# Semiconductor Device Modeling

**Lecturers:**

Abolfazl Mahmudpur

**Language:**
English

**Credit points:**

3 з.е.

**Monitoring type:**

Экзамен/Exam

**Educational Program:**

Advanced Quantum and Nanophotonic Systems

1 семестр

**Prerequisites:**

Физика твердого тела

Численные методы

| Lectures (a.h)* | Practice (a.h) | Labs (a.h) |
|---|---|---|
| 30 | | |
| *1 academic hour = 45 minutes | | |

The objective of this course is to introduce students to the various numerical methods employed in simulating electronic and ionic transport in classical and perovskite semiconductors. The course aims to equip students with a comprehensive understanding of the numerical approaches utilized for simulating transport in devices. This will be accomplished through a combination of lectures, homework assignments, and practical exercises.

The course contains 16 lectures including practices and the mid-term session. 10 lecture is devoted to theory and implementing numerical solution of drift diffusion problem using MATLAB software. (students are free to use any software for implementing their code, Python or C++, but MATLAB software will be used in the practices). 4 lectures devoted to explaining some additional features in drift diffusion problem by using COMSOL library examples. 1 lecture is devoted to the effect of mobile ions in perovskite and introducing Driftfusion open-source code.

# Course content

## Plan of a course

## Структура курса

Lecture 1: An introduction to semiconductor materials.

Lecture 2: Boltzmann's transport equation (BTE), Fermi-Dirac integral, Poisson's equation and its numerical solution using FDM.

Lecture3: Practice to simulate equilibrium condition of semiconductors.

Lecture 4: Scharfetter-Gummel (SG) discretization and Gummel solver.

Lecture 5: Practice on implementation of Gummel solver in MATLAB.

Lecture 6: Newton method.

Lecture 7: Practice on implementation of Newton method.

Lecture 8: Considering presence of source term in the continuity equations in both Gummel and Newton solver - Introducing Slotboom variable approach.

Lecture 9: holding mid-term session.

Lecture 10: Multi-layer semiconductor - Heterojunction –Internal boundary conditions.

Lecture 11: Transient Drift-Diffusion problem - Cyclic Voltammogram of a MSM structure.

Lecture 12: Simulation using COMSOL. (Modeling of electrical breakdown in a semiconductor due to the impact ionization).

Lecture 13: Simulation using COMSOL. (Calculation of IQE in a LED using optical transition feature).

Lecture 14: Simulation using COMSOL. (Density-Gradient approach for quantum confinement effect consideration).

Lecture 15: Simulation using COMSOL. (CV (capacitive voltage) measurement in a metal-oxidesemiconductor).

Lecture 16: Introduction to Driftfusion open-source code.

## Recommended resources

1) Calado, Philip, Ilario Gelmetti, Benjamin Hilton, Mohammed Azzouzi, Jenny Nelson, and Piers RF Barnes. "Driftfusion: an open source code for simulating ordered semiconductor devices with mixed ionic-electronic conducting materials in one dimension." Journal of Computational Electronics 21, no. 4 (2022): 960-991.

2) Vasileska, Dragica, Stephen M. Goodnick, and Gerhard Klimeck. Computational Electronics: semiclassical and quantum device modeling and simulation. CRC press, 2017.

3) COMSOL Multiphysics software user manual.

## Grading Policy

HomeWorks: 40 points (4 homeworks, 10 points/homework).

Final project: 60 points.

Total points: 100

0-59 – unsatisfactory (FX)

60-67 – satisfactory (E)

68-74 – satisfactory (D)

75-83 – good (C)

84-90 – good (B)

91-100 – excellent (A).

Midterm: midterm mark will be evaluated from home tasks mark that should presented by students.

## Тип самостоятельных заданий

Prove that discrete form of second derivative of any function in 1D in finite difference method (FDM) and in a non uniform grid is following: where $h(i-1)$ is the distance between node $i-1$ and node $i$, and $h(i)$ is the distance between node $i$ and node $i+1$