Flicker Noise Modeling in BSIM6 Compact Model

Harshit Agarwal, Yogesh S. Chauhan

Nanolab

Department of Electrical Engineering

Indian Institute of Technology Kanpur, India

Outline

- Introduction to BSIM6 Model
- Flicker Noise Modeling in BSIM6
- Flicker Noise Model for Halo Implanted MOSFETs

BSIM6: Industry Standard Bulk Model

- BSIM6 is the latest industry standard model of bulk MOSFET
- It inherits popular real device effects, like CLM, DIBL etc., from BSIM4.

BSIM6 Core Model

1- Calculate pinch-off potential Ψp

2- Next, source and drain inversion charge density is calculated

3- Calculate drain current

4- Obtain Charges : gate, drain, source and body charge

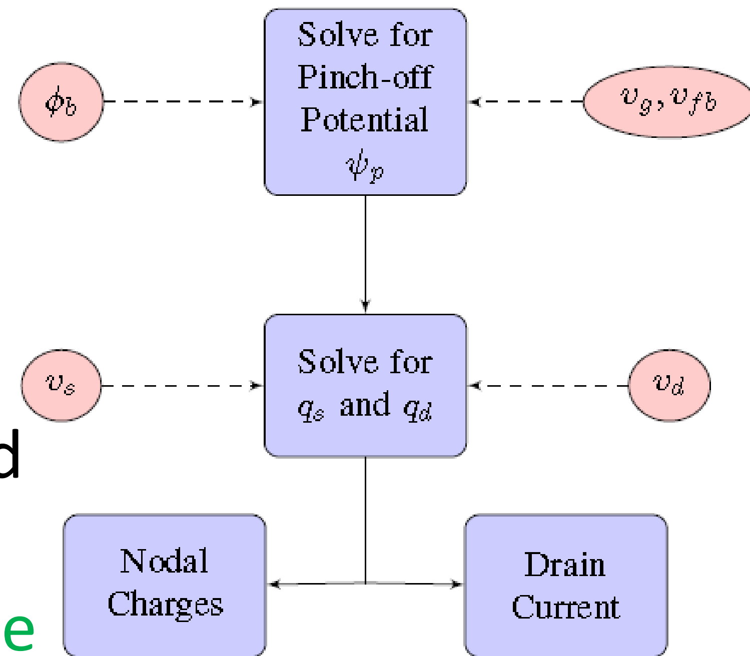
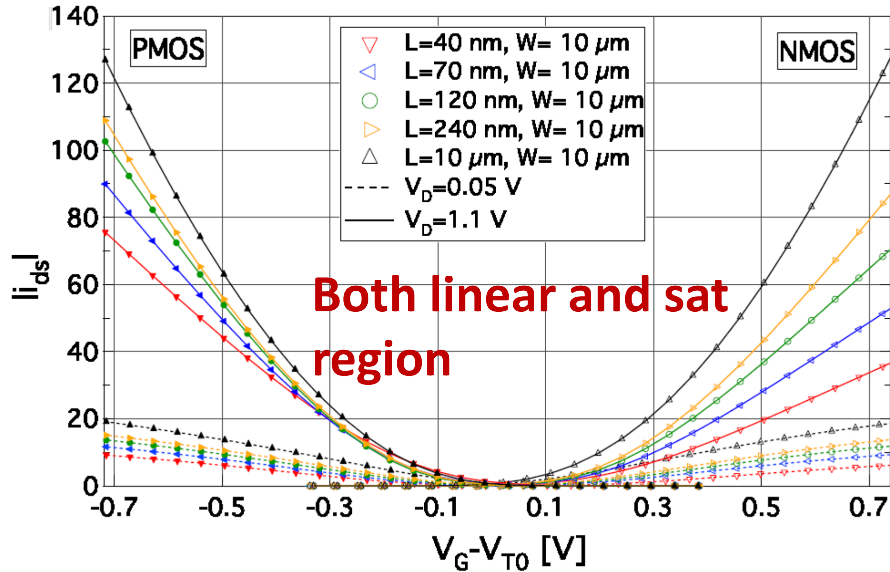
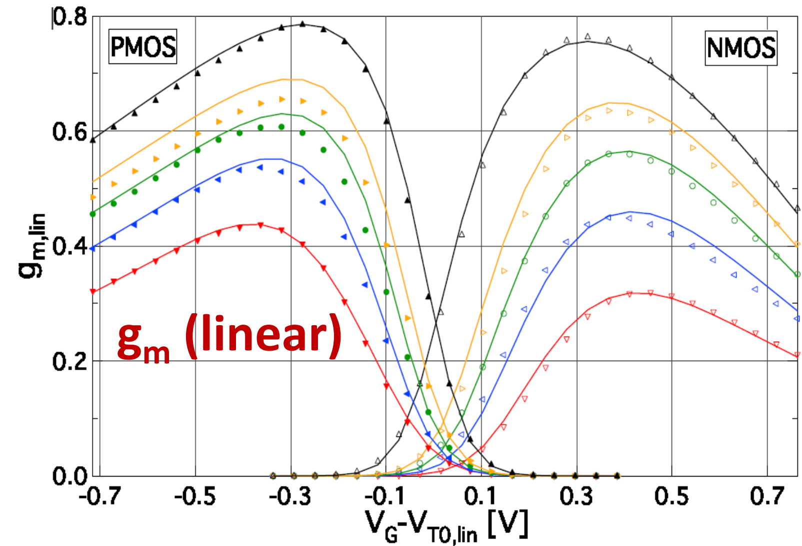
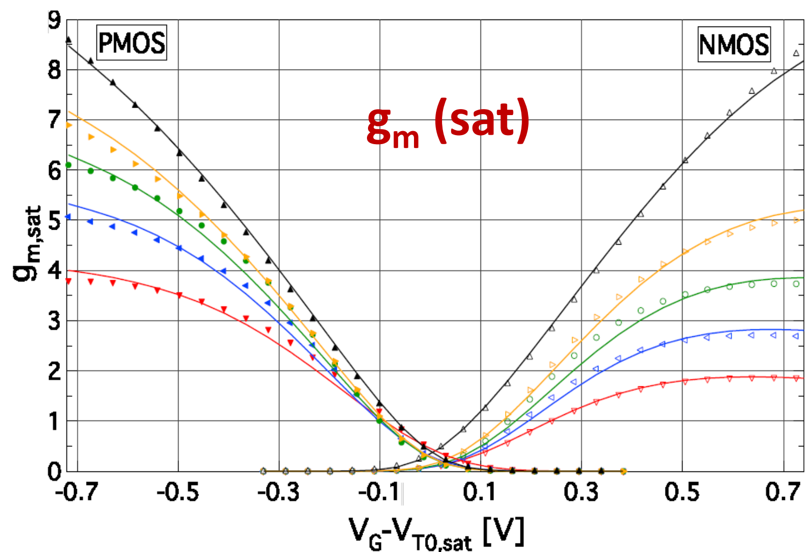


Fig: BSIM6 core model

BSIM6 Validation – I_{DS}-V_{GS}



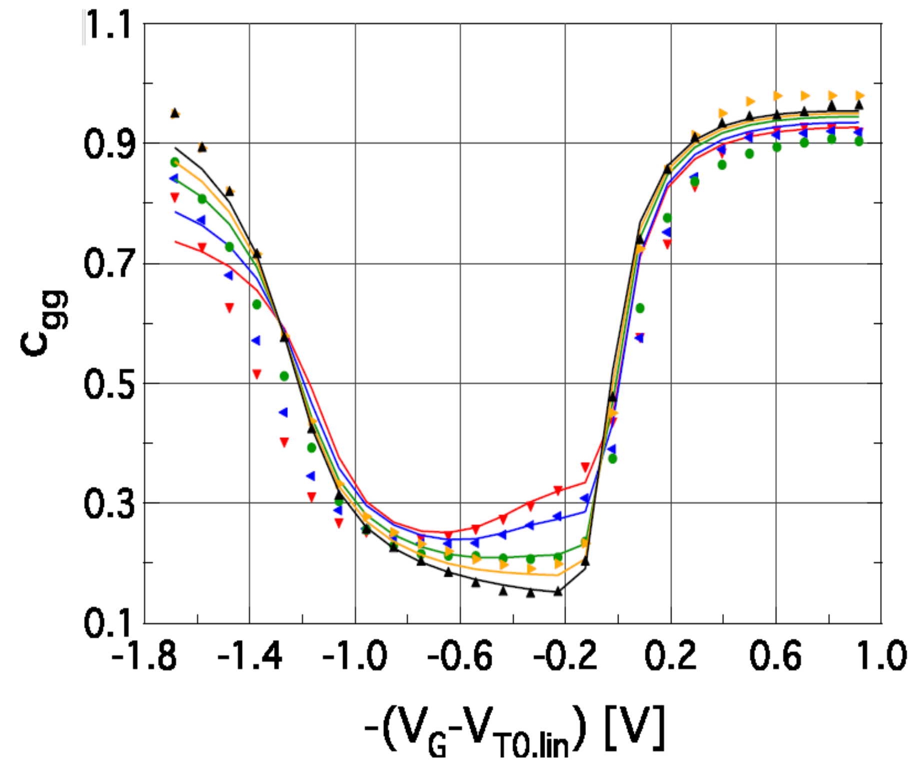




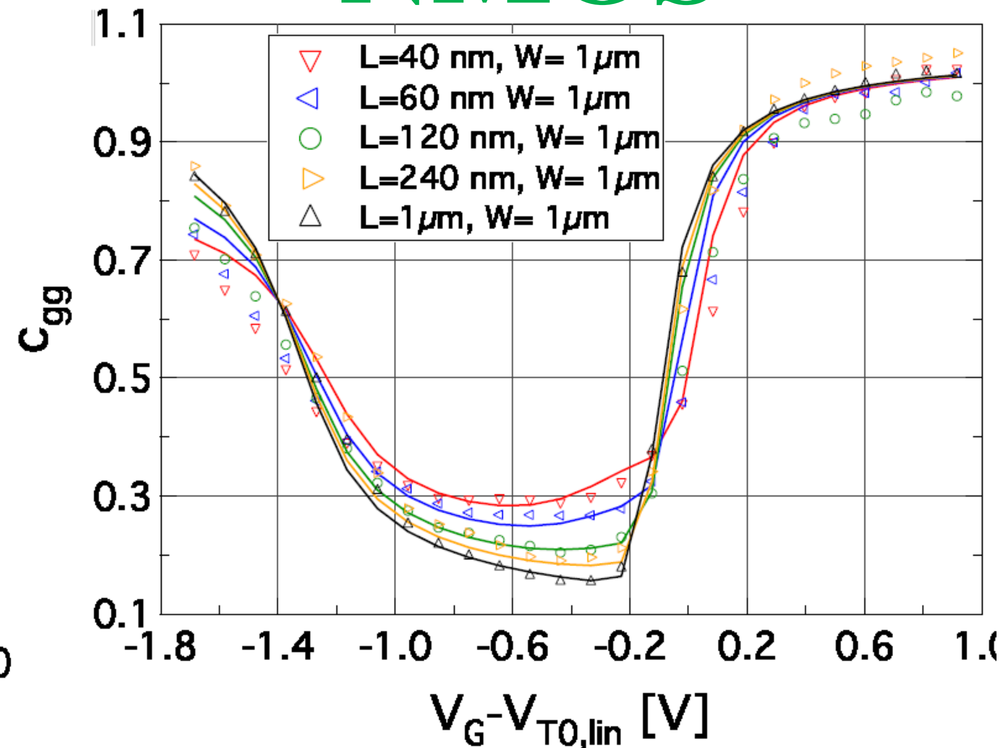
Excellent accuracy

BSIM6 Validation – Gate Capacitance

PMOS



NMOS



Flicker Noise Model

Source of Flicker Noise – Traps in Gate Dielectric

Two parallel theories for flicker noise-

1. McWhorter's – Fluctuation in carrier number due to trapping/de-trapping

$$\delta N \rightarrow \delta I_{DS}$$

2. Hooge's – Fluctuation in mobility due to phonon scattering

$$\delta \mu \rightarrow \delta I_{DS}$$

Unified Models – Takes care of **both number and mobility fluctuation** theories

K. Hung, et al., IEEE Trans. Electron Devices, vol. 37, no. 37, pp. 654-665, March 1990

Unified Flicker Noise Model

- The **unified model** takes both these into account as

$$I_D = WqN(x)\mu \frac{dV}{dy}$$

$$\frac{\delta I_D}{I_D} = \frac{\delta \mu}{\mu} + \frac{\delta N}{N}$$

Carrier number contribution

Mobility contribution

$$S_{ID} = \frac{kTI_D^2}{\gamma f W L^2} \int_0^L \frac{N_t^*}{N^2} dy$$

$$N_t^* = N_t \left(1 + \alpha\mu \frac{N}{R}\right)^2 = A + BN + CN^2$$

N^*_t: Effective trap density

- $\gamma \approx 10^8 cm^{-1}$ and α is scattering coefficient

K. Hung, et al., IEEE Trans. Electron Devices, vol. 37, no. 37, pp. 654-665, March 1990

Unified Flicker Noise Model

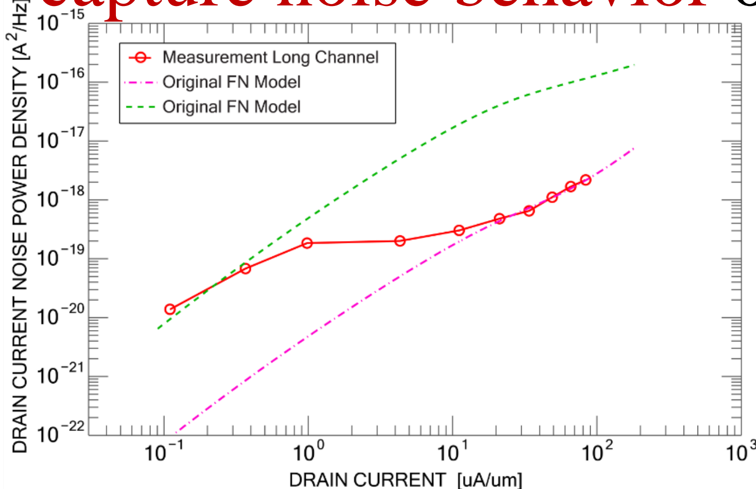
Unified flicker noise model

- Implemented in many commercial models
- More than a decade old, captures noise behavior over different technologies and across devices and biases
- Takes care of both carrier number and mobility fluctuation effects

How good is it to model noise in advance structures involving halo implants ..

Flicker Noise in Presence of Halo Implant

- Advanced CMOS structures require halo implants to control short channel effects.
- Noise behavior is qualitatively and quantitatively different from uniformly doped devices
- Unified flicker noise model in its original form cannot capture noise behavior of halo implanted devices



Possible reasons

1. Higher trap density in the halo region
2. Non-uniform threshold voltage along the channel

N. Paydavosi, et al., "Flicker Noise Analysis in Advance CMOS Technologies", ESSDERC, 2013.

Summary

- Currently BSIM6 has flicker noise model which is based on unified model
- Flicker Noise behavior of halo implanted structure is different from uniformly doped MOSFETs
- Halo MOSFETs depicts significant gate bias dependency
- Popular unified model in raw form cannot model flicker noise
- New analytical model proposed

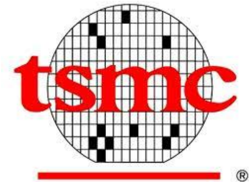
Acknowledgement

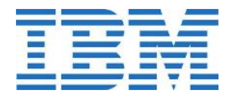
- Model users
- EDA Vendors
- CMC Members

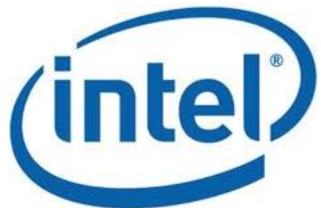
- Funding agencies
  - SRC/GRC
  - CMC
  - DST, Govt. of India
  - IIT Kanpur

Joint Development & Collaboration

- Working closely with universities/companies on model development and support







Thank You