Important points of the lecture

- **Nanomaterial: discuss definition and applications**
- **Discuss advantages and disadvantage of bottom up and top down approach**
- **Discuss size effects and give examples for related applications**
- **How is the Moores' law proceeding in future?**
- **Explain quantum confinement effect on the example of a quantum well (Particle in a box model).**
- **Discuss ground state, excitonic Bohr radius and its implications for quantum size effects**
- **What is an Exciton?**
- **How is the binding energy and the Exciton Bohr radius depending on the effective mass of the electron?**
- **What criteria/value would give you a hint to expect quantum confinement for e-h pairs in your structure?**

Important points of the lecture

- What are size effects?
- Develop a understanding of the physics for material specific properties depending on size
- What are typical examples, how can we understand the related effects and properties. (Specific resistance, melting point, vapor pressure of a droplet…)
- What are typical physical vapor deposition methods (evaporation, sputtering, MBE, ALE, ALD)
- Develop an understanding for film properties (amorphous, crystalline, polycrystalline)
- Explain advantages and disadvantages of the growth methods
- Explain homo- and hetero-epitaxy growth
- Explain the different growth modes (Van der Merwe, Vollmer-Weber, Stranski- Kraskanov)
- What kind of surface process happen during growth?
- Explain the system details of the MBE system

Important points of the lecture

Lecture 3: Preparation methods of Nanostructures

- What is the difference between PVD and CVD?
- Please discuss the construction of a PECVD system, typical reactor, advantages, disadvantages, and applications
- How can you influence the materials properties? What is the influence of process temperature?
- What is the difference between CVD and Metal Organic CVD (MOCVD)
- Discuss a typical MOCVD reactor, explain advantages, disadvantages, and applications
- What would be the main parameter to realize an atomically abrupt interface?
- Explain the process of Atomic Layer Deposition (ALD), demonstrate your understanding of the four ALD cycles
- How is the typical reactor design, explain advantages, disadvantages, applications
- What kind of precursors are used for MOCVD, ALD? Can all ALD precursors be used for MOCVD?

Important points of the lecture

- Explain the properties and difference between graphite, diamond, fullerene, graphene and carbon nanotubes
- How are fullerenes discovered?
- What kind of methods are used for poof of the structure?
- Explain the physical-technical systems used for preparation of fullerenes
- Laser vaporization, Resistive heating, Arc heating, Electric arc discharge, Laser vaporization, Chemical vapor deposition, Explain two of the methods
- Explain applications of Fullerenes

Important points of the lecture

- Explain the properties of carbon nanotubes
- How can CNT be prepared?
- Explain chirality and Translation vector, and how the rolling up of graphene layers to nanotubes results in metallic and semiconductor NTs. How are these properties influencing the band structure?
- What kind of applications are thinkable for CNTs?
- What is Graphene, and how could it be prepared?
- Explain the band structure of Graphene
- How is the effective mass related to the very high mobility of the material?

Important points of the lecture

- Why are electrons used instead of light? How can you influence the TEM resolution?
- Develop an understanding of the principal construction of the TEM system. How is the e-beam generated? (field effect cathode system, electro-optical lenses)
- What is typically be seen in electron diffraction if the sample is amorphous, polycrystalline or single crystalline?
- Explain and discuss the modus of bright and dark field imaging?
- Give an overview about the different scanning probe methods
- Explain the principle of STM, what do you see in the different modes (constant distance, constant tunnel current)? If the tip is shifted to the surface, how is the tunnel probability being influenced? What is the influence of the voltage polarity?
- Explain the principle of Scanning Force microscope (AFM), Frequency modulation, Tips
- What kind of forces is used and how do forces (potentials) depend on distance Tip-surface?
- Short overview: Magnetic Force Microscope (MFM), Scanning Thermal Microscope, Scanning near field microscope (SNOM)

Important points of the lecture

- Basics of X-ray diffraction methods (XRD): How does the X-ray interact with matter?
- Explain the basics of Bragg diffraction condition.
- Different kind of scans are possible, please understand and explain the Theta/2Theta ($\theta/2\theta$) scan in details.
- How can the line broadening method by Scherrer to estimate the size of nanoparticles be used? Discuss limits and errors.
- What is a Rocking curve? What kind of effects can influence the line broadening of a XRD measurement?
- How can Time of flight measurements be used to analyze the mass of nanoclusters? What is the influence of the charge of the cluster?

Important points of the lecture

- Compare and explain the different models for band gap of bulk and nano-Si
- Explain the effect of quantum confinement, excitonic binding energy, and singlet-triplet splitting on band gap energy
- How can size control be done for Si nanocrystals using PECVD?
- Explain the defect management at the surface of Si NCs
- What kind of defects do you find on Si and SiO_2 surfaces, how could you reduce the number of defects? What is the influence of the defect on the photoluminescence of Nano-Si?
- What are the problems of doping in case of nanostructured semiconductors?
- What happens with the donor (acceptor) levels in case of quantum confinement?
- What is Atom probe tomography and how can you use it for doping investigations?
- What is self-purification?
- How is the statistic influencing the doping of nanostructures?

Important points of the lecture

- What are potential applications for nanowires and nanotubes?
- How can we grow ZnO-NW? Explain a possible experimental set-up.
- Explain the Vapor-Liquid-Solid an Vapor-Solid mechanism of NW growth, what are the differences. Understand and explain the phase diagram of the related materials.
- What are key parameters for controlling the growth?
- How can a pattern growth of ZnO nanowires be realized?
- Compare the different methods for pattern arranged nanowire growth, advantages, disadvantages…
- Discuss possible methods for structural and optical investigation of nanowires
- What can you learn from optical investigations?
- Explain the different methods for preparing metal dots on substrate surfaces
- What is nanosphere lithography Laser Interference Lithography (LIL), and Near Field Phase Shift Lithography and how such methods be used for templates and nanowire growth?
- Describe the principle and examples of a nanowire based sensor
- How is the sensitivity depending on the size of the nanosensor? Which parameters control the limit of sensitivity?

Important points of the lecture

- Why are opto-electronic structures based on III-V semiconductors so important? Why can we not take silicon as basic material for optoelectronics?
- Explain the different types of hetero structures. Show and explain the band diagram of a quantum well structure (AlGaAs/GaAs Quantum well)
- How are band gap and lattice constant related to each other? What is the effective mass and how is it related to the band structure?
- What is the “Density of States” and how is it related to the band structure?
- How does reducing the structure (bulk, quantum well, quantum wire, quantum dot) influence the density of states?
- Explain the charge carrier concentration and the position of the Fermi level based on an intrinsic semiconductor, what happens in case of doping?
- What are excitons? Explain why confined excitons are important for optoelectronics?
- Explain the effective mass approach based on the hydrogen approach. From which dimension do we see quantum effects? How is the energy of the discrete states scaling with the dimension L and the quantum state number n?
- Describe the basic principle of lasing. How is a Quantum- Well- Laser realized?
- Explain optical and dielectric confinement of the wave in a semiconductor laser and its importance
- How can you prove lasing and gain?

Important points of the lecture

- How is a photonic crystal constructed? Discuss examples for 1, 2, and 3 dimensional photonic crystals
- Where can you find natural photonic crystals?
- Discuss analogies between semiconductors and photonic crystals.
- How can a photonic crystal based on macroporous silicon be fabricated? Explain the dissolution of the silicon, and the related macropores etching process in n-silicon. Why is the central pore larger than the surrounding pores?
- What is the interaction of 2D photonic crystals with an in-built light source? Why can a PC suppress the emission of light?
- What are photonic crystal fibers? How can PCF be fabricated? Explain the working principle and applications.