Project and Thesis Folder 2025

- Pillars of the Institute for Microelectronics
  - Teaching: Programming in Python and C/C++
  - Simulation: Numerical simulation of semiconductor devices and processes
  - Experiments: Development of characterization equipment and techniques

- Unique chance to improve teaching quality and scientific research
- Potential to earn some extra money

- Optional seminars and practical courses:
  - 360.245 Computational Electronics
  - 360.238 Experimental Device Characterization in Microelectronics
  - 360.230 Emerging Devices
  - 360.206 Programming
- Bachelor Thesis
- Master Thesis

Atomated Data Extraction From Graphs

Supervisor:

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Project BB1

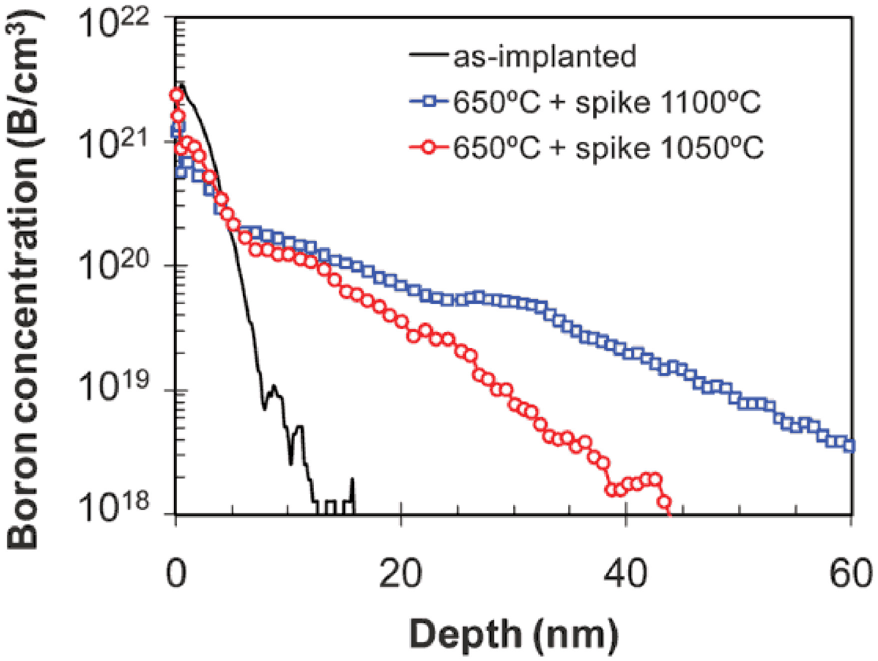
- Data extraction from scientific papers is currently done manually or semi-automatically with uncertain accuracy
- An automated tool using image processing and possibly AI methods could dramatically improve this process

Possible Tasks:

- Investigate different methods for various plot styles
- Implement image processing and/or AI algorithms for data extraction
- Extend an existing UI or create a new one

Required knowledge:

- Programming in C++
- Image processing, for example OpenCV
- Optionally deep learning
- Desktop user interfaces



Extraction of Topography Information from SEM Images

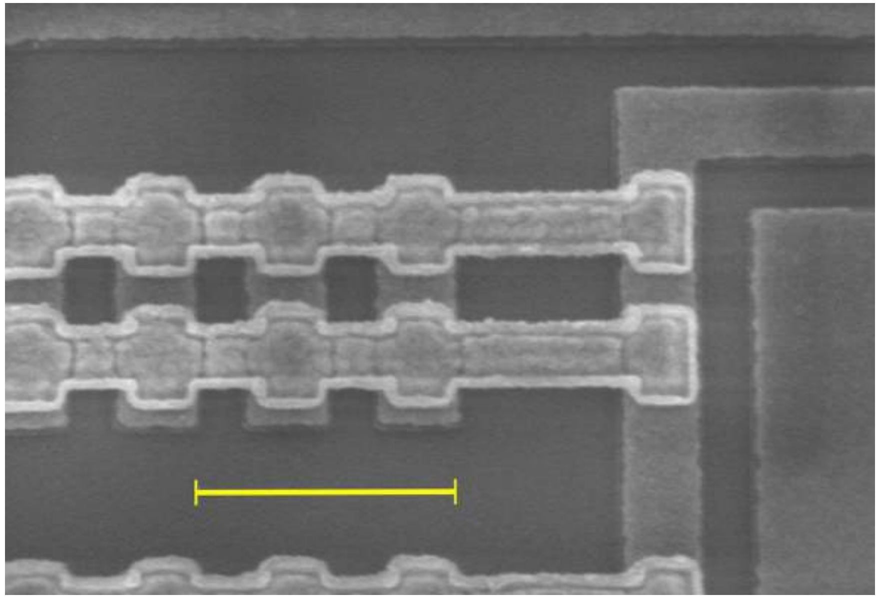
- Use many of SEM images and scan them to identify the topography after a certain process, which is defined by equipment settings
- This will allow us to use machine learning to map the equipment settings to the final topography from these samples

Possible Tasks:

- Design image pre-processing suitable for a wide range of SEM images
- Design and teach a deep learning network for predicting topography based on equipment settings

Required knowledge:

- Programming in C++
- Image processing, for example OpenCV
- Deep learning



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Project BB2

Simulation of Sensors based on 2D Materials

Supervisor:

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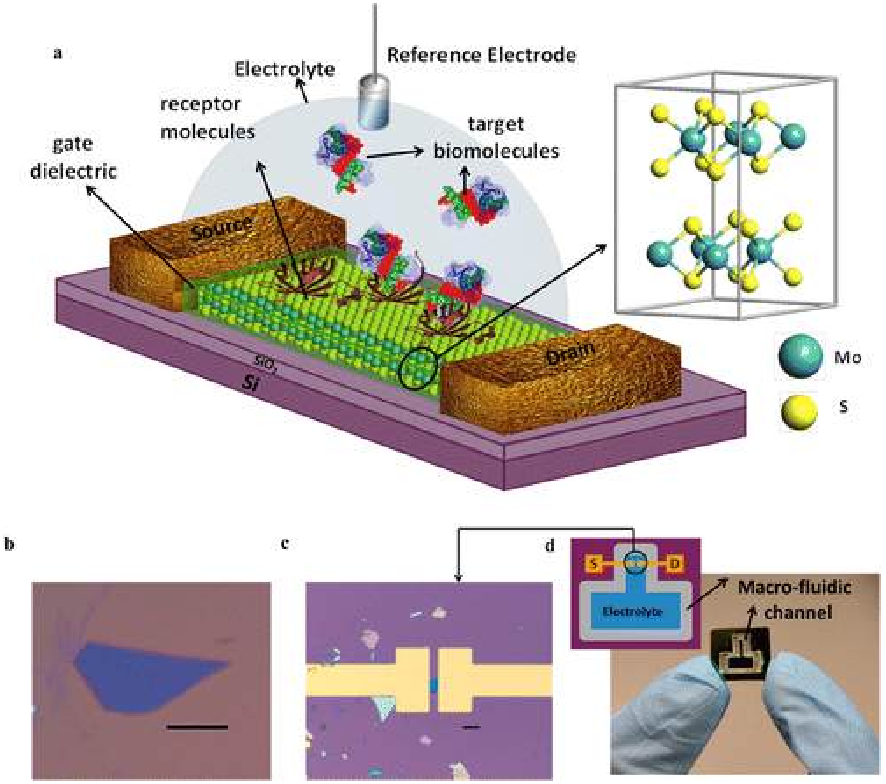
Project LF1

- 2D materials are heavily investigated for their application in disease detection, both as bio-sensors and gas sensors
- Simulation of such devices helps to understand the novel materials and to design novel sensor applications

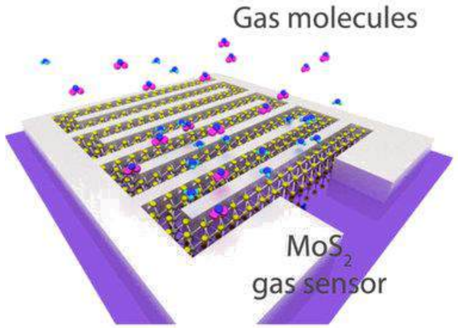


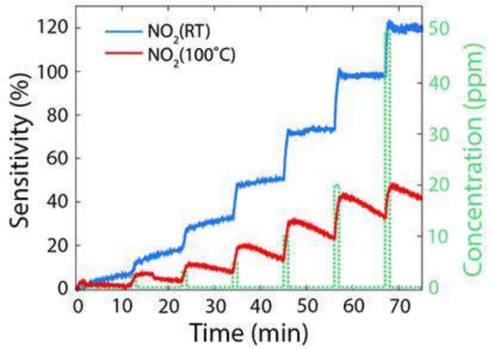
Tasks:

- Perform simulations on bio-sensors or gas sensors which are based on 2D materials
- Compare and improve models by calibrating to measurements

Required knowledge:

- Programming (Python, C, C++)
- (Rudimentary) understanding and profound interest in semiconductor physics





Characterization of Gas Sensors based on 2D Materials

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Project LF2

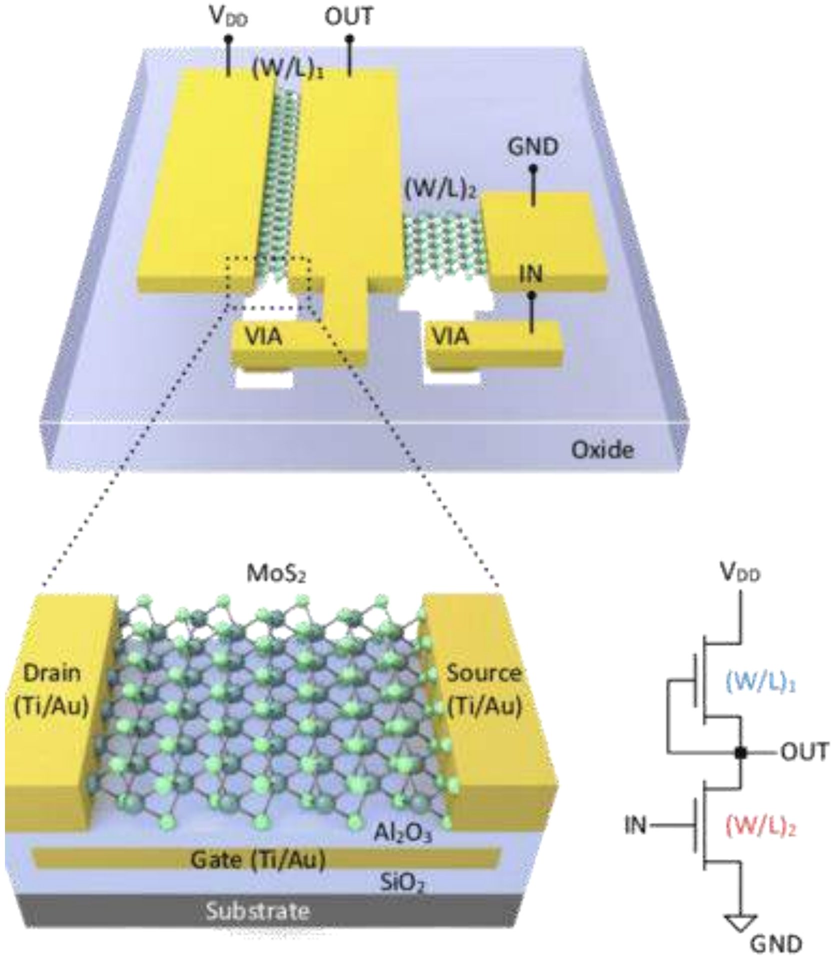
- 2D materials such as the graphene family of materials (graphene, graphene oxide, etc.) and MoS_2 have shown potential for use as a gas sensor
- Combined characterizations and modeling are essential in order to better understand the capabilities of these films for sensing

Tasks:

- Help design measurement equipment
- Write scripts to control the measurement setup
- Measure the electrical behavior of devices under varying ambient conditions

Required knowledge:

- Basic knowledge of Python
- Interest in sensor physics



Physical Modeling of Novel Semiconductor Devices

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Project LF3

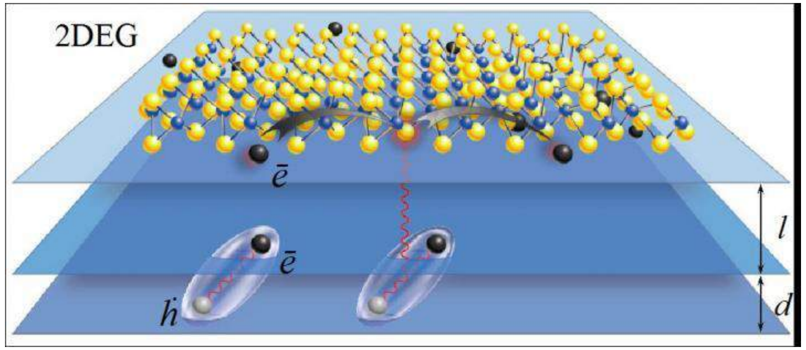
- To investigate new devices, based on novel materials such as 2D materials and Perovskites, physical modeling tools are essential
- We are developing a framework in C++ to model electron transport in semiconductors under various scattering phenomena

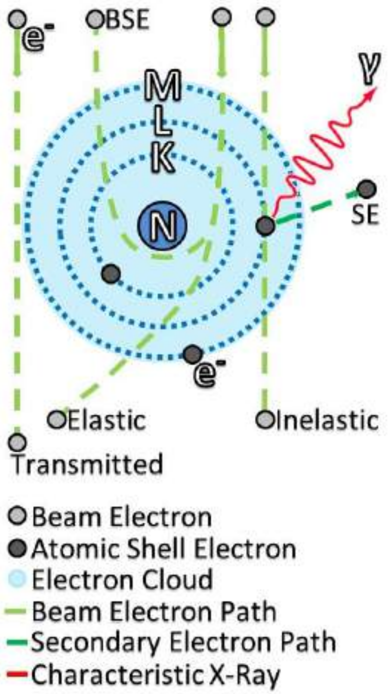
Tasks:

- Implement models for different types of electron scattering mechanisms in C++

Required knowledge:

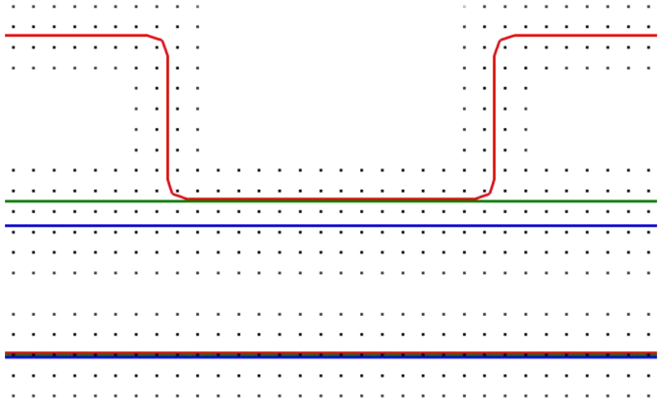
- Programming in C++
- (Rudimentary) understanding and profound interest in semiconductor physics





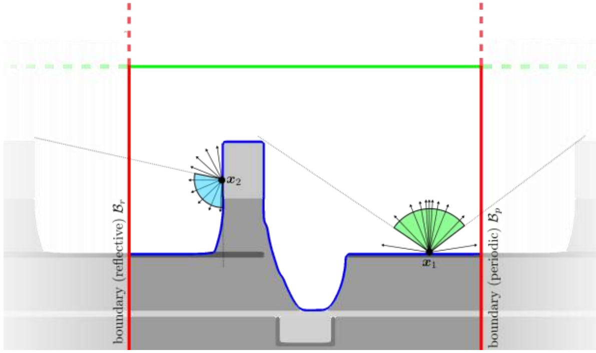
Modeling Atomic Layer Deposition (ALD)

- ALD is a crucial step in modern semiconductor fabrication
- The fundamental aspect of ALD is that the films grown by it show self-limiting behavior
- This type of growth is not directly available from Level-set based simulators



Tasks:

- Develop a mathematical model for self-limiting growth within the Level-set method
- Implement this model in an existing simulator



Required knowledge:

- Programming in C++
- Knowledge of Finite Differences is a plus
- Familiarity with semiconductor processing is NOT necessary

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Project LF4

Machine Learning for Process TCAD

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Project LF5

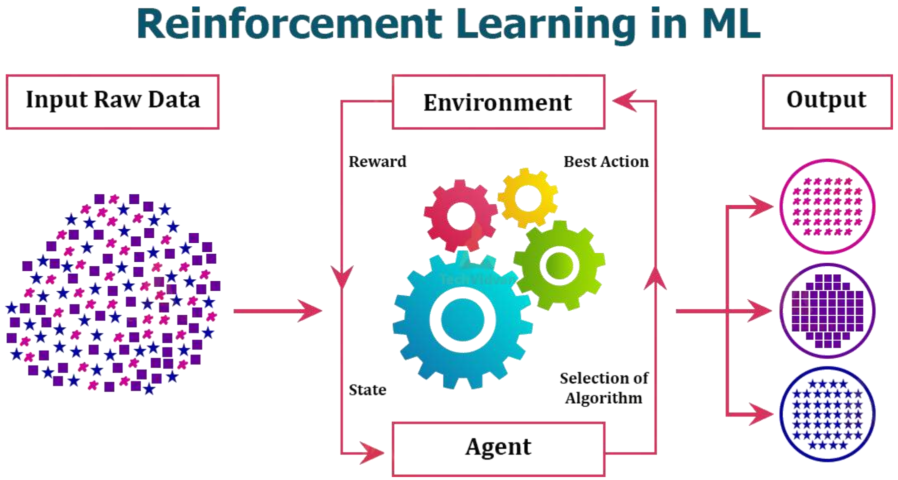
- Physical process simulations are memory- and time-intensive, giving rise to the need for emulation
- Emulation, or process compact modeling, allows to accelerate simulations for many processes
- Machine learning can be applied to train a compact model which is based on physical or experimental results

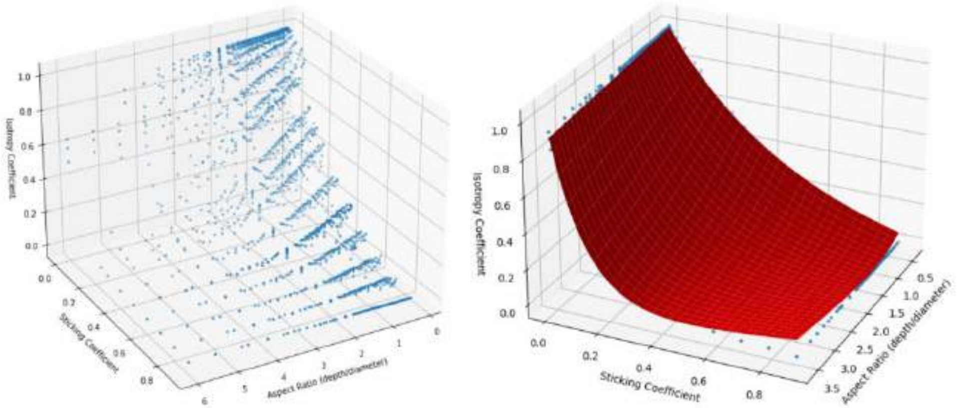
Tasks:

- Use machine learning to generate a compact model based on physical data
- Implementation of the model in an in-house process TCAD framework *ViennaPS*
- Test the model under various conditions

Required knowledge:

- Programming in C/C++, Python
- Interest in solid state physics and/or semiconductor process engineering





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Physical Modeling of MOSFETs based on 2D Materials

Supervisor:

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Project TK1

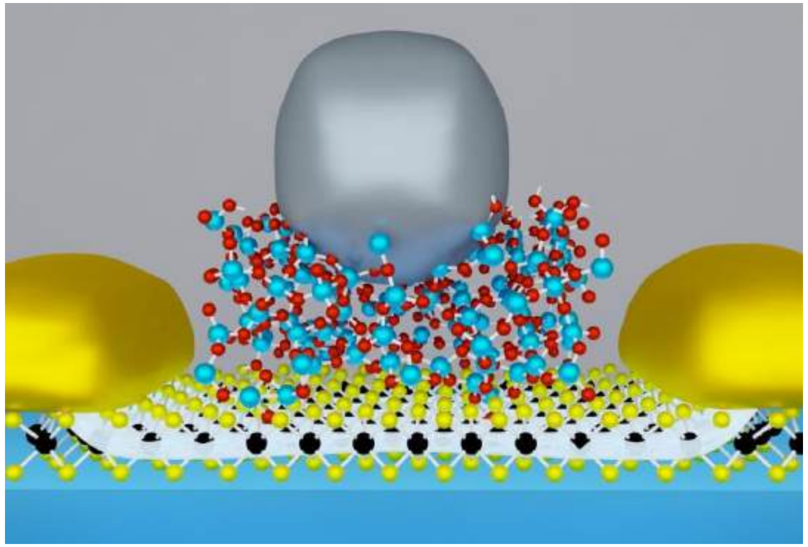
- 2D material-based FETs offer performance improvements for next-generation integrated circuits.
- We have adapted industrial device simulators to describe the device behavior of 2D FETs.

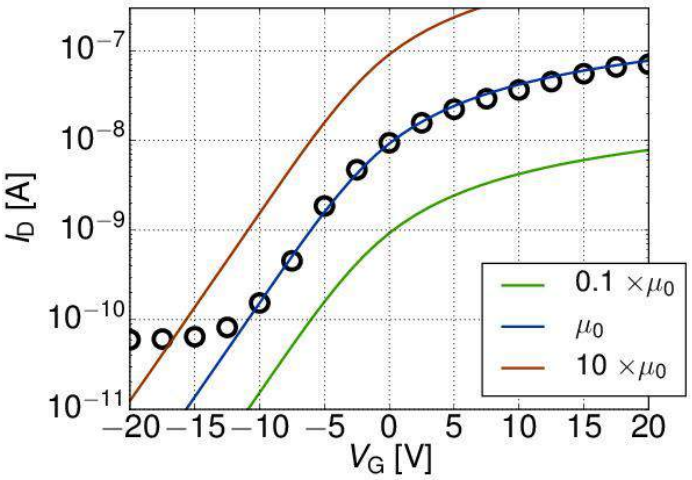
Possible Tasks:

- Compare simulated transfer characteristics based on different simulation methods
- Include the anisotropic permittivity of 2D materials in our model
- Study the impact of the contact geometry of prototype FETs on the device performance
- Study the impact of charge trapping on the FET reliability.
- Compare the simulation results to measurement data

Required knowledge:

- Programming with Python
- Interest in semiconductor physics





Calculating Tunnel Currents through Novel Gate Insulators

Supervisor:

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Project TK2

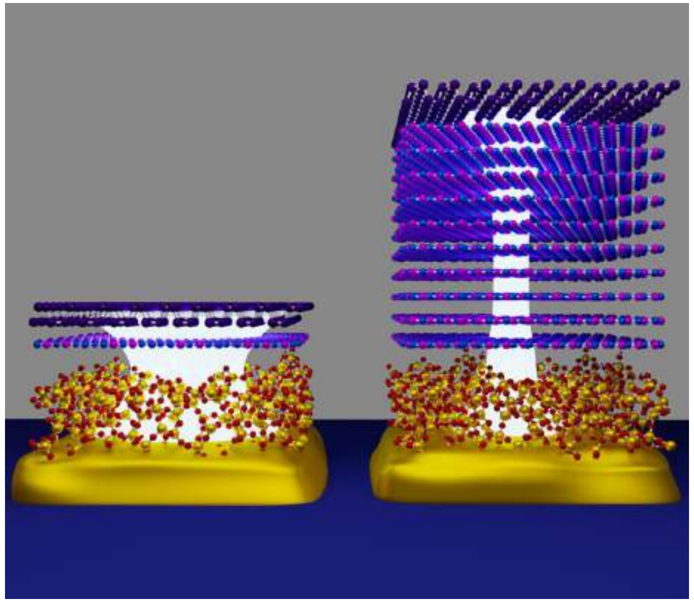
- As the thickness of the gate insulator is scaled down gate leakage currents become a major problem.
- We have implemented a semi-classical model in a compact Python simulator (Comphy) to describe the leakage currents through novel gate stacks.

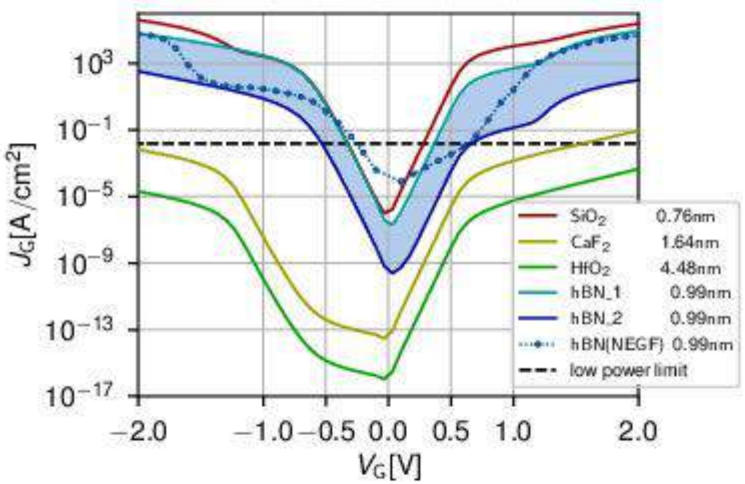
Possible Tasks:

- Adapt the model to describe complex gate stacks consisting of combinations of insulators
- Adapt the model to include the van der Waals gap
- Benchmark gate leakage currents for different combinations of metal-insulator-semiconductors

Required knowledge:

- Programming with Python
- Interest in semiconductor physics





Visualizing Research Results for the General Public

Supervisor:

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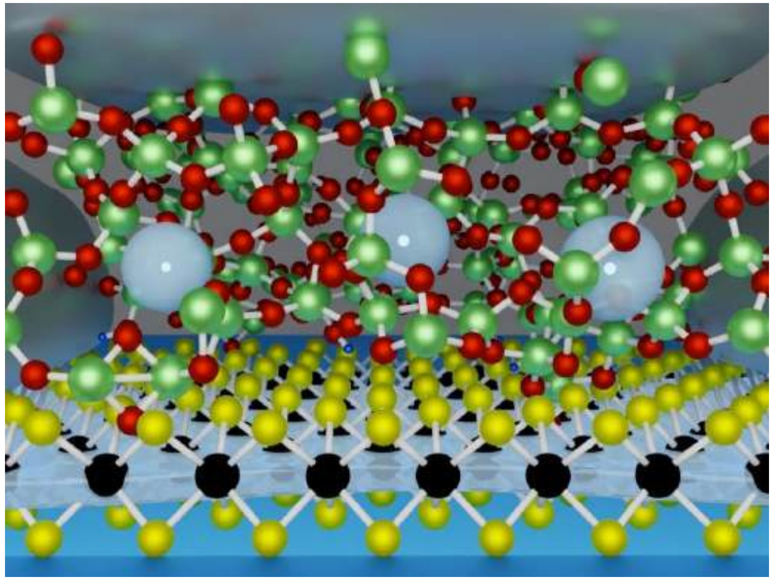
Project TK3

- Science communication is highly important to make new research insights visible and understandable for a broad public audience.
- Using the open-source, professional rendering and animation software Blender we are working to create videos to describe our findings in a scientifically accurate yet easily accessible way.



Possible Tasks:

- Create an animation for the fabrication of 2D material-based FETs
- Create an animation about charge transport through a FET and the impact of charge trapping

Required knowledge:

- Programming with Python
- Creativity
- Interest in semiconductor physics and processes
- Some first steps with Blender are an asset

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Algorithm for Electron-Electron Scattering in Monte Carlo Device Simulation

Supervisor:

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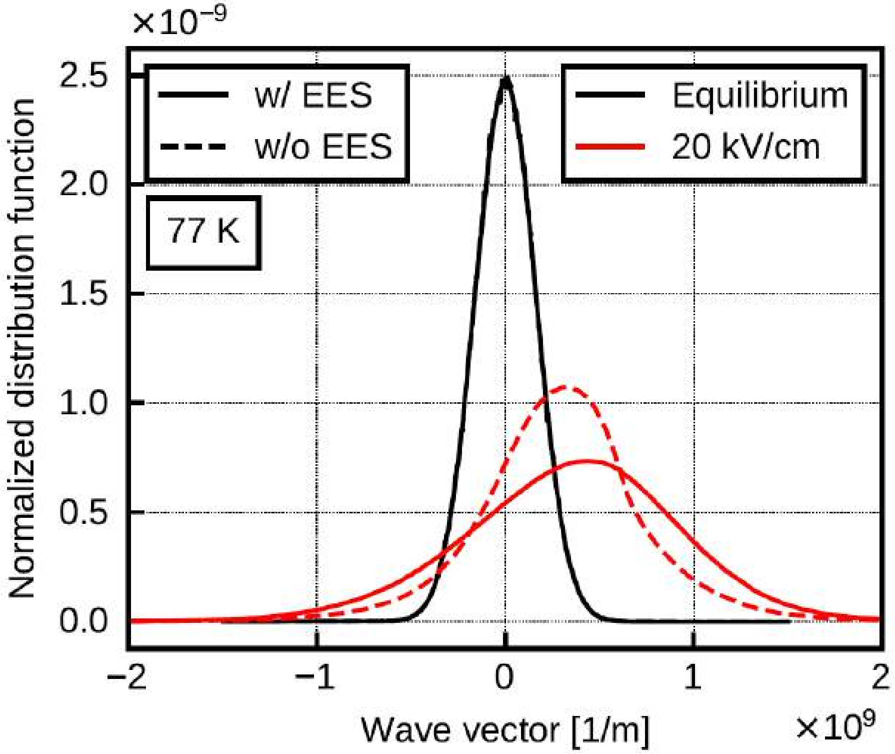
Project HK1

- Hot carriers occuring in integrated transistors cause a degradation of the electrical characteristics
- Understanding on this degradation effect requires knowledge of the energy distribution of the carriers
  - This distribution is strongly affected by electron scattering (EES)
- The aim of this work is to implement a novel algorithm for EES in the Vienna Monte Carlo (VMC) simulator



Possible Tasks:

- Implement a recently developed algorithm for EES in the VMC simulator
- Test the implementation against other models and implementations

Required knowledge:

- Programming in C
- Interest in semiconductor physics

Simulate Large Structures using ViennaLS

Supervisor:

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Project PM1

- ViennaLS is a high-performance level set engine tailored towards micro-electronic fabrication simulations
- Its full capabilities have not yet been explored on a modern high performance computer
- Simulations of even large ICs should be possible

Tasks:

- Benchmark large scale simulations using ViennaLS on our new high performance cluster (2x 20 Cores, 768GB RAM)

Required knowledge:

- Advanced Knowledge of C++

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Investigation of Byproduct Diffusion during Wet Etching

Supervisor:

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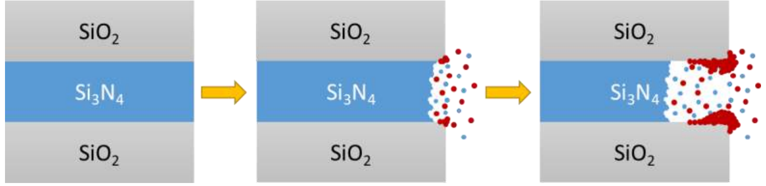
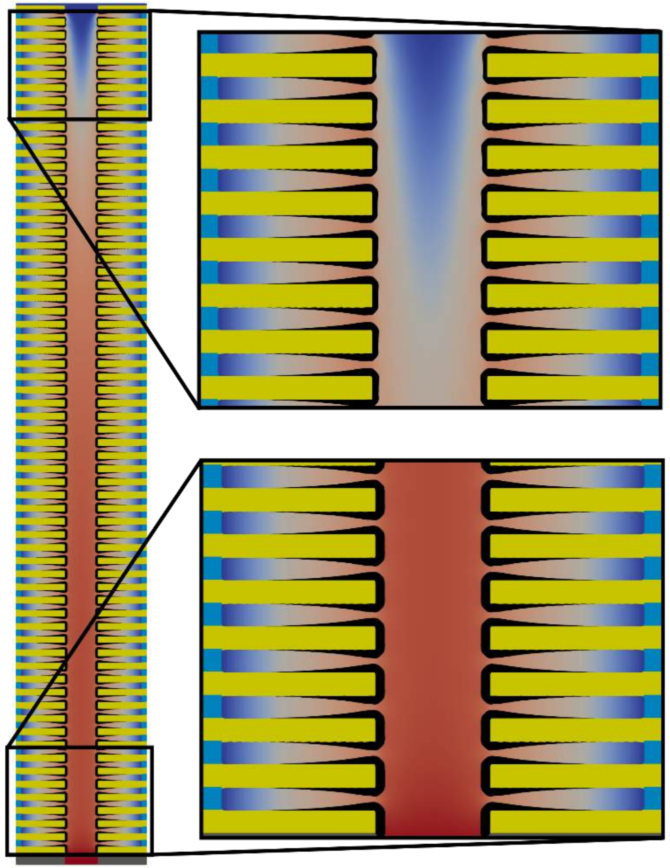
Project TR1

- Wet etching of Silicon Nitride in high-aspect-ratio structures can lead to undesired byproduct redeposition phenomena
- This can be modeled by solving the convection-diffusion equation on a volume representation of the etching solution
- A good understanding of the convection field is necessary to accurately predict the outcome of the etching step





Tasks:

- Test and investigate the convection field and other process parameters
- Work with the process simulation library ViennaPS to improve the existing model

Required knowledge:

- Programming in C++
- Interest in modeling and simulation

ParaView Plugin based on ViennaPS

Supervisor:

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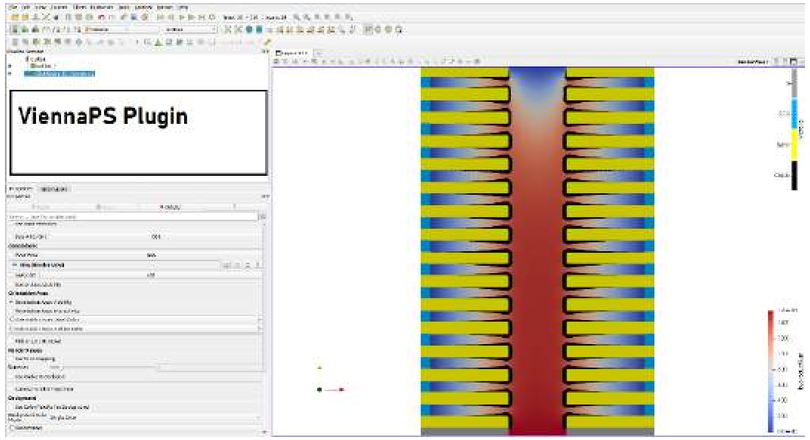
Project TR2

- ViennaPS is a process simulation library for microelectronic fabrication processes written in C++
- ParaView is a visualization engine based on VTK and allows writing custom plugins to use in its graphical user interface

Tasks:

- Write a ParaView plugin to access ViennaPS functionalities
- Design the GUI to enable to use ViennaPS without having to write C++ code



Required knowledge:

- Advanced Knowledge of C++
- Some willingness to work with CMake

Modelling of Ion Implantation

Supervisor:

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Project TR3

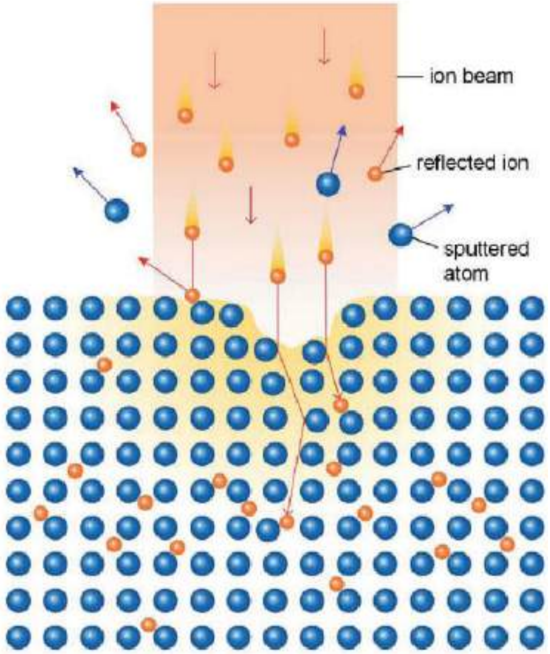
- Ion implantation is a standard technology to dope substrates in semiconductor fabrication processes
- Energetic Ions lead to strong effects on the surface (charging, crystal damage, etc.)
- Particle-based Monte Carlo simulation approaches are able reproduce realistic implantation profiles

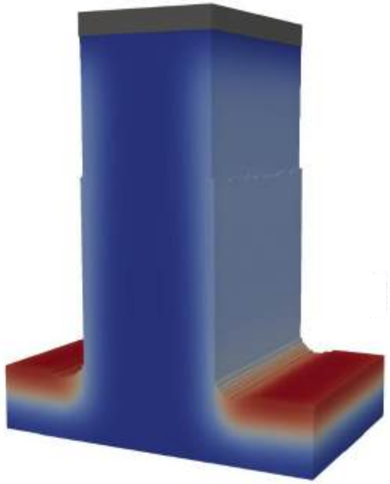
Tasks:

- Implement an ion implantation model based on Monte Carlo raytracing and the cell-set volume representation in ViennaPS
- Calibrate the model to reproduce experimental results

Required knowledge:

- Programming in C++
- Interest in modeling and simulation





Atomistic Modeling: Interaction of Oxide Defects with Electric Fields

Supervisor:

Dominic Waldhoer

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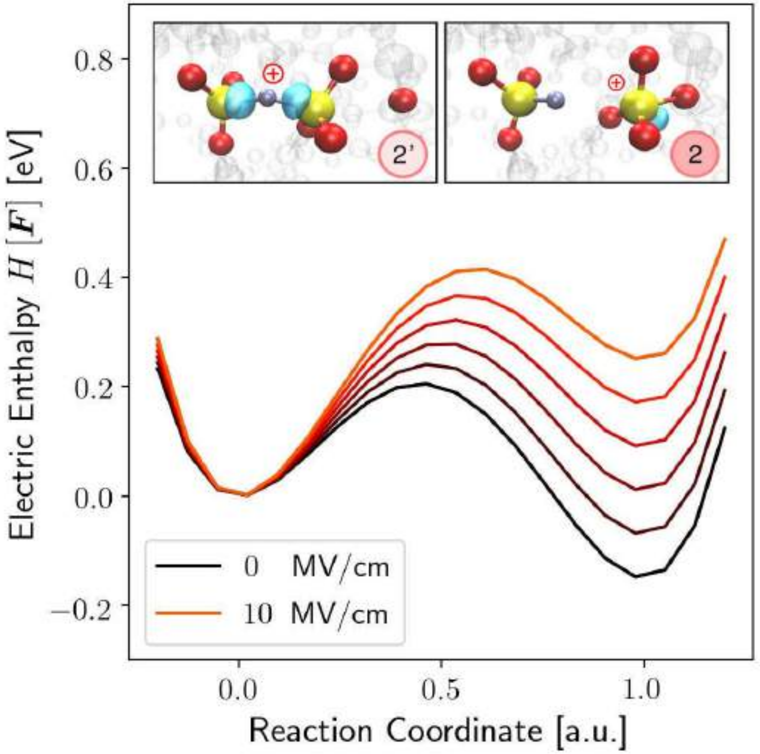
Project DW1

- Oxide defects in MOSFETs can act as charge trapping sites, causing various reliability issues like the *Bias Temperature Instability (BTI)*
- In our current BTI models the electric field across the gate oxide only affects the charge trapping levels of the defect
- However, the electric field can also interact with the charge distribution of the defect and potentially alter transition barriers between different defect states
- *Density Functional Theory (DFT)* allows us to simulate individual defects at an atomistic level and quantify these effects theoretically



Tasks:

- Use DFT to investigate the impact of electric fields on defect transition barriers due to dipole interaction
- Deduce a simplified model from your results which can be used in device simulators

Required knowledge:

- Solid understanding of electrodynamics and quantum mechanics
- Linux, Programming in Python

Atomistic Modeling: Extending the 4-State Defect Model

Supervisor:

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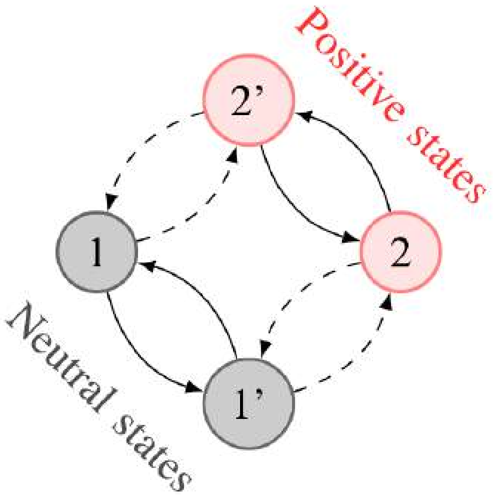
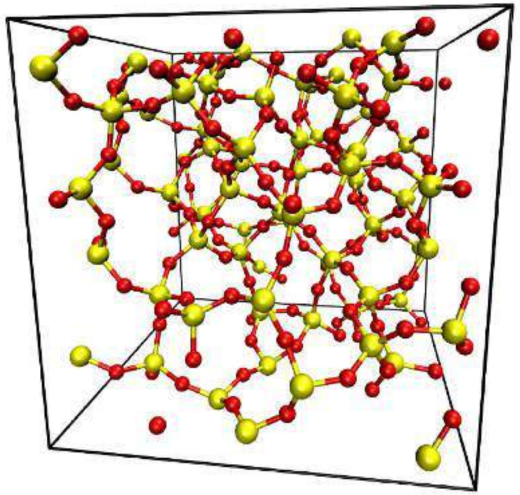
Project DW2

- *Bias Temperature Instability (BTI)* and *Random Telegraph Noise (RTN)* are caused by oxide defects which can trap/emit electric charges from/to the device substrate
- These defects are usually described by a 4-state *Markov* chain
- Although this 4-state model accounts for many experimental findings, it cannot explain certain observed defect behaviors like volatility or double capture/emission events
- *Density Functional Theory (DFT)* is an invaluable tool for the atomistic modeling of defects. DFT can be used to search for additional defect states and predict how these new states change the observable defect behavior





Tasks:

- Use DFT to identify possible defect states which can account for defect volatility and/or double capture/emission events
- Include these states in a Markov chain model and simulate the resulting RTN signals

Required knowledge:

- Solid understanding of physics
- Linux, Programming in Python

Web Interface to Control *Defect Probing Instruments* for Transistor Single-Defect Spectroscopy

Supervisor:

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Project MW1

- Electrical characterization of single defects in MOSFETs
- Use *Defect Probing Instrument* (right) developed at IuE
- Measurement sequences controlled by *jobserver*
- *Jobserver* communicates with SQL database

Tasks:

- Develop a web interface in Python (Django)
- Control of measurement flow
- Configuration of measurement tool
- Live tracking of measurement data

Requirements:

- Basic knowledge of Python
- Handling of UNIX operating system

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Hardware- and Software Development for *Defect Probing Instrument*

Supervisor:

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Project MW2

- Electrical characterization of single defects in MOSFETs
- *Defect Probing Instrument* (right) developed at IuE
- Communicates with measurement host via USB interface

Tasks:

- Development of a calibration tool for DPI
- Development of a switching matrix
- Femto-ampere measurements
- Stepping motor controller and autofocus
- Enhancement of current control modul
- Application of zoom-and-scan method for single defect spectroscopy
- Driver development for general purpose measurement instruments (wafer prober, Keithleys, etc.)

Requirements:

- Knowledge of programming languages C/C++ and Python
- Profound knowledge of hardware development and PCB design

Atomistic Simulations

Supervisor:

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Project CW2

- Ab-initio simulations on an atomistic level are needed to identify the properties of defects
- In this context, Density Functional Theory (DFT) is used to calculate e.g. the energetic position of defects, activation energies, ...

Possible Tasks:

- Analyze defect creation and H migration in SiO_2
- Characterize new and emerging technologies and materials
- Explore new simulation approaches

Required knowledge:

- Solid knowledge/interest in physics
- Postprocessing data (bash/python/...)