



# Numerical Modeling of Metal-Oxide-Semiconductor Device Characteristics

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AIP/SPS Intern, Summer 2003

National Institute of Standards and Technology



# Introductions

## ○ Justin Stimatze

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## ○ Dr. Eric Vogel

Advanced Microelectronics Technology Group

Semiconductor Electronics Division

Electronics and Electrical Engineering Laboratory

National Institute of Standards and Technology

# National Institute of Standards and Technology



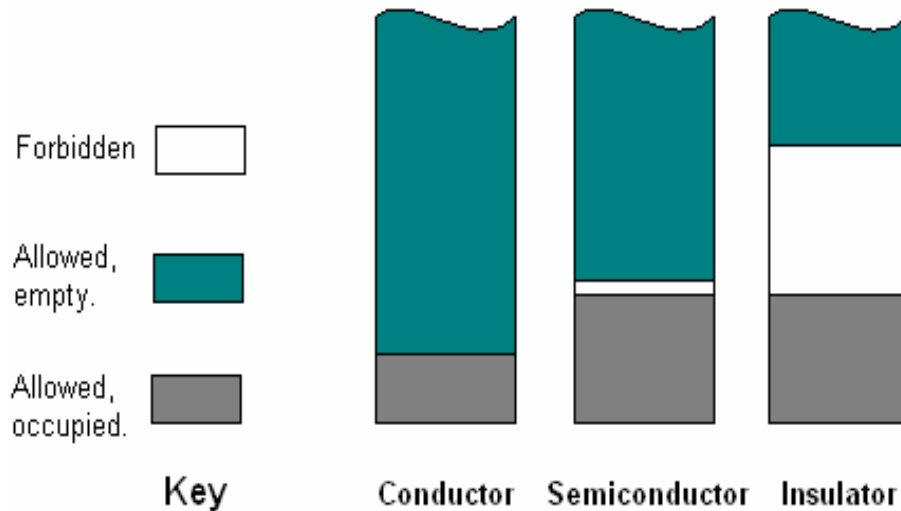
- Founded in 1901 as the National Bureau of Standards
- Part of U.S. Commerce Department's Technology Administration
- Mission Statement:  
"To develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life."



# Outline

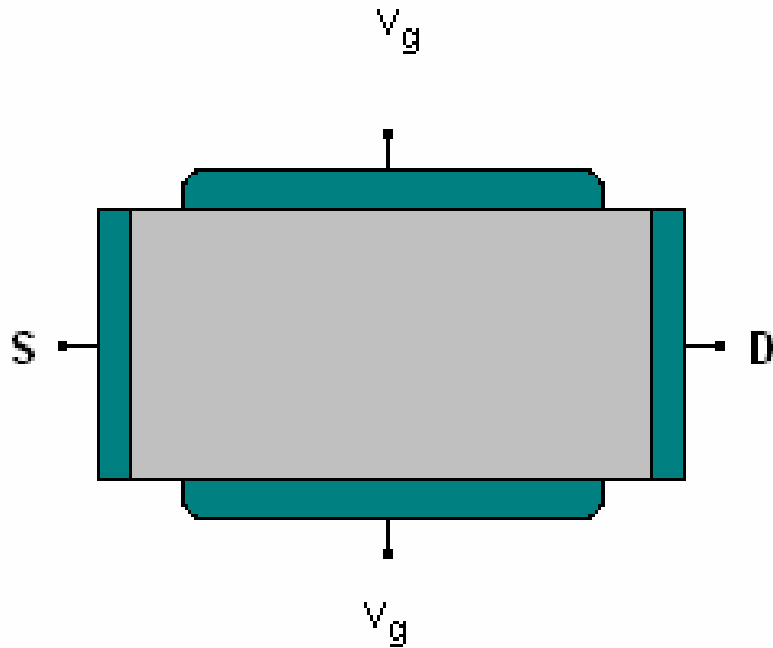
- Theory
  - Basic Semiconductor Physics
  - Ideal MOS Transistor
  - Ideal MOS Capacitor
  - Capacitance-Voltage Characteristics
- Project
  - Description of Model
  - Existing Implementation
  - Proposal
  - Structure
  - Progress
  - Remaining Goals
- Results
- Conclusion

# Basic Semiconductor Physics



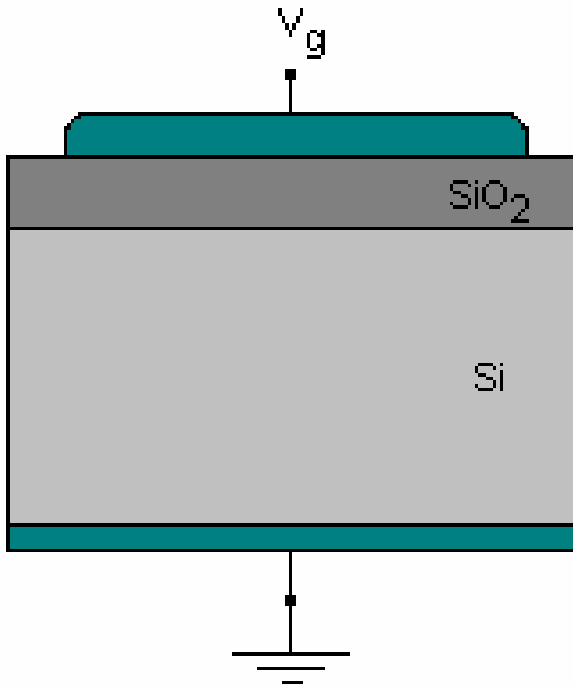
- Band theory
- Classification
  - Conductors
  - Insulators
  - Semiconductors
- Silicon
  - Doping

# Ideal MOS Transistor



- Basic Description
- Applications

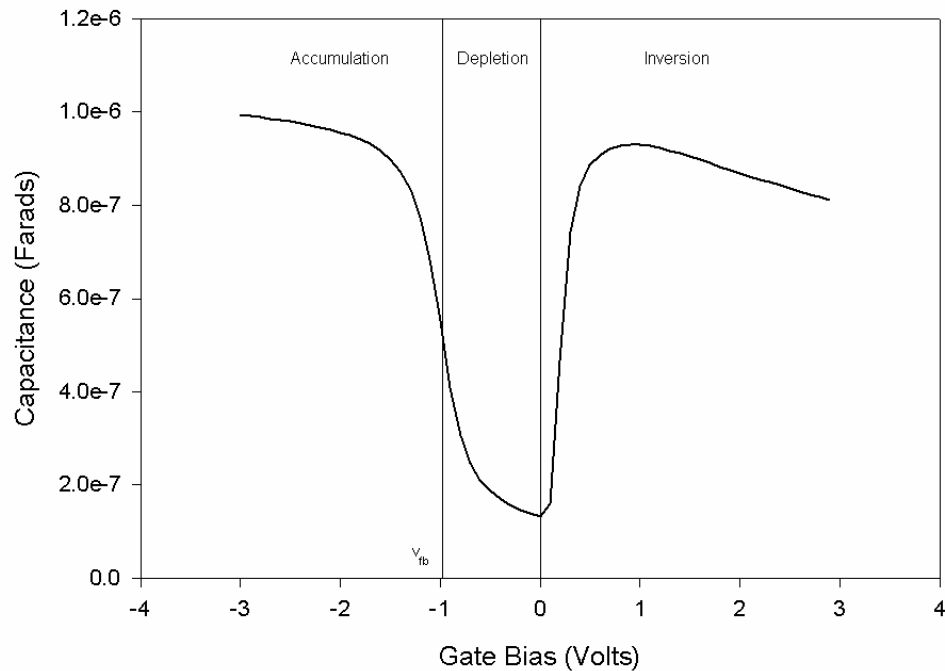
# Ideal MOS Capacitor



- Applicability
- Idealizations

# Capacitance-Voltage Characteristics

Sample C-V Curve  
(Low Frequency / Quasi-static)



- CV Curve Regions
  - Accumulation
  - Depletion
  - Inversion
- Practical implications.



# Description of Model

Numerical model emphasizing:

- Thin Oxides
- QM Corrections
- Interface Effects
- Polysilicon Gate

(See “A capacitance-voltage model for polysilicon-gated MOS devices including substrate quantization effects based on modification of the total semiconductor charge.” by Eric M. Vogel, Curt A. Richter, Brian G. Rennex, Solid-State Electronics, SSE3465, 2003.)



# Existing Implementation

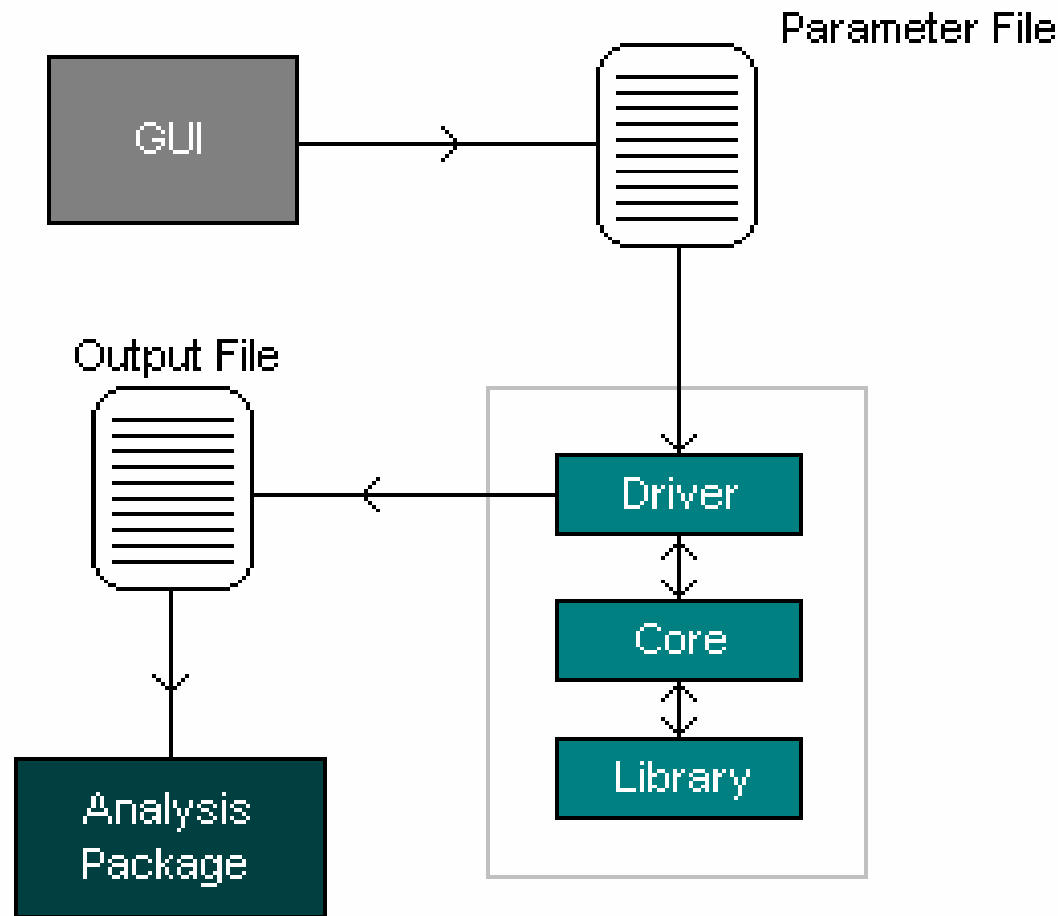
- Model coded entirely in Visual Basic
  - Explicitly tied to graphical user interface.
  - Inherently inefficient execution environment.
- Lacking modularity, documentation, optimization, error-checking.
- Difficult to debug if output is not what is expected.



# Proposal

- Recode model in standard ANSI C++.
  - Improves execution speed.
  - Improves program structure and demands explicit information flow.
  - Highly modular organization simplifies process of adding functionality to computational model.
- Strict separation of simulation into Graphical User Interface (GUI), Driver, Core, and a custom Numerical Library.

# Structure



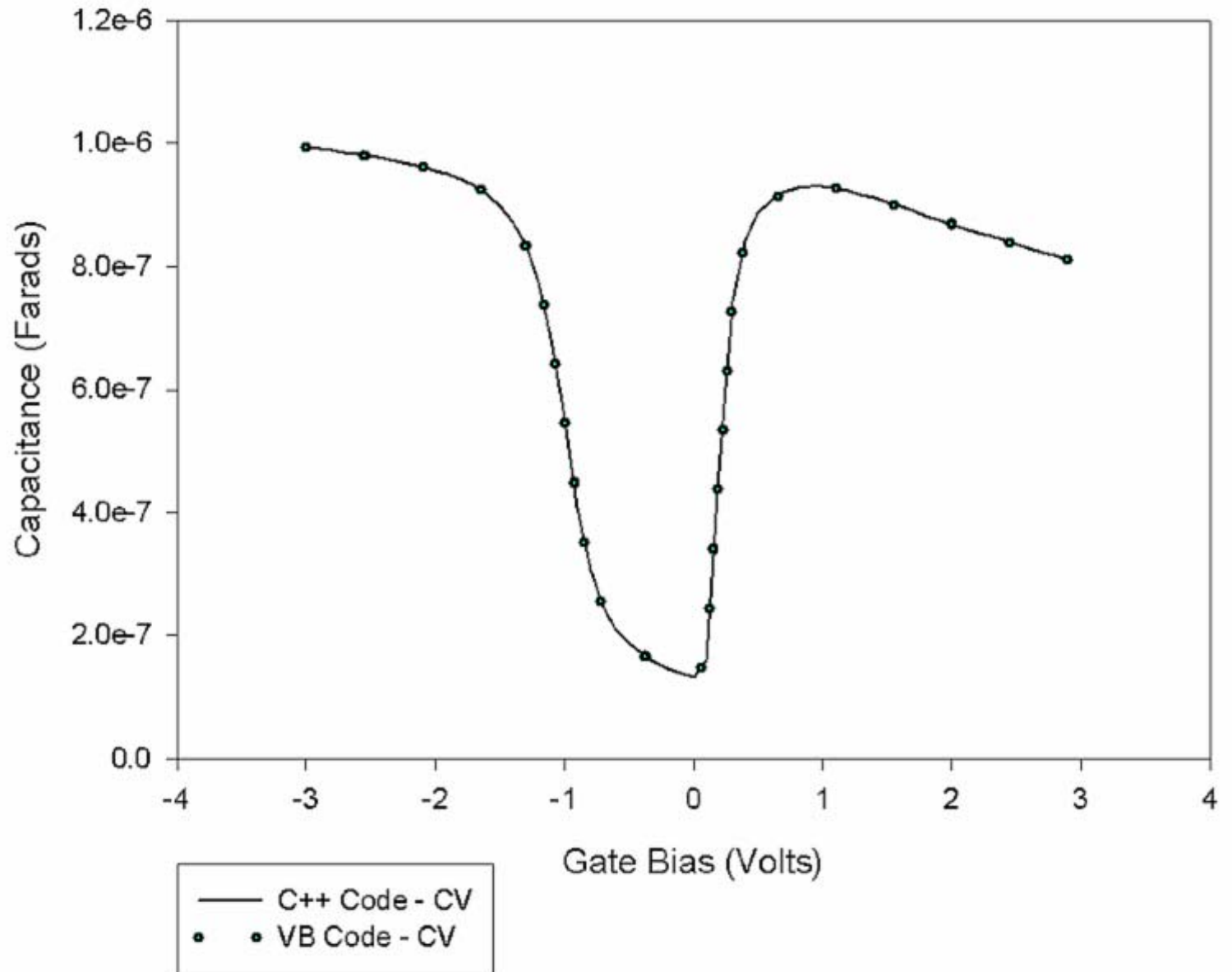


# Progress

- **Simulation Driver:**  
Complete. Provides disk I/O services to Core, and handles command-line user interface.
- **Simulation Core:**  
Currently able to use Classical (vs. QM) model, assuming quasi-static response. Results agree with existing implementation.
- **Numerical Library:**  
Functionality exists, but most numerical methods are still embedded in the Core to simplify the porting process.
- **Graphical User Interface:**  
In the process of being redesigned.

# Simulated Capacitance - Voltage Curve

*(Classical Model, Quasi-Static)*





# Remaining Goals

- Thoroughly verify output of new simulation code against old implementation.
- Finish graphical-user-interface component. GUI allows convenient, ‘user friendly’ generation of simulation parameter files.
- Add additional features to computational model, leveraging the modular nature of the new simulator.
- Explore additional applications of the simulator, such as self-correcting brute-force CV curve fitting against given experimental data.



# Conclusion & Acknowledgements

**This internship has been an incredible opportunity to...**

- Gain practical, “hands-on” experience in a modern field of applied physics.
- Work with motivated and enthusiastic scientists, and to make a useful contribution to their ongoing research.
- Experience the culture and history of the Washington D.C. area.

**I'd like to thank:**

- Dr. Eric Vogel
- Dr. John Suehle
- Dr. David Seiler

# Questions?

