



UNIVERSITY OF CALIFORNIA, BERKELEY

BSIM4.4.0 Release Enhancement and Technical Notes

BSIM group

University of California, Berkeley



OUTLINE

New Features of BSIM4.4.0 release

- ❑ Trap-assisted tunneling and recombination current model
- ❑ Flatband voltage offset parameter for overlap gate overlap tunneling current
- ❑ Length reduction parameter offset for flicker noise

Bug Fixes



Source/Body, Drain/Body Junction Diode Model with Trap-Assisted-Tunneling Current in BSIM4

$$\begin{aligned} I_{bs,d} = & I_{sbs,d} \left[\exp\left(\frac{qV_{bs,d}}{NJS,D \cdot k_B T}\right) - 1 \right] \cdot f_{breakdown} \\ & - W_{effej} \cdot NF \cdot J_{tsswgs,d}(T) \cdot \left[\exp\left(\frac{-V_{bs,d}}{NJTSSWG(T) \cdot Vtm0} \cdot \frac{VTSSWGS,D}{VTSSWGS,D - V_{bs,d}}\right) - 1 \right] \\ & - P_{s,deff} J_{tssws,d}(T) \left[\exp\left(\frac{-V_{bs,d}}{NJTSSW(T) \cdot Vtm0} \cdot \frac{VTSSWS,D}{VTSSWS,D - V_{bs,d}}\right) - 1 \right] \\ & - A_{s,deff} J_{tss,d}(T) \left[\exp\left(\frac{-V_{bs,d}}{NJTS(T) \cdot Vtm0} \cdot \frac{VTSS,D}{VTSS,D - V_{bs,d}}\right) - 1 \right] \\ & + V_{bs,d} \cdot G_{min} \end{aligned}$$

$$Vtm0 = \frac{k_B \cdot TNOM}{q}$$



Proposed Temperature Model

$$J_{tsswgs,d}(T) = J_{tsswgs,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tsswgs,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$J_{tssws,d}(T) = J_{tssws,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tssws,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$J_{tss,d}(T) = J_{tss,d}(TNOM) \cdot \exp\left[\frac{-Eg(TNOM)}{k_B T} \cdot X_{tss,d} \cdot \left(1 - \frac{T}{TNOM}\right)\right]$$

$$NJTSSWG(T) = NJTSSWG(TNOM) \cdot \left[1 + TNJTSSWG\left(\frac{T}{TNOM} - 1\right)\right]$$

$$NJTSSW(T) = NJTSSW(TNOM) \cdot \left[1 + TNJTSSW\left(\frac{T}{TNOM} - 1\right)\right]$$

$$NJTS(T) = NJTS(TNOM) \cdot \left[1 + TNTJS\left(\frac{T}{TNOM} - 1\right)\right]$$



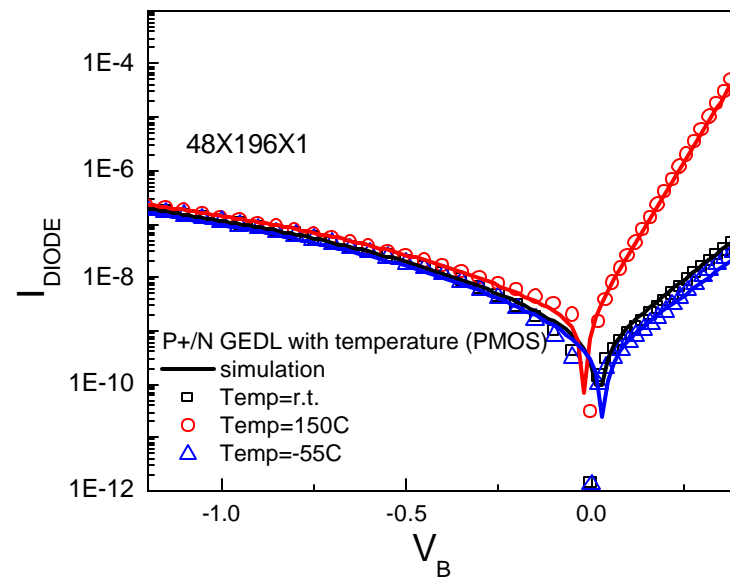
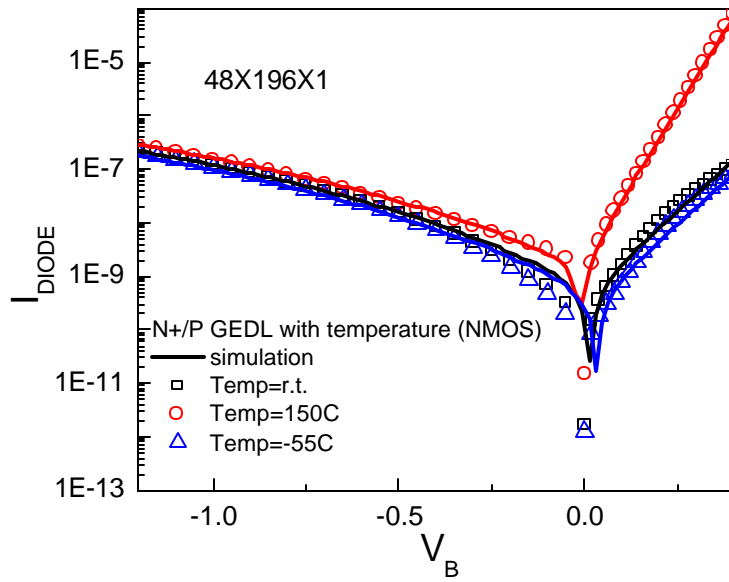
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Proposed TAT Model New Parameters

Parameter Name	Description	Default Value	Binnable ?	Note
JTSS, JTSD	Bottom trap-assisted saturation current density	0.0	no	
JTSSWS, JTSSWD	STI sidewall trap-assisted saturation current density	0.0	no	
JTSSWGS, JTSSWGD	Gate-edge sidewall trap-assisted saturation current density	0.0	no	
NJTS	Non-ideality factor for JTSS, JTSD	20.0	no	
NJTSSW	Non-ideality factor for JTSSWS, JTSSWD	20.0	no	
NJTSSWG	Non-ideality factor for JTSSWGS, JTSSWGD	20.0	no	
XTSS, XTSD	Power dependence of JTSS, JTSD on temperature	0.02	no	
XTSSWS, XTSSWD	Power dependence of JTSSWS, JTSSWD on temperature	0.02	no	
XTSSWGS, XTSSWGD	Power dependence of JTSSWGS, JTSSWGD on temperature	0.02	no	
VTSS, VTSD	Bottom trap-assisted voltage dependent parameter	10.0	no	
VTSSWS, VTSSWD	STI sidewall trap-assisted voltage dependent parameter	10.0	no	
VTSSWGS, VTSSWGD	Gate-edge sidewall trap-assisted voltage dependent parameter	10.0	no	
TNJTS	Temperature coefficient for NJTS	0.0	no	
TNJTSSW	Temperature coefficient for NJTSSW	0.0	no	
TNJTSSWG	Temperature coefficient for NJTSSWG	0.0	no	

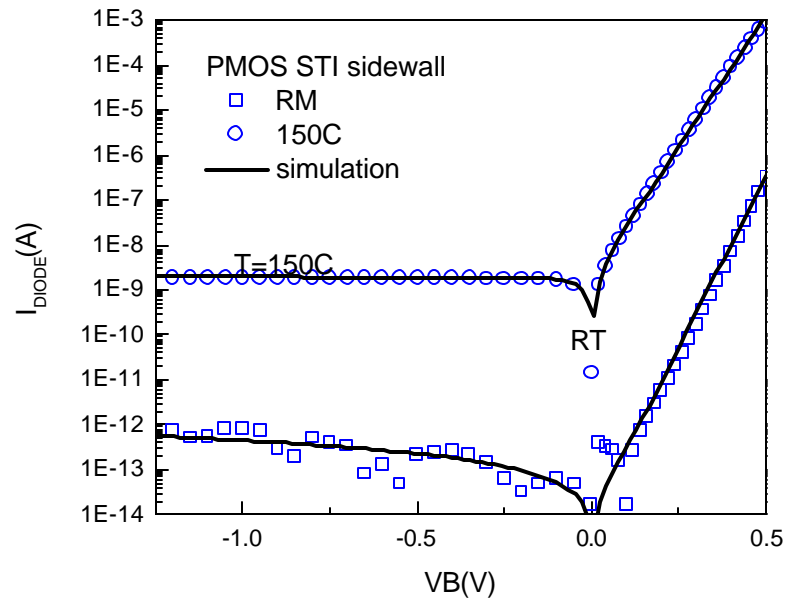
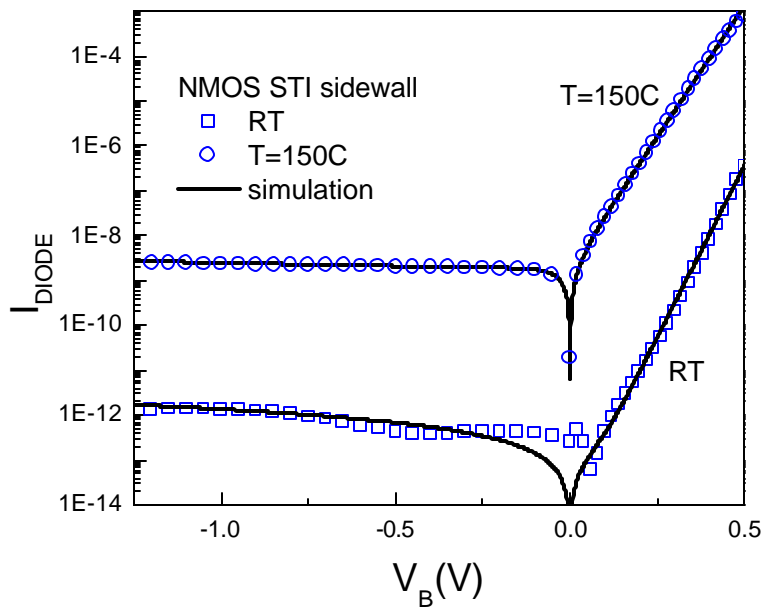


Simulation Results (TI)



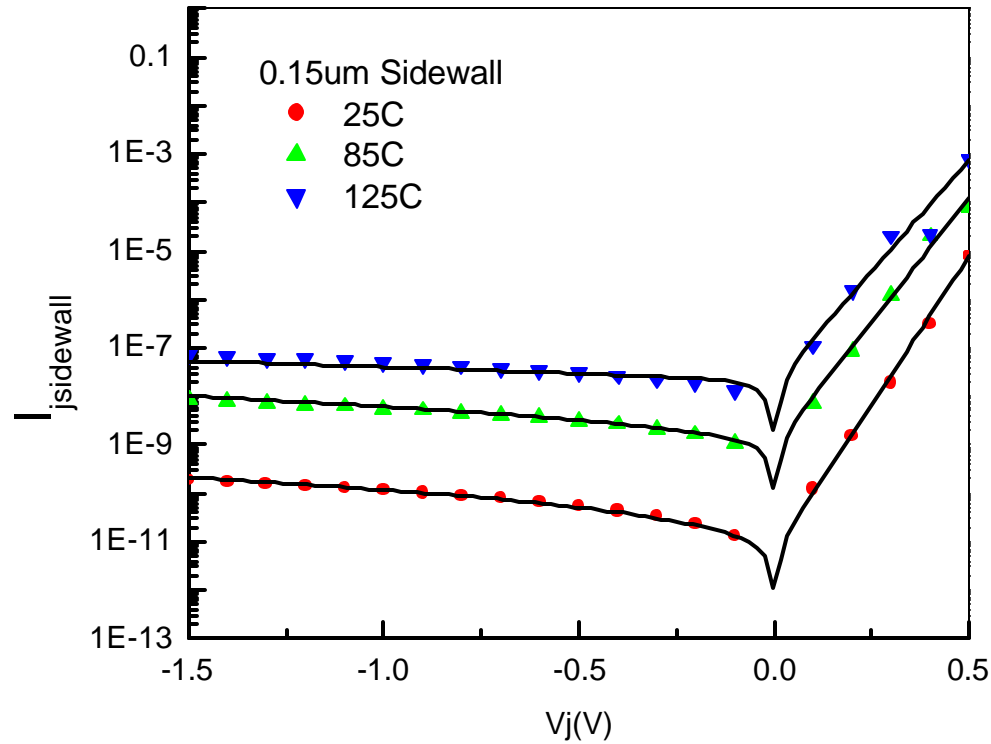


Simulation Results (TI)



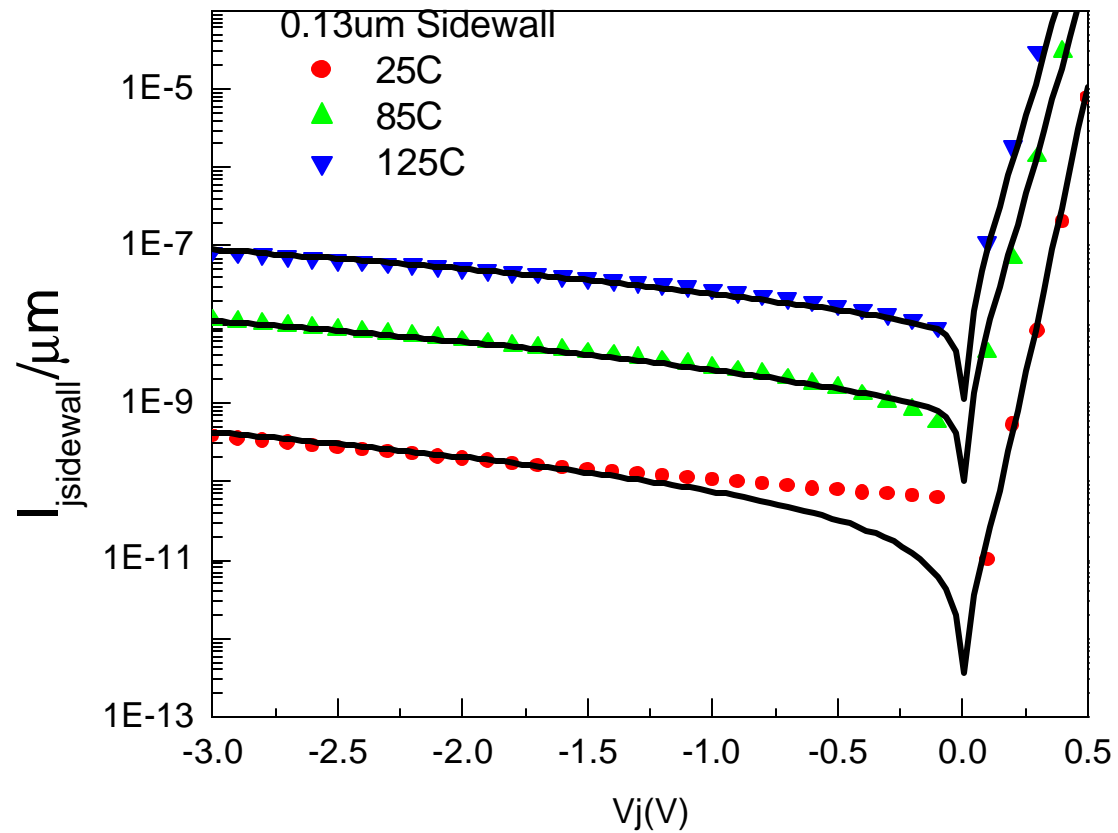


Simulation Results (Renesas)



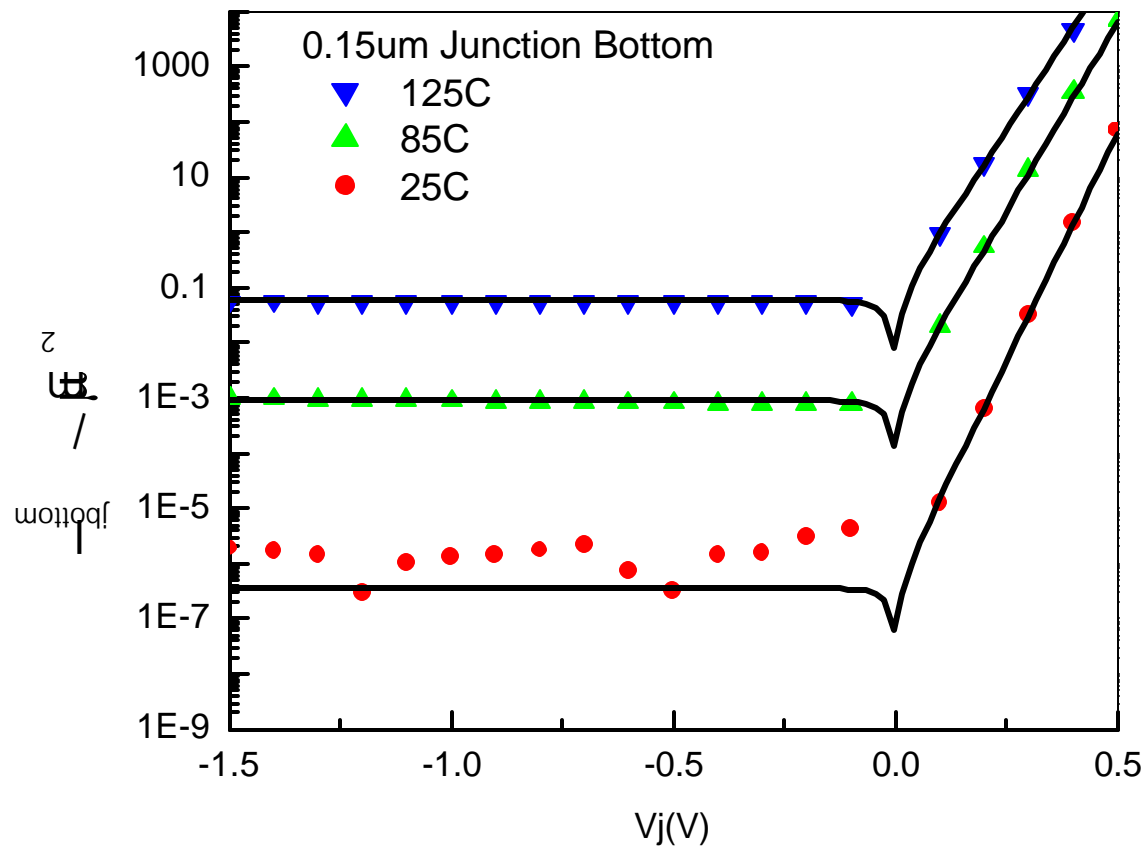


Simulation Results (Renesas)



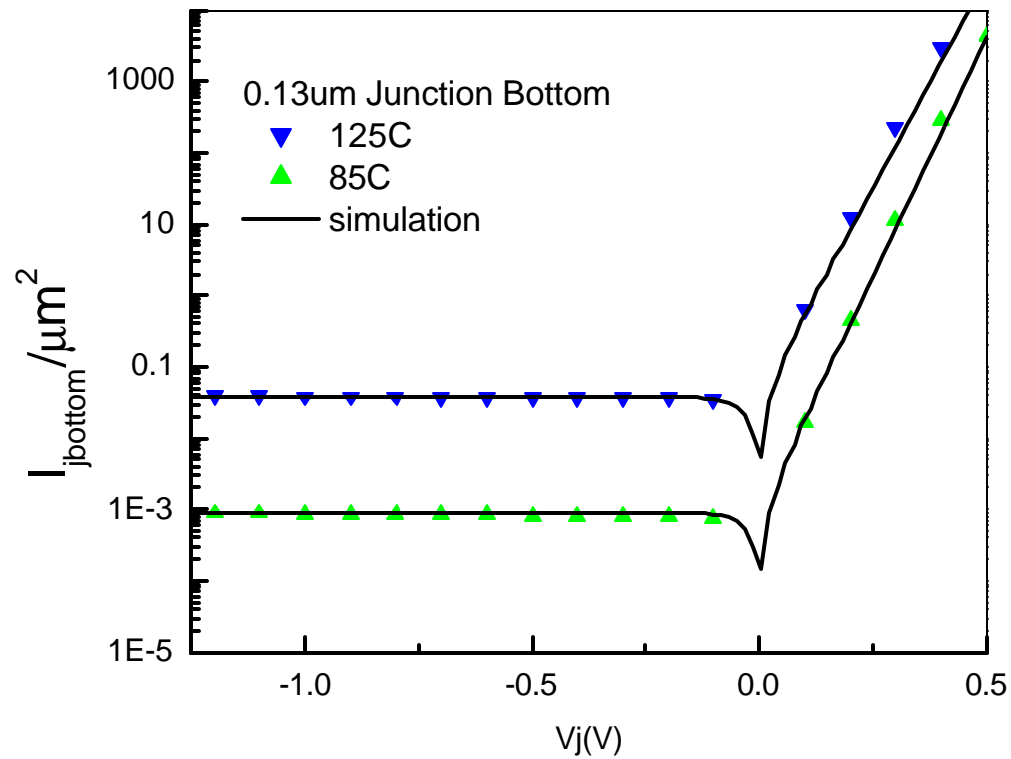


Simulation Results (Renesas)





Simulation Results (Renesas)





Flatband Voltage Offset Parameter for Gate Overlap Tunneling Current

- **VFBSDOFF**—an offset voltage added to the original source/drain flatband voltage which allows independently setting of V_{fbsd} to model gate overlap tunneling current accurately.

$$V_{fbsd} = k_B T / q \log(NGATE/NSD) + VFBSDOFF$$

Parameter Name	Description	Default Value	Binnable?	Note
VFBSDOFF	Flatband Voltage Offset Parameter	0.0	yes	



Length Reduction Parameter Offset for Flicker Noise

- **LINTNOI**—an offset to length reduction parameter(Lint) for flicker noise

For $fnoiMod = 1$ (unified model)

In the inversion region, the noise density is expressed as:

$$S_{id,inv}(f) = \frac{k_B T q^2 m_{eff} I_{ds}}{C_{oxe} (L_{eff} + LINTNOI)^2 A_{bulk} f^{ef} \cdot 10^{10}} \left(NOIA \cdot \log\left(\frac{N_0 + N^*}{N_l + N^*}\right) + NOIB \cdot (N_0 - N_l) + \frac{NOIC}{2} (N_0^2 - N_l^2) \right) + \frac{k_B T I_{ds}^2 \Delta L_{clm}}{W_{eff} \cdot (L_{eff} + LINTNOI)^2 f^{ef} \cdot 10^{10}} \cdot \frac{NOIA + NOIB \cdot N_l + NOIC \cdot N_l^2}{(N_l + N^*)^2}$$

Parameter Name	Description	Default Value	Binnable ?	Note
LINTNOI	Length Reduction Parameter Offset	0.0	no	