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## **Unified Length-/Width-Dependent Drain Current Model for Deep-Submicron MOSFETs**

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## Introduction

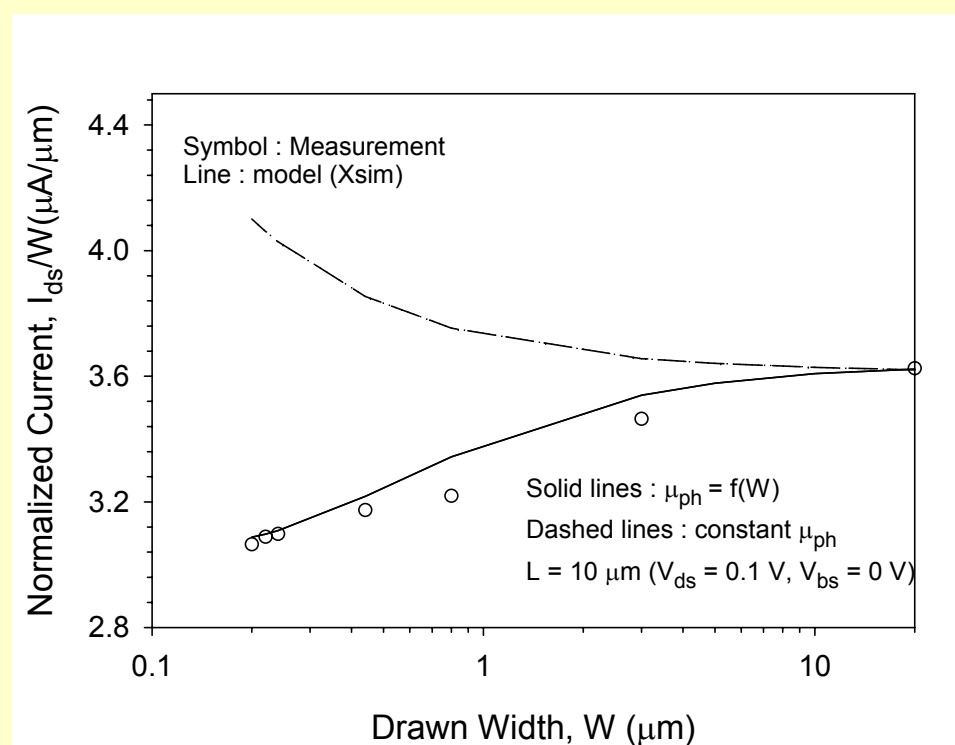
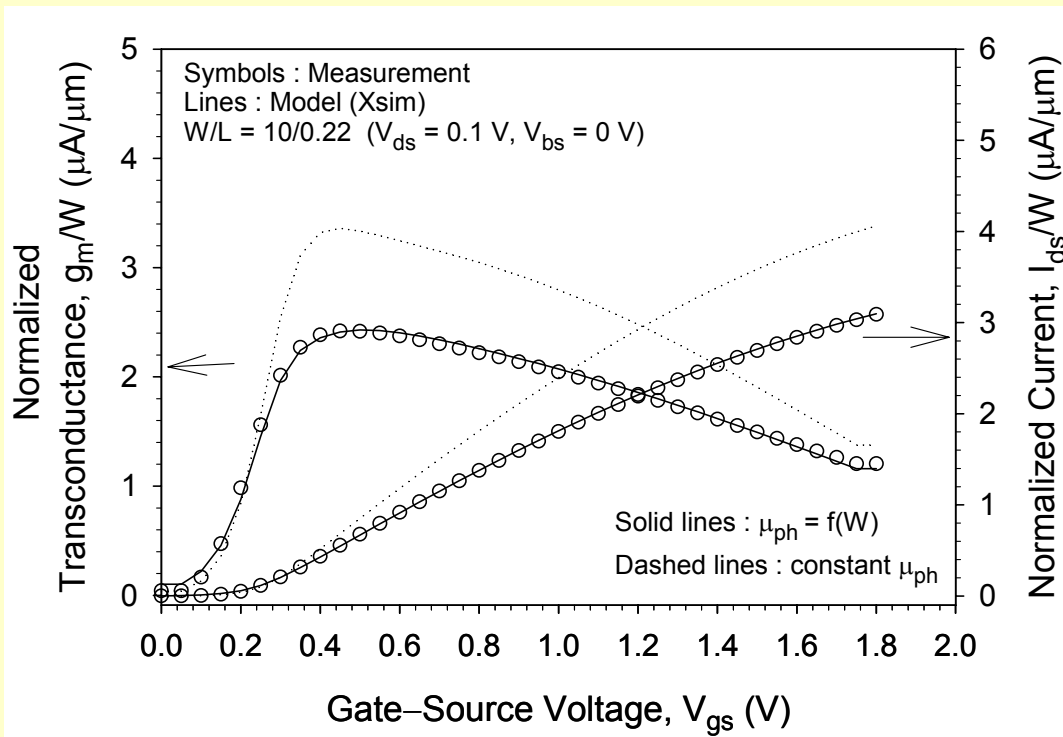
- **Measurement data show drain current increases at decreasing channel length but decreases at decreasing channel width.**
- **The current degradation is related to the STI stress, which degrades the mobility in the narrow-width device.**
- **It has been reported that for  $L_{min}/W_{min}$  MOSFET with dog-bone layout, total  $R_{sd}$  is overestimated when conventional width scaling  $R_{sd} \propto W^{-1}$  is applied.**

## Modeling Approach for $I_{ds}(L, W)$

- From our previous  $I_{ds}(L)$  by including width-dependent mobility model and source/drain resistance for dog-bone layout, which allows unified  $I_{ds}$  model “**without binning**” to be extended to  $I_{ds}(L, W)$ .
- This is achieved based on the accurate width-dependent threshold voltage modeling, which allows less effort to model width dependence in the drain current model.

# nMOSFET's with Long-/Narrow-Channel (width-dependent mobility model)

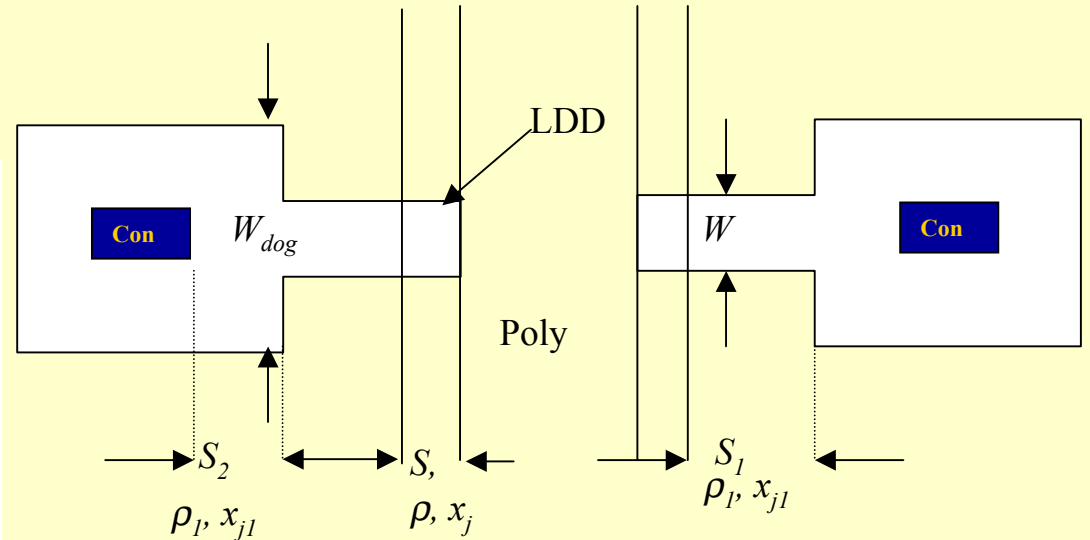
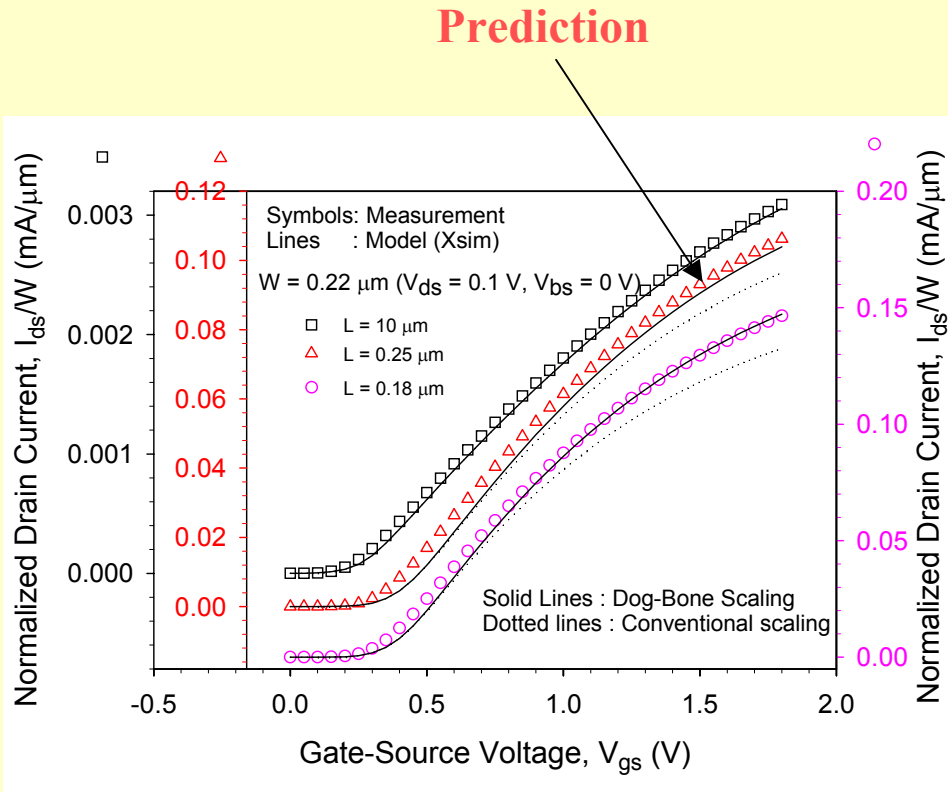
- We assumed linear width dependence in the phonon-scattering term in mobility, which has good agreement with the measurement data.



fitting:  $\mu_{2,narrow}$

$$\mu_2 = \mu_{2,narrow} + \frac{W - W_{min}}{W_{max} - W_{min}} (\mu_{2,wide} - \mu_{2,narrow})$$

# nMOSFET's with Short-/Narrow-Channel (Layout-dependent source/drain resistance model)



$$R_{ext} = \frac{2\rho S}{x_j W_{eff}} + \frac{2\rho_1 S_1}{x_{j1} W_{eff}} + \frac{2\rho_1 S_2}{x_{j1} W_{dog}}$$

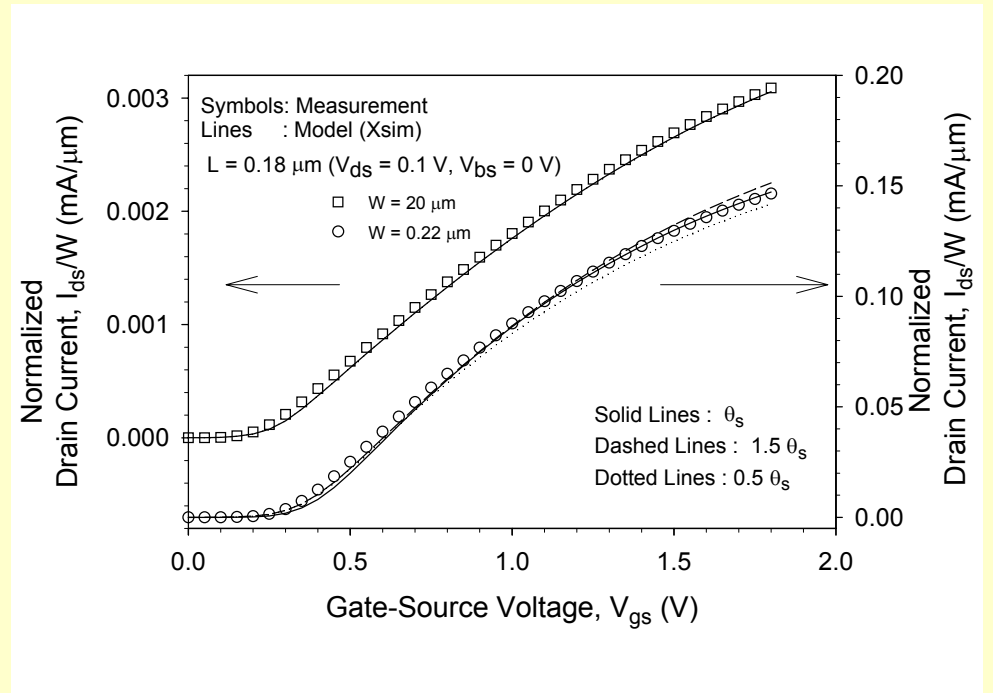
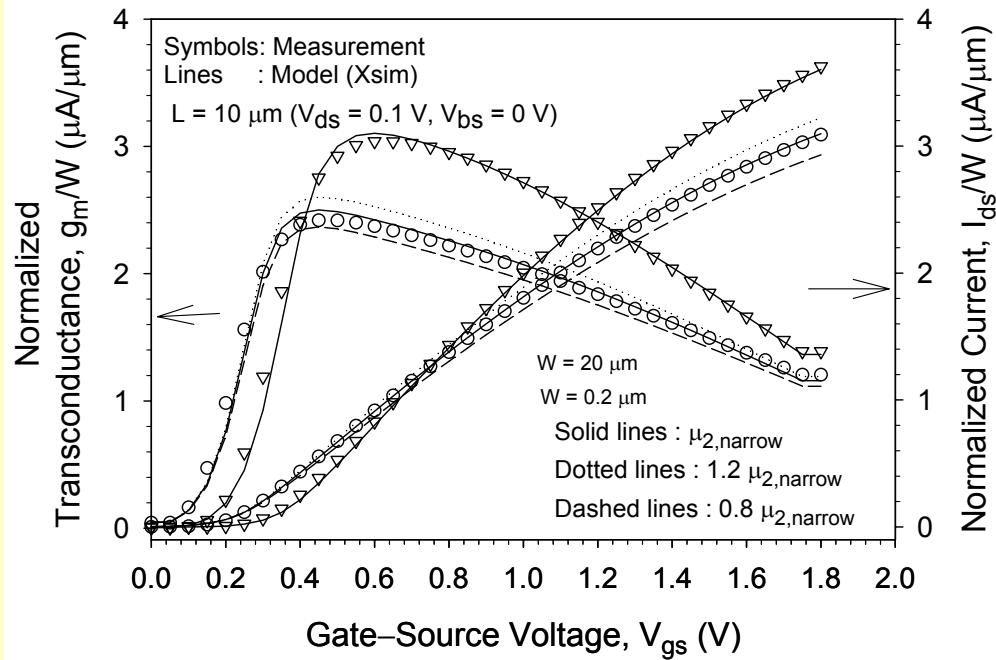
$$= \frac{2\rho}{x_j W_{eff}} \left[ (S + \theta_r S_1) + \frac{(\theta_r S_2) W_{eff}}{W_{dog}} \right]$$

$$= \frac{2\rho S'}{x_j W_{eff}} \left[ 1 - \theta_s \left( 1 - \frac{W_{eff}}{\theta_d W_{dog}} \right) \right]$$

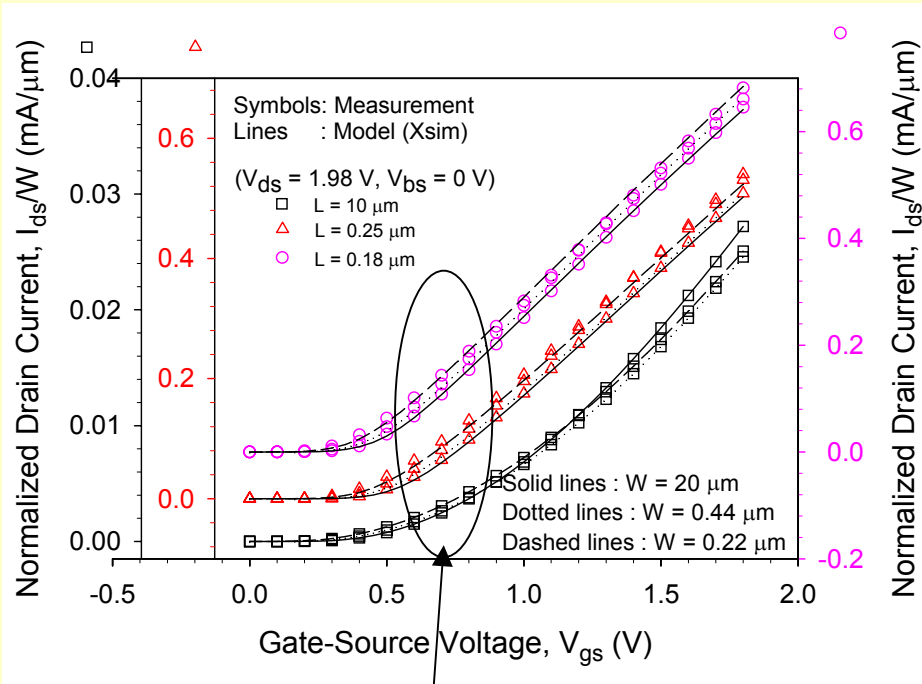
$$\theta_r = \frac{\rho_1/x_{j1}}{\rho/x_j} \quad \theta_s = \frac{\theta_r S_2}{S + \theta_r S_1 + \theta_r S_2}$$

$$S' = S + \theta_r (S_1 + S_2) \quad \text{Fitting: } \theta_r, \theta_d$$

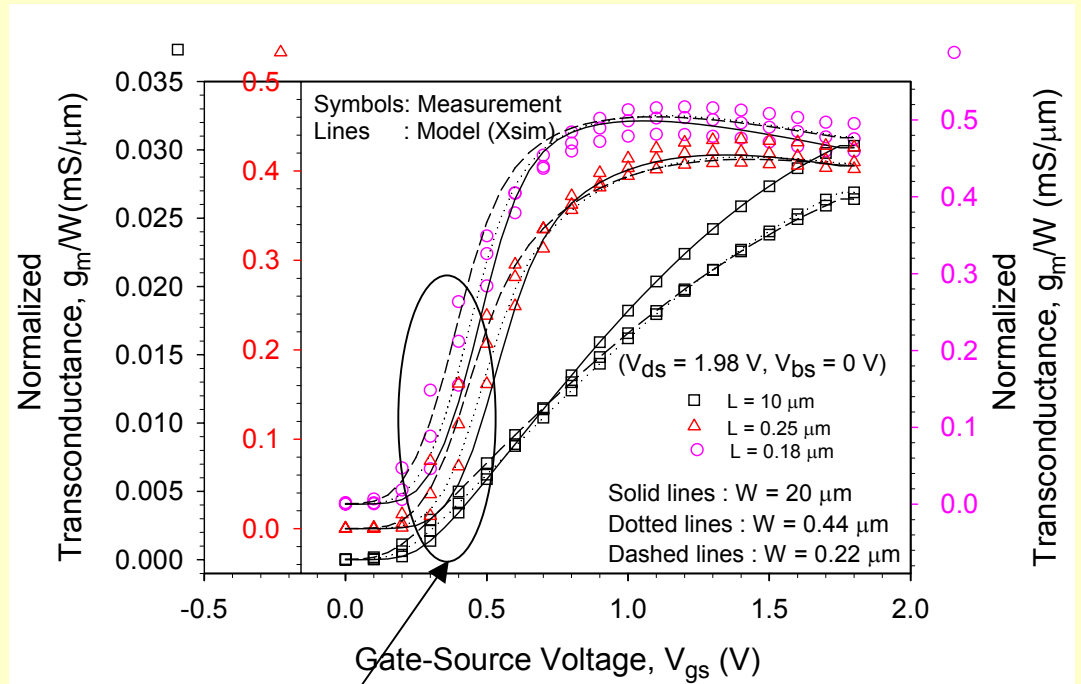
# Features in the New Model (Parameter variation)



# Model Verification and Prediction

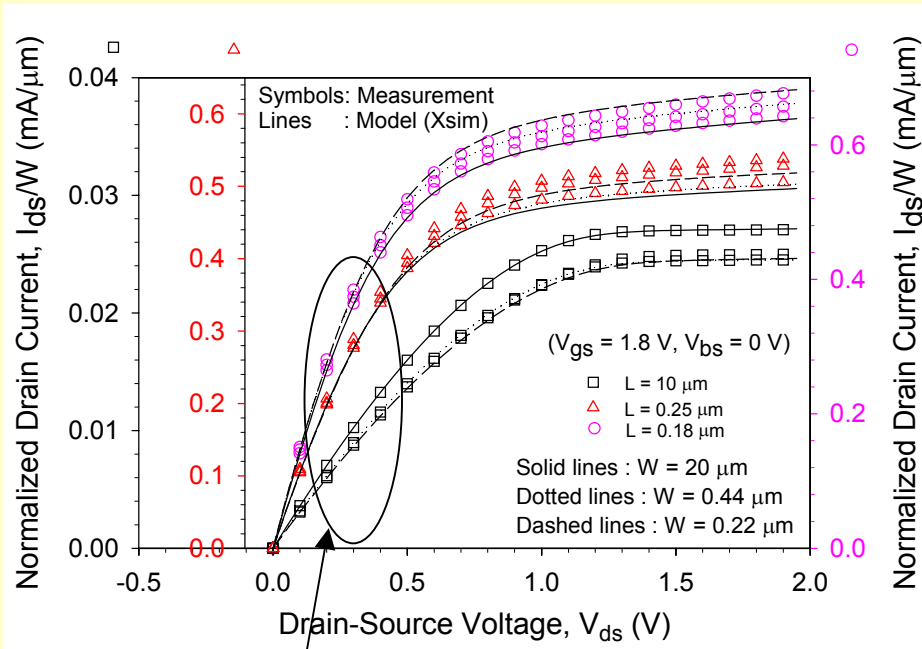


Prediction

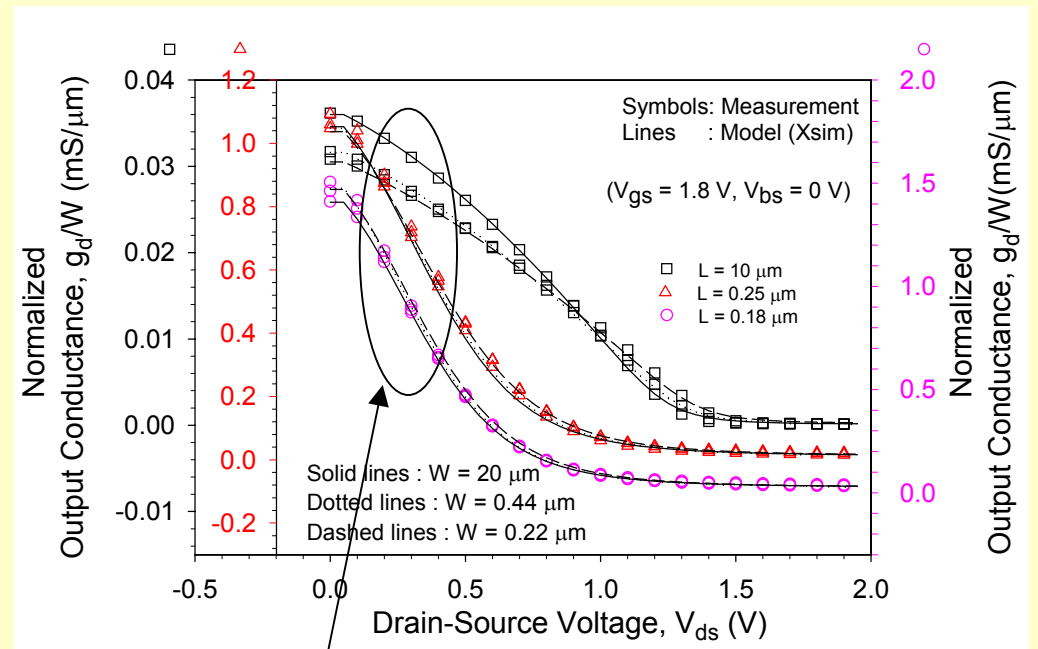


Prediction

# Model Verification and Prediction



Prediction



Prediction

## Conclusion

- Our previous length-dependent drain current model is extended to both length and width dimensions at various bias conditions.
- NWEs are modeled through width-dependent mobility (within the MOSFET core model, **one fitting**) and dog-bone layout effect (outside the MOSFET core model, **two fittings**).
- The simplicity in width-dependent drain current modeling is a result of accurate geometry dependent  $V_t$  prediction for the entire length and width dependency.