Simplicity in simulation and study
   - No geometrical effects
   - Single implant and oxide layer

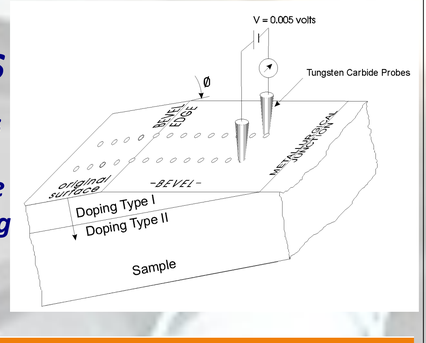


Simulations

- √ SYNOPSYS TCAD simulator
- √ Fabrication and implantation process simulation
- √ MC full cascade and damage calculation
- √ Exact processing parameters from foundries
- √ Thermal stresses and diffusion
- √ Cross-check with different models and simulators

Measurements

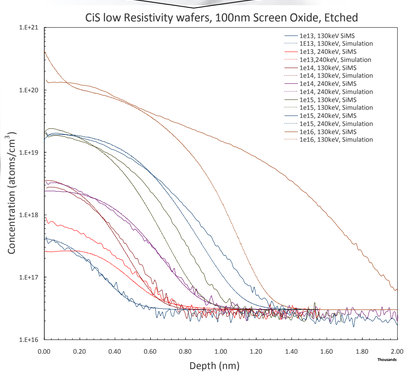
- √ SiMS—Secondary ion mass spectroscopy
- √ SRP—Spreading Resistance
- √ SSRM—Scanning Spreading Resistance Microscopy



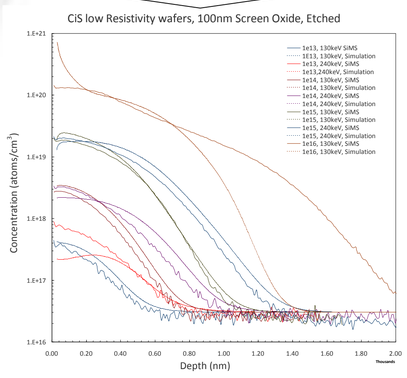
N in N, CiS production, <100> orientation

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													

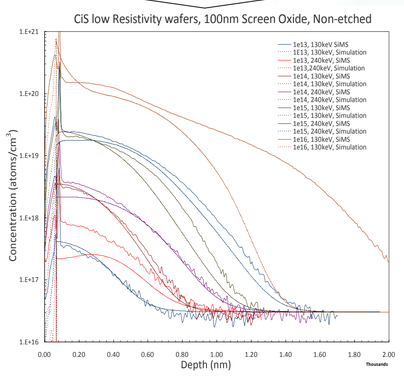
Simulation of 100nm oxide layer deposition with no process parameters taken into account. A systematic deviation towards shallower implant is observed between SiMS and simulations



Detailed oxidation process simulations with foundry parameters. No systematic tendency, rather statistical deviations due to production non uniformity effects. Discrepancy in highest dose.



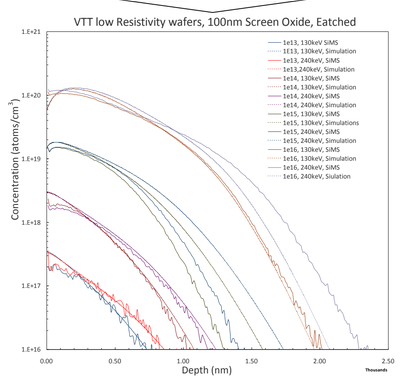
Comparison of SiMS and simulated results for the silicon and the preceding oxide layer. Small disagreement in the level of layer transition due to experimental ion speed corrections.



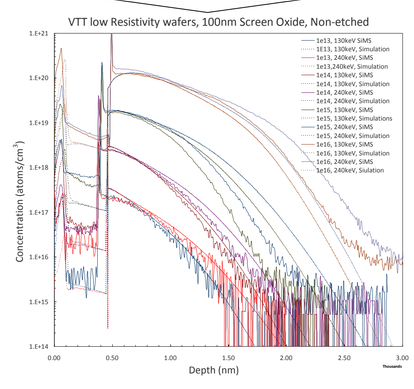
N in P, ADVACAM <100> production, thickness of 675 μm or less

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^{16} cm^{-2}	
Implantation energy (keV)	130	240	130	240	130	240	130	240	130	240	130	240	130	240	130	240
Annealing	3hours, 1000 °C (1h annealing + 1h wet oxidation +1h dry oxidation)															

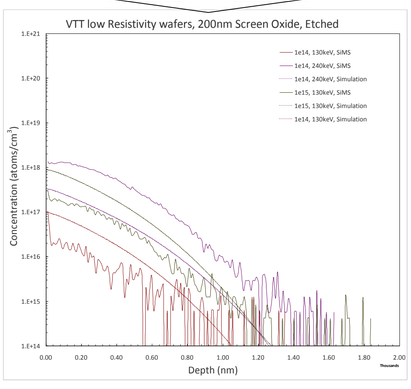
Good agreement between measurements and simulations, no surface effects due to the annealing process of oxide regrowth. Statistical deviations subject to process non-uniformities during production,



Comparison of measurements and simulations with the presence of screen oxide layer. Oxide peak displacement due to ions velocity effect within oxide during SiMS measurements.

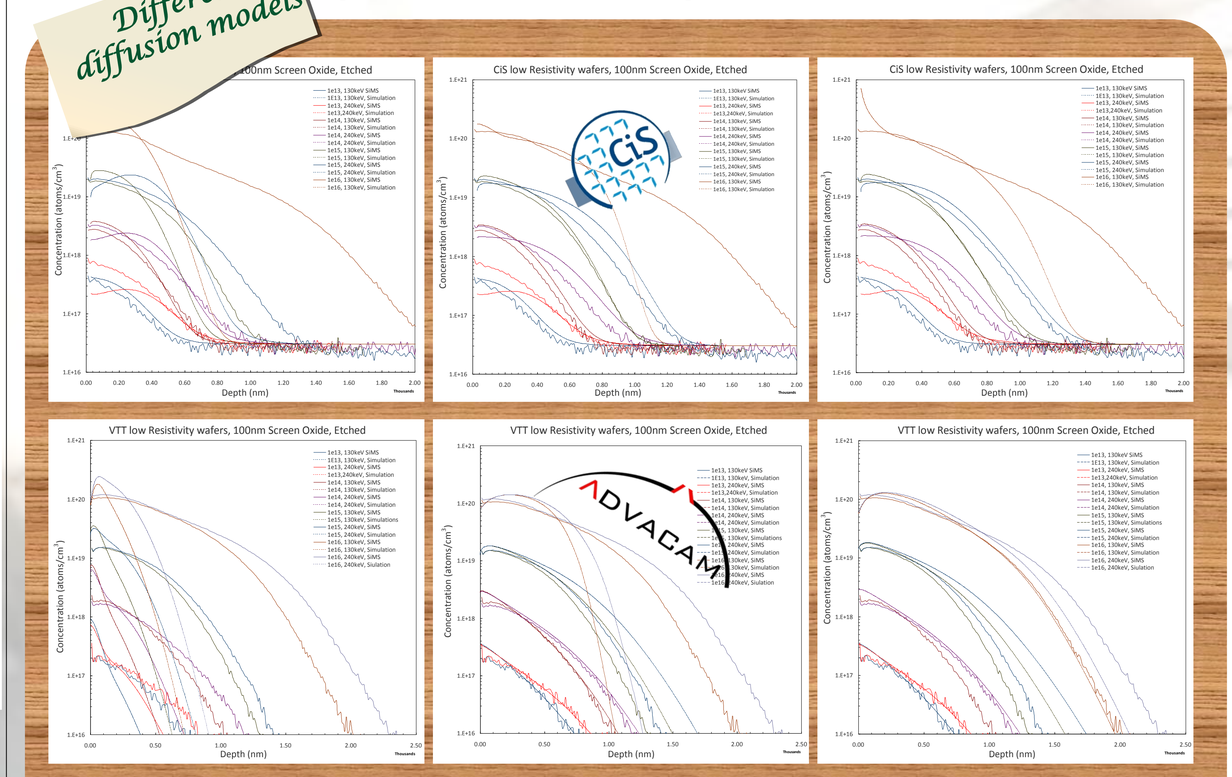


Simulated and measured wafers with growth of a 200nm oxide layer. Implant quantities substantially lower with good agreement for lower doses within the limits of experimental accuracy.



Different analytic diffusion models used to compensate high dose discrepancy. Standard Fermi model is validated for low and intermediate concentrations while charged pair model has better validity at slightly higher concentrations. No single model is sufficient for doses >10^{15}/cm^2

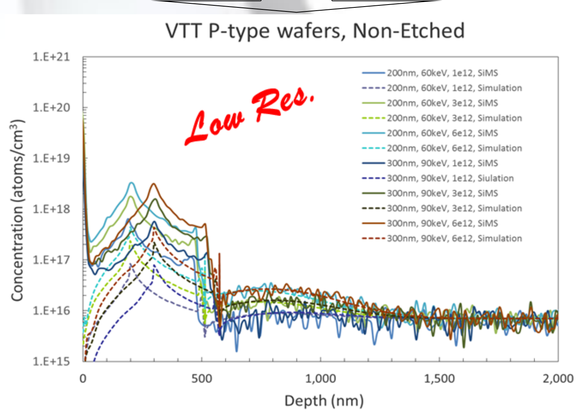
Different diffusion models



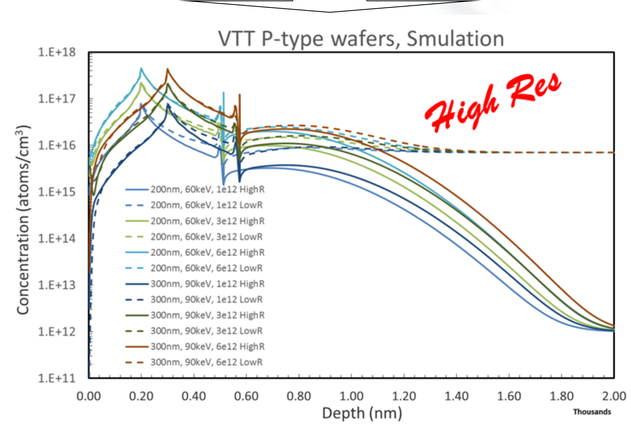
N in P, VTT production, <100> orientation

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					

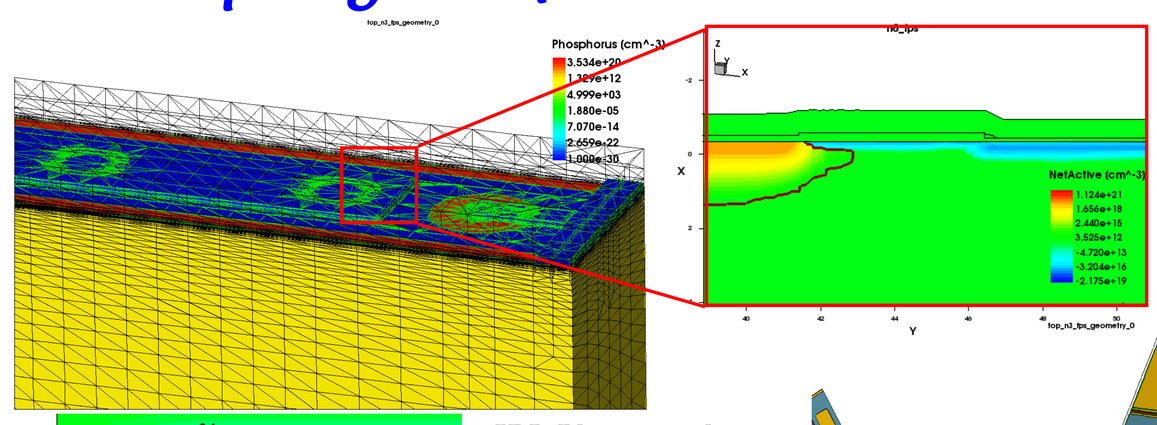
P-Spray implanted p type wafers with different doses and energies. Substrate is low resistivity limiting discriminating ability. Good agreement between measurements and simulations with a slight mismatch in the oxide region due to SiMS calibration effects.



Simulation of the same parameters for the high resistivity substrate and comparison with the low resistivity delivered wafers. Profiles show same tendency and behavior between the two substrates with no deviation effects but discriminating ability is better.



3D Doping Profile Simulations



IBL Planar pixel geometry and doping profile in a 3D process flow. 2D cuts demonstrate lateral diffusion of the order of 1μm under the metallization electrode. Backside process confirms equivalent result