Thin-body FinFET Powers ICs To Beyond 10nm

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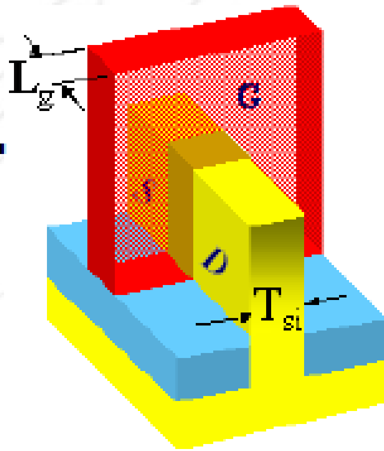
May 4 2011
New York Times front page

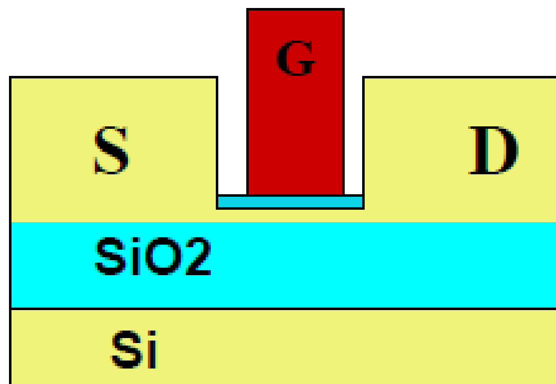
- Intel will use 3D FinFET at 22nm
- Most radical change in decades
- There is a competing SOI technology

New MOSFET Structures

FinFET

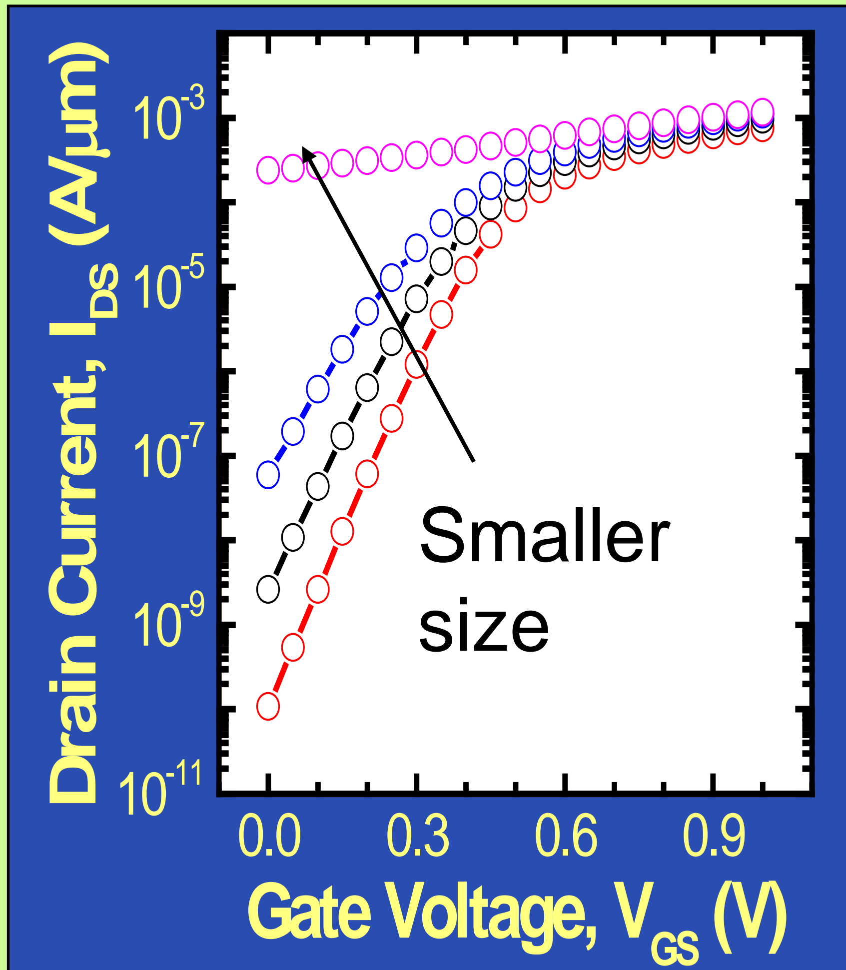


UTBSOI



Ultra **T**hin **B**ody **SOI**

Good Old MOSFET Nearing Limits

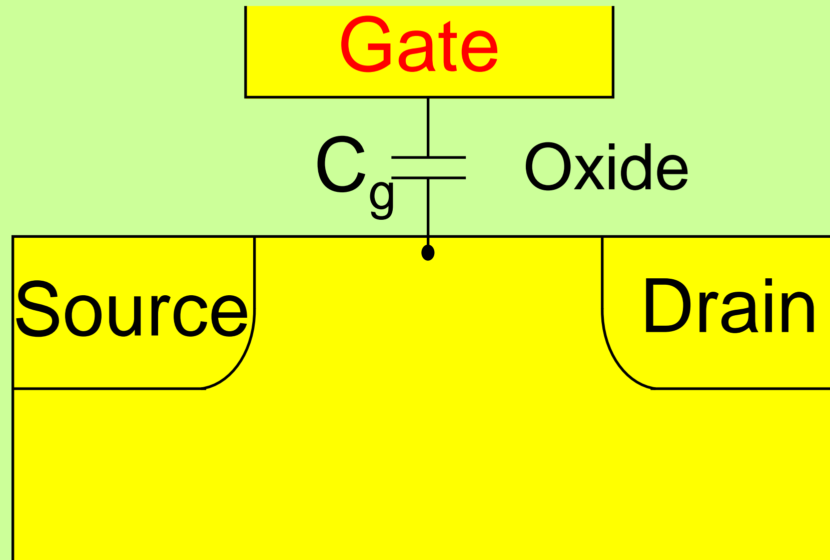


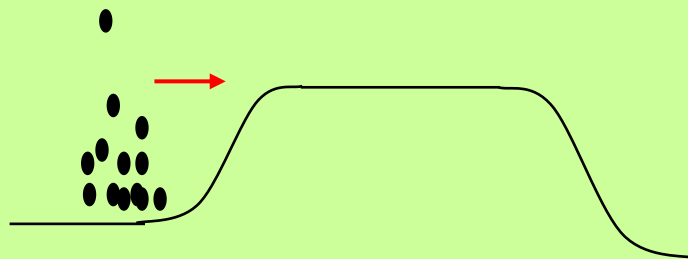
- Ioff is bad
- Size and dopant variations

High Vdd, power, design cost

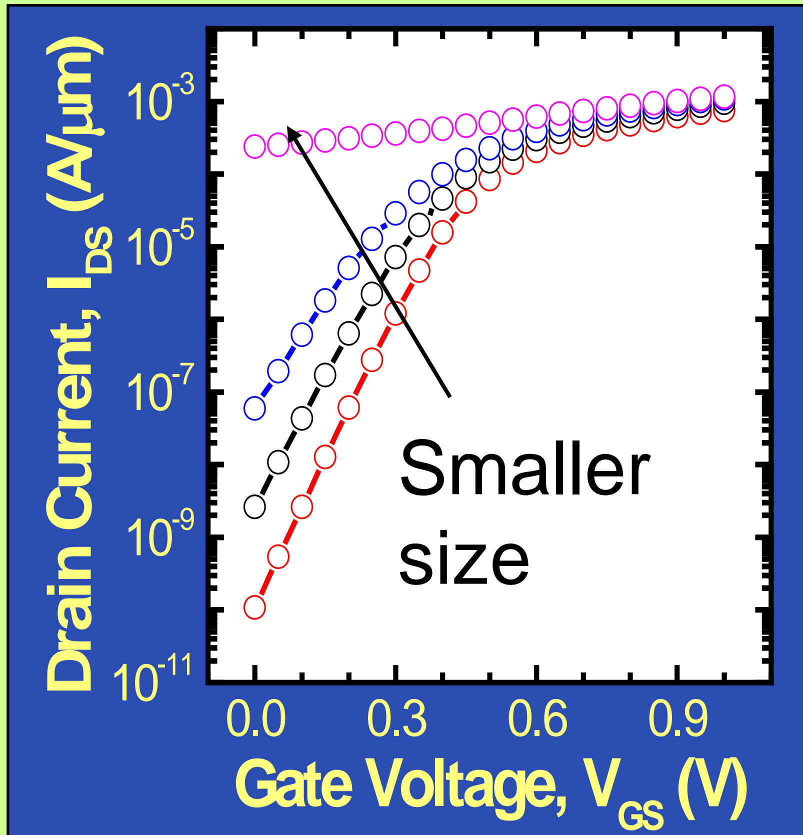
Finally painful enough for change.

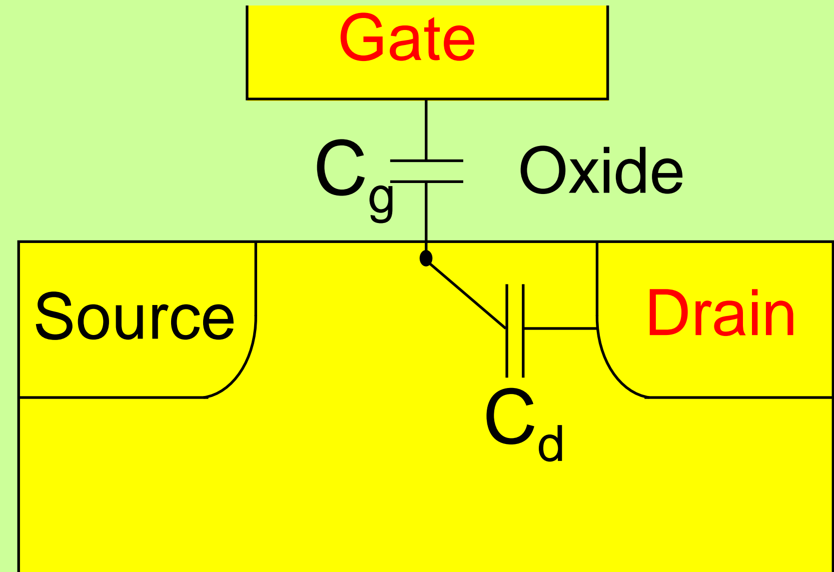
Long Channel MOSFET





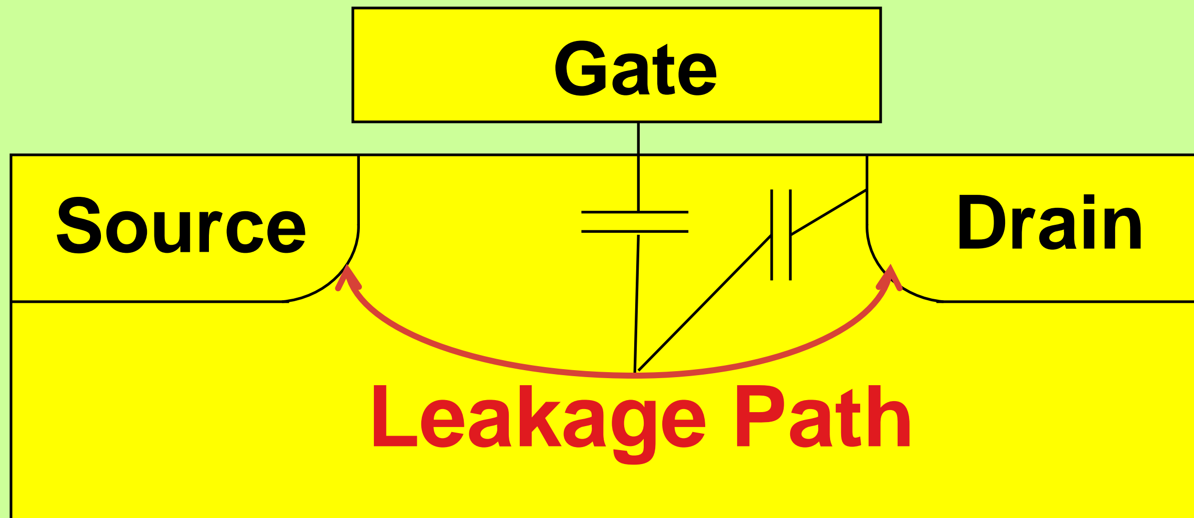
Why Ioff and Variations Got Worse





MOSFET becomes "resistor" at very small L

Making Oxide Thin is Not Enough

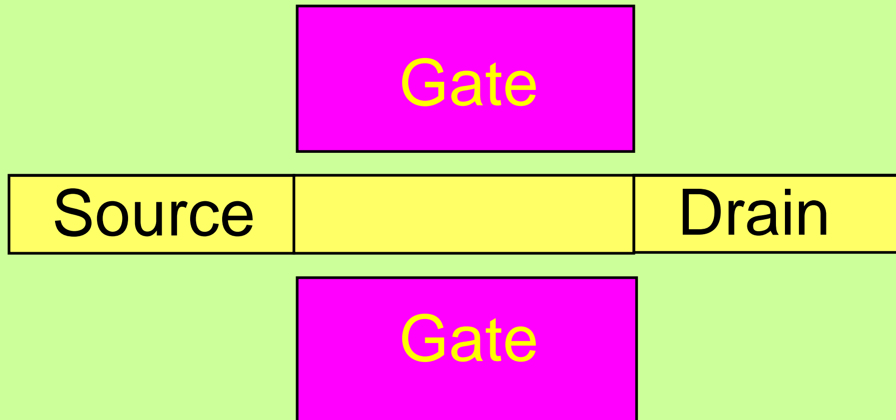


Gate cannot control the leakage current paths that are far from the gate.

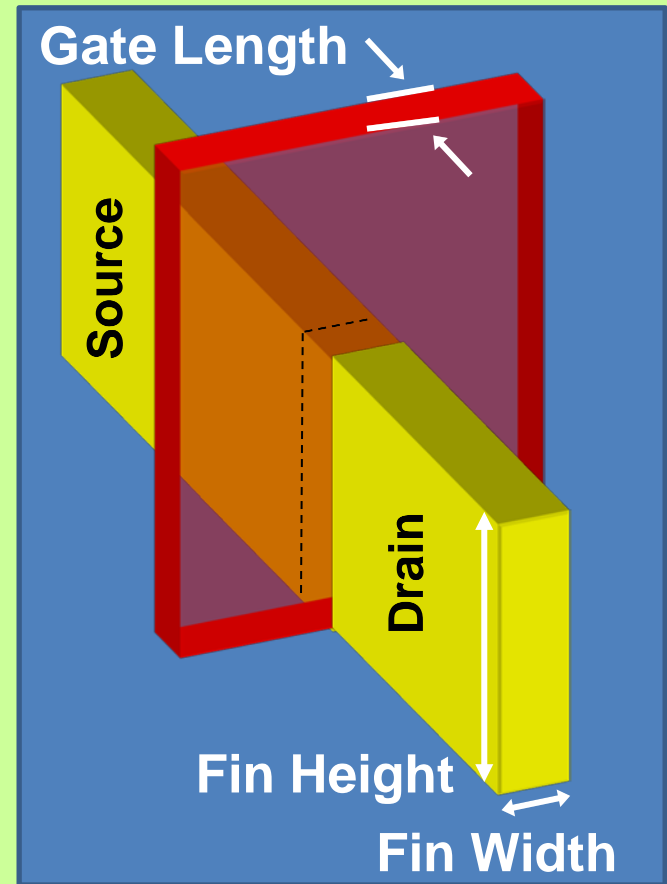
C.Hu,"Modern Semicon. Devices for ICs" 2010, Pearson

One Way to Eliminate Si far from Gate

A **thin** body controlled by gate from more than one side.



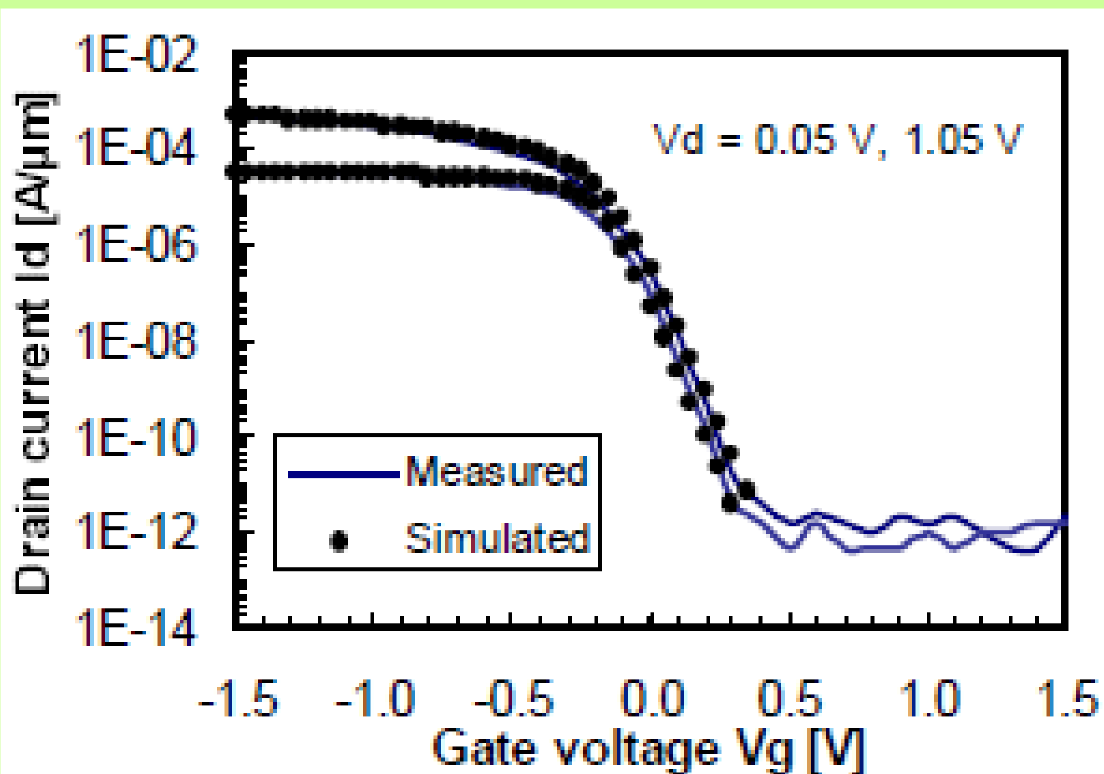
FinFET body is a thin fin

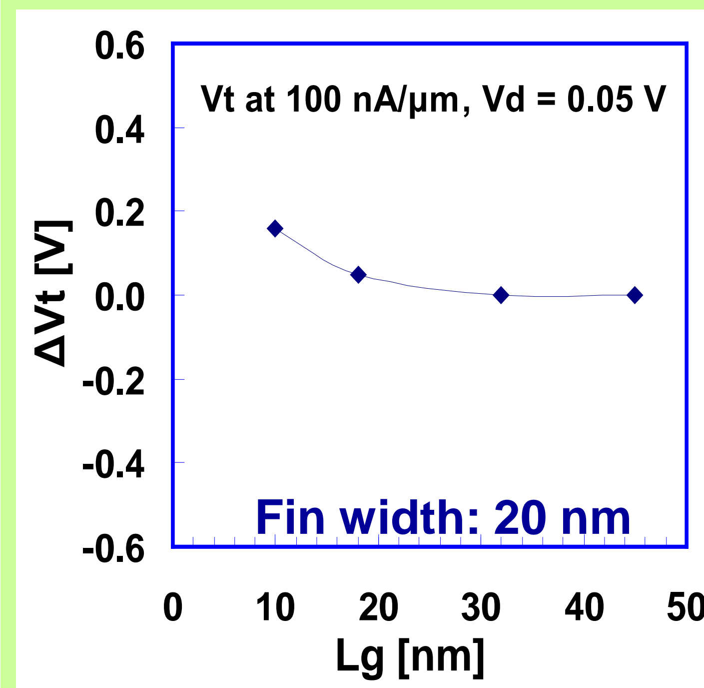


N. Lindert et al., DRC paper II.A.6, 2001

FinFET- 1999

Undoped Body. 30nm etched thin fin. Vt set with gate work-function.

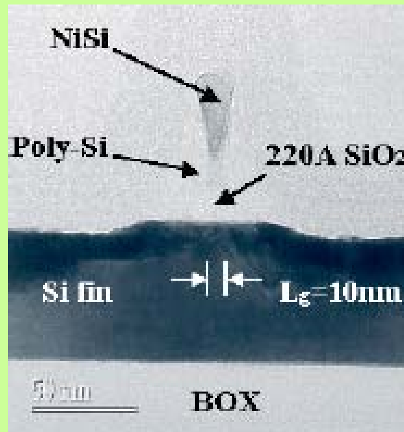


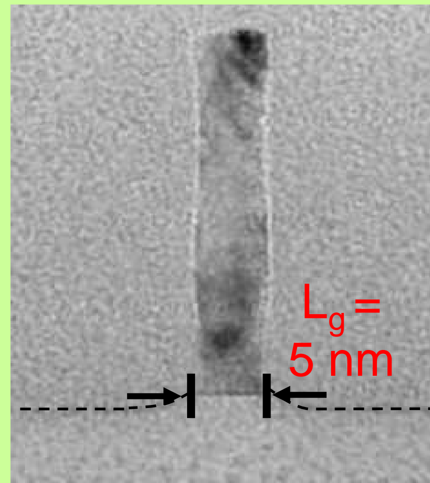


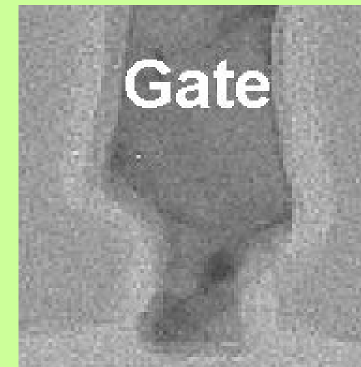
X. Huang et al., IEDM, p. 67, 1999

FinFET is "Easy" to Scale

10nm Lg AMD 2002 IEDM	5nm Lg TSMC 2004 VLSI Symp	3nm Lg KAIST 2006 VLSI Symp





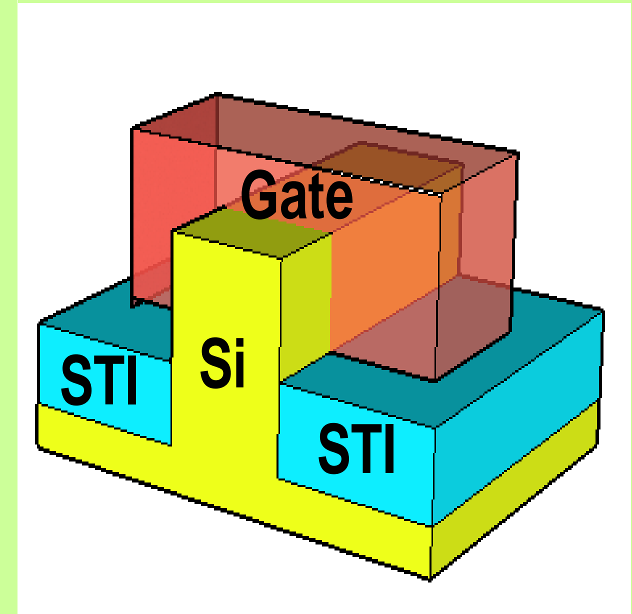


Leakage is well suppressed if

Fin thickness < Lg

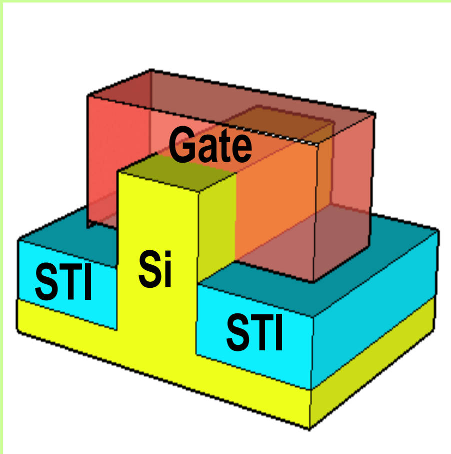
Two Improvements Since 1999

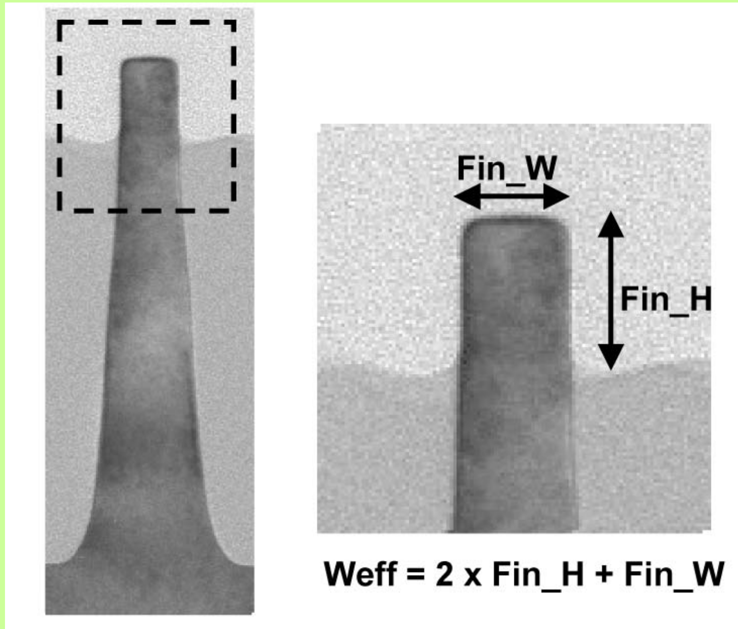
- 2002 FinFET with thin oxide on fin top.
F.L.Yang et al. (TSMC) 2002 IEDM, p. 225.

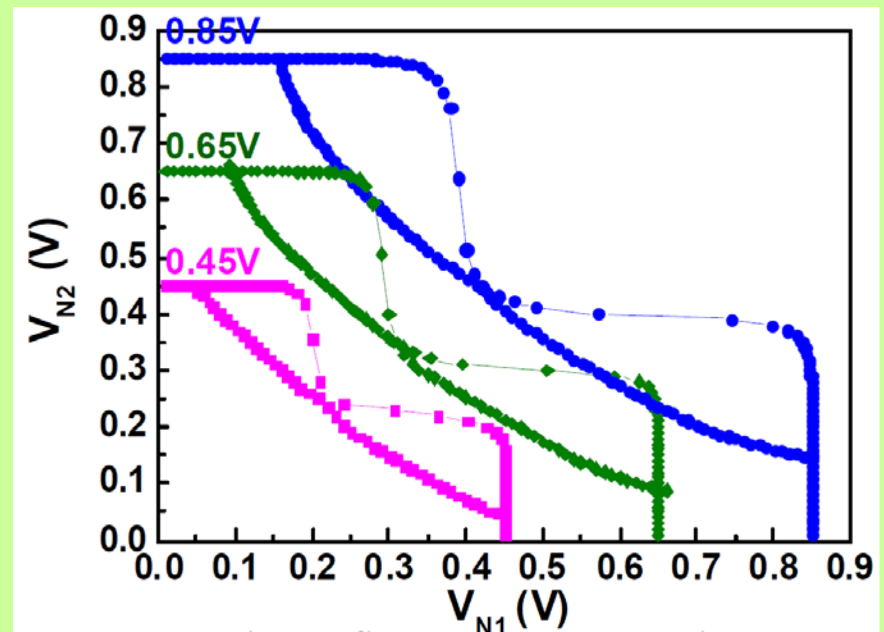


- 2003 FinFET on bulk substrate.
T. Park et al. (Samsung) 2003 VLSI Symp. p. 135.

State-of-the-Art FinFET

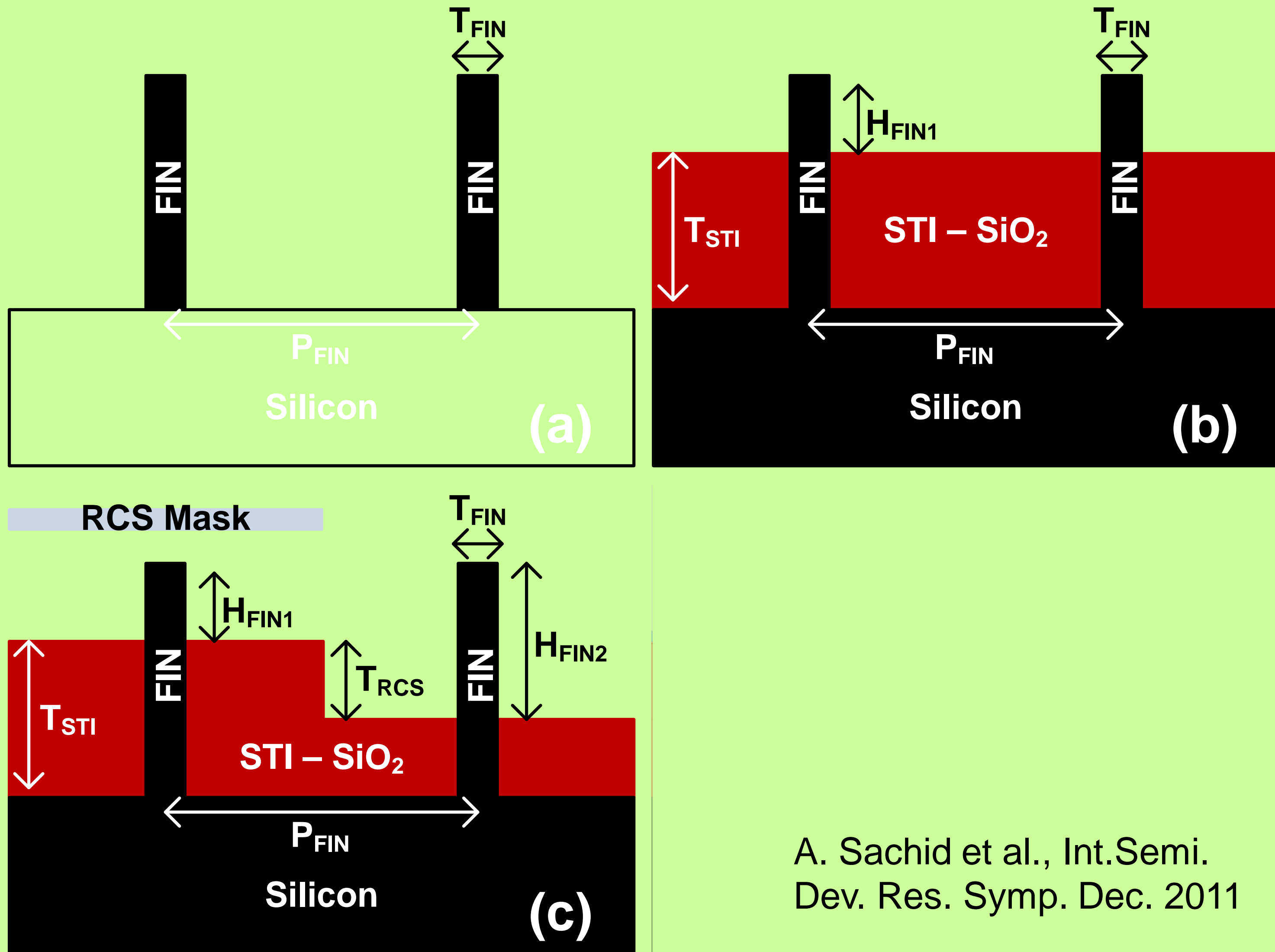






20nm Hi Perf
C.C. Wu et al.,
2010 IEDM

Multiple Fin Heights

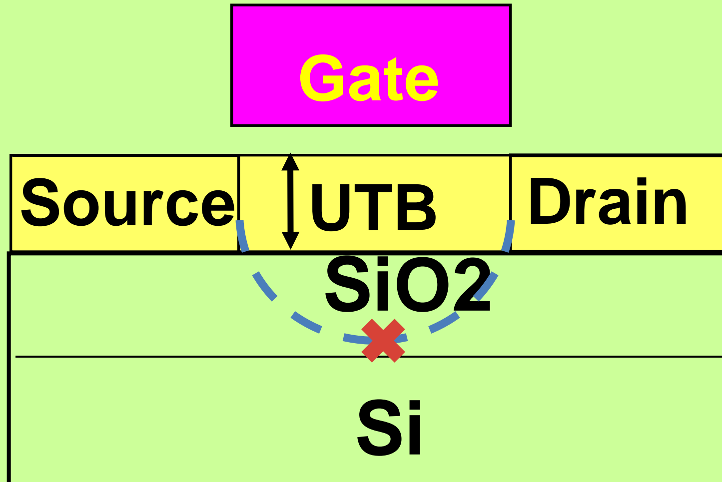


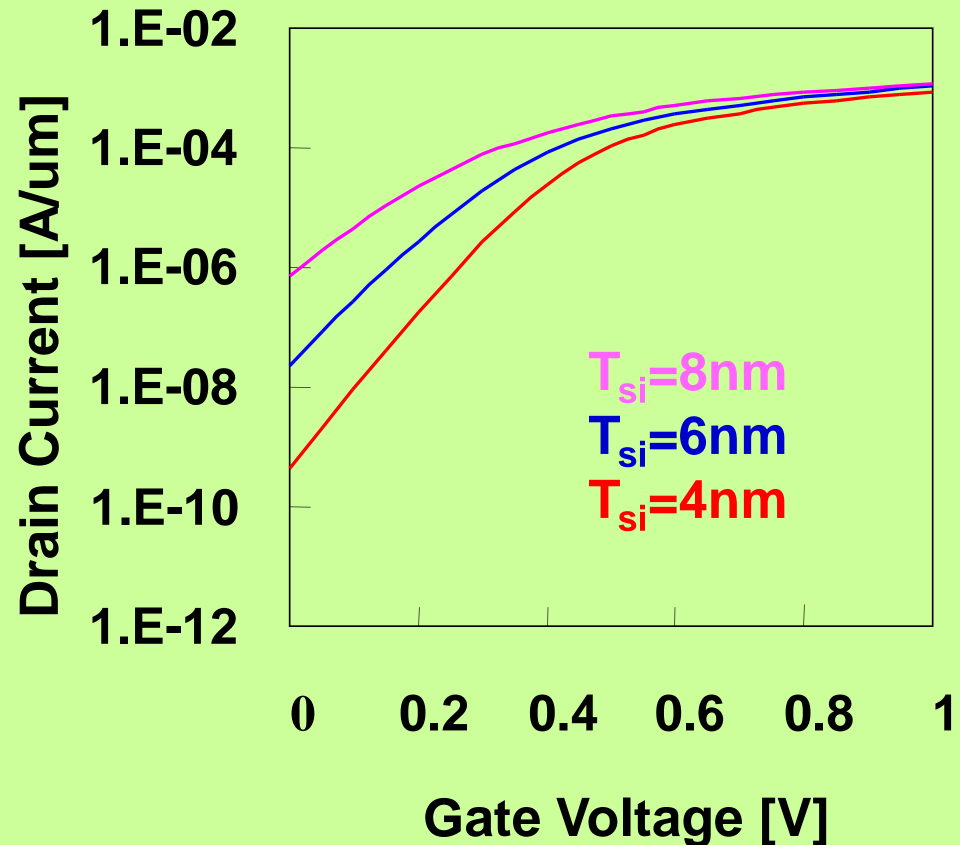
A. Sachid et al., Int.Semi. Dev. Res. Symp. Dec. 2011

2nd Way to Eliminate Si far from Gate

Ultra-thin-body SOI (UTB-SOI) →

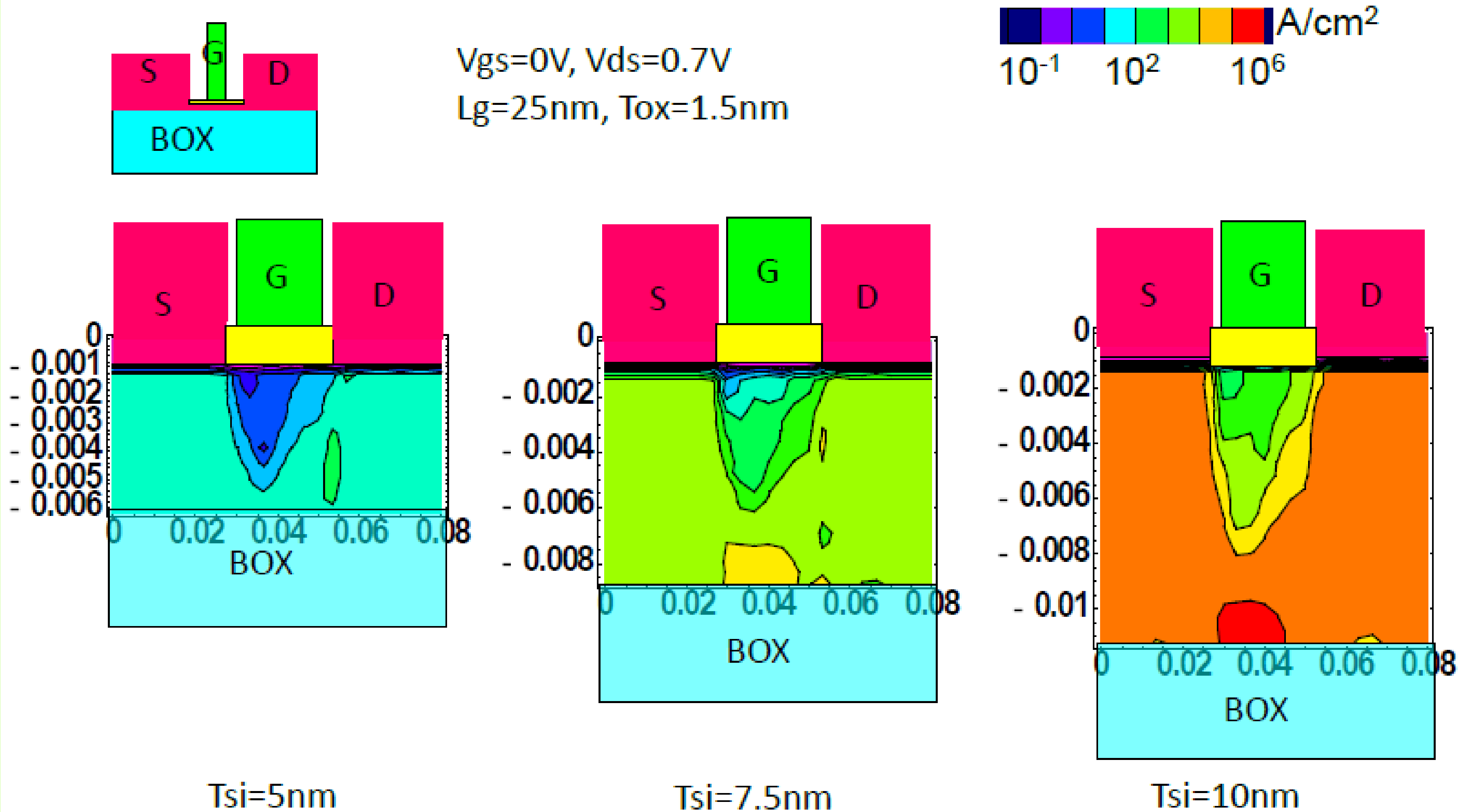
No leakage path far from the gate.





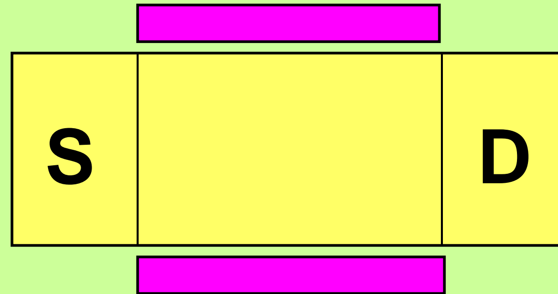
Y-K. Choi, IEEE EDL, p. 254, 2000

Most Leakage Flows >5nm Below Surface



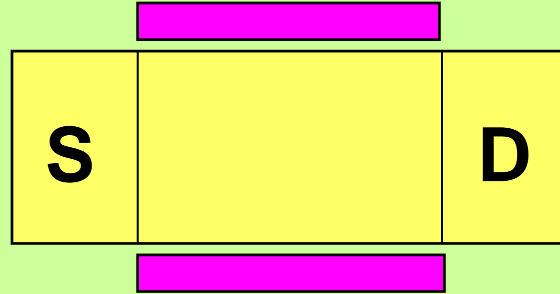
Y-K. Choi et al., IEEE Electron Device Letters, p. 254, 2000

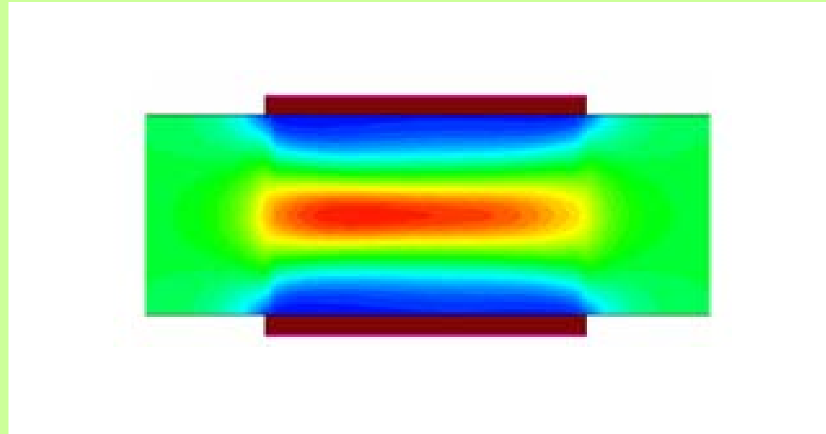
FinFET's Worst Leakage Path



C.Hu,"Modern Semicon. Devices for ICs" 2010, Pearson

FinFET's Worst Leakage Path

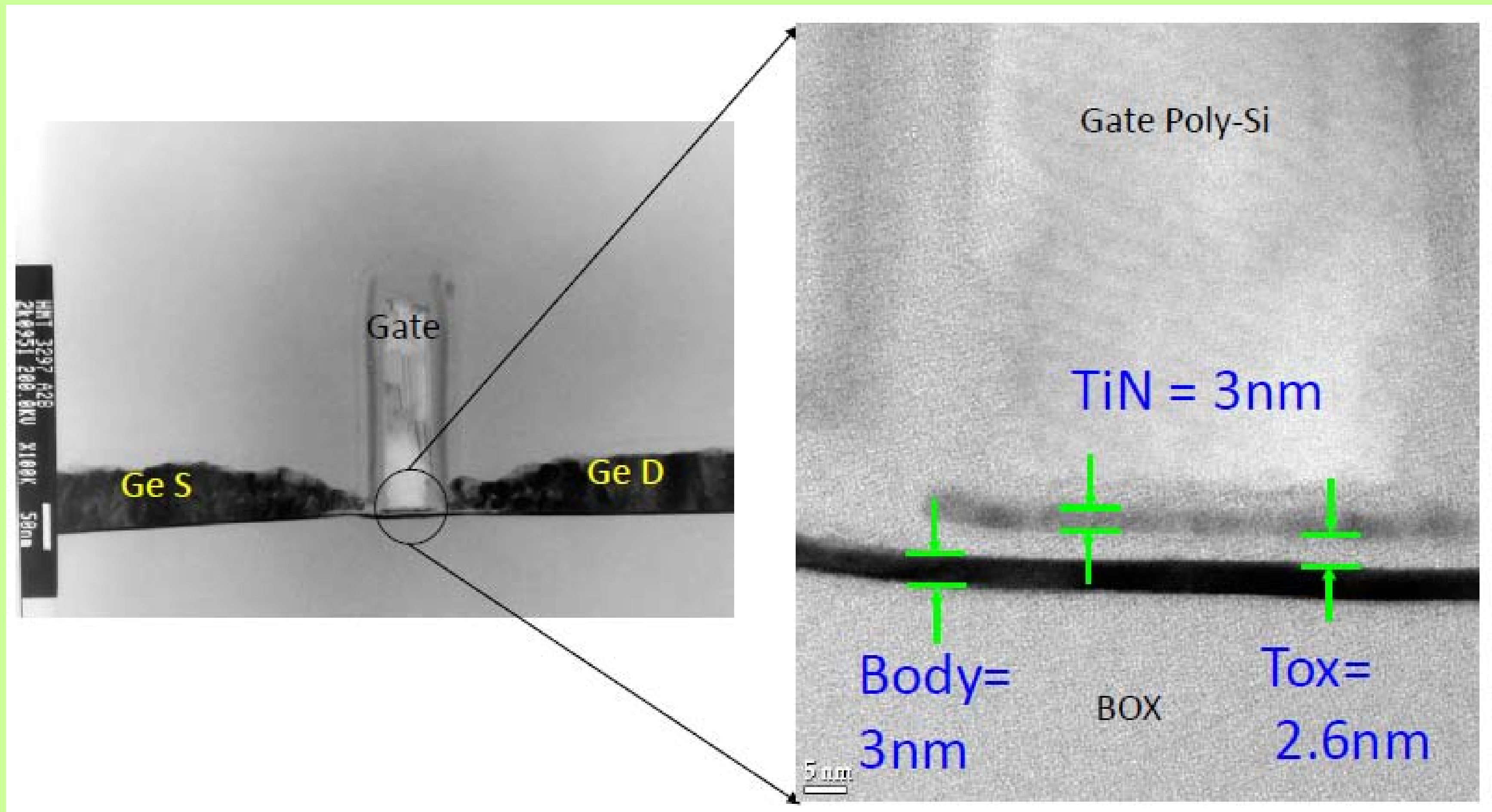




Body thickness is the new scaling parameter.

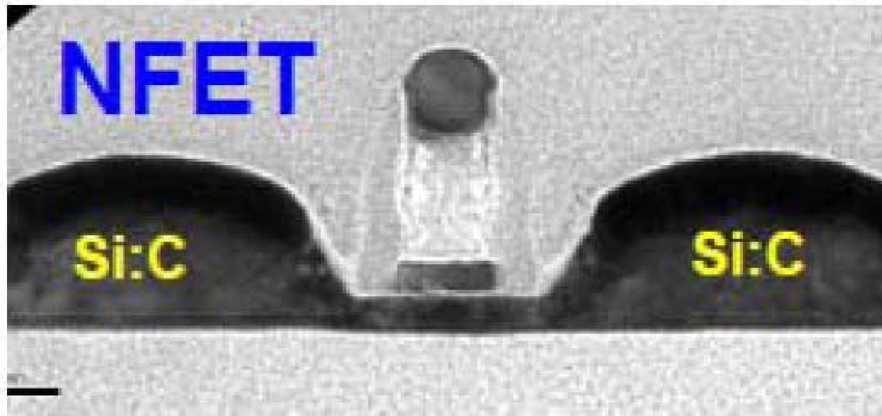
C.Hu,"Modern Semicon. Devices for ICs" 2010, Pearson

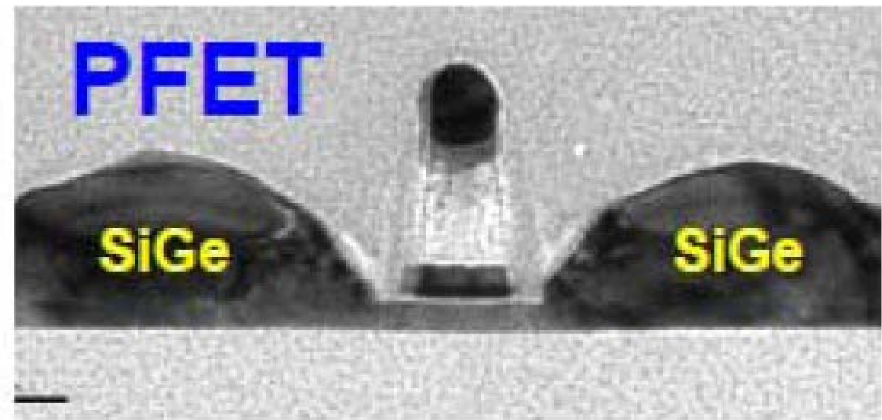
2001 UTB-SOI
3nm Silicon Body, Raised S/D



Y-K. Choi et al, VLSI Tech. Symposium, p. 19, 2001

2009 State-of-the-Art
5nm Body UTB-SOI





ETSOI, IBM

K. Cheng et al, IEDM, 2009

Other Names:
FDSOI
UTBB-SOI

Both Thin-Body Transistors Provide

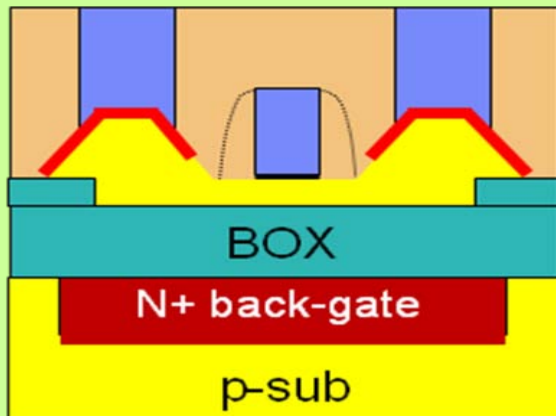
- Higher speed and lower leakage
- Lower Vdd and power
- Further scaling and lower cost

- Better S & Vt and less variations
- No random dopant fluctuation.
- Better mobility, especially for future subthreshold design.

Main Differences

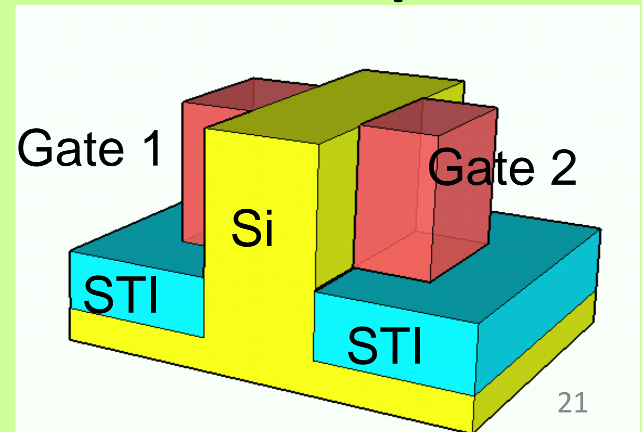
- FinFET body thickness ~Lg.
  Investment by fab.
  UTBSOI thickness ~1/3 Lg.
  Investment by Soitec.

- FinFET has larger Ion.
  UTBSOI has a good back-gate bias option.



UTBSOI

FinFET



Outlook

- FinFET usage starts at 22nm by Intel and 14nm by foundries--- to beyond 10nm.
- ST will use UTBSOI to gain market from regular CMOS at 28nm, 20nm…
- Competition will bring out the best of both.