

# **RF Modeling for FDSOI MOSFET and Self Heating Effect on RF Parameter Extraction**

---

**Hui Wan, Pin Su, Samuel Fung,  
Ali Niknejad, Chenming Hu**

**University of California, Berkeley**

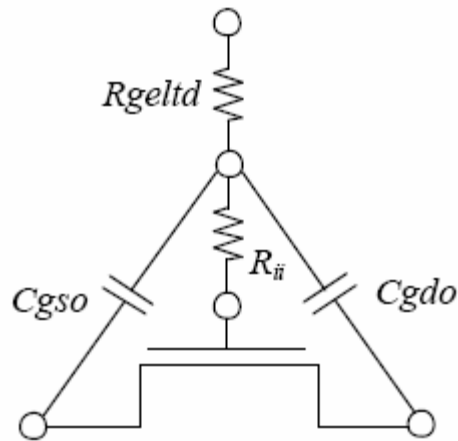
# Introduction

---

- RF modeling for Fully Depleted SOI MOSFET
  - Gate resistance modeling for Fully Depleted Device
  - Self heating effect on RF fitting
- A simple way of thermal resistance extraction of SOI MOSFET
- Conclusion

# RF model in BSIMSOI

- Gate Resistance Model (BSIM4 compatible gate resistance model is developed)



( RgateMod =3 )

S11 could be easily fit by  
Gate Resistance Model

- Body Resistance Network: Definitely important in bulk and PD SOI MOSFET, how about for FDSOI device?

# RF model in BSIMSOI

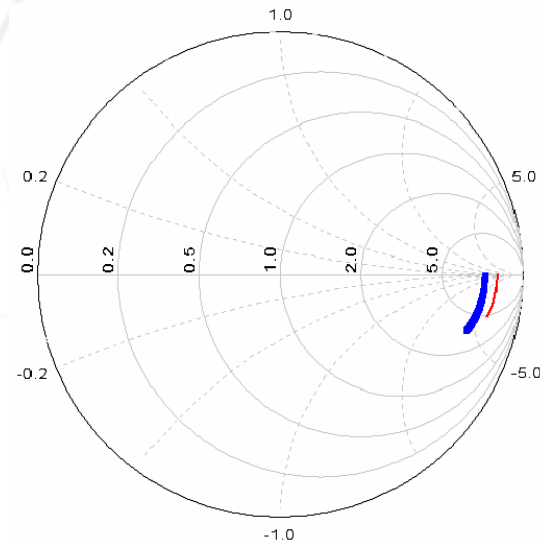
- Body Resistance Network
  - For FD SOI, there is no neutral body, do we still need body resistance network?

The blue line is data

The red line is model simulation after DC fitting

Even though DC fitting is good, the S22 data indicate higher AC conductance compare to the result from the model

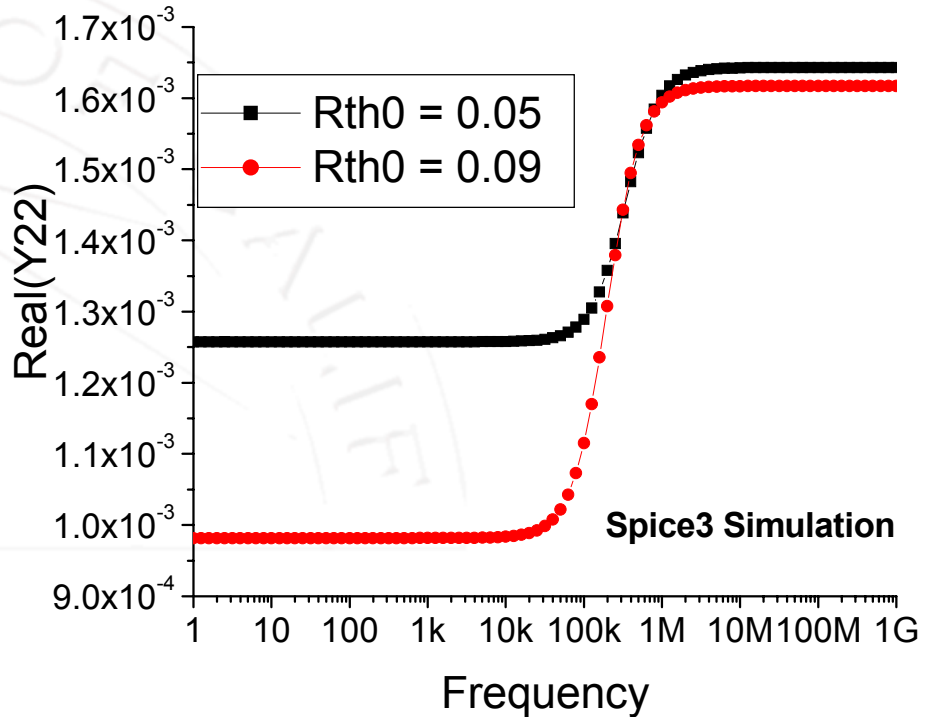
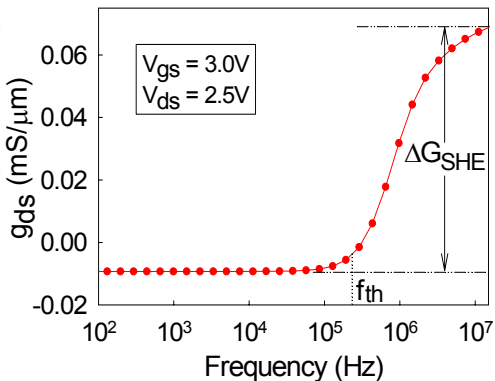
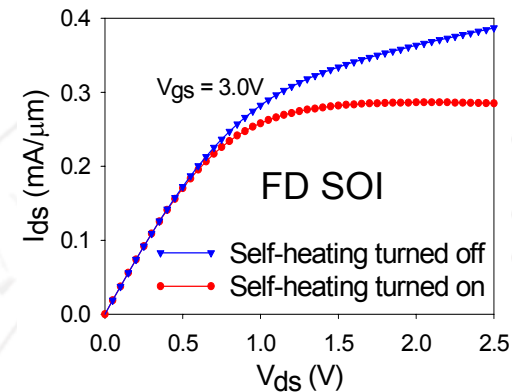
Frequency: 45M~20GHz



$$Y_{22} = \frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{\Delta} Y_0$$

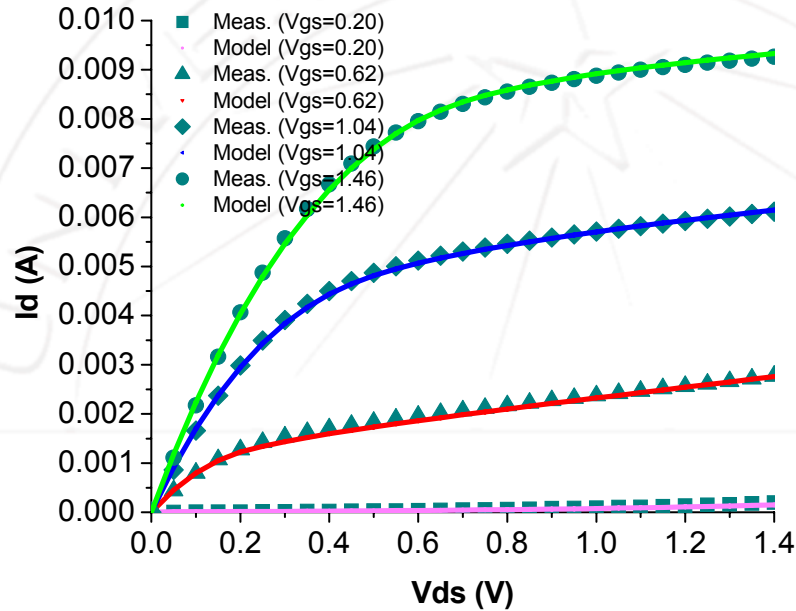
$$\Delta = (1 + S_{11})(1 + S_{22}) - S_{12}S_{21}$$

# Self Heating Effect on Real(Y22)

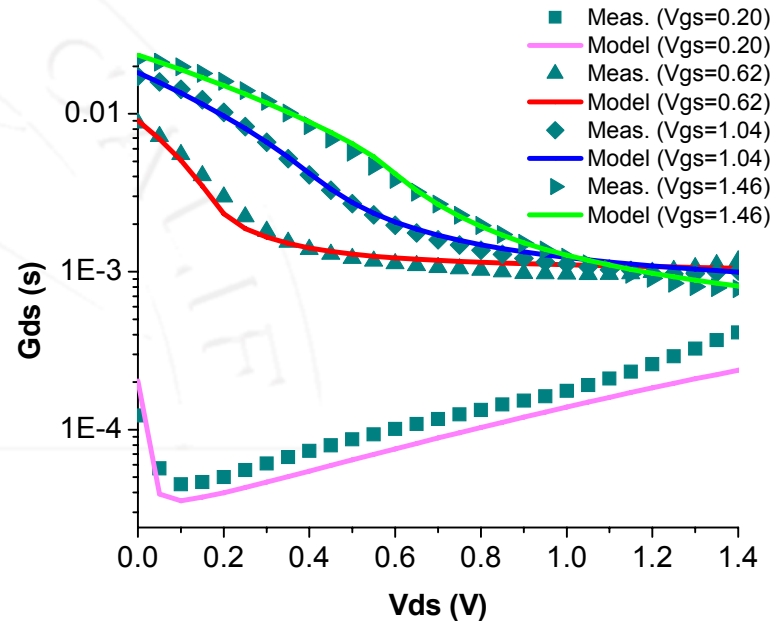


- Both output conductance model and self heating model will affect the DC current and conductance fitting
- At High Frequency, SHE won't follow the signal changes
- Self heating affects both DC and RF fitting

# DC Fitting of Fully Depleted SOI Device



$I_d \sim V_{ds}$

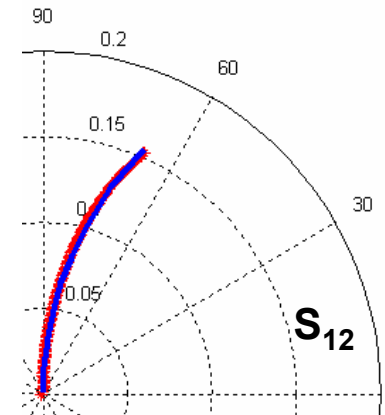
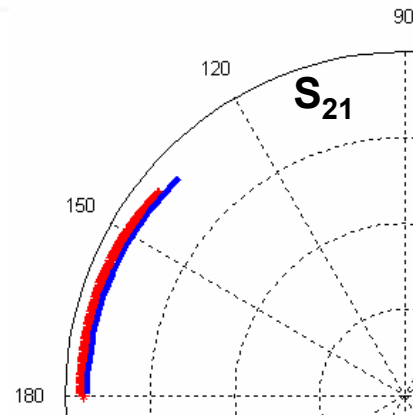
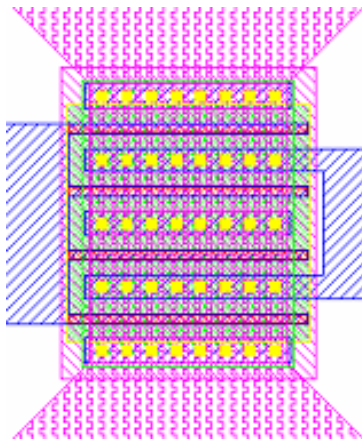
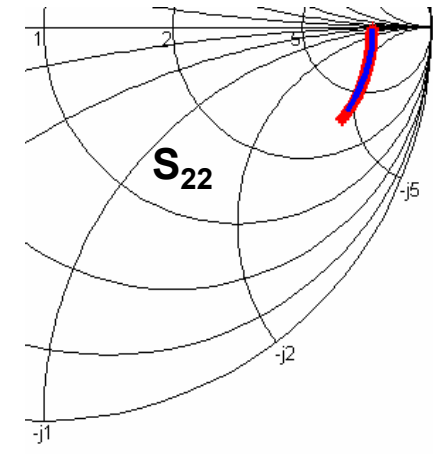
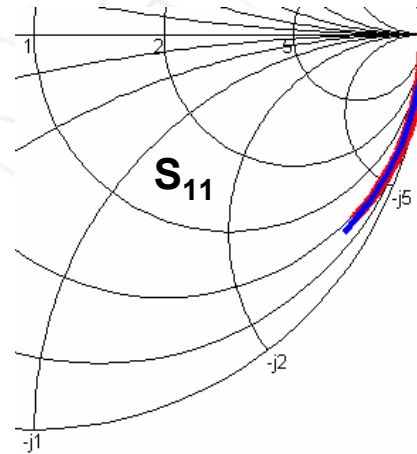


$G_{ds} \sim V_{ds}$

Measured = Symbols    Simulated = Lines

# RF model for Fully Depleted SOI Device

- Fitting example of a four-finger device
- No body resistance network
- 45 MHz to 20 GHz



# RF Fully Depleted SOI Device

---

- RF characteristic of fully depleted SOI device can be captured by gate resistance model and DC model
- Body resistance network is not needed for fully depleted SOI device
- Frequency dependent phenomena are very critical to RF fitting. For example, self heating effect.

# Outline

---

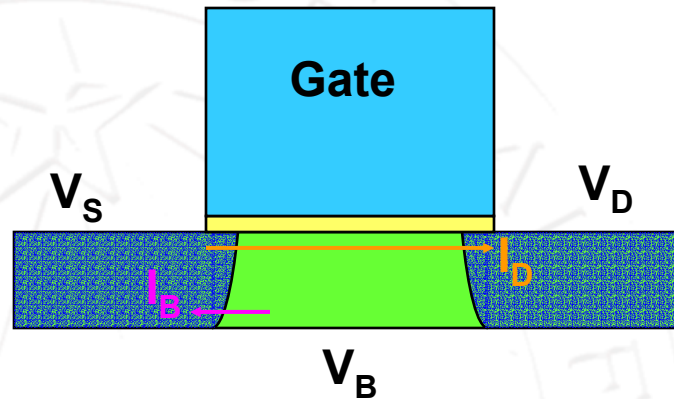
- RF modeling for Fully Depleted SOI MOSFET
  - Gate resistance modeling for Fully Depleted Device
  - Self heating effect on RF fitting
- Thermal resistance extraction of SOI MOSFET
- Conclusion

# Self Heating in SOI Device

---

- Self heating effect is important for both DC and AC modeling of SOI device
- A simple method to extract thermal resistance parameter is by using body-source diode as a thermometer to determine thermal resistance

# Self Heating in SOI - $R_{th}$ Extraction



$$\text{Power} = I_D \times V_{DS}$$

$$R_{th} = \frac{\Delta \text{Temperature}}{\Delta \text{Power}}$$
$$= \frac{d \log(I_{BS}) / d P}{d \log(I_{BS}) / d T}$$

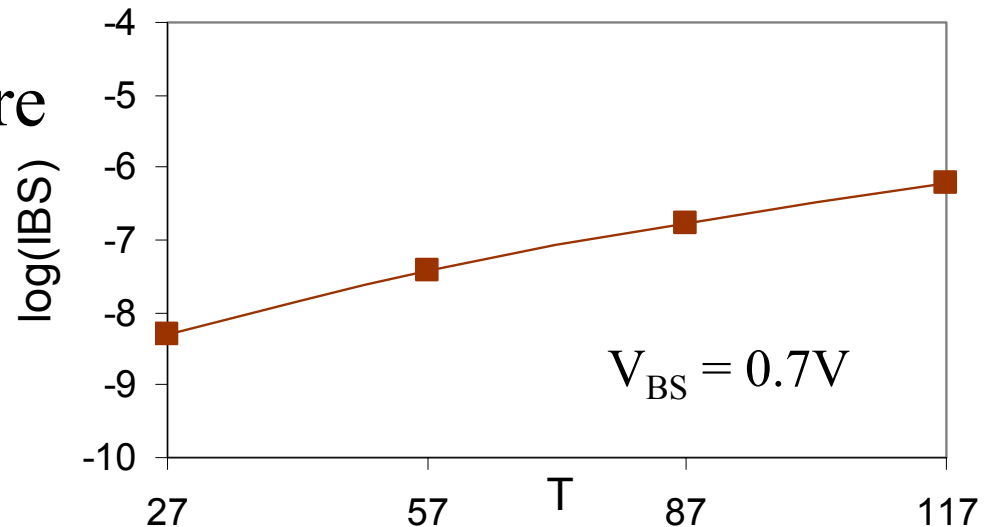
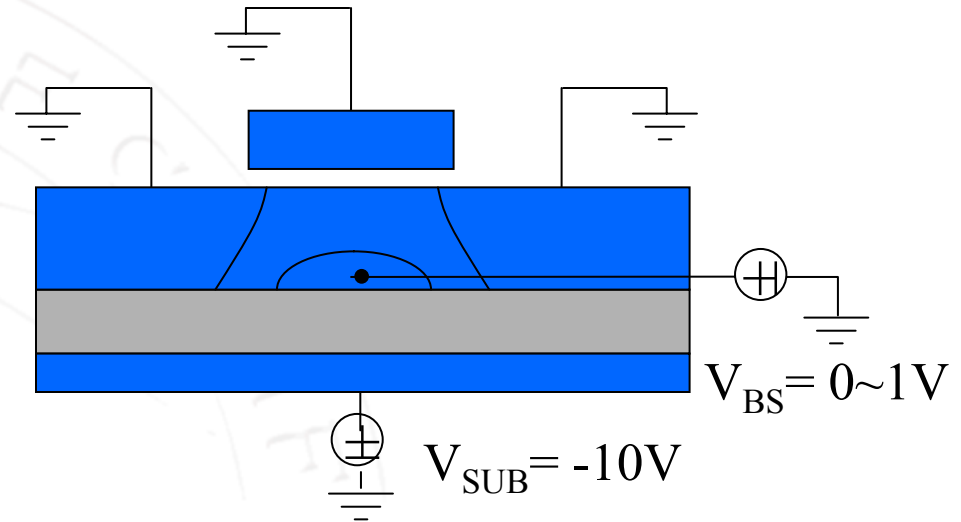
- Use body-source diode current as a thermometer to determine thermal resistance

# Self Heating in SOI - $R_{th}$ Extraction

$$\frac{d \log I_{BS}}{dT}$$

- Body contact transistor is needed
- Transistor is off
- Measurement of  $I_{BS}$  changing with temperature

(Temperature changes from 27°C to 117 °C with 30 °C step)

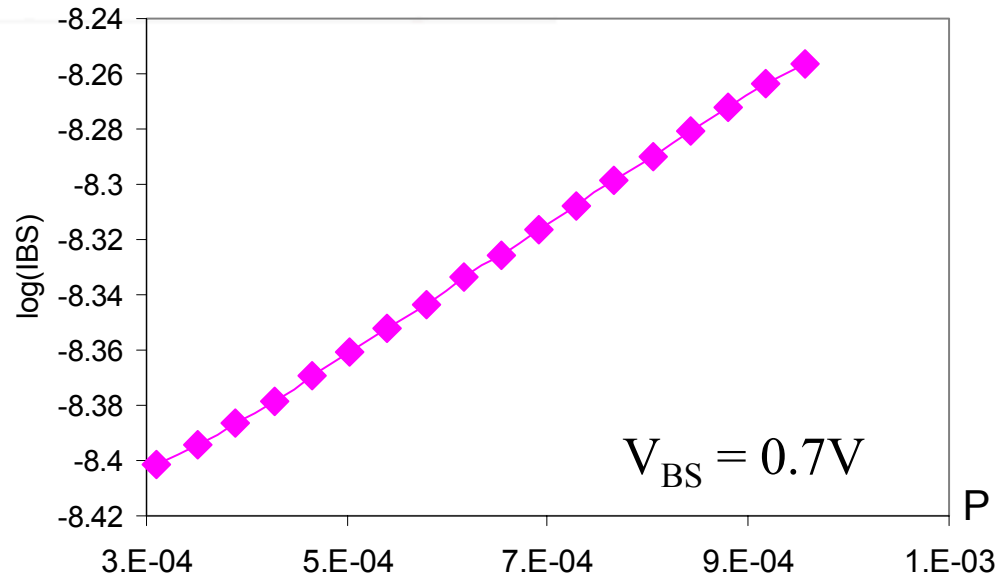
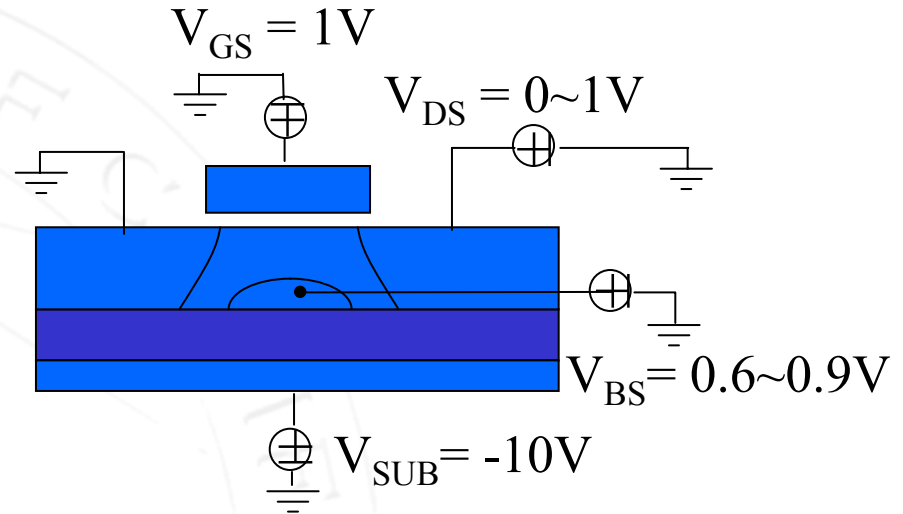


# Self Heating in SOI - $R_{th}$ Extraction

$$\frac{d \log I_{BS}}{dP}$$

- Transistor is on
- Measurement of  $I_{BS}$  changing with power

( $P = V_{DS} \times I_{DS}$ ),  
 $T = 27^\circ\text{C}$



# Self Heating in SOI - $R_{th}$ Extraction

---

$$\text{Power} = I_D \times V_{DS}$$

$$R_{th} = \frac{\Delta \text{Temperature}}{\Delta \text{Power}} = \frac{d \log(I_{BS}) / d P}{d \log(I_{BS}) / d T}$$

Model Parameter  $R_{th0}$  can be found by:

$$R_{th0} = R_{th} * W \text{ (Refer to BSIMSOI manual)}$$

# Conclusion

---

- DC current and Gds fitting is affected by output conductance model and self heating in SOI device
- Self Heating plays an important role in both DC and RF
- Thermal resistance is very critical to RF fitting
- Body resistance network is not needed for fully depleted SOI device
- A simple thermal resistance extraction method is proposed using body-source diode as a thermometer