Project and Thesis Folder 2021

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

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

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

Numerical Solvers for Diffusion Equations (using Python)

Supervisor:

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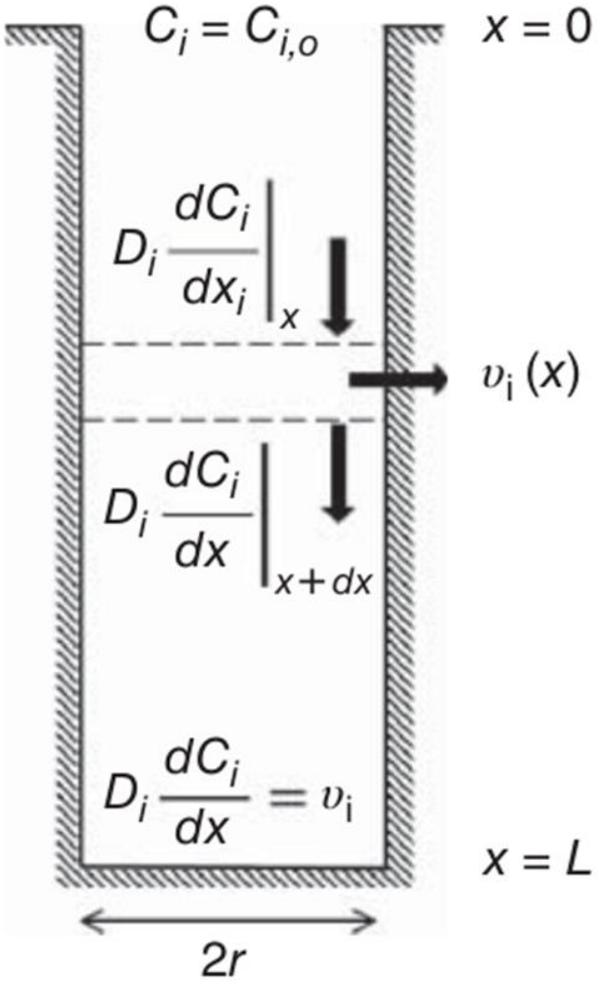
Project LA1

- One crucial challenge in the production of high aspect ratio (HAR) structures is the depletion of etchant/depositant species at the bottom
- One approach to model neutral species (e.g. ALD precursors) is using Knudsen diffusion
- When the Knudsen approach is extended to take into account arbitrary geometries, we encounter a system of coupled ODEs



Tasks:

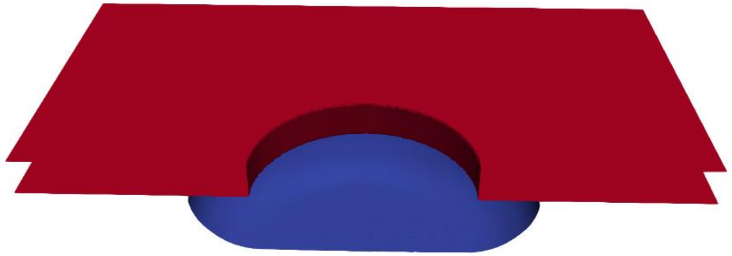
- Implement a framework to test different ODE system solvers
- Investigate the impact of each computational method
- Compare to available Monte Carlo and radiosity models

Required knowledge:

- Numerical methods for ODE (Runge-Kutta, Euler, …)
- Experience with Python/SciPy is a plus
- Familiarity with semiconductor processing is NOT necessary

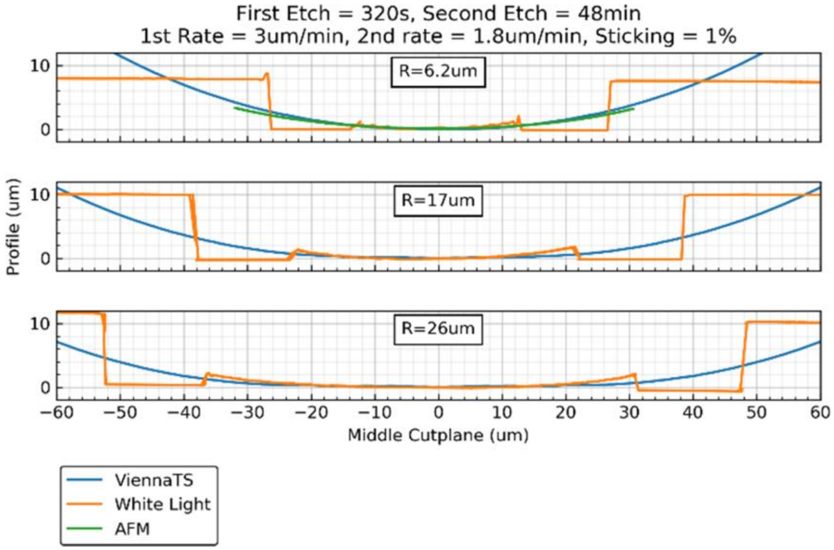
Optimization of Plasma Etching Simulations

- Plasma etching simulations have many free parameters
- Mapping these parameters to experimental inputs is not straightforward
- Computational optimization of the parameters is a key approach



Tasks:

- Explore optimizers to calibrate the simulations to available experimental data
- Develop a methodology to use the calibrated simulations to optimize fabrication figures of merit



Required knowledge:

- Programming in C/C++ or Python
- Familiarity with semiconductor processing is NOT necessary

Supervisor:

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Project LA2

Modeling of Atomic Layer Deposition (ALD)

Supervisor:

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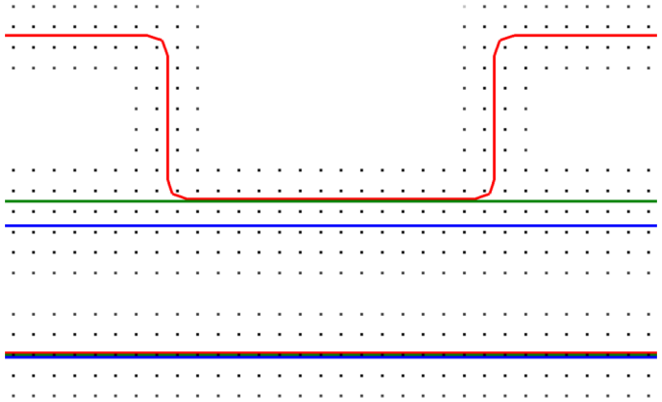
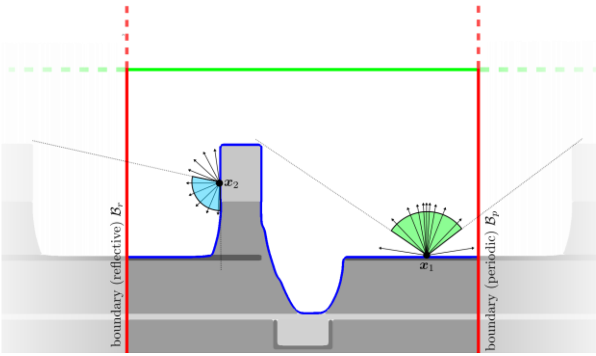
Project LA3

- 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

Absence and Leave Management System

Supervisor:

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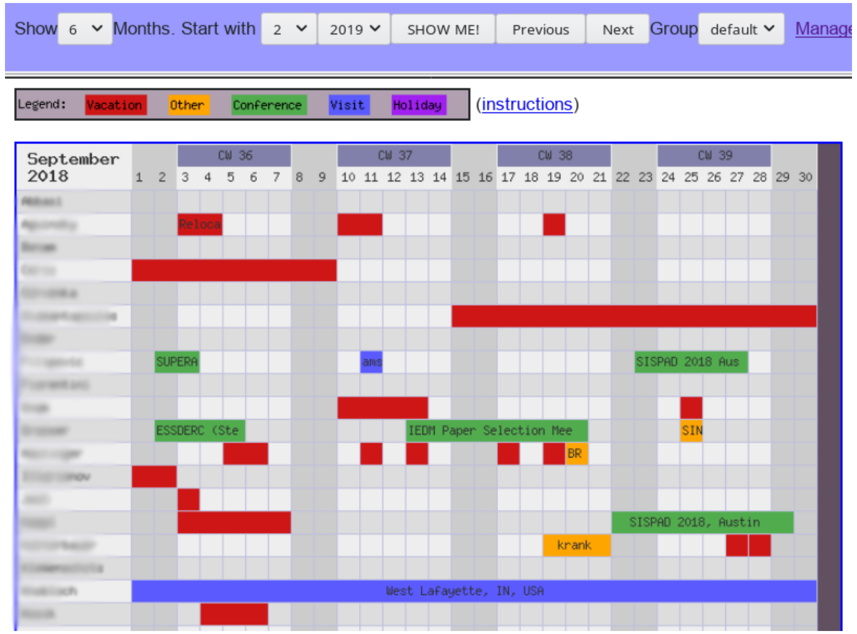
Project JC1

- Web-based holiday and absence planner application is desired
- It should be viewable and acccesible from everywhere
- Adapt to the existing design of the IuE hompage
- A standalone tool is desired



Tasks:

- Implement a simple leave management system
- User access rights should be made simple
- Primary calendar view should be one month
- Responsive design

Required knowledge:

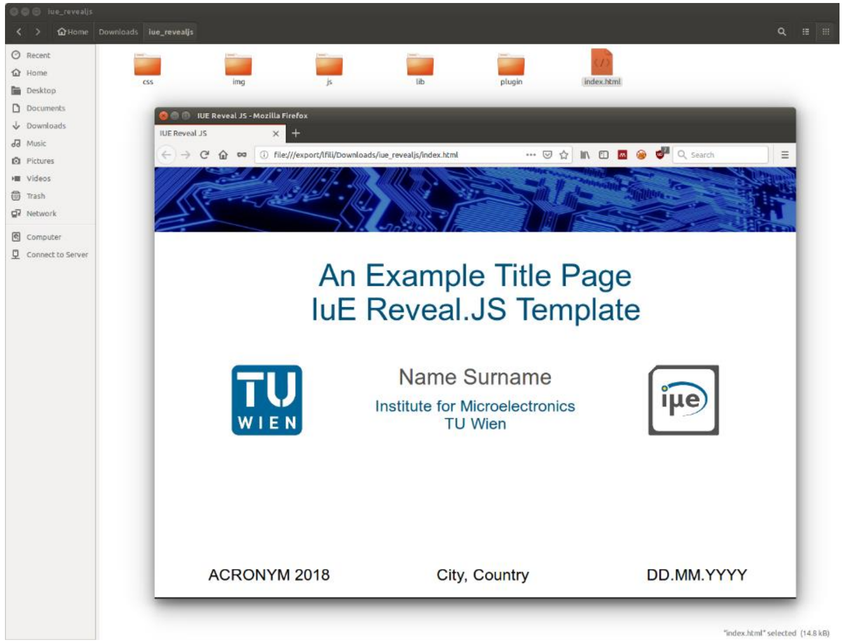
- Webpage and database programming
- HTML, CSS, Python/Perl/Java (open source, no restrictions)
- Some knowledge in graphic conceptualization and design desired

Web-based Interactive Slide Development

- Reveal.JS offers interactive, web based presentations
- The IuE is developing set of interactive slide templates
- Design engaging, interactive elements using web development tools

Tasks:

- Fine-tune the presentation template
- Implement responsive version of the slides
- Design system to serve uploaded slides
- Create new components in line with existing style



Required knowledge:

- HTML, CSS, Javascript or a desire to learn them

Supervisor:

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Project TE1

Characterization of the Gas Sensing Capability of 2D Materials

Supervisor:

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Project LF1

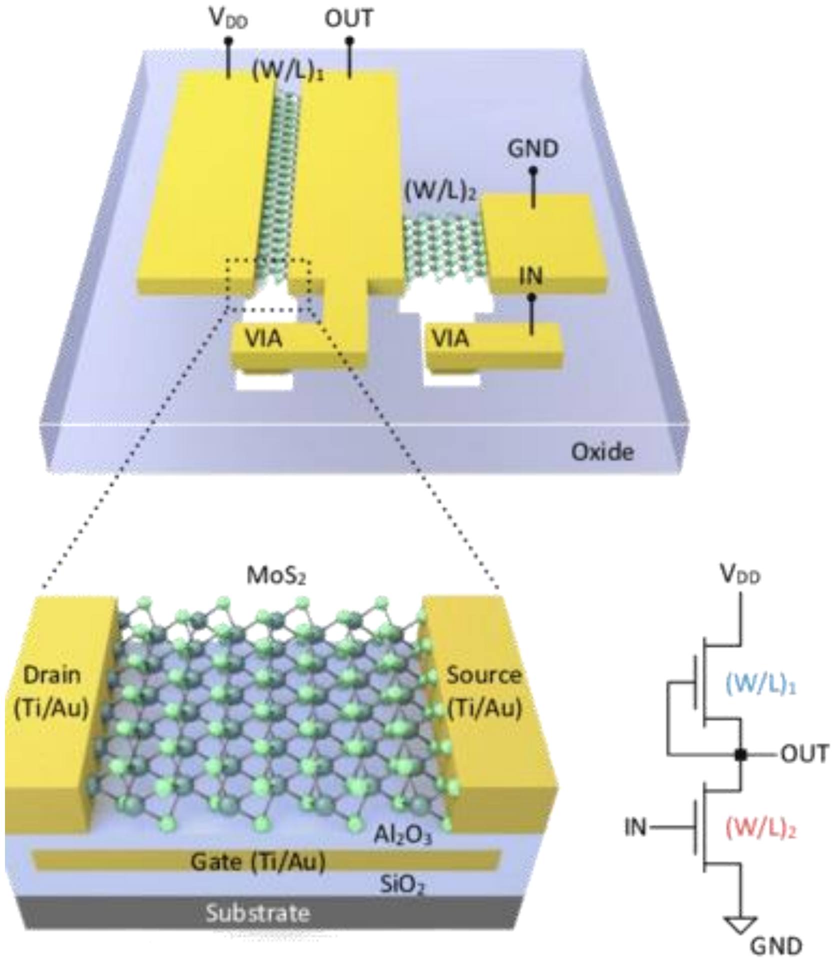
- 2D materials such as the graphene family of materials (graphene, graphene oxide, etc.) and MoS_2 have shown potential for use as a gas sensor
- Combined characterizations and modeling are essential in order to better understand the capabilities of these films for sensing

Tasks:

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

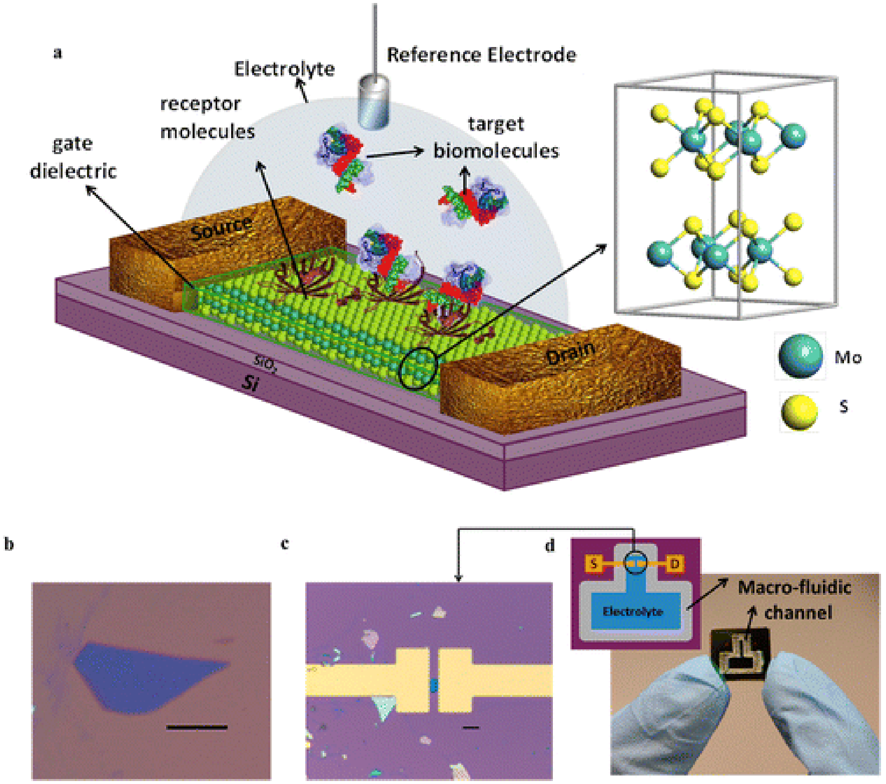
Required knowledge:

- Basic knowledge of Python
- Interest in sensor physics



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

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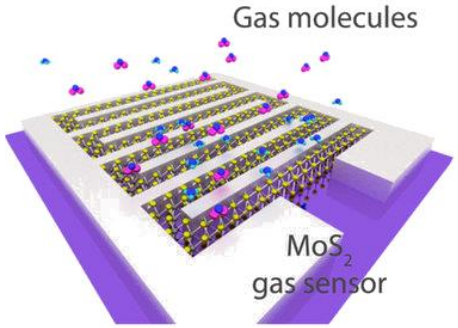
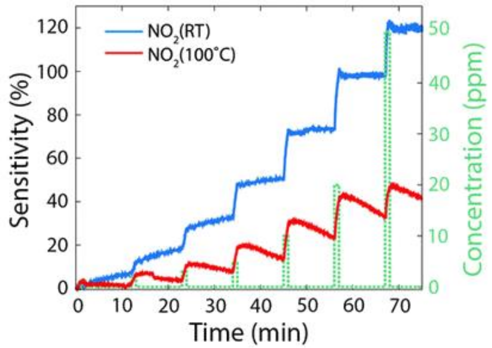
Project LF2

Required knowledge:

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





Physical Modeling of Novel Semiconductor Devices

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Project LF3

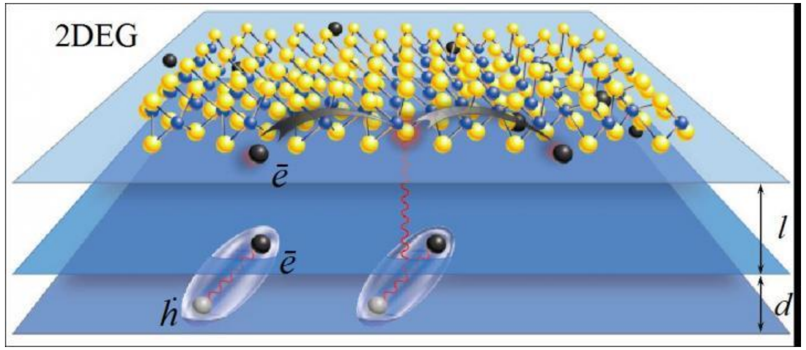
- To investigate new devices, based on novel materials such as 2D materials and Perovskites, physical modeling tools are essential
- We are developing a framework in C++ to model electron transport in semiconductors under various scattering phenomena

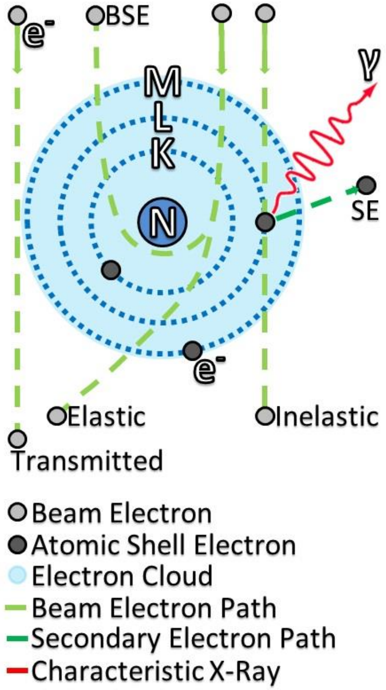
Tasks:

- 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 Electromigration in Platinum Microheaters

Supervisor:

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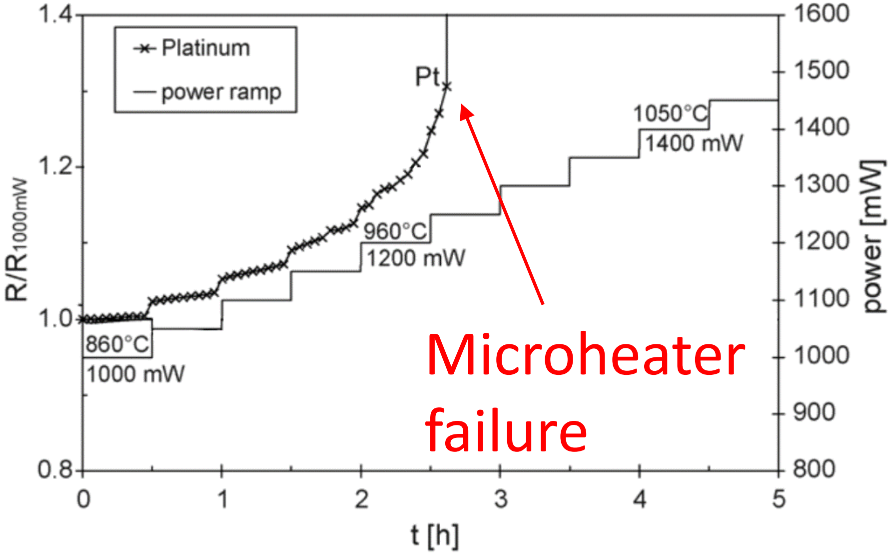
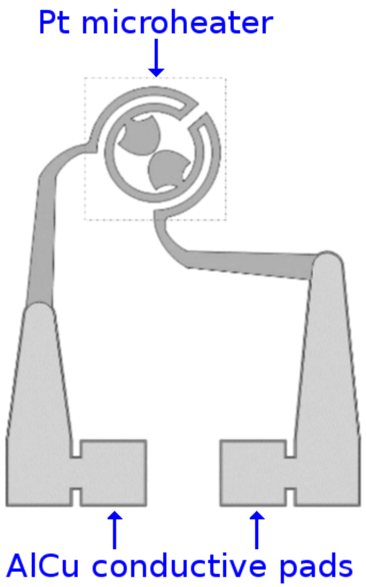
Project LF4

- Microheaters are frequently used for sensor structures to heat up the sensing layer
- The heat provides enough energy to activate the sensing interaction between ambient molecules and sensing film
- The microheater can frequently fail due to applied heating/cooling cycles and operation at high temperature due to electromigration



Tasks:

- A model for electromigration is already provided and is frequently applied to copper lines
- The tasks are to modify the model for platinum and test it on common microheater geometries

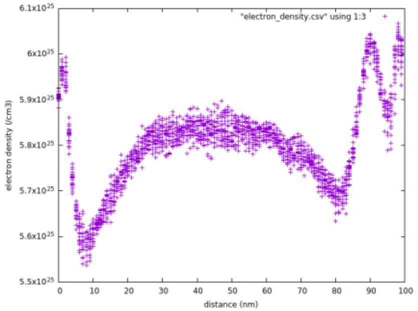


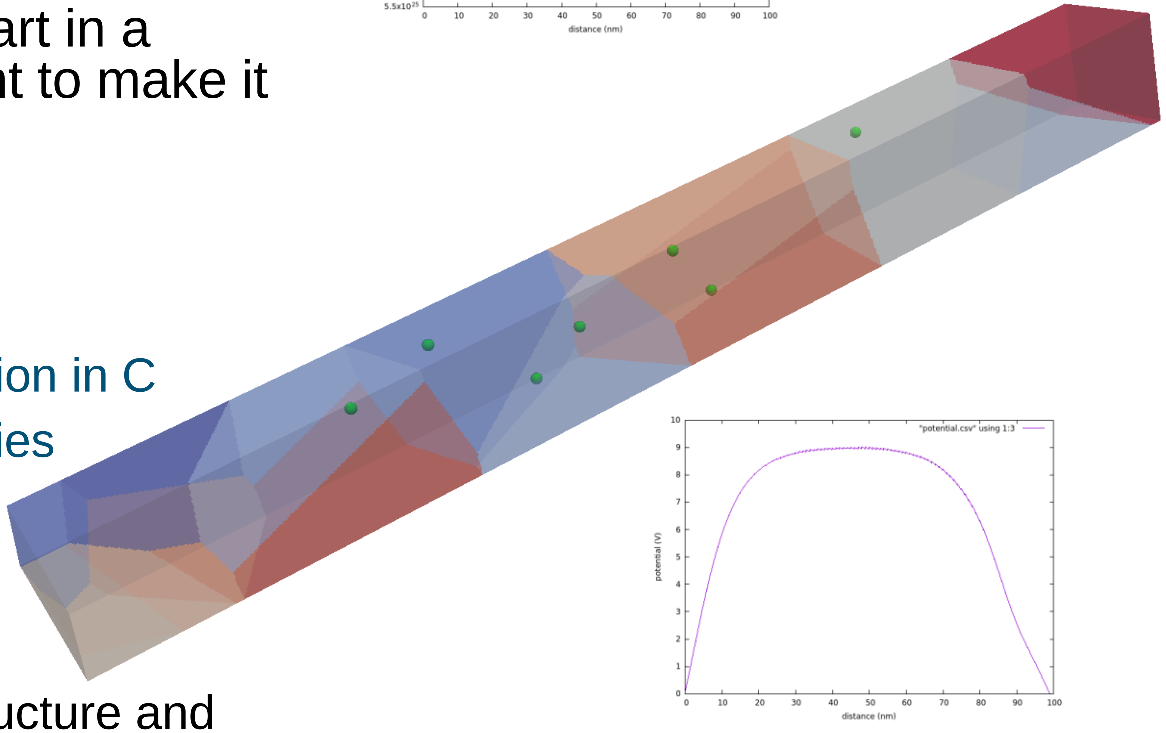
Required knowledge:

- Some knowledge in electro-thermo-mechanical simulations is helpful, but not essential

Modeling Electron Transport in Metals

- A software tool written in C can track how electrons move in different materials, such as silicon or copper
- Metals are of particular interest due to the added scattering off of grain boundaries
- The software is currently a small part in a larger code framework, but we want to make it an independent code





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Project LF5

Tasks:

- Implement models for electron motion in C
- Test the model for various geometries

Required knowledge:

- Programming in C or C++
- Some knowledge in metal microstructure and conductivity

Hot-Carrier Degradation (HCD)

Supervisor:

Markus Jech

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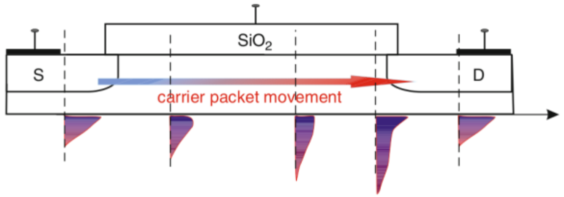
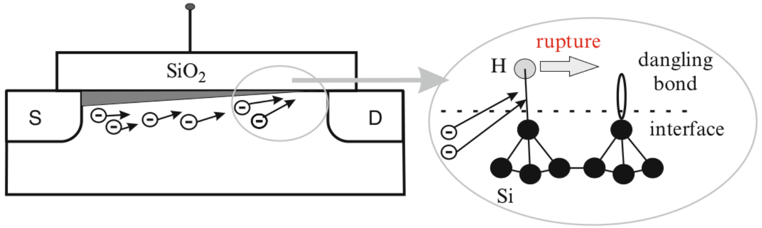
Project MJ1

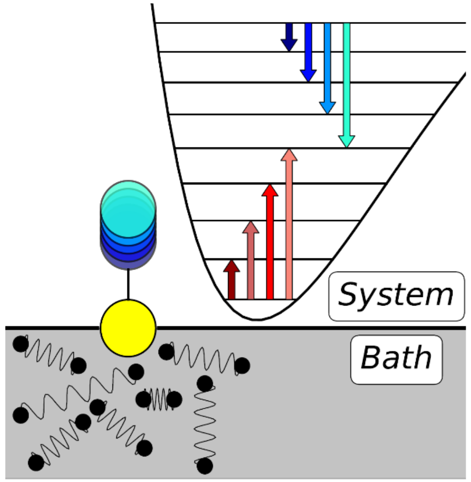
- Charge carriers in the channel can gain high kinetic energy and trigger the creation of defects at the Si/SiO_2 interface
- To understand how carriers are distributed over energy (energy distribution function), a full solution of the Boltzmann transport equation is needed
- Combining a physics-based model and a state of the art device simulator enables us to gain insight into this degradation phenomenon





Possible Tasks:

- Experimental characterization
  (e.g. the variability, different exp. methods)
- Modeling of HCD related phenomena
- Development of physics-based model



Required knowledge:

- Programming with Python/C++
- (Basic) knowledge of device simulations
- Interest in physics

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Interplay of Degradation Mechanisms

Supervisor:

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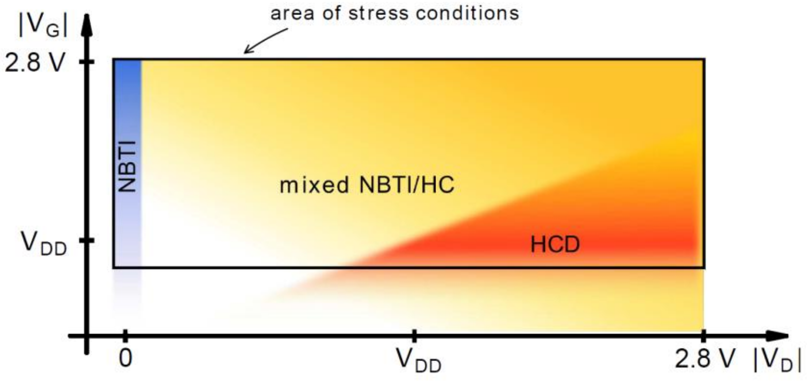
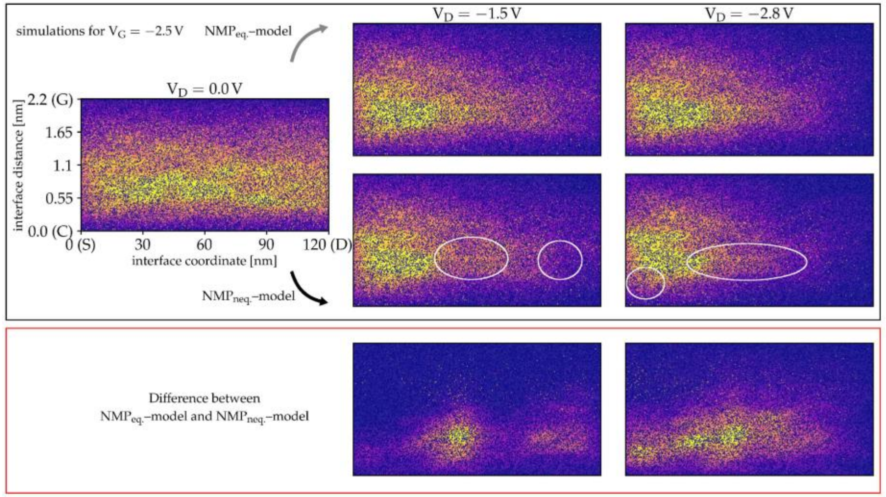
Project MJ2

- Bias Temperature Instability (BTI) and Hot Carrier Degradation (HCD) are two major device reliability issues
- However, both degradation modes are generally described and characterized independently
- We aim to understand and model the interplay between BTI and HCD



Possible Tasks:

- Experimental characterization
  (e.g. stress maps over bias space)
- (Improve) Modeling of degradation phenomena



Required knowledge:

- Programming with C++/Python
- (Basic) knowledge of device simulations
- Interest in experimental work

Atomistic Simulations

Supervisor:

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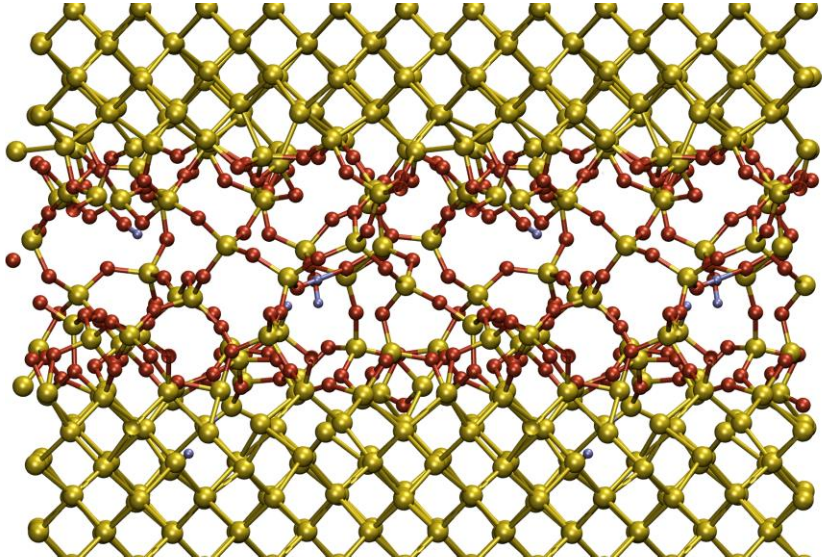
Project MJ3

- 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:

- Characterize realistic interface structures (e.g. Si/SiO_2)
- Characterize new and emerging technologies and materials
- Explore new simulation approaches

Required knowledge:

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

Simulation Framework

Supervisor:

Markus Jech

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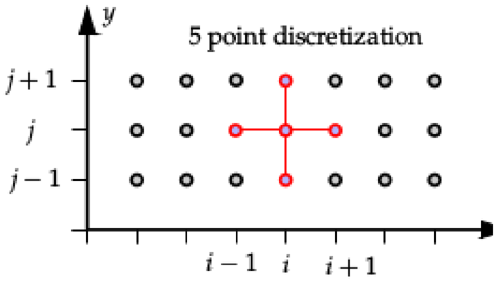
Project MJ4

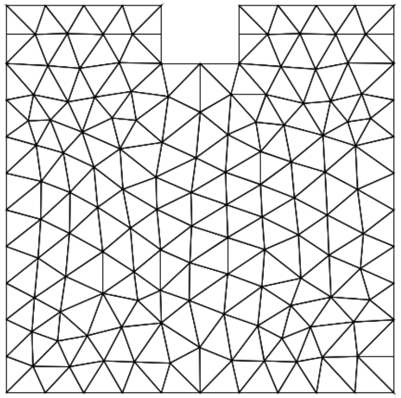
- Analysis of differential equation systems using numerical methods (e.g. spatial and time discretization schemes)
- Simulation of semiconductor devices
  - Drift-diffusion model
  - Modeling of physical parameters

$$\nabla^2\psi = q(n - p - C)/\varepsilon$$

$$\nabla \cdot (\mu_n n \nabla\psi - \mu_n V_T \nabla n) + \frac{\partial n}{\partial t} = -R \ ,$$

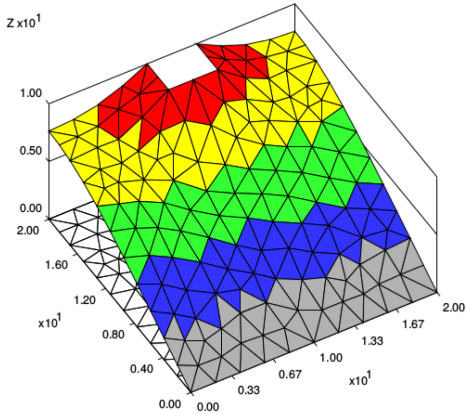
$$\nabla \cdot (\mu_p p \nabla\psi + \mu_p V_T \nabla p) - \frac{\partial p}{\partial t} = R \ .$$





Possible Tasks:

- Development a new simulation framework
- (preferable) Python based using existing libraries



Required knowledge:

- Good knowledge of device simulations (MEB)
- Programming with Python
- Interest in numerics

Band Structure Calculation for Silicon Carbide

Supervisor:

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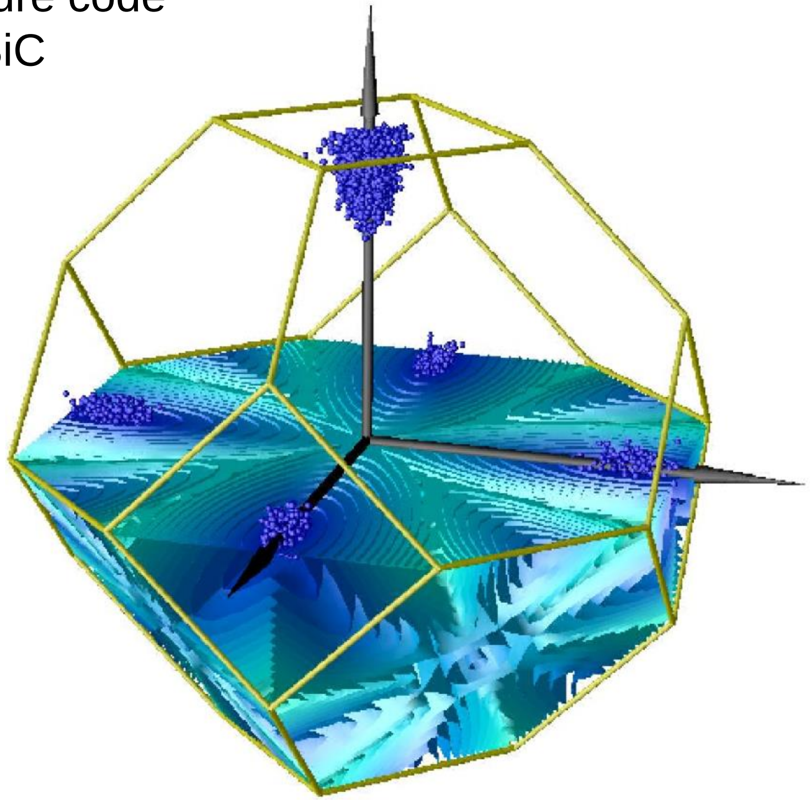
Project MK1

- Silicon Carbide (SiC) is a wide bandgap material often used in modern power devices
- Knowledge of the electronic band structure is important in order to understand carrier mobility and device performance
- The aim of this project is to extend an existing band structure code which assumes a cubic lattice to the hexagonal lattice of SiC

Tasks:

- Augment the empirical pseudopotential code (EPM) to deal with the Wurtzite lattice
- Verify already published fitting-factors for SiC
- Compare the results with data from literature



Requirements:

- Programming in C
- Interest in semiconductor physics

Automatic Python Wrapper for C++ projects

Supervisor:

Xaver Klemenschits

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Project XK1

- Semiconductor process simulations require high performance implementations for reasonable runtimes (so not in python, but C or C++)
- Using C/C++ libraries can be complex
- Wrapping such simulators as python libraries makes them accessible to a wide audience, without the need to understand everything the library does

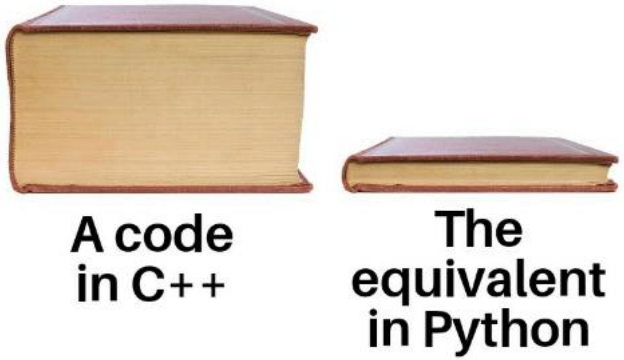
Tasks:

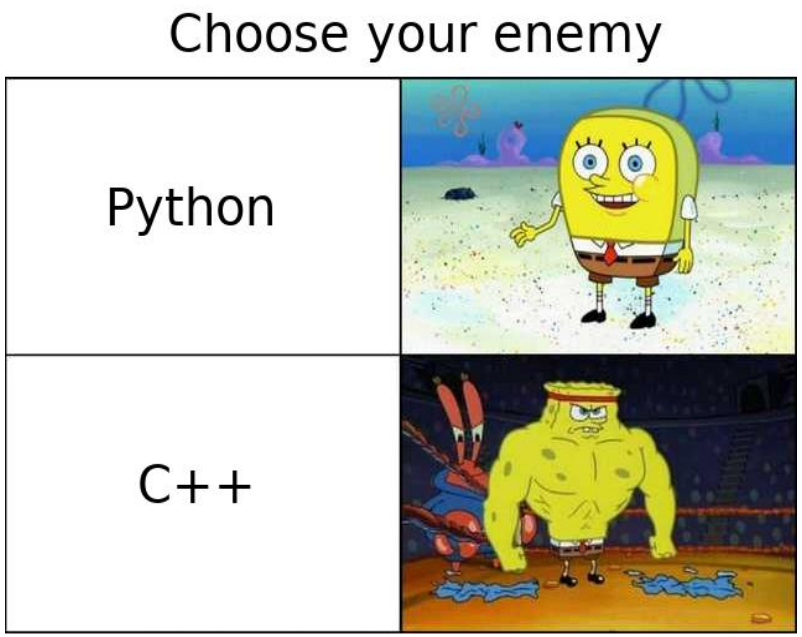
- Wrap a large C++ project with the necessary interfacing code to expose it to the python language
- Develope a C++ parser, which does this automatically for any project

Required knowledge:

- Programming in C++

Usability of C++ / Python:





Build a Parameter Parser for ViennaTS

Supervisor:

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Project XK2

- ViennaTS is a process simulation tool used to model semiconductor fabrication steps
- Currently only text based parsing
- Especially web technology relies on JSON formatted data for its robustness

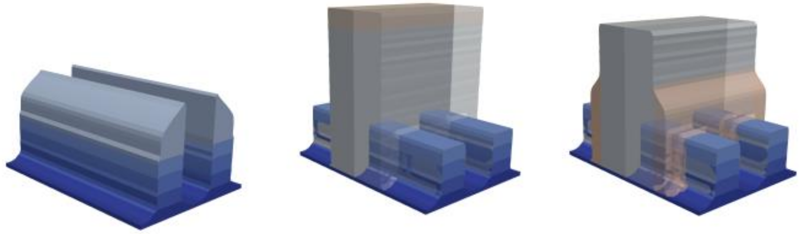
Tasks:

- Redesign the way information is passed to the simulator and implement a JSON based parameter input with automatic input checks

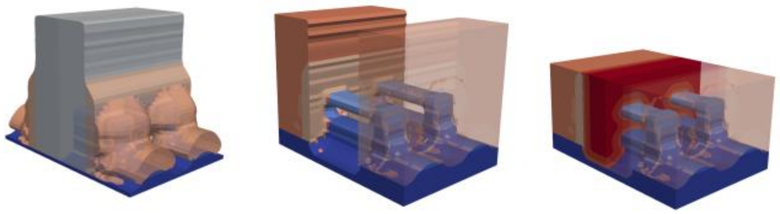
Required knowledge:

- Programming in C++


```
		model_name="SF6_CH2F2PlasmaEtching";
		//active_layers = {5};
		//mask_layers = {4};
		process_time=1;
		//add_layer=1;

		output_times={0};
	}
};
/*
		output_times_period_length=10;
		output_times_periodicity=5;

		parameters= {
			direction={1,0,0};

			statistical_accuracy=10000;

			min_ion_energy=50;
			delta_ion_energy=40;

			flux_ion=1.5e15;
			flux_etchant=1.3e16;
			flux_polymer=4.5e15;

			temperature=298.;
		};
	},
	{
		model_name="HBr_O2PlasmaEtching";
		active_layers={5,6};
		mask_layers = {4};
		process_time= 6;
		add_layer=1;

		output_times={0};
		output_times_period_length = 1;
		output_times_periodicity=6;

		parameters= {

			direction={1,0,0};

			statistical_accuracy=10000;
```



(a) Epitaxial growth and double patterning. (b) Dummy gate patterning. (c) Spacer formation and patterning.



(d) Source/drain epitaxy. (e) Channel release. (f) Final geometry after gate material deposition.

Ray Tracer for ViennaTS

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Project XK3

- Recently, the ViennaTS codebase was modernised. The ray tracer is not refactored yet
- Although the ray tracer is powerful, it is hard to maintain and adapt, because of its unclean interfaces
- Great project to learn about fundamentals of ray tracing engines as used in graphics applications

Tasks:

- Re-implement the ray tracer as a standalone library for modern use and develop clean and portable interfaces.

Required knowledge:

- Advanced Knowledge of C++

Without Ray Tracing:

With Ray Tracing:

Surface Advancement using Task Multithreading

Supervisor:

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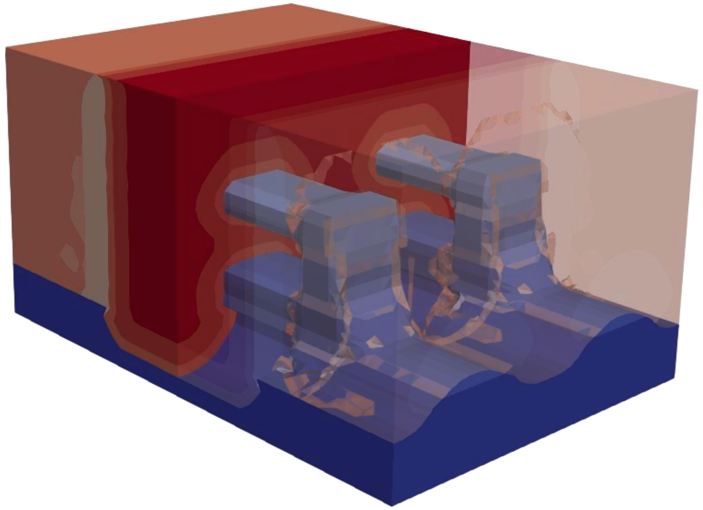
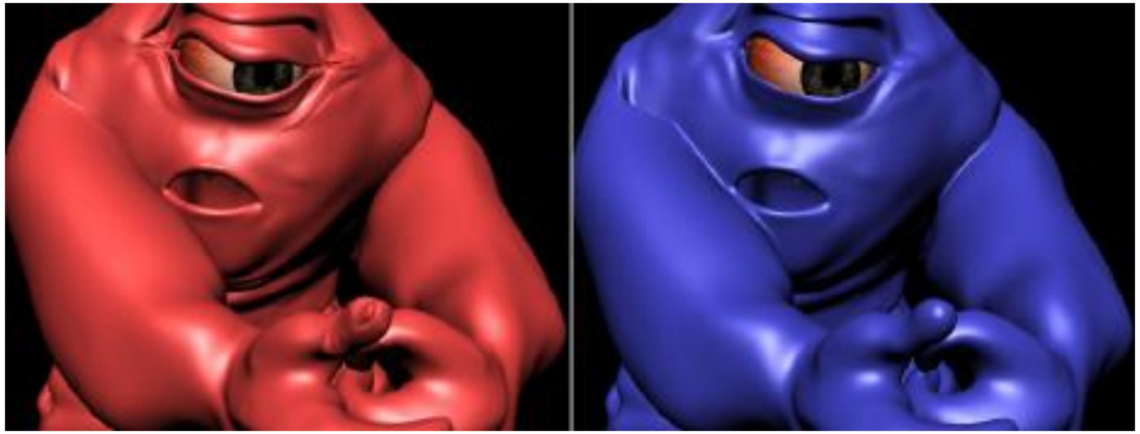
Project XK4

- ViennaLS is a level set engine for describing surfaces during micro-processor fabrication;
  The same concept is used by Disney / Pixar for animation films
- We have developed a fast algorithm for computing surface movement over large distances
- This algorithm could be even faster using a tasking approach for multithreading with each thread doing calculations, once it is available until all calculations are done



Tasks:

- Refactor the algorithm
  to allow for this new approach
- Distribute work across threads



Required knowledge:

- Advanced Knowledge of C++

Modeling of MOSFETs based on 2D Materials

Supervisor:

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Project TK1

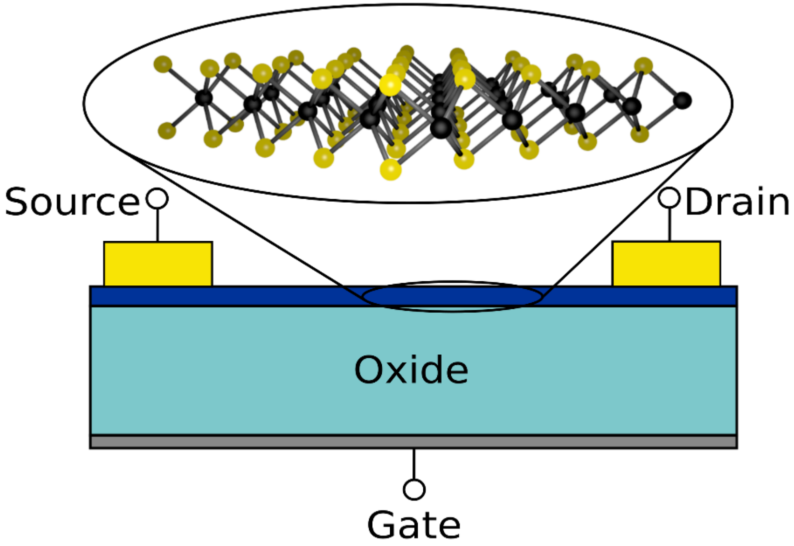
- Benchmarking of different approaches
  - TCAD vs. compact model
  - scattering dominated vs. ballistic
- Calibrate the models to measurement data

Tasks:

- Simulate transfer characteristics with 2 models
- Compare the simulation to measurement data
- Interpret observed differences

Required knowledge:

- Programming skills (Python)
- Profound physical understanding
- ev. Circuit modeling skills (HSPICE, Verilog-A)



3D Printing of FET Models

Supervisor:

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Project TK2

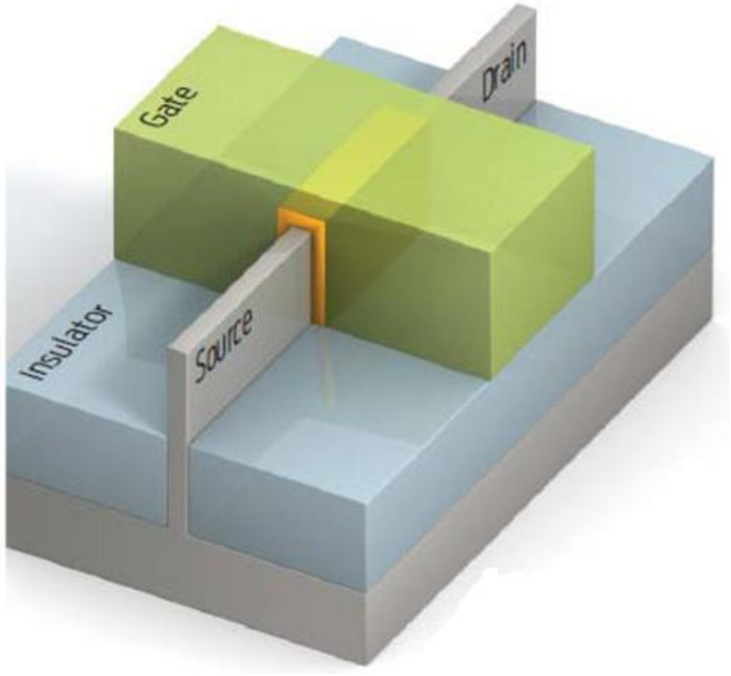
- Drawing 3D models of a FinFET in a CAD-tool
- Disassemble the model into individual components
  - parts should form a 3D puzzle
- 3D Printing of the components

Tasks:

- Draw a 3D CAD model
- 3D Printing of the puzzle components
- User manual for didactic purposes

Required knowledge:

- 3D Modeling experience (FreeCAD, Blender, ...)
- ev. Experience with 3D printing



Algorithm for Electron-Electron Scattering in Monte Carlo Device Simulation

Supervisor:

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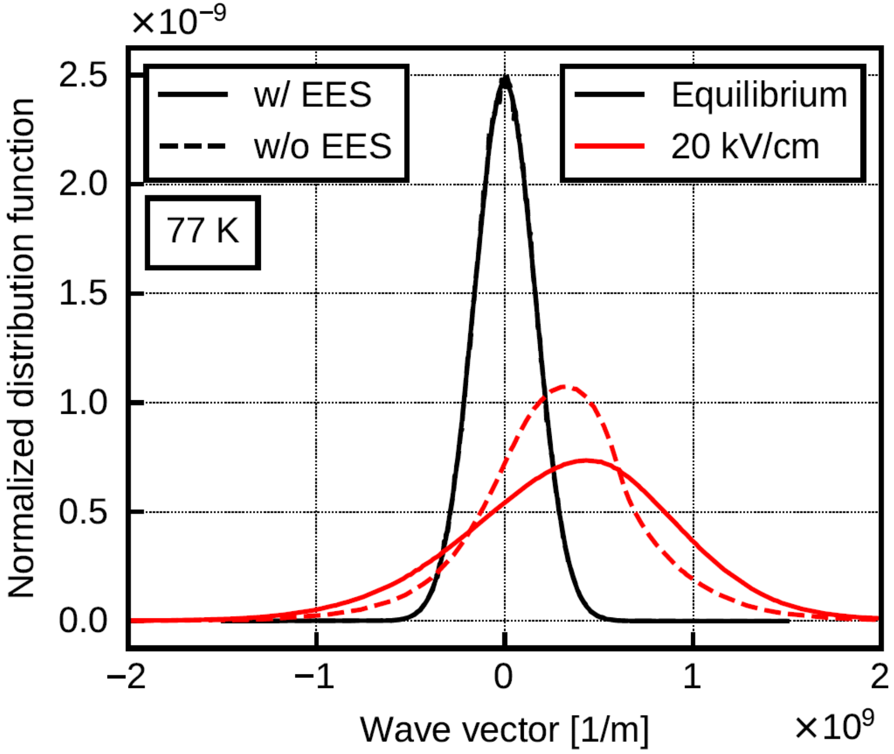
Project HK1

- 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

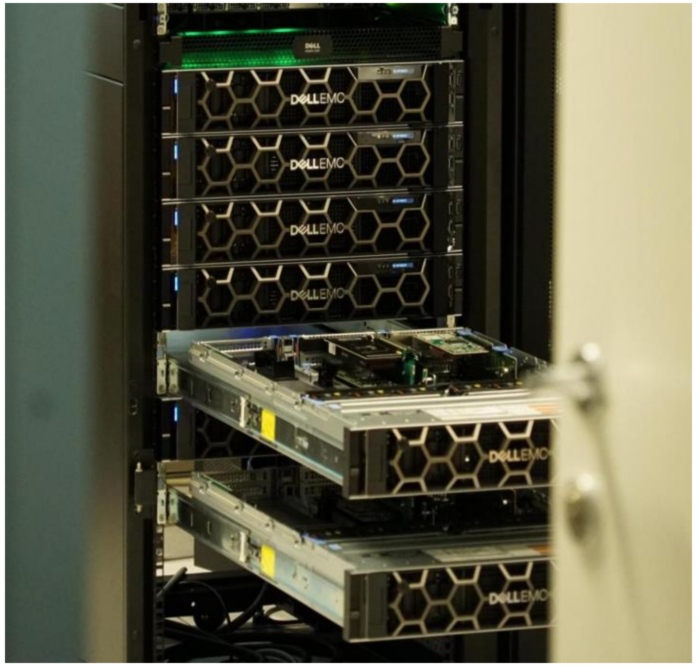
- ViennaLS is a high-performance level set engine tailored towards micro-electronic fabrication simulations
- Its full capabilities have not yet been explored on a modern high performance computer
- Simulations of even large ICs should be possible

Tasks:

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

Required knowledge:

- Advanced Knowledge of C++



Domain Decomposition for Parallel Velocity Extension

Supervisor:

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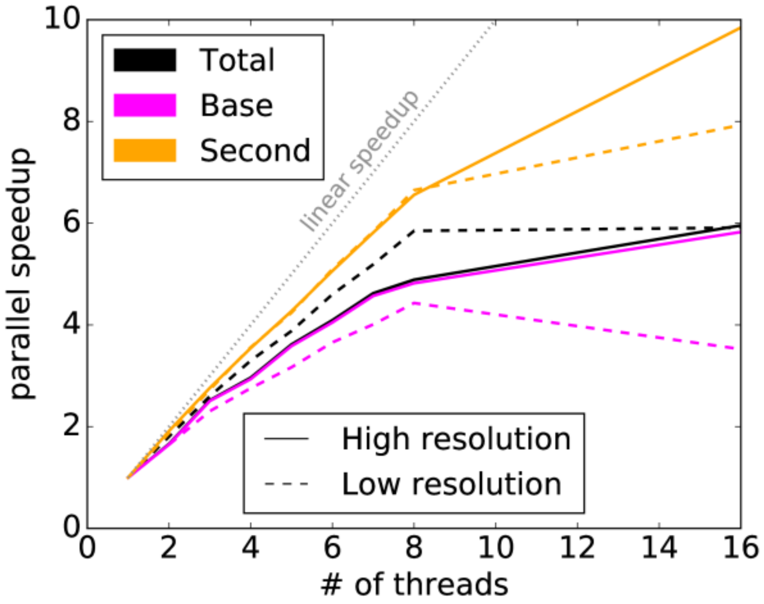
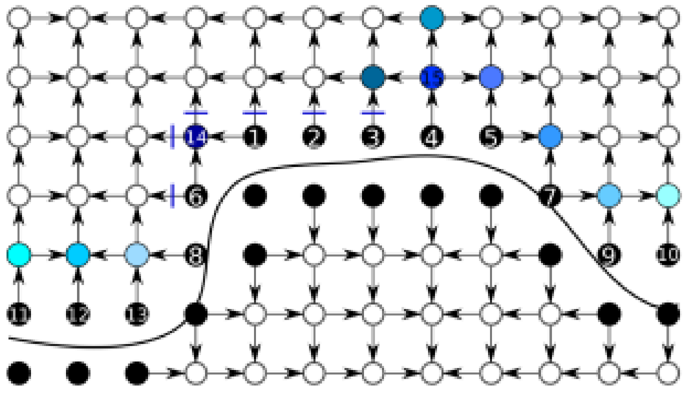
Project MQ1

- In process TCAD, interfaces are tracked using the level-set method
- A crucial step for the level-set method is the extension of the interface velocity to a narrow-band around the interface
- A parallel algorithm on a hierarchical grid has been implemented for shared memory systems



Tasks:

- Implement a new parallelization based on mesh decomposition / adaptive load balancing in the given C++ framework
- Compare it to the existing parallelization



Required knowledge:

- Programming in C++ under GNU/Linux
- OPENMP, Parallel programming

Dopant Diffusion in Process TCAD

Supervisor:

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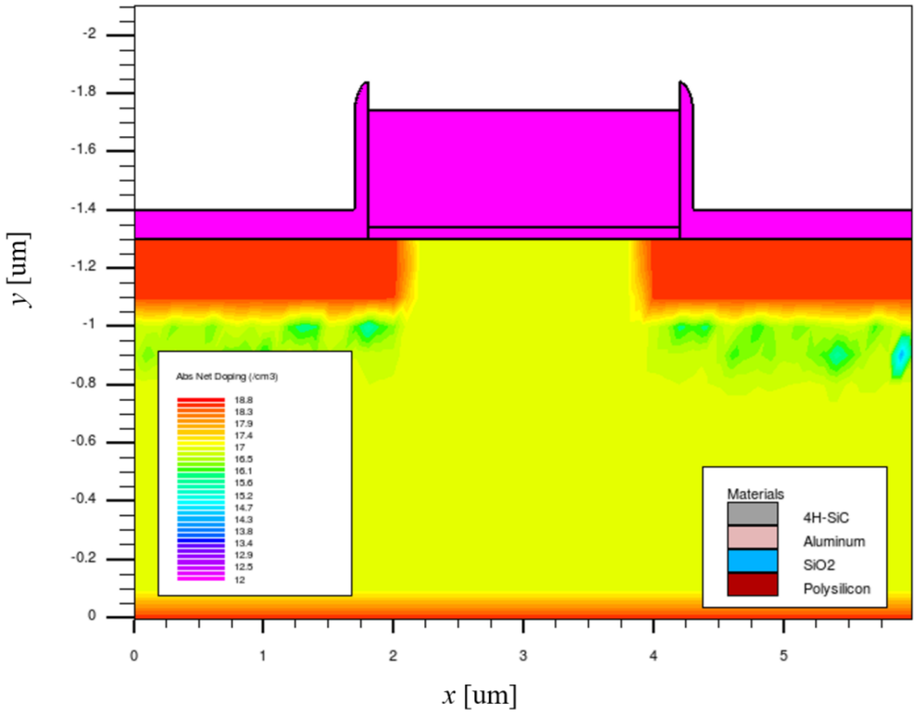
Project AT1

- Control of doped regions is critical for every semiconductor device
- Dopants diffuse during implantation and annealing process steps prohibiting sharp doping profiles
- Coupling process and device TCAD (technology computer-aided design) provides the tools to predict the device characteristics of the final device



Tasks:

- Modeling dopant diffusion in ‘hot‘ materials such as GaN, AlGaN, InP and SiGe
- Extending the diffusion framework of the commercial *Silvaco Victory Process* simulator
- Process and device Simulations of power and optoelectronic devices

Required knowledge:

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

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Atomistic Modeling: Interaction of Oxide Defects with Electric Fields

Supervisor:

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Project DW1

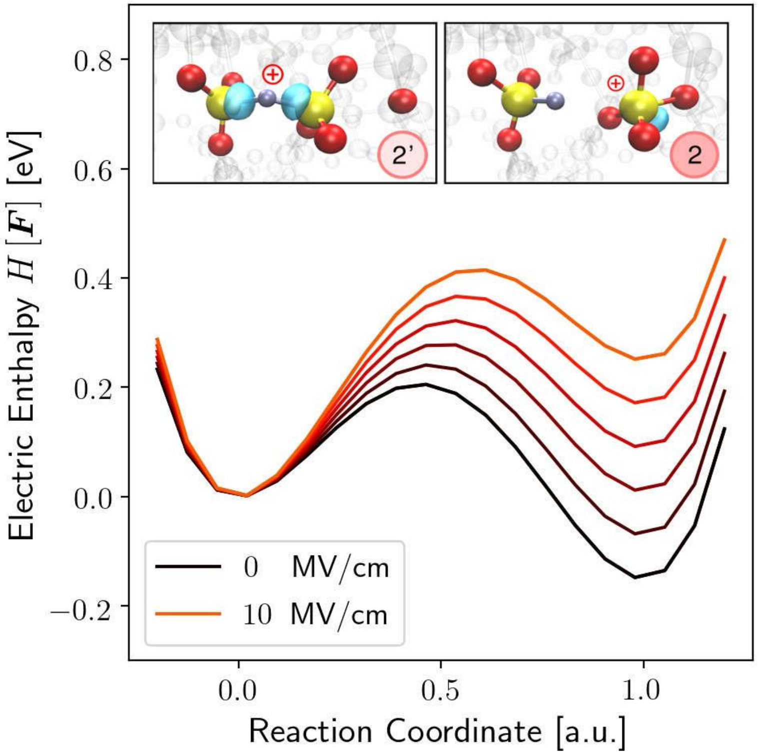
- Oxide defects in MOSFETs can act as charge trapping sites, causing various reliability issues like the *Bias Temperature Instability (BTI)*
- In our current BTI models the electric field across the gate oxide only affects the charge trapping levels of the defect
- However, the electric field can also 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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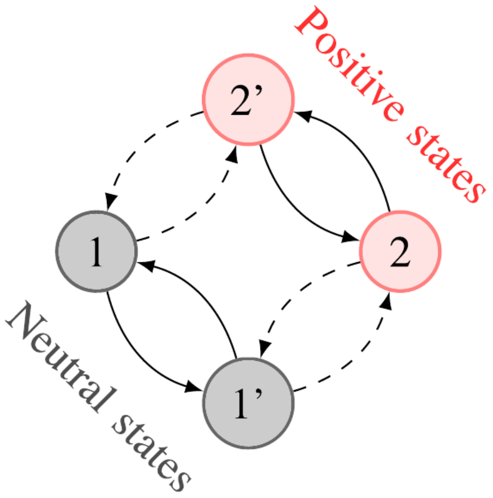
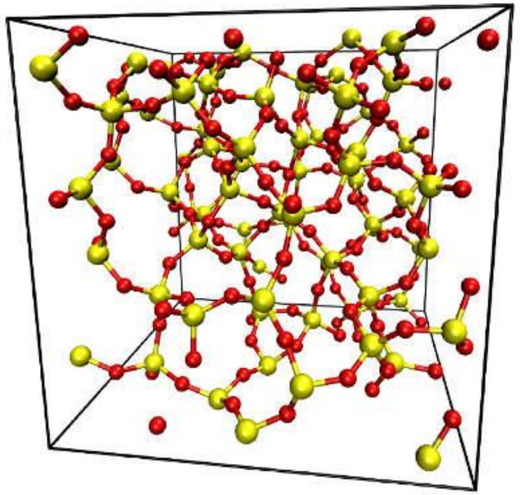
Project DW2

- *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:

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*

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