Seminar: Semiconductor Physics and Nanoscience
Semiconductor Nanowires

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1 Synthesis of Nanowires

There are several methods to create Nanowires, which we can divide into **pseudowires** and **free standing wires**.

1.1 Pseudowires

Pseudowires are wires, which are enclosed in another material.

Following methods are the most popular forms of synthesis:

- lithography and etching
- electrostatically induced wires
- strain induced wires
- growth on patterned surfaces
- cleaved edge overgrowth

Litography and etching is a top down approach. A 2D Quantum well is grown and then coated with a resists which is patterned. Then the resist is etched away until the wire only remains. The wire is then overgrown again to shield it. A disadvantage of this technique is, that a optical and electrical dead layer is created because of defects due to etching.

Electrostatically induced wires are created by first making a Schottky contact (metal on semiconductor). The application of voltage raises/lowers the band structure. Thus a wire is created for electrons/holes at certain voltages

For **strain induced wires** carbon is put on top of the semiconductor and strains the material. So a wire is created. The disadvantage though is, that the potential is very shallow and the wire exists only for low Temperature.

An example for **growth on patterned surfaces** are *V-groove nanowires*. The V-shape is created created by etching, as for different directions the etching is stronger or weaker. Then the material is grown on top. Finally a second barrier material is added to sharpen the groove.

Cleaved edge overgrowth works as following: A quantum well is grown. Then the whole block is rotated and a second quantum well is grown. The intersection of those two wells is the wire.

All these pseudowires have the disadvantage that they are embedded in a certain material which is not changeable.

1.2 Free standing wires

Methods for synthesis of **free standing wires** include

- VLS (Vapour Liquid Solid) method

Modification of VLS:
- CVD (Chemical Vapour Deposition)
- LCG (Laser Ablation catalytic Growth)
- Low temperature VLS method

- FLS (Fluid Liquid Solid) mechanism
- SLS (Solution Liquid Solid) mechanism
- OAG (Oxide Assisted Growth)mechaism

The **VLS method** works by means of an eutectic. A liquid metal droplet is saturated with the semiconductor until supersaturation. Then the solid, pure semiconductor wire is starting to grow.
Modifications of the **VLS method** are the Chemical Vapour Deposition method, the Laser Ablation Catalytic Growth method and the Low temperature VLS method.

The **FLS mechanism** works e.g for the growth of Si nanowires: Alcanethiol coated Au nanocrystals are tethered on a Si substrate. Diphenysilane decomposes in supercritical cyclohexane and the Sie particles attach to the gold particles and start to form wires.

In the **SLS mechanism** a metal is placed on top a semiconductor substrate. Then it is heated. The semiconductor diffuses into the metal until supersaturation occurs and the the growth of the Nanowire.

The **OAG mechanism** uses oxide instead of metal as catalyst. Silicondioxide powder is added to pure Si. Then the whole mixture is ablazed. Danglings bonds are created which act as nuclei for the growing nanowire.

OAG favours lower temperatures, while the VLS method prefers higher temperatures.

2 Properties of nanowires

PL depends on the direction of the light:
If the light is parallel polarized you get a signal, but when the light is polarized perpendicular to the wire nothing is observed.

PL also depends on the diameter of the wire. The energy is shifted to higher energies with decreasing diameter. Quantum confinement effects can be observed below a diameter of about 20 nm.

As the mean free path of phonons is in the nanometer range the phonon transport in nanowires is changed. That is why the **thermal conductivity** changes in nanowires. In fact it is 2 orders of magnitude smaller than in bulk material.

It is also possible to **dope** nanowires, thus many new exciting possibilities for nanowire application arise.

3 Application

Applications include **nanowire heterostructures**, **sensors** (like gas sensors), **single mode optical waveguides**, **nanoLEDs**, **Tips for Atomic Force Microscopy**, **nanoFETs** and many more.