Quantum transport simulation of extraordinary magnetoresistance (EMR) in graphene devices

In this project we want to use large-scale quantum transport simulations to understand why graphene devices can show the largest magnetoresistance and exceptional sensitivity for measuring ultra-small magnetic fields. The high-sensitivity magnetic field sensors can, for example, be used in bio-magnetic field detection to help study human brain diseases.

In the project you will learn about the experiments done locally at DTU-NANOMADE and help develop the theoretical models. For these we will use quantum transport (Greens functions) and tight-binding electronic structure methods implemented in python.

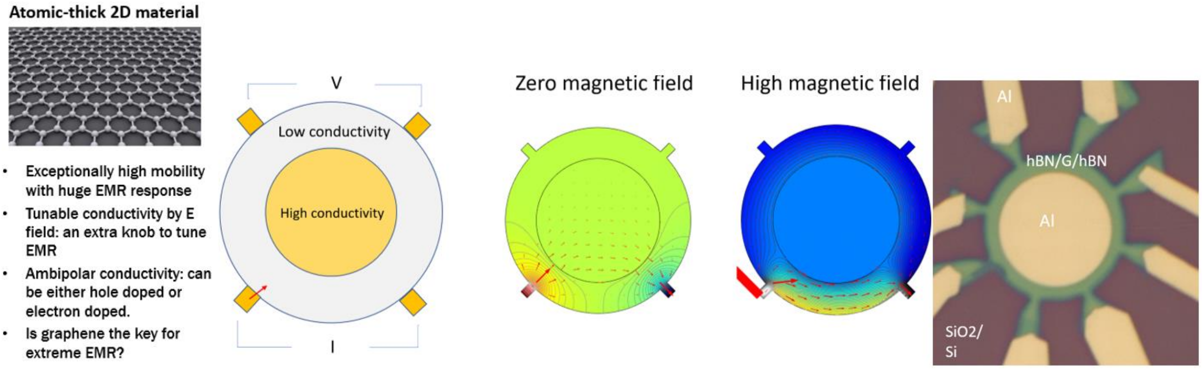
The goal is to understand the ultra-sensitivity, use the calculations to help in optimizing the devices, and possibly also the more intriguing quantum effects (weak localization, weak antilocalization, magnetic focusing, and even valley Hall effect),

You will work closely together with an experimental postdoc Bowen Zhou <bowez@dtu.dk> and two professors Mads Brandbyge <mabr@dtu.dk> and Peter Bøggild <pbog@dtu.dk> at DTU Physics.

More info:

Extraordinary magnetoresistance (EMR) effect: The EMR device is typically constructed with a circular semiconductor having an embedded circular metal shunt in the center. Here we use graphene instead of a semiconductor and gain a much stronger effect due to its high mobility and quantum properties.

At zero B-field, the metal shunt short-circuits current through the middle low-resistivity region of the device. In a perpendicular B-field, the charge carriers are deflected around the shunt as the current density ***J*** becomes orthogonal to the interfacial electric field E at the interface of the shunt and the semiconductor. Current is forced to travel through the longer high-resistivity material around the shunt, leading to a magnetoresistance enhanced over the zero-field value by up to several orders of magnitude. In the figure, you see classical simulations which we want to extend to the quantum regime in this project.



- Exceptionally high mobility with huge EMR response
- Tunable conductivity by E field: an extra knob to tune EMR
- Ambipolar conductivity: can be either hole doped or electron doped.
- Is graphene the key for extreme EMR?