Projects 2018.

You should contact your supervisor before the project, to set up a meeting time. In some projects it will be very useful to study some literature in advance.

1. **Title: Photocurrent mapping of a nanowire solar cell, Supervisor:** Dan Hessman **(dan.hessman@ftf.lth.se)**

In this project you will create a two-dimensional map of how an array of nanowires converts light into current. The map will be constructed by measuring the photocurrent induced by a tightly focused laser beam while raster scanning the nanowire device. Possible outcomes of the project are a characterization of the conductivity of the transparent top contact and the identification of imperfections in the solar cell.

2: Determination of the Band-Offset between wurtzite and zinc-blende InP using photoluminescence. : Supervisor: Irene Geijselaers (irene.geijselaers@ftf.lth.se)

InP is in bulk found in the cubic crystal structure of zinc-blende (zb). However in the form of nanowires, it can be grown in the hexagonal wurtzite (wz) structure. The band structure of wz InP is different from zb InP, as the bandgap is approximately 80 meV larger. The bandgap of wz InP is positioned in such a way that there is a staggered band alignment at the interface between wz and zb InP. This creates much interesting physics to be seen in wz-zb InP heterostructures.

An unknown parameter is the band-offset between wz and zb-InP. This can be found using power dependent PL. In this project we will try to find the band-offset. If we have time, we will also have a look at the triangular-well states at the wz-zb interface and calculate the energy levels.

3. IV-measurements of InP NW solar cells
Supervisor: Lukas Hrachowina **lukas.hrachowina@ftf.lth.se**

Description: Photovoltaics enable the direct conversion of solar energy to electricity and thus play an important role in sustainable energy production. Although III/V semiconductor solar cells reach better efficiencies than silicon based solar cells, they are mainly used in space applications because they are too expensive to compete with silicon based solar cells when efficiency is not the predominant factor. Nanowires have several superior properties compared to their bulk material and with a specific pattern of a nanowire array it is possible to reach the same efficiency of a thin film by using only a fraction of the material. In this way the price can be reduced which makes it possible to compete with silicon solar cells.
In this project you will investigate InP nanowire solar cells and measure the efficiency and other important characteristic values like V_{OC}, J_{SC}, FF, etc.

4. Title: Nanofabrication of channels using Electron beam lithography
Supervisor: Pradheebha Surendiran pradheebha.surendiran@ftf.lth.se

Description: Nanofabrication can be broadly defined as the design and manufacture of devices at the nanoscale. There are techniques of nanolithography which are widely used for nanofabrication (eg: IC chips in computers) among which Electron Beam Lithography(EBL) is a high-resolution technique to fabricate structures with high resolution. In this project, we are going to demonstrate patterning of channels on oxidized silicon wafers which can be potentially used for movement of molecular motors such as actin filaments. This will be carried out in three main stages: Sample preparation(spin coating), patterning of channels(EBL) and development of channels (wet etching). The developed samples can then be characterized using an optical microscope and ellipsometry can be used to measure the thickness of the surface before and after etching. Also, the effect of the etching rate and the importance of motility of molecular motors on the channels can be studied. Hence the overall aim of this work is to understand the importance of nanofabrication with EBL in specific and also the different steps involved.

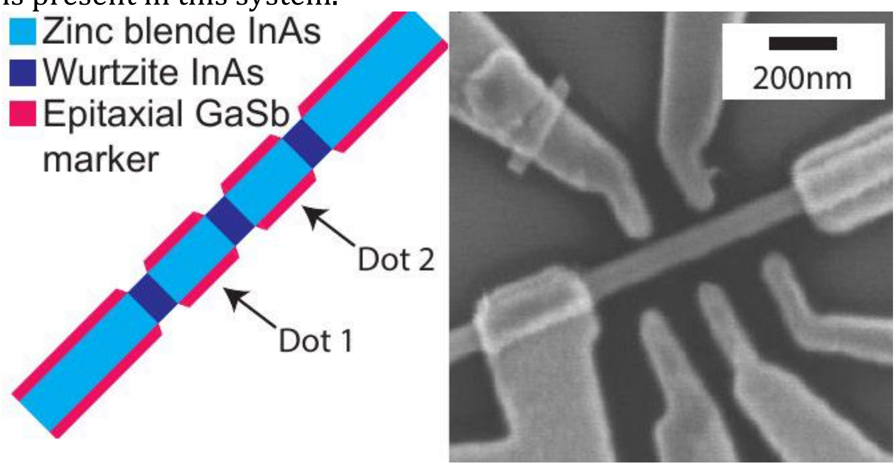
5 Spin blockade in Double Quantum Dots

Supervisor: David Barker (david.barker@ftf.lth.se)

A double quantum dot (DQD) is formed by coupling two quantum dots, separating them with a tunnel barrier. An interesting feature of this system is that it allows you to couple two discrete energy states and study transport between them.

In series-coupled DQDs, a mechanism called Pauli spin blockade exists. As the name suggests, it arises due to the Pauli exclusion principle. Since spin is conserved in a tunneling event, this places constraints on the tunneling events involving already populated states. For example, if an electron with spin up occupies an energy level in one quantum dot, only a spin down electron can tunnel into the same level. Under the right conditions, this will lead to transport being blocked.

In this project, you will measure charge stability diagrams for a material-defined DQD in an InAs nanowire. In addition, you will investigate if Pauli spin blockade is present in this system.



Left: Schematic of the DQD, where the tunnel barriers and QDs are defined by different InAs crystal structures. Right: SEM image of a finished DQD device, with gates to control the electron population.

6 Transport characterization of p-type GaSb nanowire quantum dot devices
Supervisor: Sven Dorsch sven.dorsch@ftf.lth.se

Description: In this project, you will look at electrical transport through GaSb p-type nanowires. By using Schottky contacts and different gating geometries, single quantum dots and double quantum dots can be formed and characterized via transport measurements.
You will perform transport measurements on these devices in a dilution refrigerator with a base temperature lower than 15mK to ensure sufficiently low temperatures for resolving relevant features.
Possible project outcomes are g-factor studies on excited states of single quantum dot devices or tuning of the interdot tunnel coupling between two dots in a double dot geometry.

7. **Coulomb blockade theory with rate equations**
Supervisor: Martin Josefsson martin.josefsson@ftf.lth.se

Theoretical modeling of Coulomb blockade using rate equations

In this project you will write a small computer program to calculate the current and conductance of a quantum dot with discrete energy levels and a large charging energy. You'll be able to model the Coulomb diamonds that you measure in the lab. To do this we will focus on the regime of small tunnel couplings, where the electrons tunnel one by one through the quantum dot and the mathematics becomes relatively simple. However, to obtain the correct IV-behavior it is necessary to solve so-called rate equations to get the occupation probabilities of the many-body states of the dot, from which the current can be obtained.

8. **High aspect ratio etching of SiO2 using ICP-RIE**
Supervisor: Reza Jafari Jam**:** reza.jafari_jam@ftf.lth.se
For this project it is likely that Reza would like to meet you already Dec. 7

Anisotropic etching of semiconductors and dielectrics are crucial part of today's Microelectromechanical system, MEMS, technology. Reactive ion etching (RIE) is a dry etching method with chemical physical nature for anisotropic etching but it is not easy to satisfy the desired profile. Etch passivation is one approach; first you etch and then protect the sidewalls with a passivation polymer and this will be repeated until the desired etch profile is achieved. The well-known method for this is the Bosch process. Another approach is the suede Bosch process where the passivation and etching is happening simultaneously. Cryogenic etching is another approach were the etch process happens at very low temperature, around -150 ^{0}C, to eliminate the chemical reactions.

Project description

In this project we examine the deep high aspect ratio, HAR, etching of SiO2 in a simultaneous etch and passivation process. Inductively coupled plasma reactive ion etching, ICP-RIE, will be used to etch sub 100 nm holes in a 1 um thick SiO2 slab. Chromium, Cr, will be used as hard mask for the etching. Profile anisotropy and mask selectivity will be studied using scanning electron microscope, SEM. Figure 1 is an example of the etch profile**.**

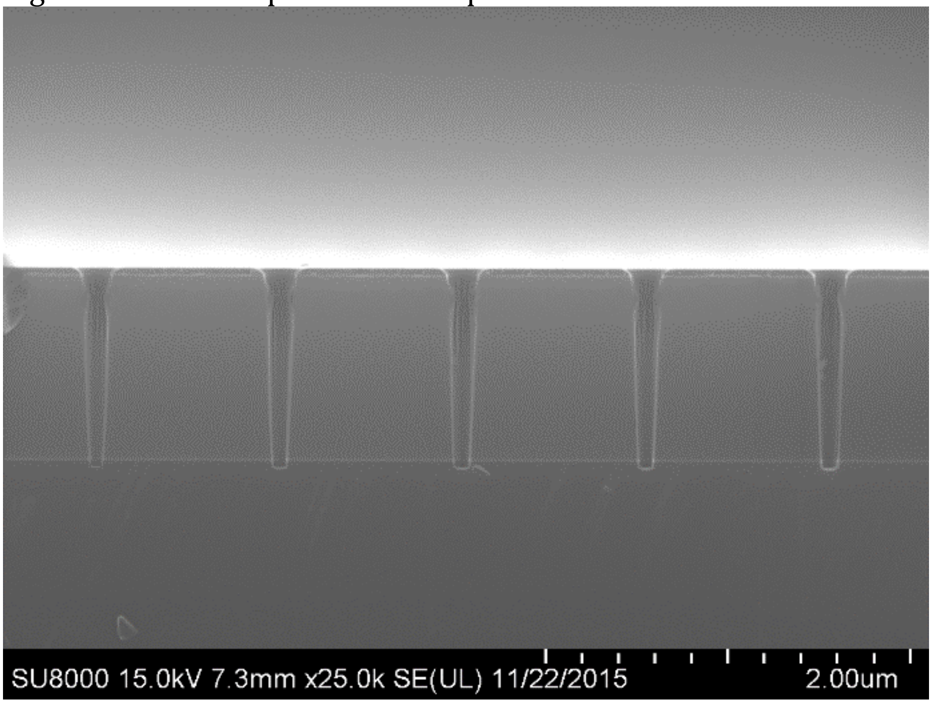


Figure 1: Anisotropic etching of SIO_2 with ICP-RIE. Recipe is highly selective toward the Cr mask while low selectivity with the Si substrate is visible

9. **Calculation of the band-structure of GaAs using k.p-theory**

Supervisor: Mats-Erik Pistol, e-mail: mats-erik.pistol@ftf.lth.se

In this theory project we will calculate the conduction and valence band structure of normal GaAs using a quite sophisticated 8-band k.p-model. This is the standard model to calculate bandstructure and is described to some extent in Davies book. We will also include strain in the model to see how the light and heavy hole in the valence band maximum split in energy when we strain the crystal. We will finally calculate the bandstructure of GaAs with a wurtzite lattice which is a new material, although quite related to GaAs with the zincblende structure.

10. Diodes based on graded potential barriers in InAs-InP nanowires

Supervisor: Ville Maisi, e-mail: ville.maisi@ftf.lth.se

In this project we will measure current - voltage curves of a graded potential barrier in InAs nanowire to observe current flowing in one direction but not in the other. We then link the current - voltage curves to the properties of the potential barrier with simple theoretical considerations and aim to determine the barrier height and the ratio between forward and reverse current.