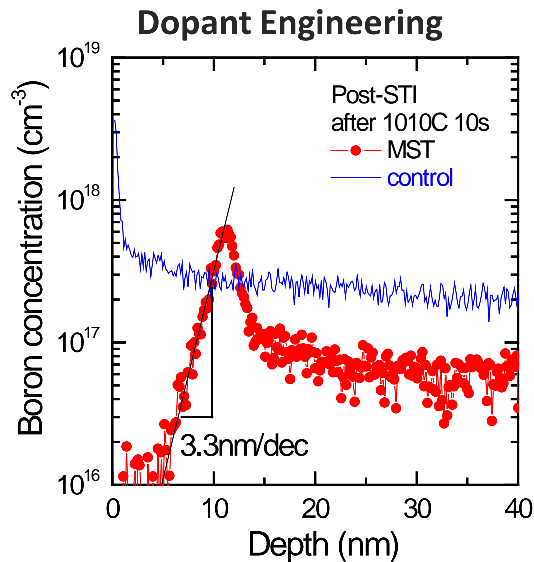
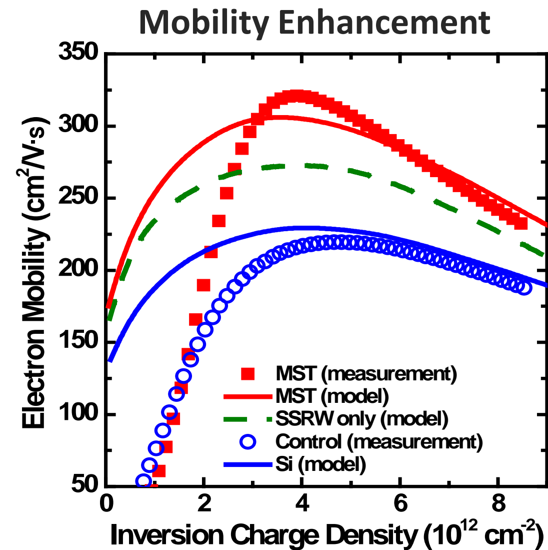
atomera

MST® for Improved Variability

www.atomera.com

MST®: Mechanism and Benefits

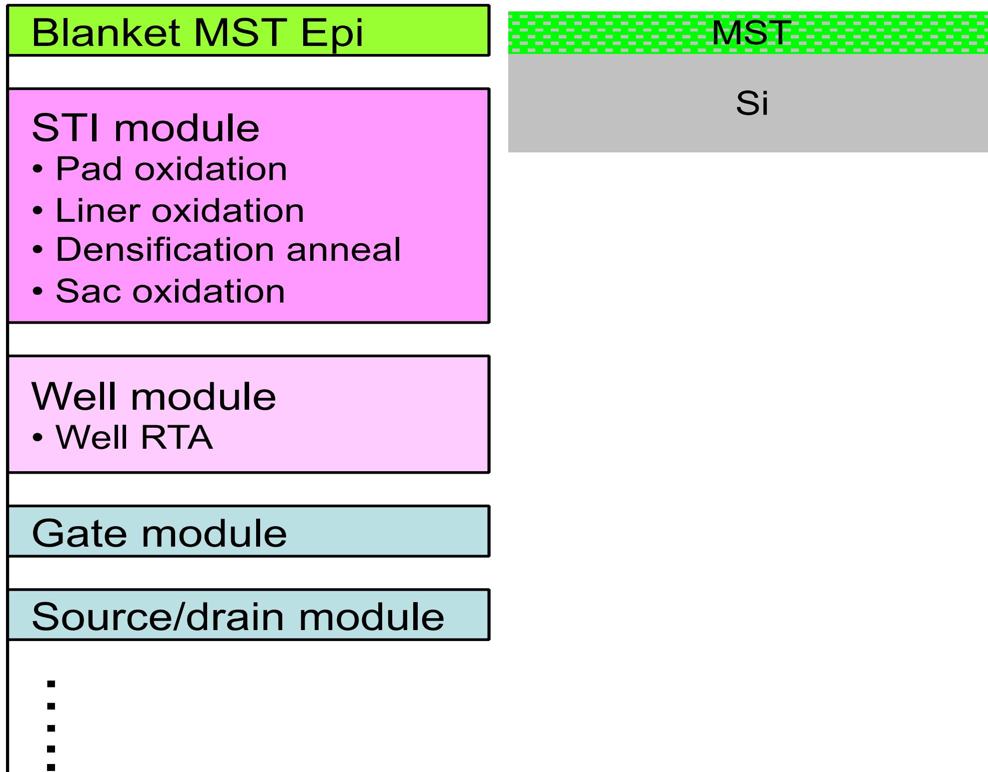




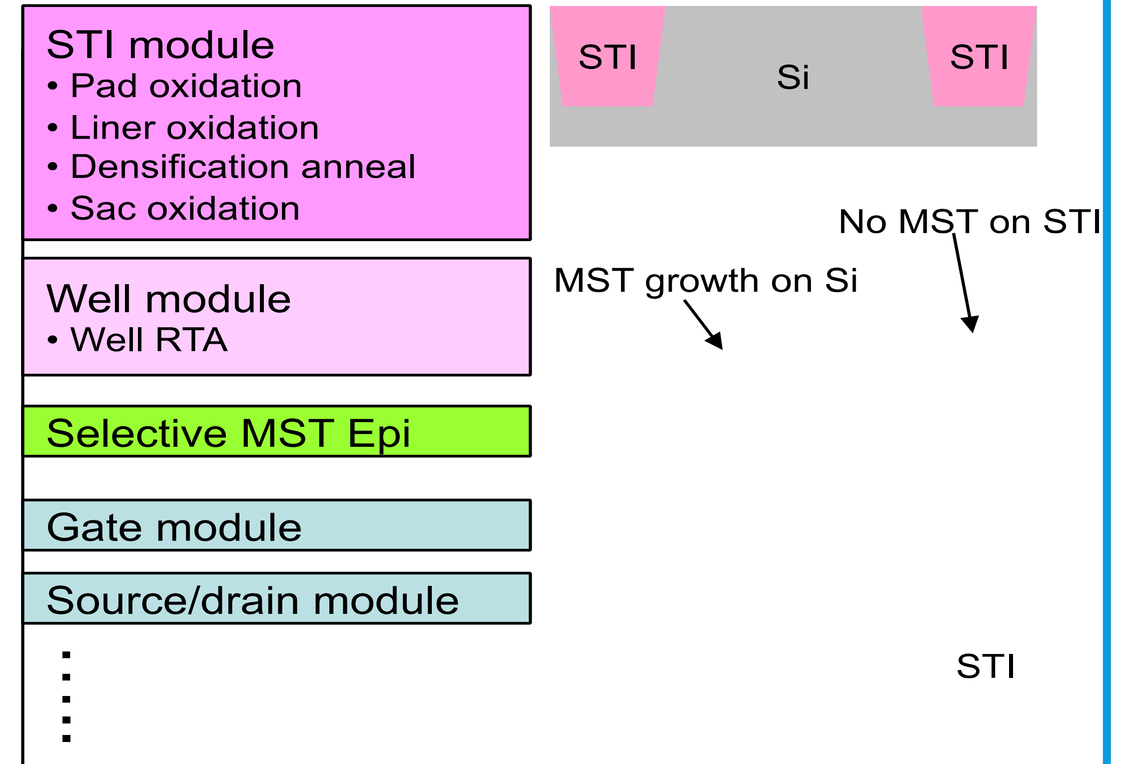
- Both NMOS and PMOS
- I_{dsat} and G_m enhanced
- Gate Leakage reduced
- Precision Doping Profiles
- Variability reduced & Matching improved
- Potential 1/f Noise reduction
- TDDB & NBTI Reliability improved

MST Integration

MST 1 (Pre-STI)



MST 2 (Post-STI)

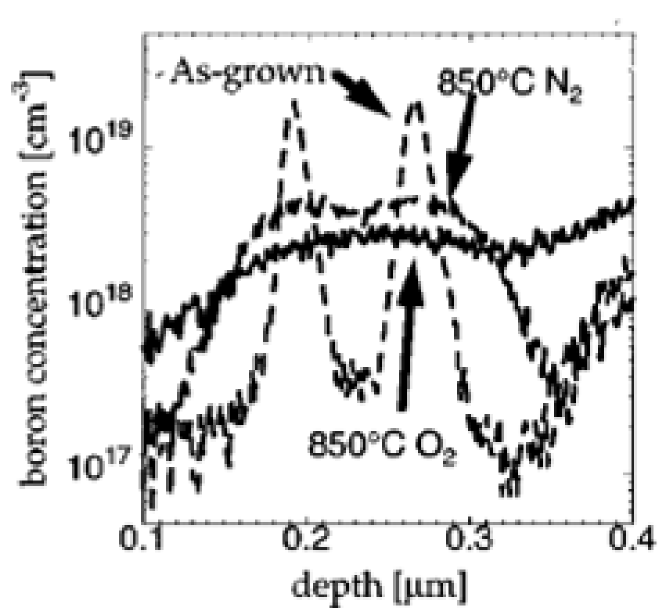


MST Interstitial Blocking vs $Si_{1-x-y}Ge_xC_y$

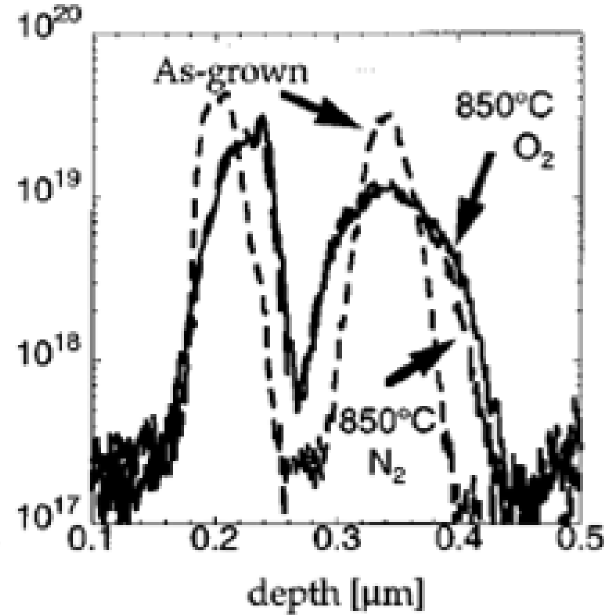
atomera

- Boron Marker/Si/Interstitial Blocking Layer/Si/Boron Marker after 850°C 30min. anneal

Control Si



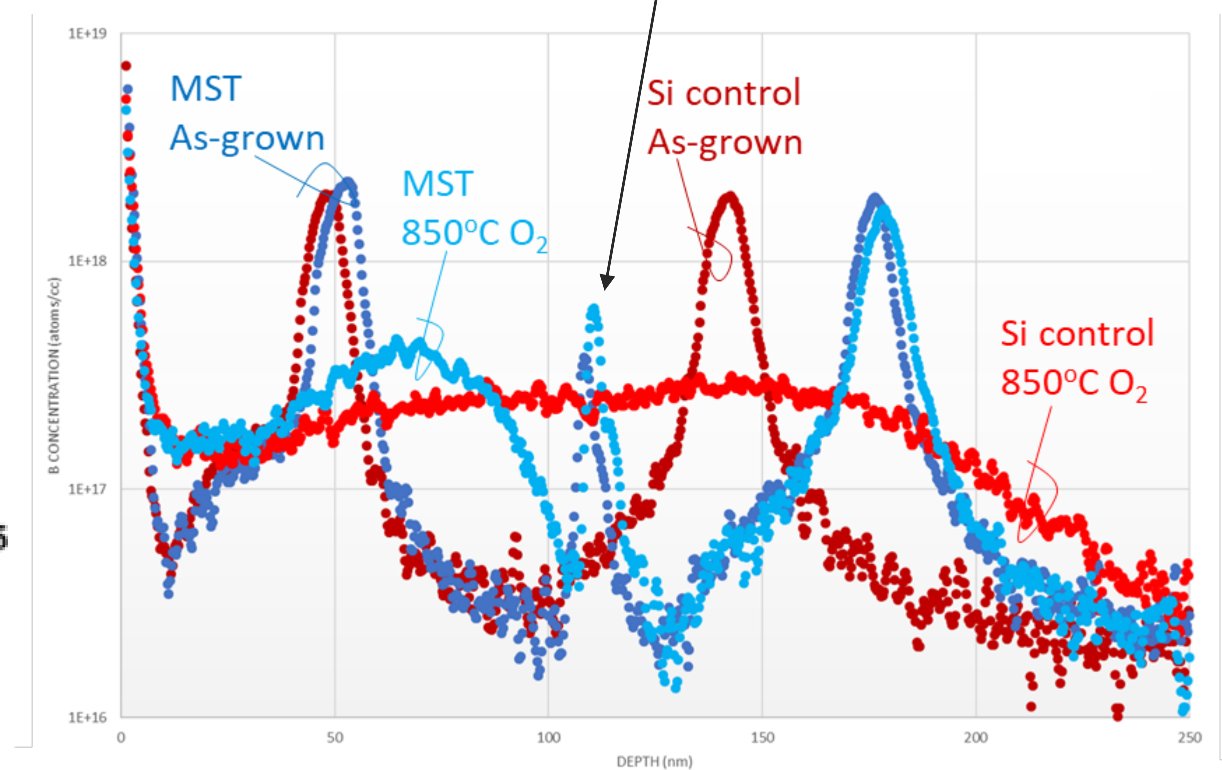
$Si_{0.795}Ge_{0.2}C_{0.005}$



M.S. Carroll, et al., APL, pp.3695-3697 (1998)

Control Si vs. MST

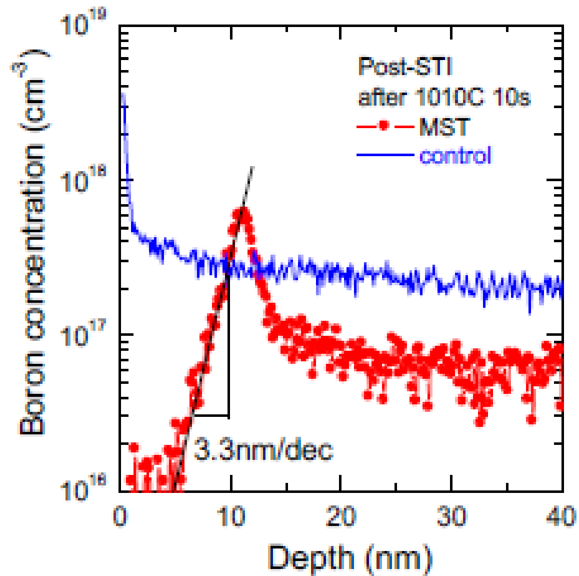
MST layer position



No broadening of Boron peak below MST layer

MST Dopant Blocking vs. Thermal Budget

After ISSG (945C 20s) + 1010C 10s



After 800C 60min. (thick GOX) + 850C 30min (thin GOX) + 1000C 2min

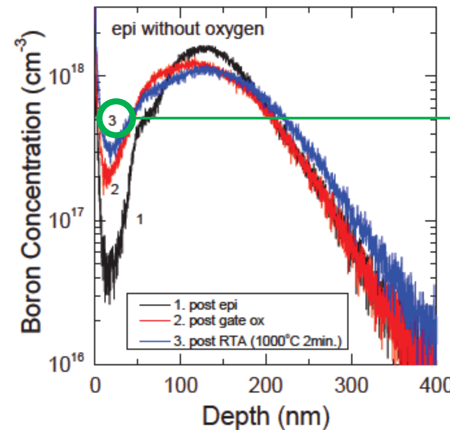


Fig. 3: Boron depth profiles: 1. after implantation (B11 25keV, 2E13/cm^2, 0°) and undoped epi Si growth(20nm); 2. after 800C 60min and 850C 30min. gate oxidations; 3. 1000°C 2min anneal.

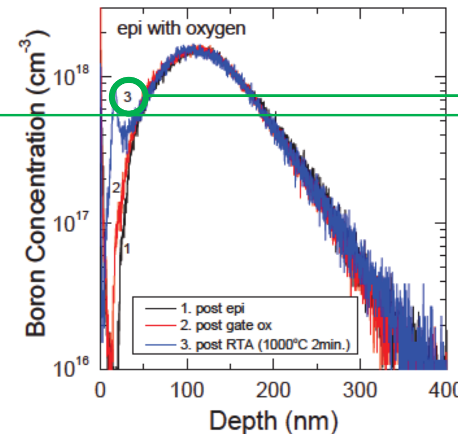
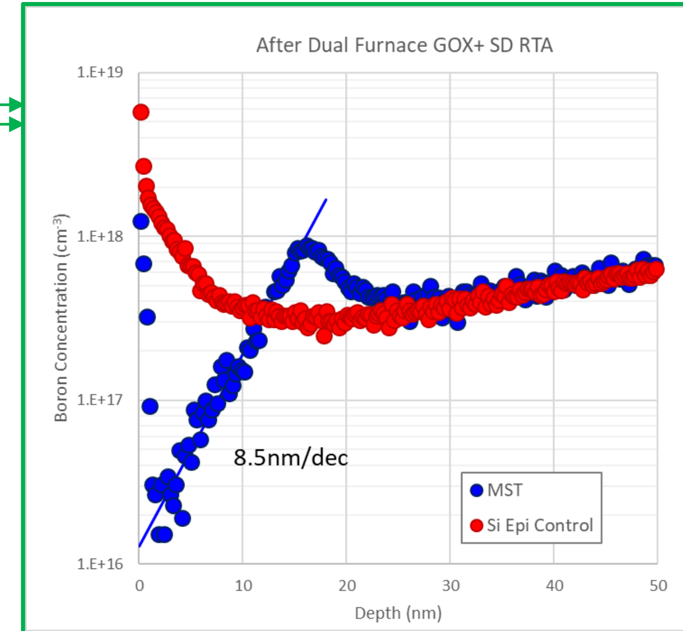


Fig. 4: Boron depth profiles: 1. after implantation (B11 25keV, 2E13/cm^2, 0°) and undoped epi Si growth with the OI layer (20nm); 2. after 800C 60min and 850C 30min. gate oxidations; 3. 1000°C 2min anneal.



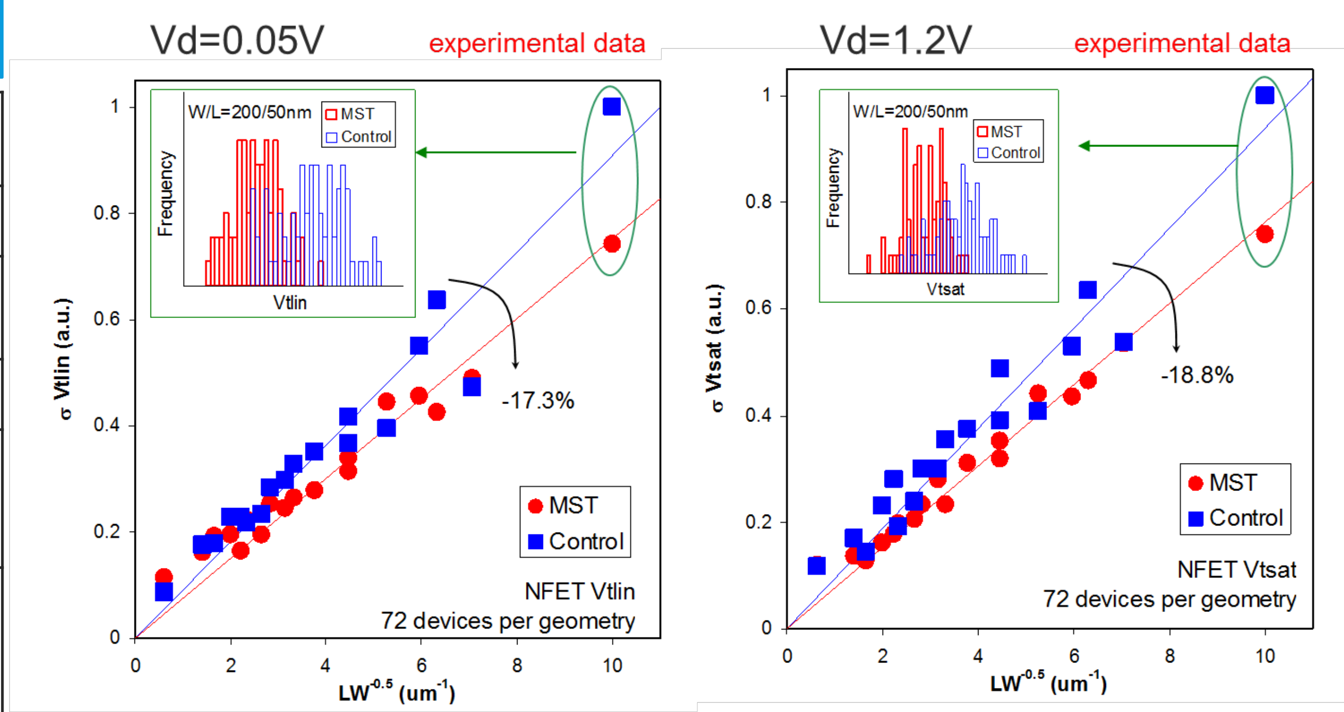
See Paper 4B-2 EDTM 2017

Vt Variability and Matching Improvement

MST 1 Integration

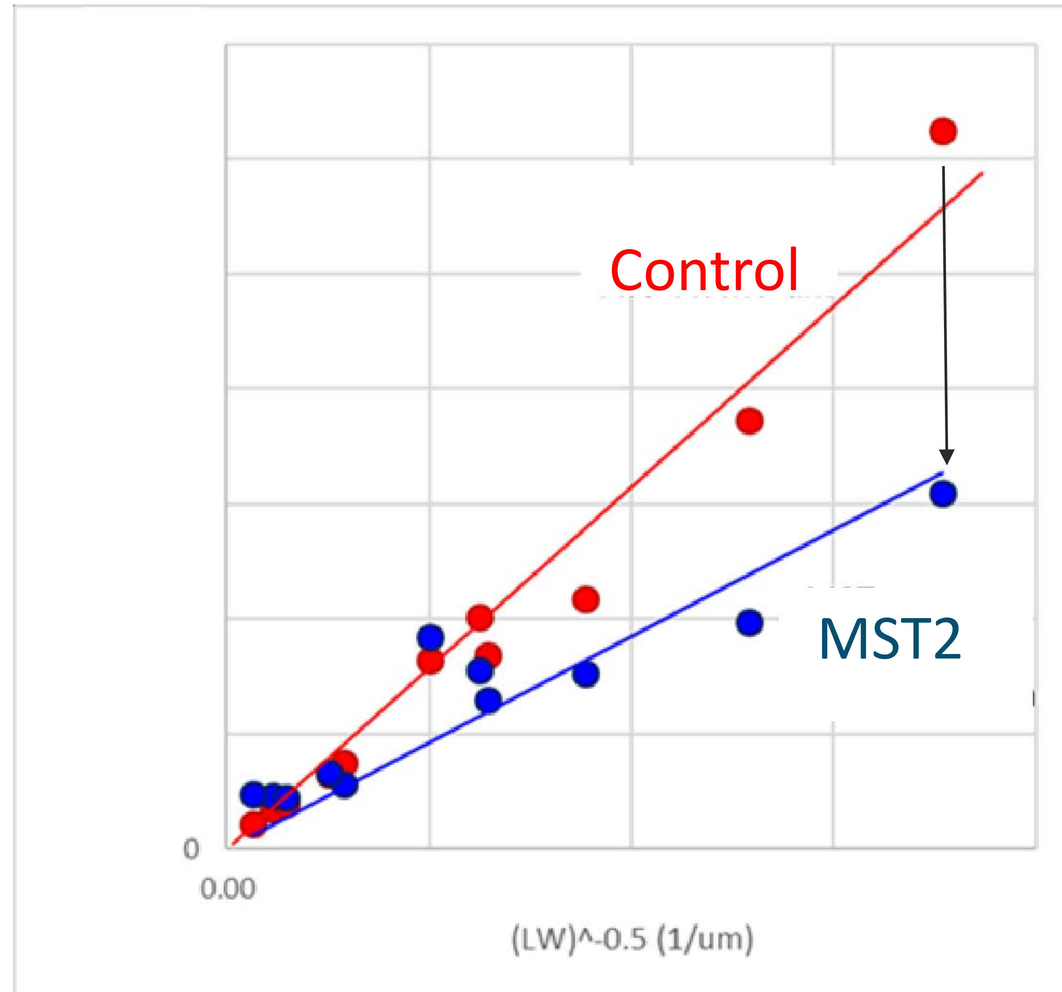
Device Characteristics		NMOS	PMOS
Reduction of Vt variation of individual transistors	Vtlin	17%	8%
	Vtsat	19%	9%
Matching improvement of paired transistors	ΔVtlin	14%	12%
	ΔVtsat	19%	15%
	ΔId	20%	14%

NMOS Vt Pelgrom Plots



>40% Improvement in Matching Avt

$\sigma(\Delta Vt)$



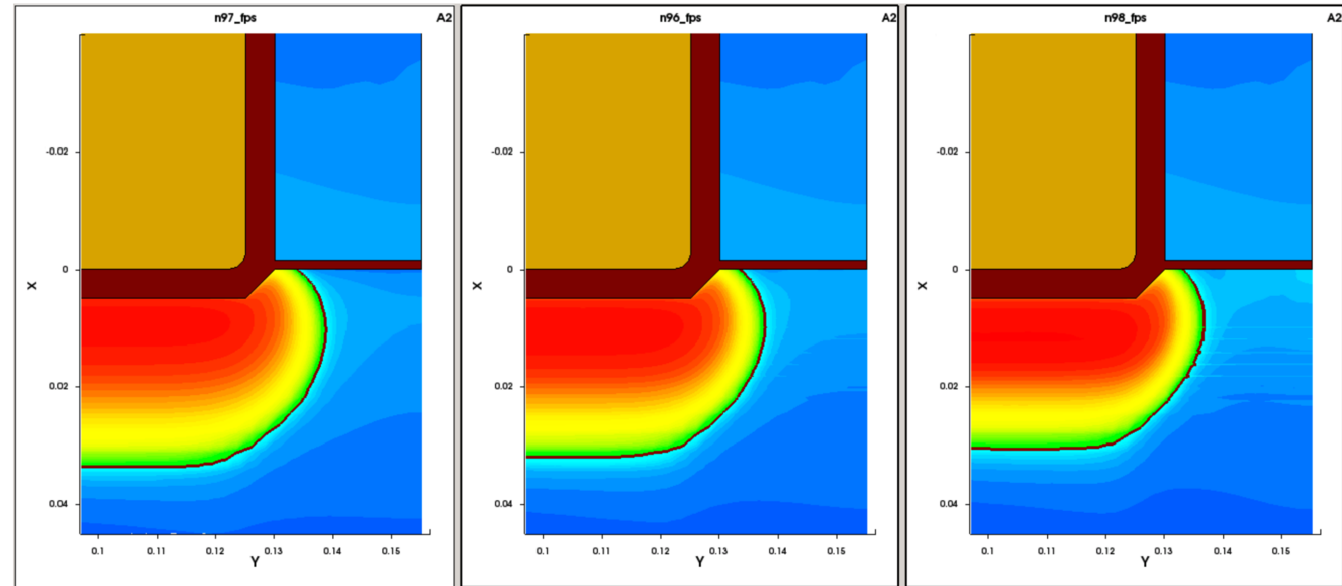
- MST2 Integration
- >40% Avt reduction
- >50% $\sigma(\Delta Vt)$ reduction for smallest devices at matched Vt

MST in Synopsys TCAD

Sample Simulation of MST using Sentaurus™

Sentaurus Process:

- Atomera developed Alagator script to:
  - Provide Initial MST Film structure
  - Capture MST O process dependence
  - Capture dopant (B, As, P …) interactions



Baseline
w/o Oxygen

With MST film
increased Oxygen dose

Abrupt extension and lower channel doping (better SSR)

Summary

- MST enables significant σVt and $\sigma(\Delta$Vt) reduction by engineering vertical doping profile
  - Robust to oxidation and RTA steps
  - Demonstrated in pre-and post-STI deposition

- Support for MST dopant profile engineering in Synopsys Sentaurus™ TCAD

atomera

www.atomera.com