Project and Thesis Folder 2023

- 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:

Balázs Bámer

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Project BB1

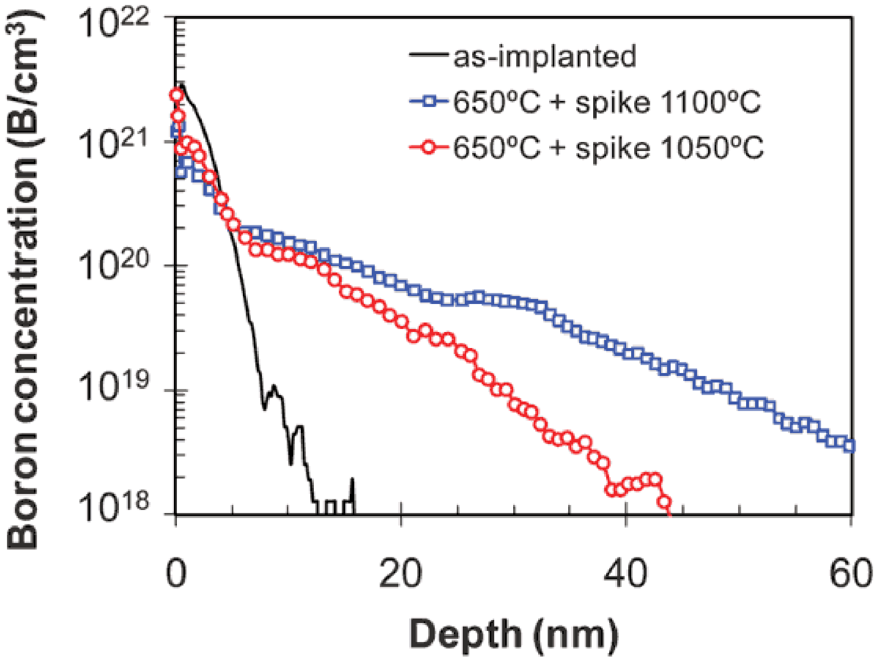
- Data extraction from scientific papers is currently done manually or semi-automatically with uncertain accuracy
- An automated tool using image processing and possibly AI methods could dramatically improve this process

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

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Project BB2

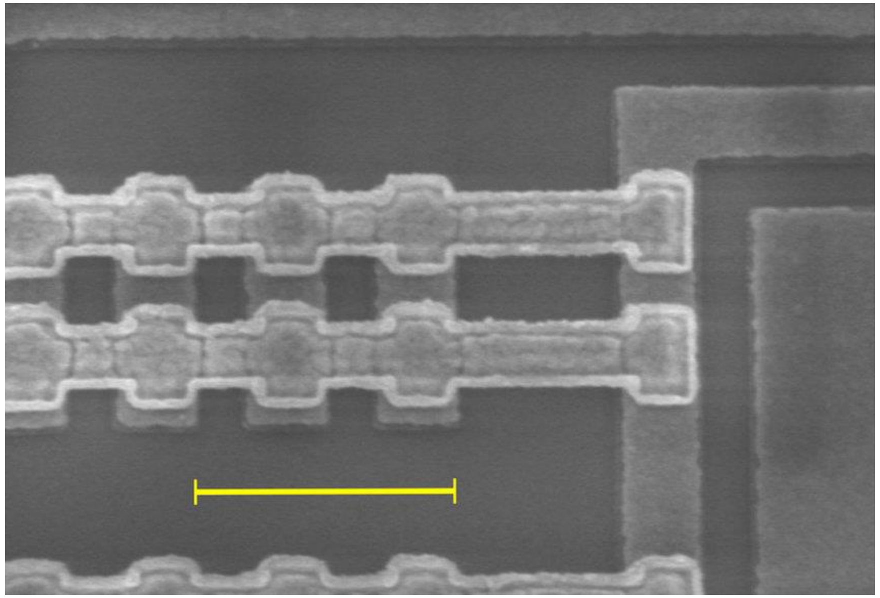
- Use many of SEM images and scan them to identify the topography after a certain process, which is defined by equipment settings
- This will allow us to use machine learning to map the equipment settings to the final topography from these samples

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

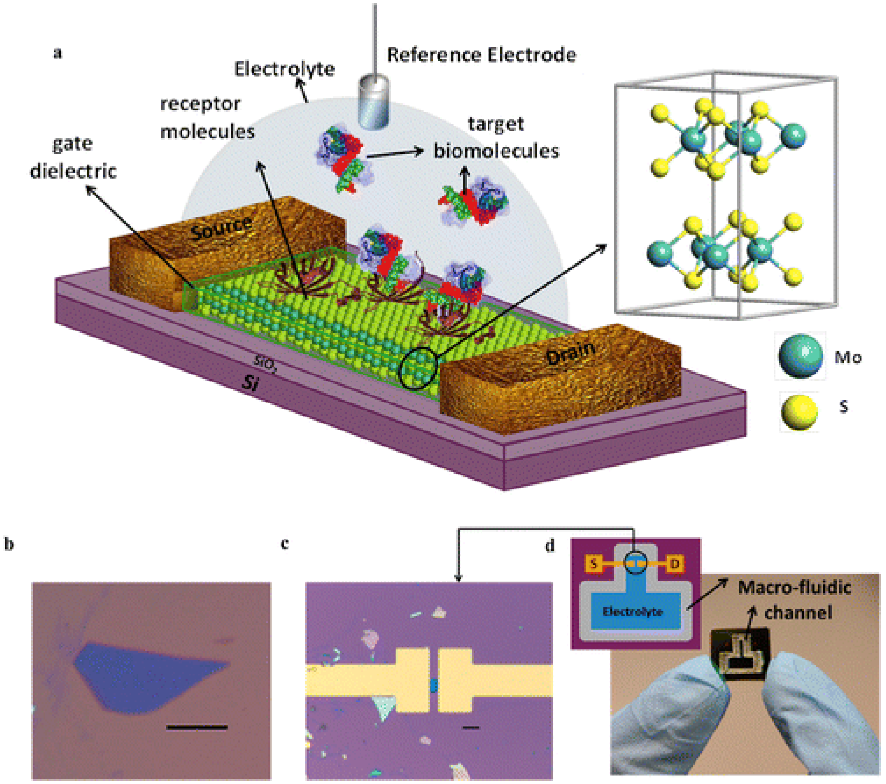
Required knowledge:

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



Simulate Sensors Based on 2D Materials

- 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

Supervisor:

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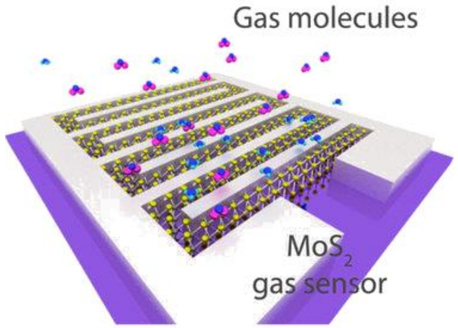
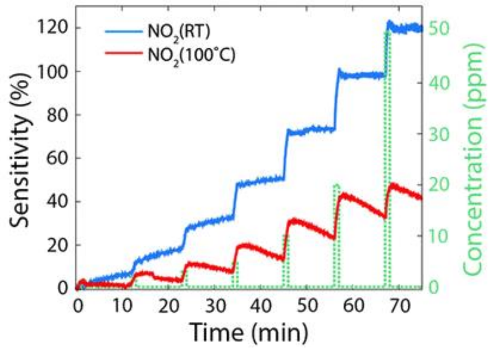
Project LF1

Required knowledge:

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





Measuring Gas Sensors based on 2D Materials

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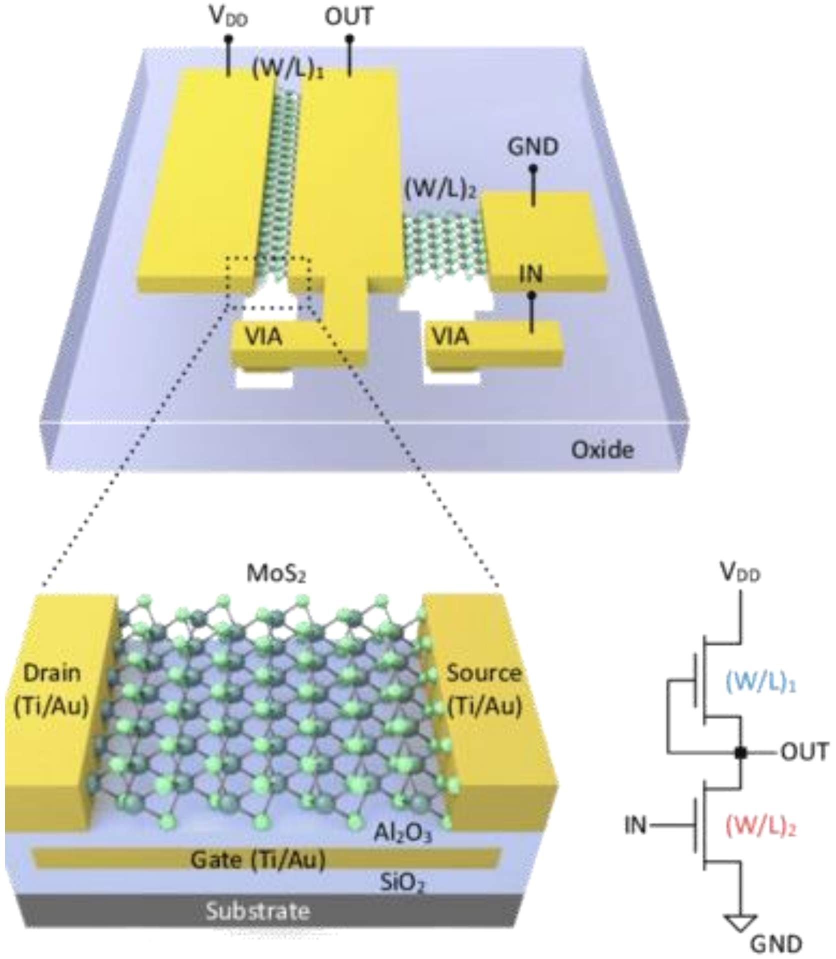
Project LF2

- 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:

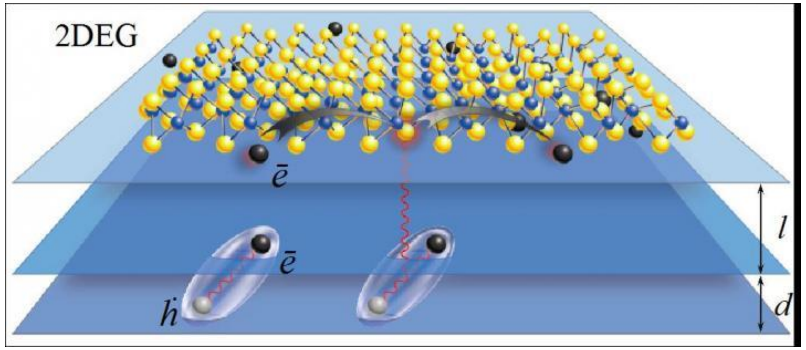
- Perform characterizations of the electrical behavior of several devices under varying ambient conditions
- Write scripts to control the measurement setup

Required knowledge:

- Basic knowledge of Python
- Interest in sensor physics

Physical Modeling of Novel Semiconductor Devices

- 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



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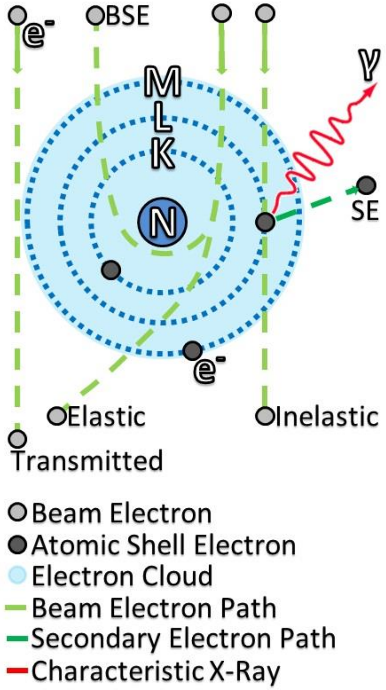
Project LF3

Tasks:

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

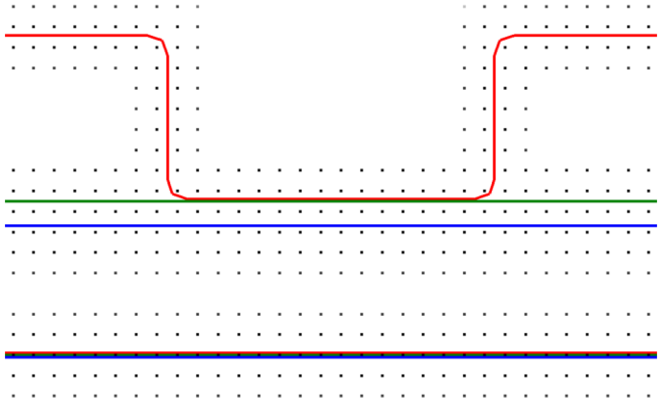


Required knowledge:

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

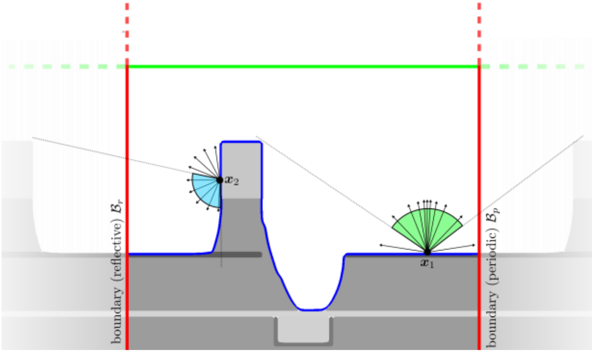
Modeling Atomic Layer Deposition (ALD)

- 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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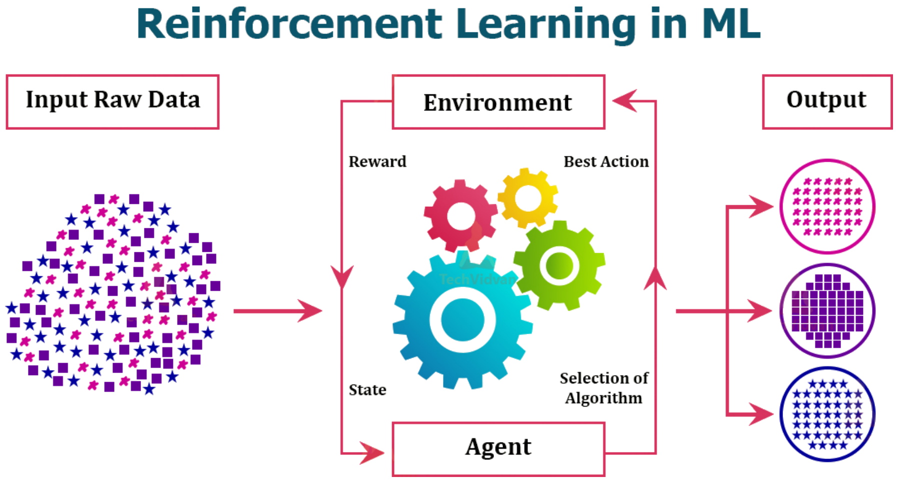
Project LF4

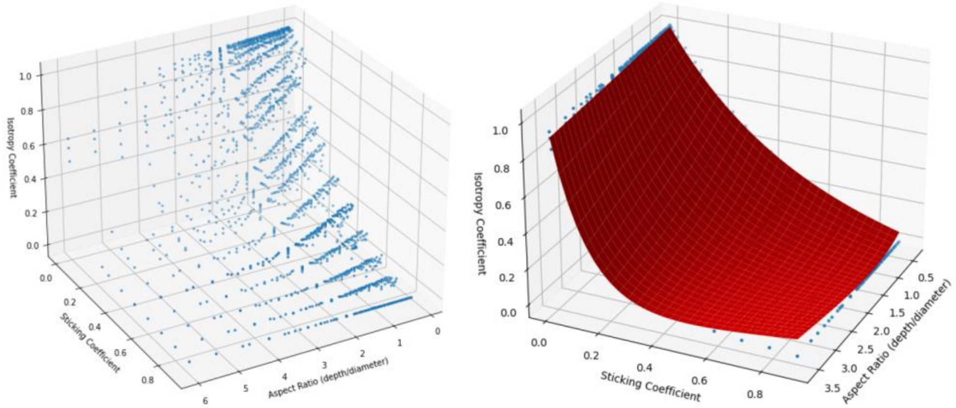
Machine Learning for Process TCAD

- 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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Project LF5

Physical Modeling of MOSFETs based on 2D Materials

Supervisor:

Theresia Knobloch

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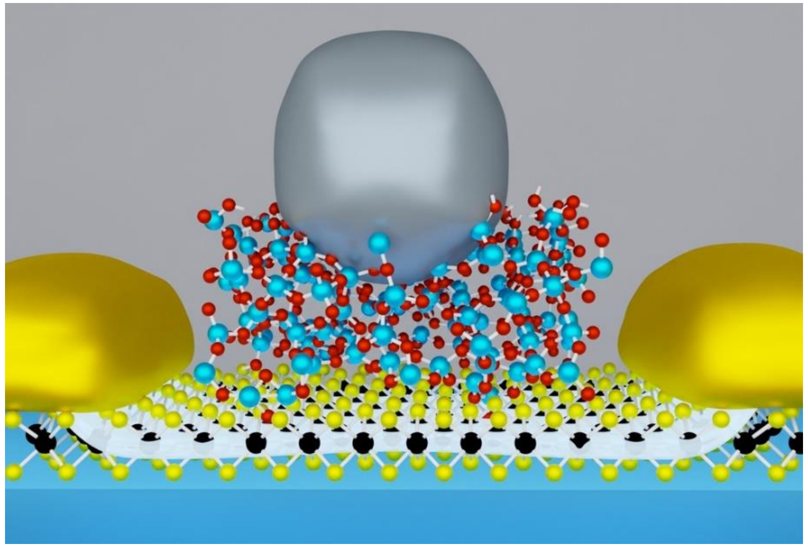
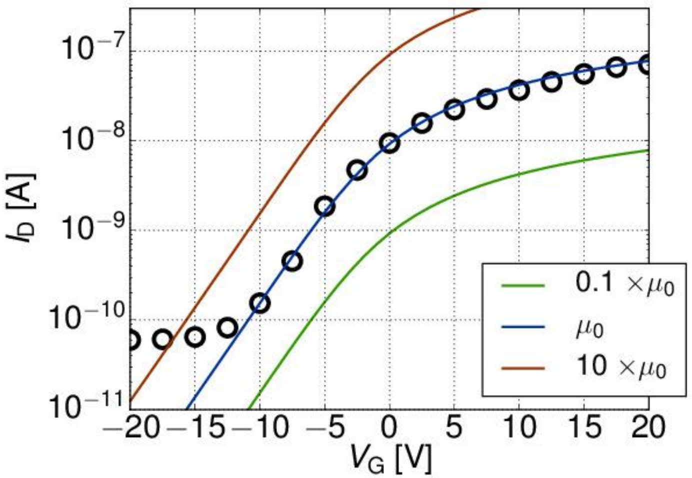
Project TK1

- 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:

Theresia Knobloch

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Project TK2

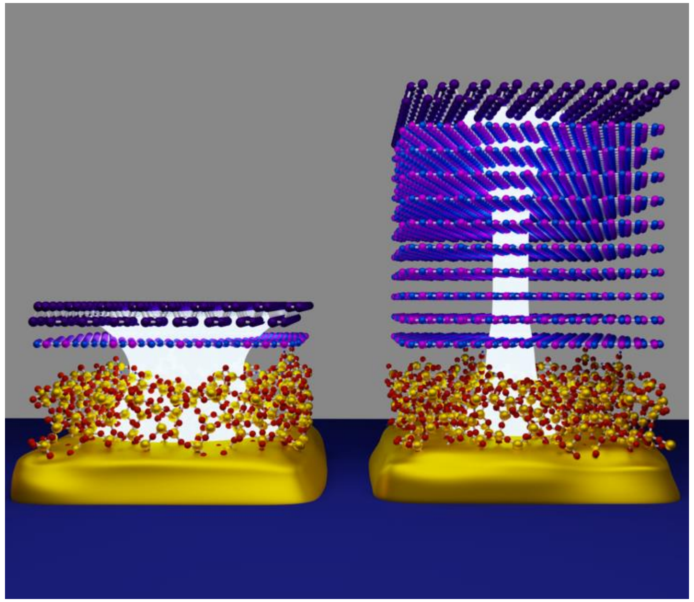
- As the thickness of the gate insulator is scaled down gate leakage currents become a major problem.
- We have implemented a semi-classical model in a compact Python simulator (Comphy) to describe the leakage currents through novel gate stacks.

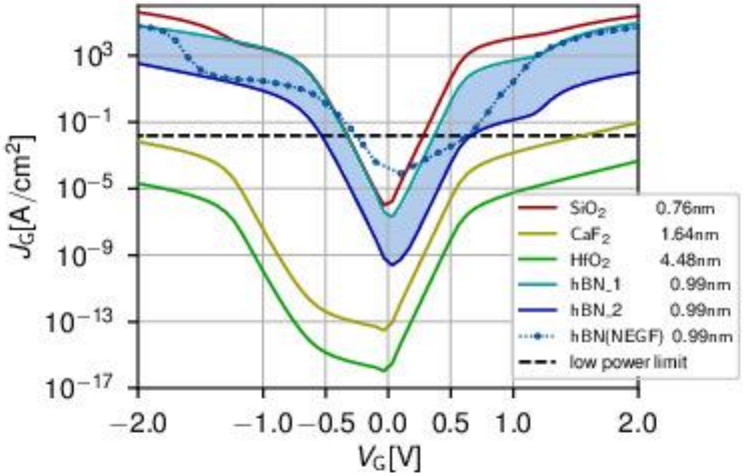
Possible Tasks:

- 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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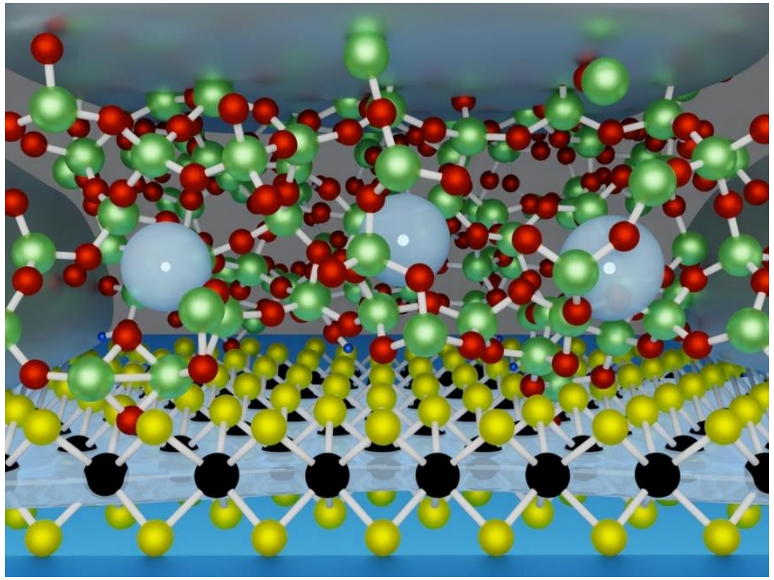
Project TK3

- 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

Algorithm for Electron-Electron Scattering in Monte Carlo Device Simulation

Supervisor:

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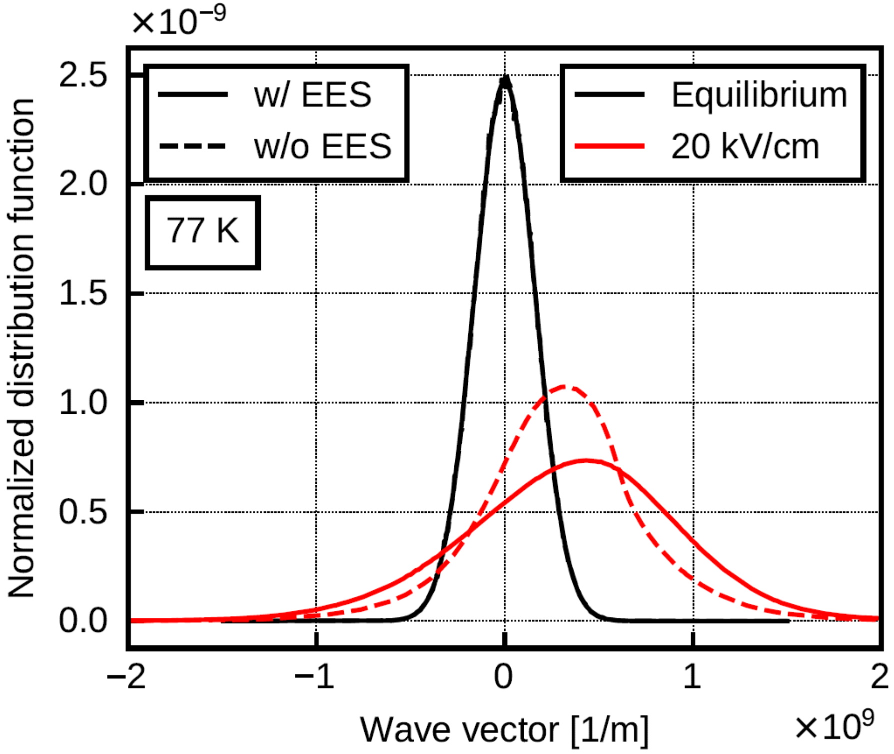
Project HK1

- 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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Xaver Klemenschits

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Project PM1

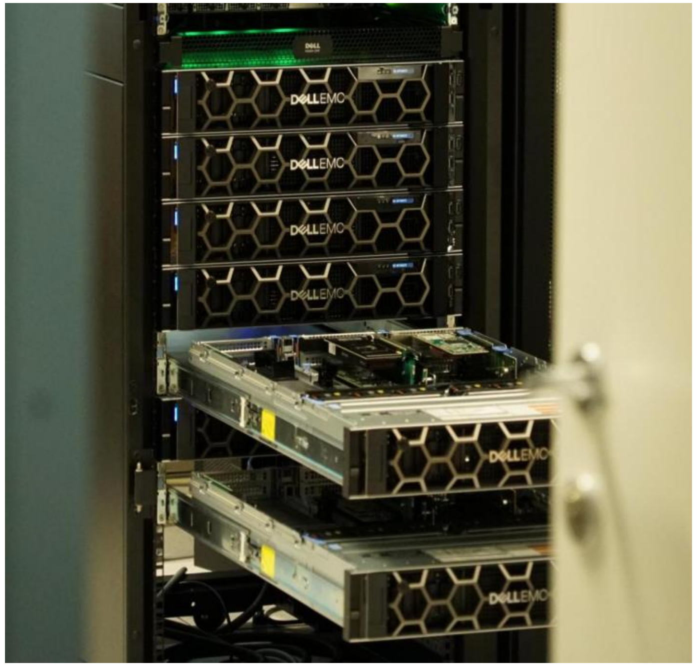
- ViennaLS is a high-performance level set engine tailored towards micro-electronic fabrication simulations
- Its full capabilities have not yet been explored on a modern high performance computer
- Simulations of even large ICs should be possible

Tasks:

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

Required knowledge:

- Advanced Knowledge of C++



Simulation of Spintronic Memory Device

Supervisor:

Roberto L. de Orio

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Project RO1

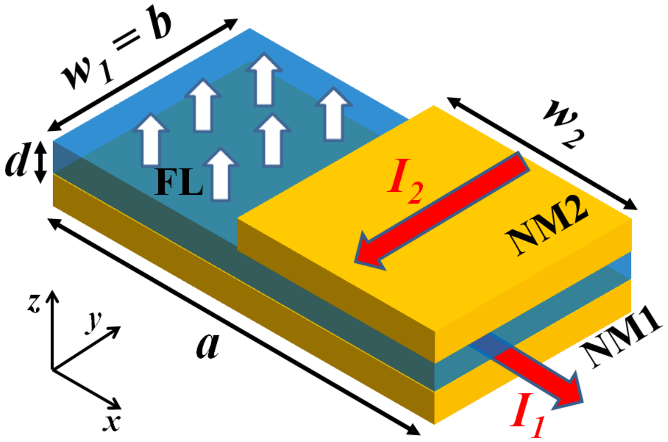
- Magnetoresistive random access memory (MRAM) is a new memory technology under development
- In MRAM, a bit is stored as a magnetization direction in a magnetic layer
- Simulation of MRAM devices is an interesting and challenging task

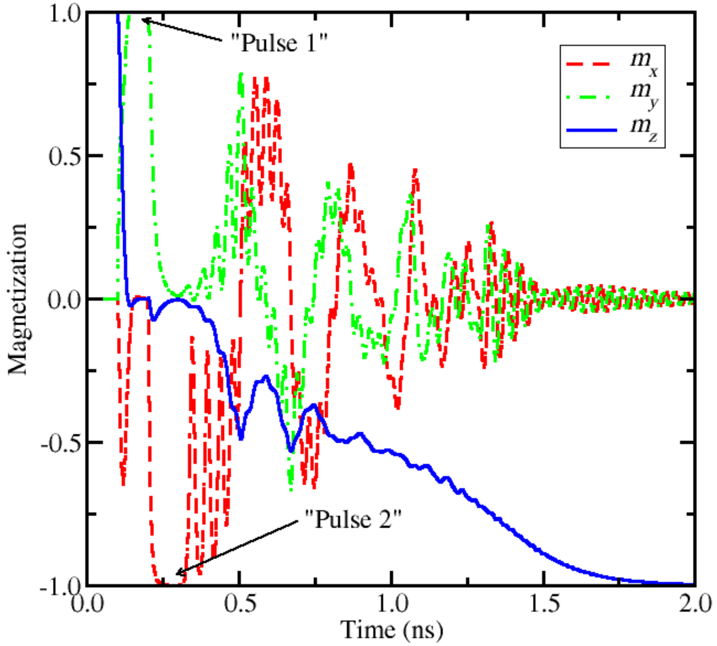
Tasks:

- Simulation of MRAM cells for different conditions and parameters
- Extend an in-house simulation tool to incorporate new features

Required knowledge:

- Programming in C/C++
- Interest in modeling and simulation
- Familiarity with MRAM is NOT necessary





Compact Modeling for Spintronic Memory Device

Supervisor:

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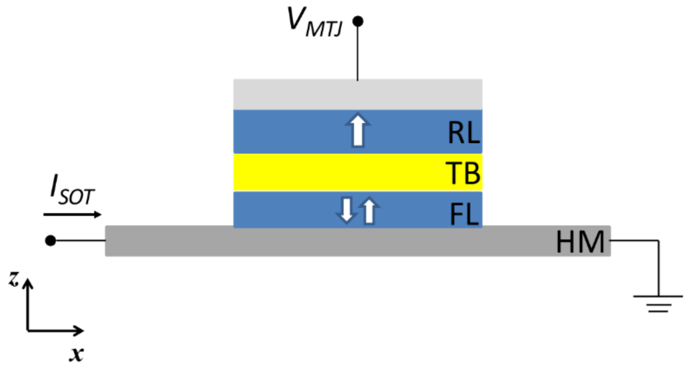
Project RO2

- Magnetoresistive random access memory (MRAM) is a new memory technology under development
- In MRAM, a bit is stored as a magnetization direction in a magnetic layer
- Compact models are important for simulation of MRAM-based circuits

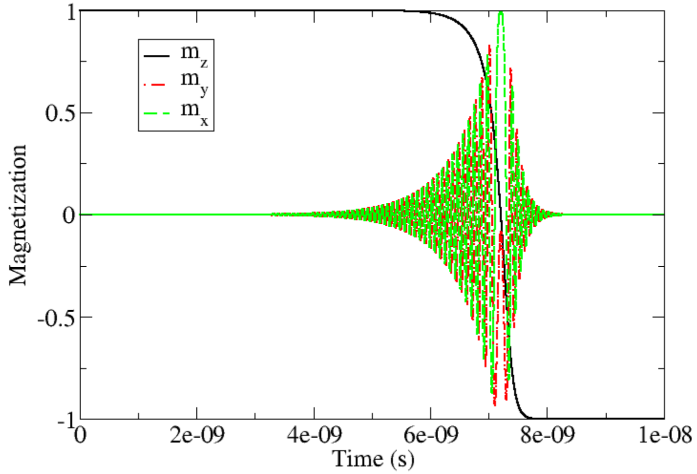


Tasks:

- Development of models suitable for simulation of MRAM circuits
- Extend available tools to incorporate new features

Required knowledge:

- Programming in Python
- Knowledge of circuit simulation and HDL languages is a plus
- Familiarity with MRAM is NOT necessary



MRAM Circuit Simulation

Supervisor:

Roberto L. de Orio

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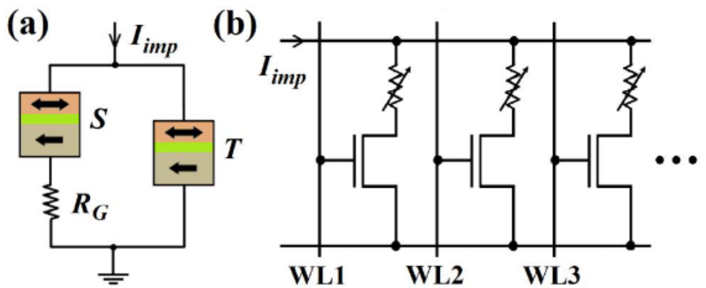
Project RO3

- Magnetoresistive random access memory (MRAM) is a new memory technology under development
- In MRAM, a bit is stored as a magnetization direction in a magnetic layer
- Circuit simulation (spice-like) is a fundamental step during design of new technologies

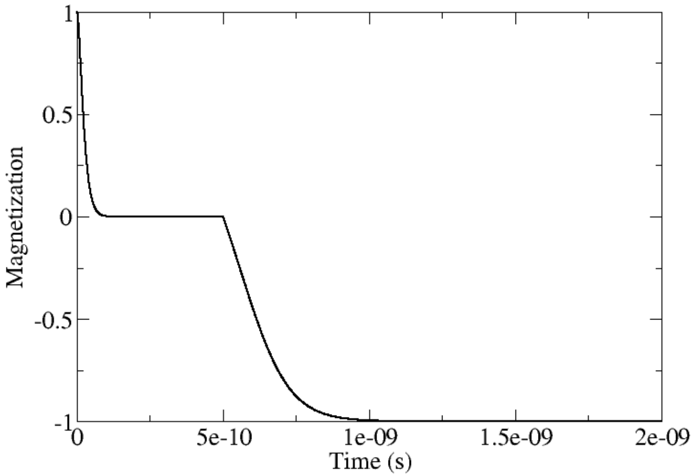


Tasks:

- Simulation of basic circuits for MRAM
- Investigation of possible simulation tools and framework

Required knowledge:

- Basic circuit simulation
- Knowledge of HDL languages is a plus
- Familiarity with MRAM is NOT necessary



Simulation Framework Development

Supervisor:

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Theresia Knobloch

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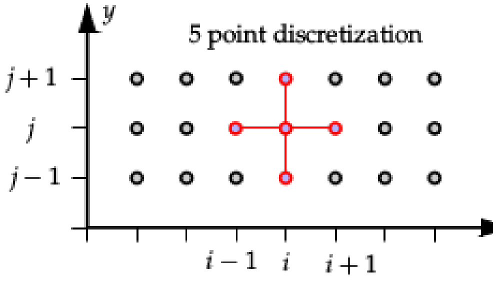
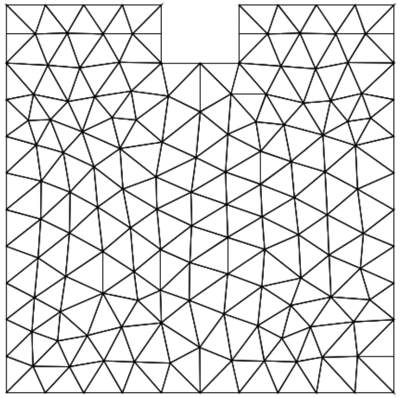
Project RO4

- Analysis of differential equation systems using numerical methods (e.g. spatial and time discretization schemes)
- Simulation of semiconductor devices
  - Drift-diffusion model
  - Modeling of physical parameters

$$\nabla^2\psi = q(n - p - C)/\varepsilon$$
$$\nabla \cdot (\mu_n n \nabla\psi - \mu_n V_T \nabla n) + \frac{\partial n}{\partial t} = -R\ ,$$
$$\nabla \cdot (\mu_p p \nabla\psi + \mu_p V_T \nabla p) - \frac{\partial p}{\partial t} = R\ .$$



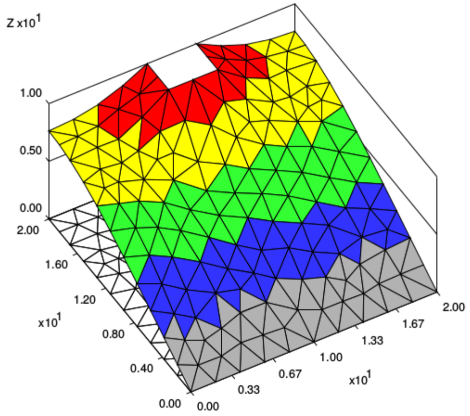


Task:

- Development of an academic simulation framework using Python

Required knowledge:

- Basic knowledge of semiconductor devices
- Programming in Python
- Interest in semiconductor devices and numerical simulations



Atomistic Modeling: Interaction of Oxide Defects with Electric Fields

Supervisor:

Dominic Waldhoer

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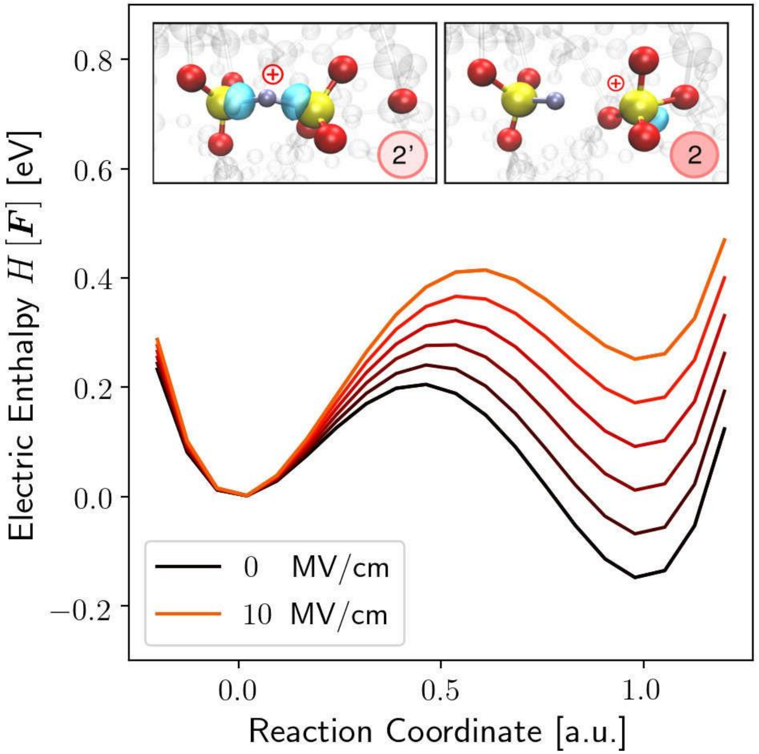
Project DW1

- 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:

Dominic Waldhoer

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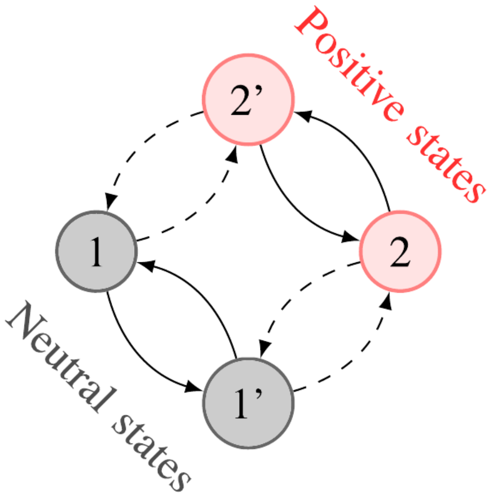
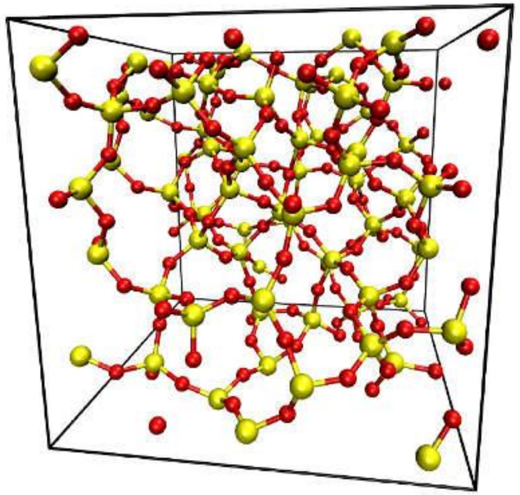
Project DW2

- *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:

Michael Waltl

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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

Hardware- and Software Development for *Defect Probing Instrument*

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

Supervisor:

Michael Waltl

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Project MW2

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

CSE & HPC: Quantum Monte Carlo Simulator on Supercomputers

Supervisor:

Josef Weinbub

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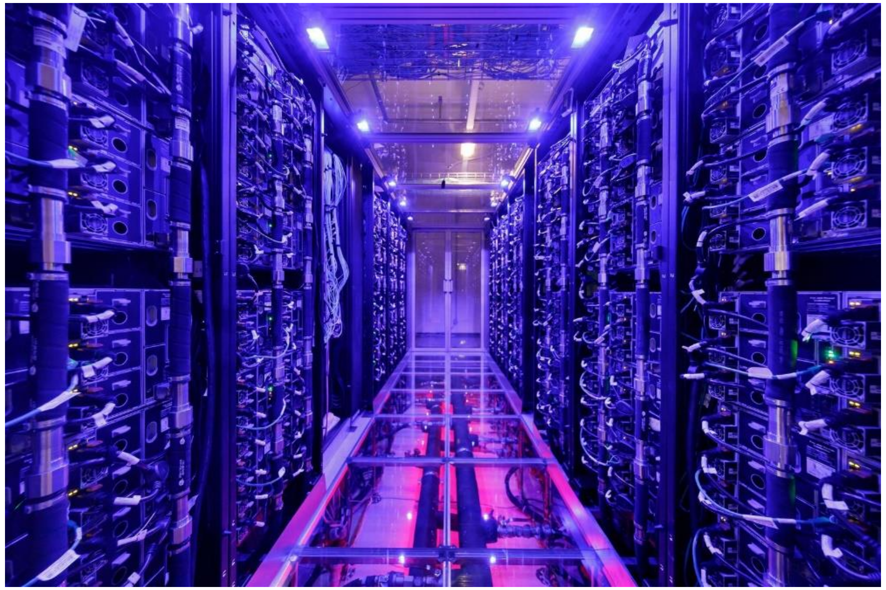
Project JW2

- Development of new highly parallel C++ Monte Carlo Simulator
- Several parallelization layers: MPI/OpenMP/CUDA
- Tailored to Supercomputers

Tasks: (several options based on one of the following)

- Switchable OpenMP/CUDA kernels
- MPI domain decomposition
- Structure generator
- Performance studies: Algorithms, data structures ..
- Automated testing pipelines

and many more ..



Required knowledge: (at least one of the following)

- C++
- MPI
- OpenMP
- CUDA

Atomistic Simulations

Supervisor:

Christoph Wilhelmer

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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/...)