

TCAD Simulations of 4H-SiC MOS Transistors: Dependence on Oxide, Interface and Temperature



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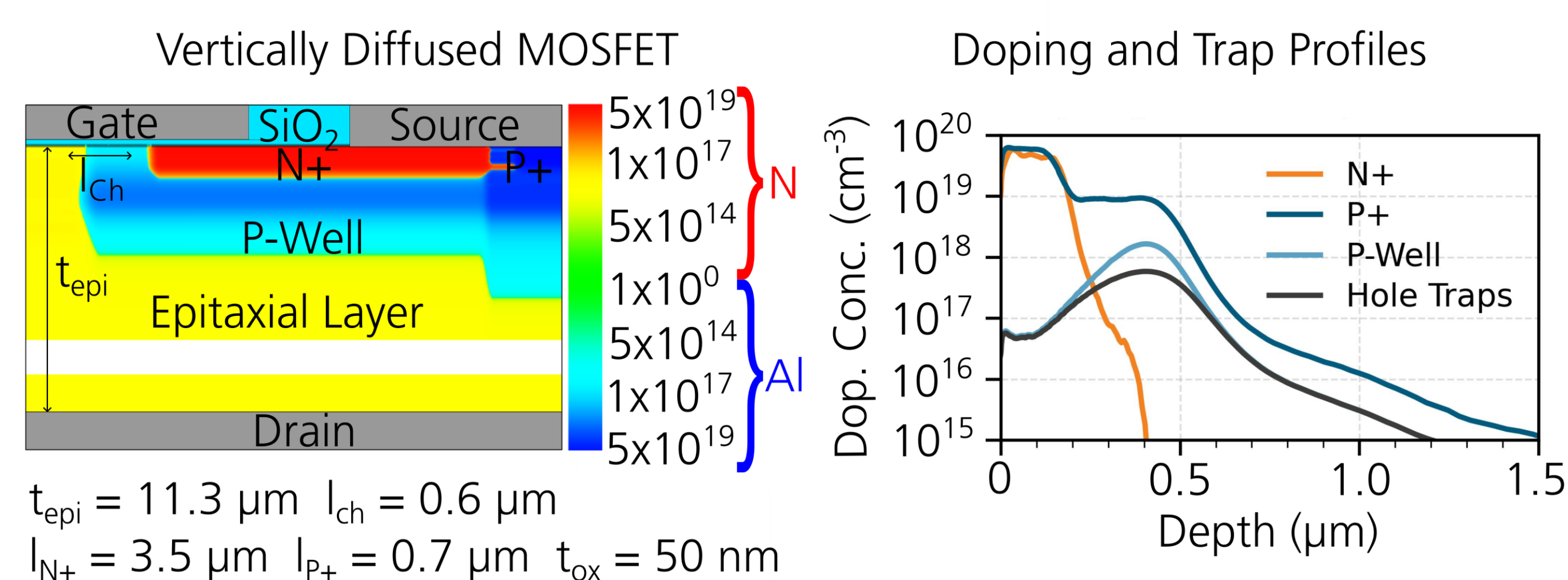
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Problem

Temperature-consistent 4H-SiC TCAD simulations are challenging. We suggest a simplified temperature-consistent model for a vertically diffused MOSFET across 100°C to 400°C based on **interface states (D_{it})** and **oxide charges (Q_{ox})**.

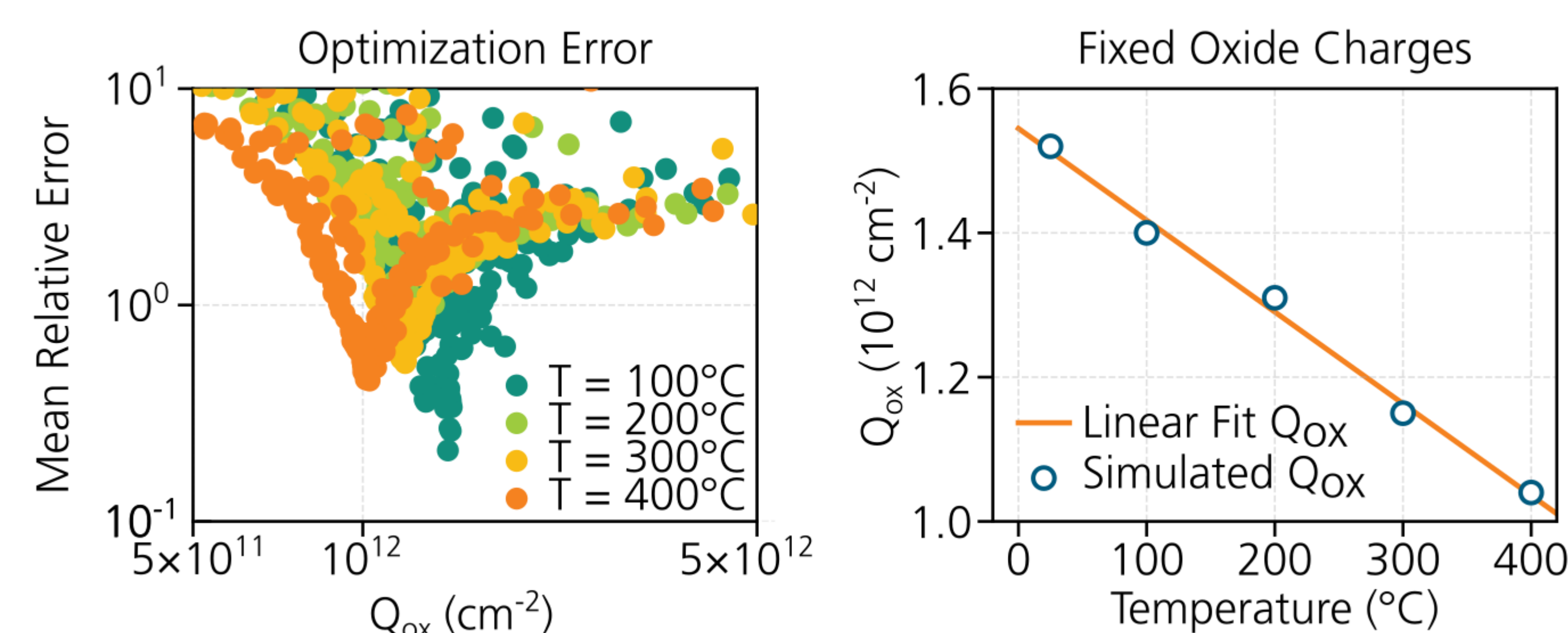
Simulation



Physics	Sentaurus Device TCAD Model [1]
Mobility	Inversion and Accumulation Layer Mobility (IALMob) + HighFieldMobility and InterfaceCharge
Recombination	Auger + Shockley-Read-Hall (SRH)
Bulk Traps	According to Kimoto [2]
Incomplete Ionization	Hole-trap model according to Mletschnig [3]

Pytaurus – IISB In-House Optimizer

- Optuna-based hyperparameter optimizer
- Python based calibration and optimization tool for Sentaurus simulations
- Single and multi-target fitting
- Optuna-dashboard for detailed analysis and visualization



Temperature Dependent Oxide Charge Model

- **Fixed Q_{ox}** : Temperature-consistent modeling (100 - 400°C) failed
- **Q_{ox}** : Optimization error minimum **shifts** systematically **with temperature**
- **$Q_{ox}(T)$** : Linear temperature dependent description of Q_{ox} is introduced
- Phonon-Assisted tunneling transmission time : $\tau = \tau_0 * \exp\left(\frac{E_a}{k_B T}\right)$
- Measurement time: τ_m Trap transition time: τ
- **Static trap: $\tau_m < \tau$** **Dynamic trap: $\tau_m > \tau$**
- With increasing temperature the trap transition time τ is reduced
- With increasing T **border traps evolve from static to dynamic states**

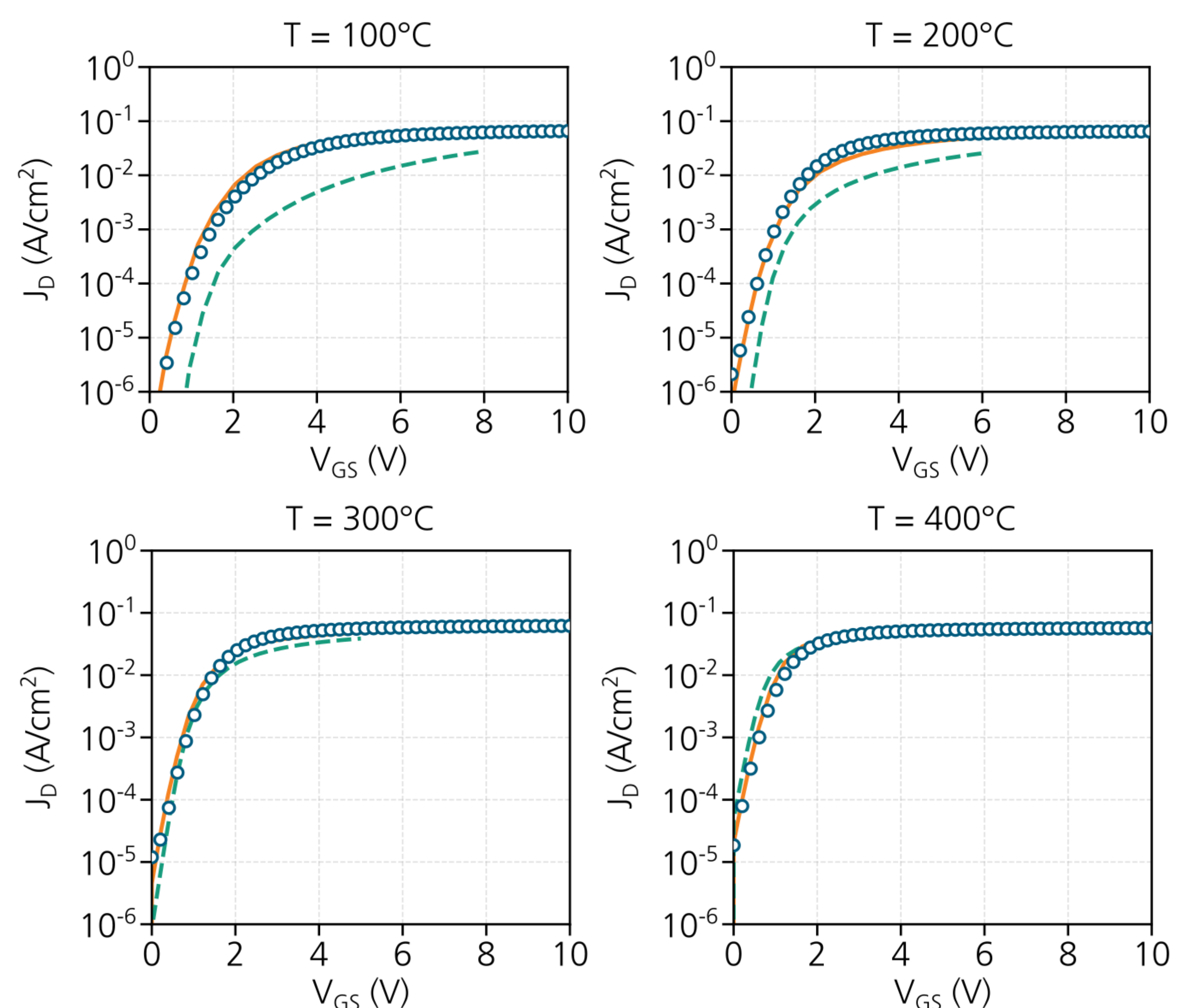
Best-Fit Parameterset

Physics	Sentaurus TCAD Model
$D_{it,c}$	$7.10 * 10^{-2} eV^{-1}$
E_σ	$1.48 * 10^{-1} eV$
ρ_c	$4.59 * 10^{-2} \Omega cm^2$
$Q_{ox, fixed}$	$1.06 * 10^{12} cm^{-2}$

$$Q_{ox}(T) = -2.05 * 10^9 cm^{-2} K^{-1} * T_{Kelvin} + 2.14 * 10^{12} cm^{-2}$$

$$D_{it} = D_{it,c} * \exp\left(-\frac{|E - E_c|}{E_\sigma}\right)$$

Simulation Model Comparison



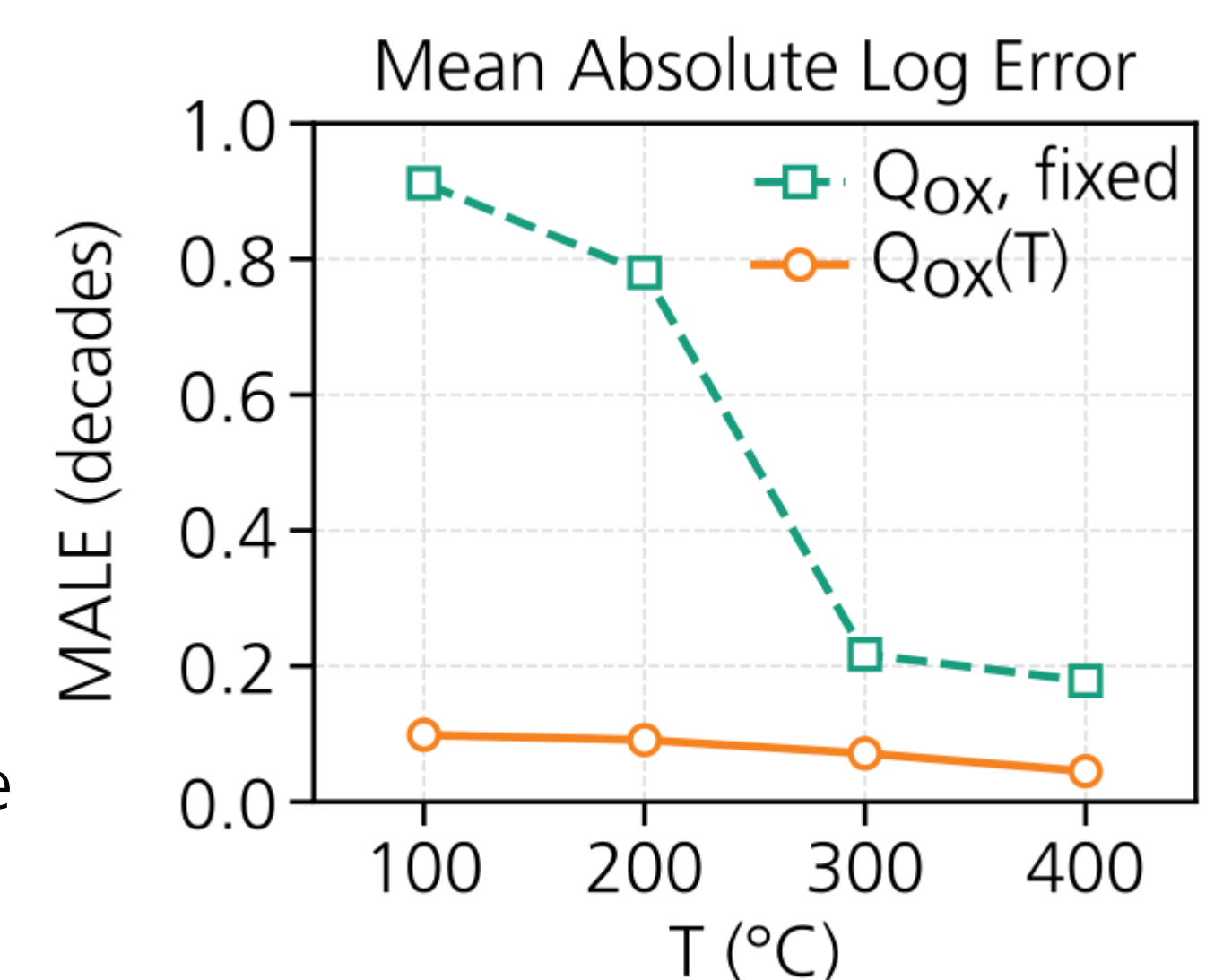
Simulation Model Error Comparison

Q_{ox} – fixed value

- MALE : 0.2 to 0.86 decades
- Strong drop below 300°C
- Not consistent across temperature

$Q_{ox}(T)$ – linear dependence

- MALE < 0.15 decades
- No abrupt deviations
- Consistent across temperature range



Conclusion

- Temperature-dependent $Q_{ox}(T)$ modeling reduces the MALE in the range 100°C to 400°C below 0.15 with a single parameter set.
- The reduction in Q_{ox} compensates the transition of border traps from static to dynamic trap states.