138.065 Crystal Growth: Theory and Practice

Outline of the lecture course

Part I (Prokofiev)

Theory of the crystal growth

- Crystalline state
- Nucleation
- Processes on the crystal's surface. Microscopic mechanisms of the crystal growth
- Bulk mass- and heat-transport processes
- Growth morphology

Single crystal growth technology (Bulk crystals)

- Review of the main methods
- Material-specific choice of an appropriate technique
- Crystal quality
- Examples from industry (Si, GaAs, diamond)

Part II (Eisenmenger-Sittner)

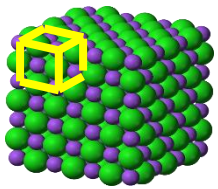
Thin film growth, technology and applications

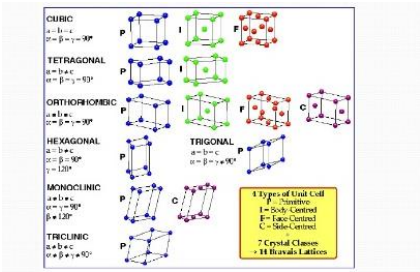
Part III. Nanotechnology (Prokofiev)

Fabrication and properties of nanostructures

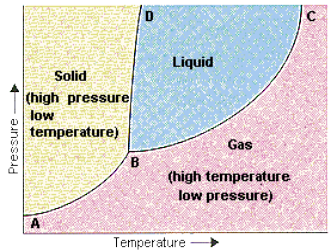
Introduction: Crystalline state

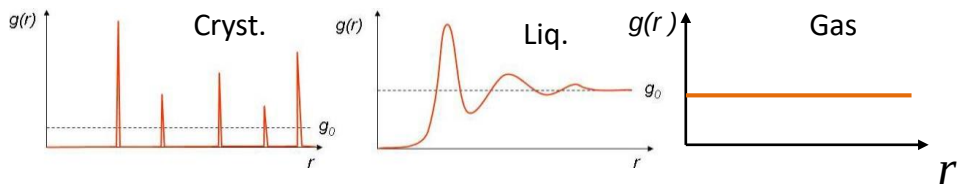
The ABC of crystal structures



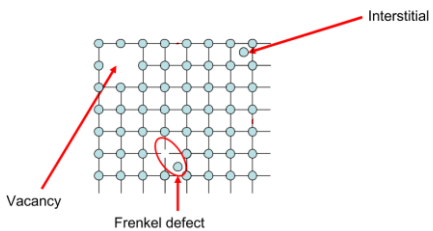


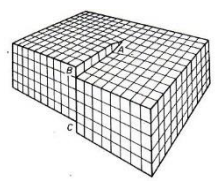
Crystals vs. fluids





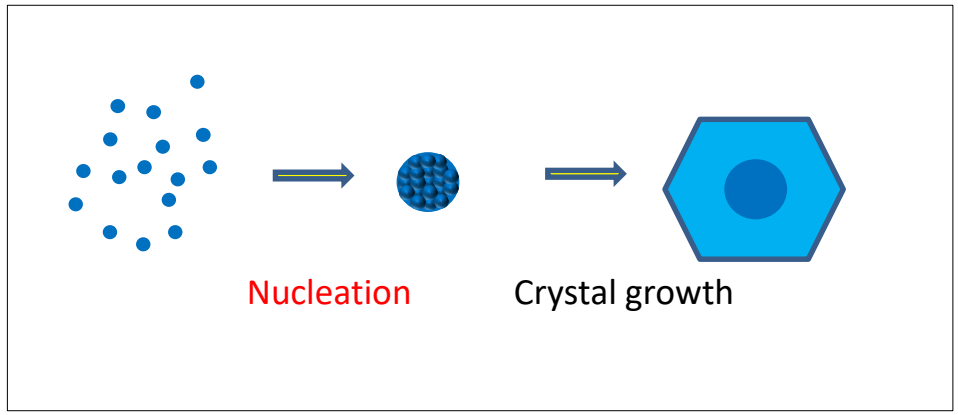
Crystal imperfections, defects



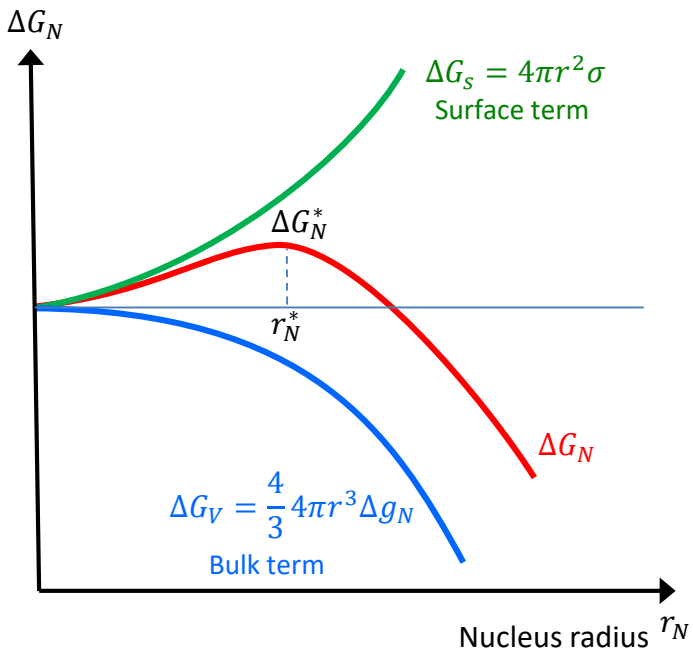


Theory of the crystal growth

Nucleation

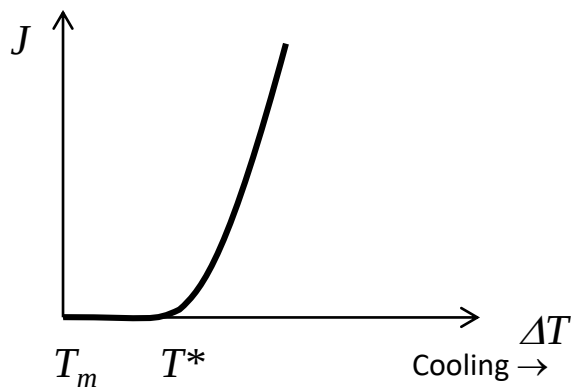


Critical nucleus concept



Nucleation kinetics

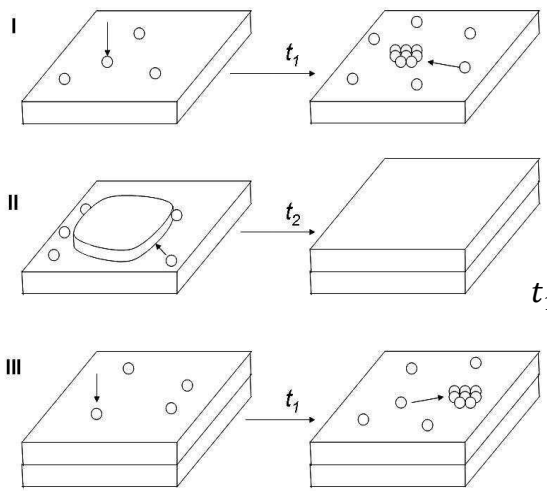
$$J = Ae^{-\frac{\Delta G_N^*}{kT}} = Ae^{-\frac{C}{kT(\Delta T)^2}}$$



Theory of the crystal growth

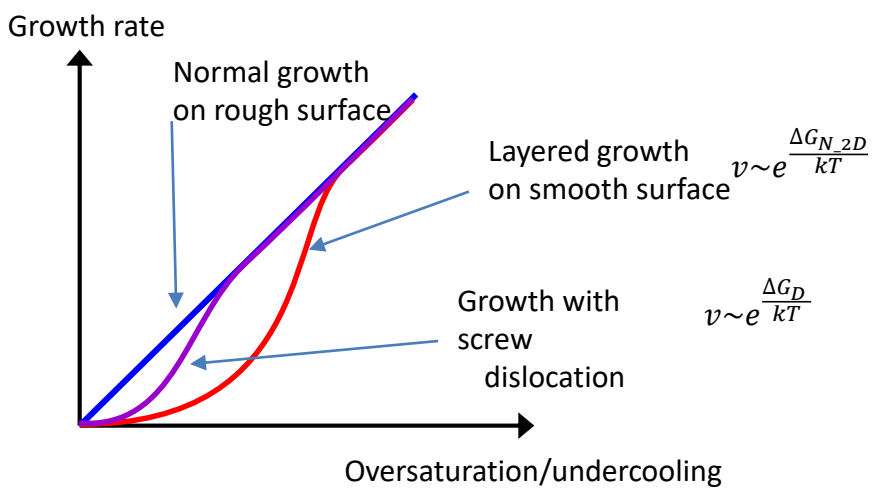
Growth mechanisms

Layered growth



$t_1 \gg t_2$

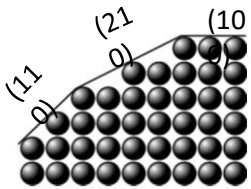
Spiral growth

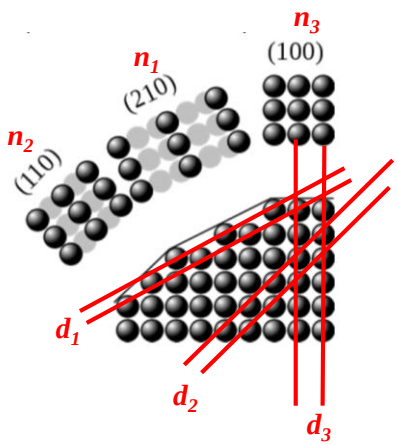


Theory of the crystal growth

Growth morphology

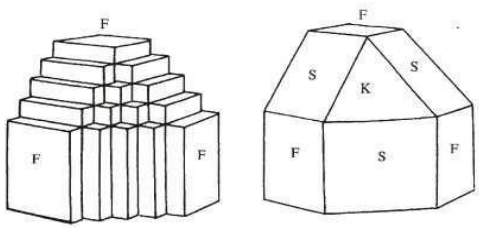
Interplanar distance law of
Bravais, Friedel, Donnay and Harker



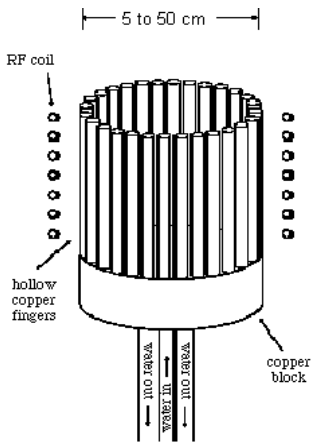


Diffusion-limited regime
at high supersaturation

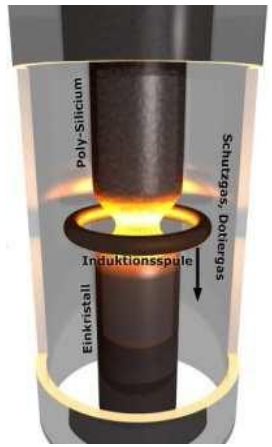
Periodic bond chain theory.
Hartman–Perdok theorem



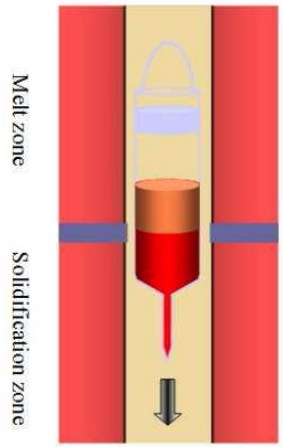
Crystal growth techniques



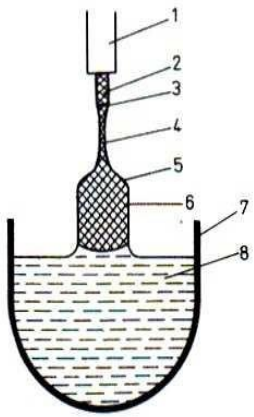
Scull melting

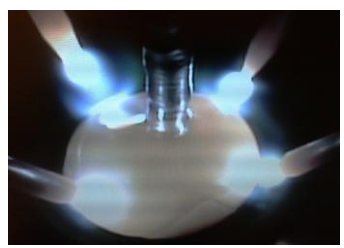


Floating zone



Bridgman





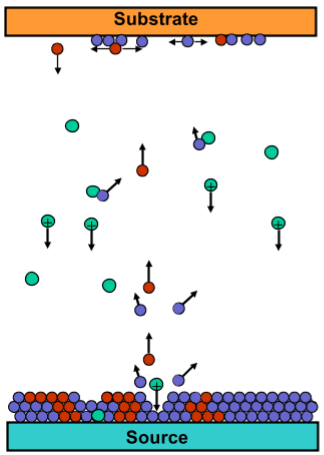
Czochralski

Crystal growth of industrially important materials

Silicon
GaAs
Diamond

Thin film growth and technology

Schematic of a PVD process



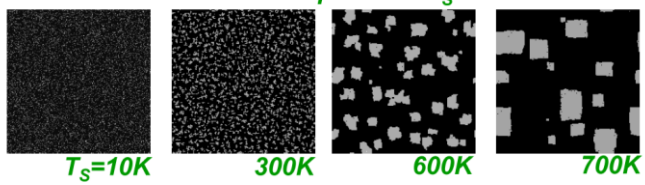
Impingment at carrier

Transport

Ejection from source

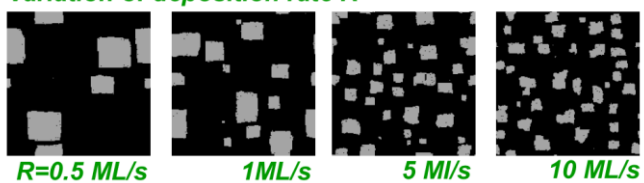
Kinetic Monte Carlo Simulation

Variation of substrate temperature T_S



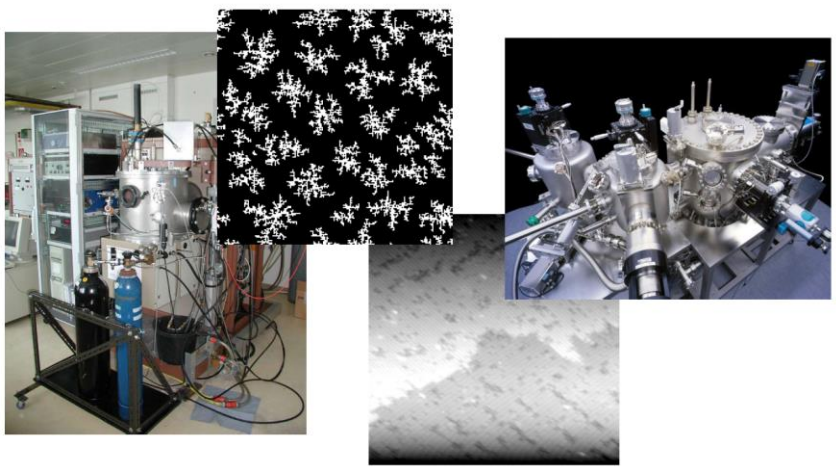
R=1ML/s
E_{Diff}=0.5 eV
E_{Des}=1 eV
E_b= 0.5 eV

Variation of deposition rate R



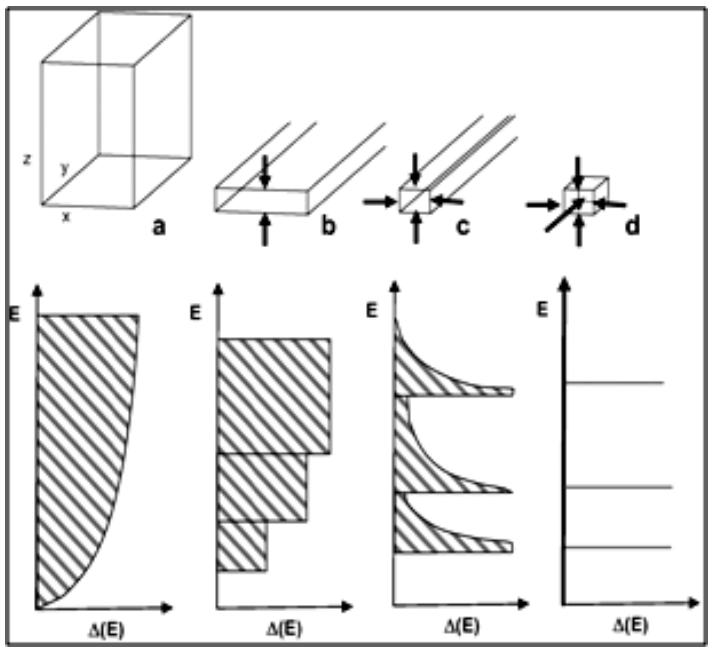
T_S=700 K
E_{Diff}=0.5 eV
E_{Des}=1 eV
E_b= 0.5 eV

Vapor Phase Deposition Technology

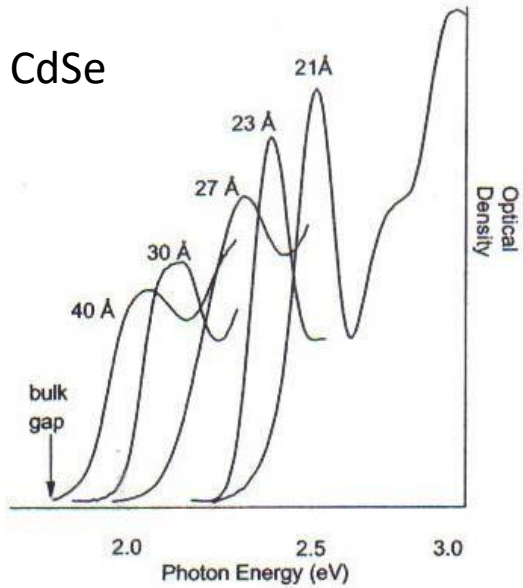


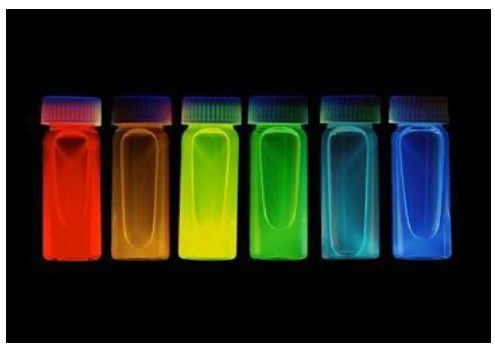
Nanomaterials

Dimension of quantum confinement 0 1 2 3



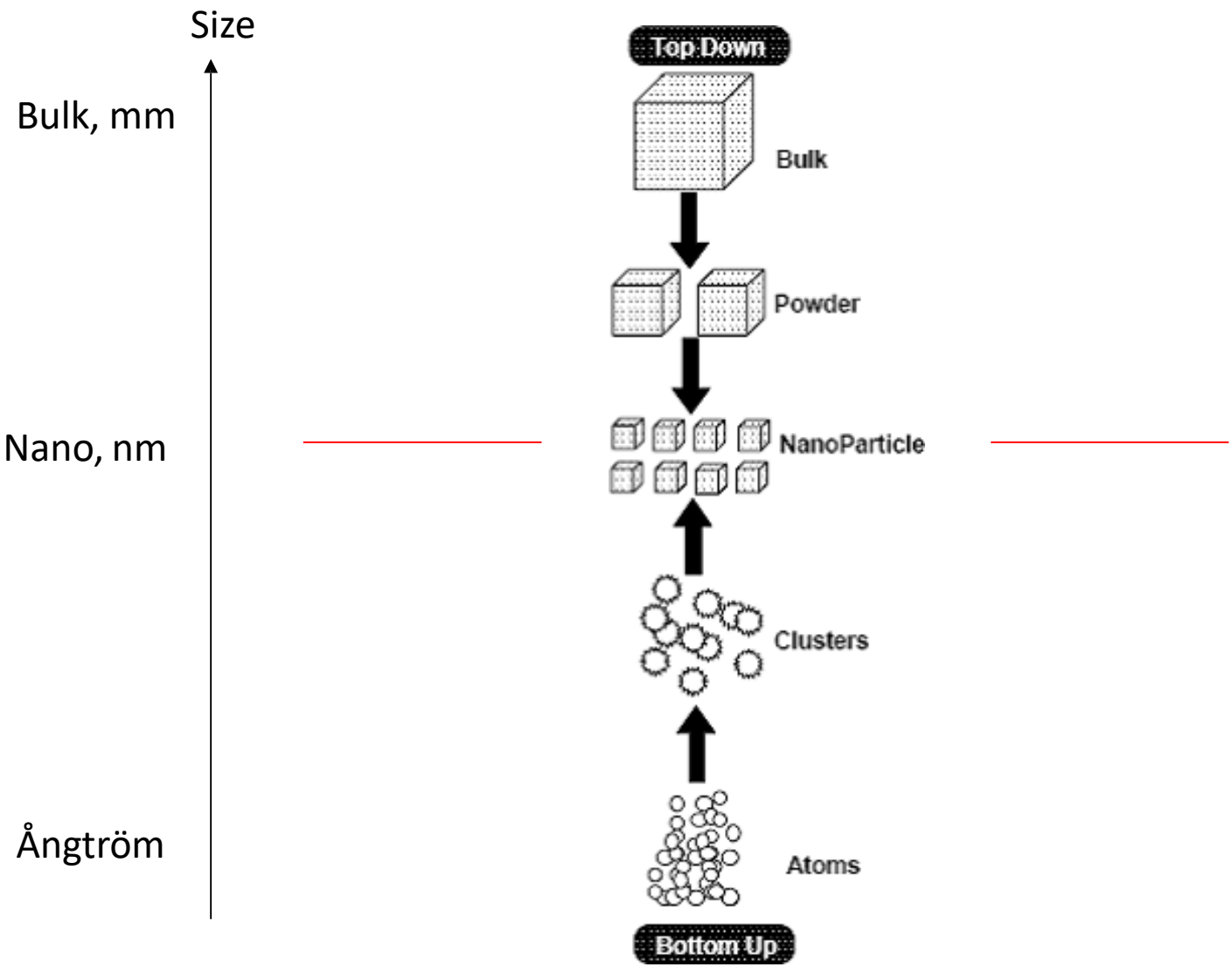
Bulk | Quantum well | Quantum wire | Quantum dot





Blue shift of fluorescence

Two basic approaches in the nanotechnology

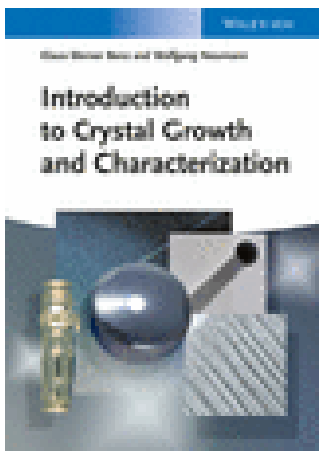


Exam

Oral

Literature

Recommended:



Klaus-Werner Benz, Wolfgang Neumann

Introduction to Crystal Growth and Characterization
(with a contribution by Anna Mogilatenko)
Chapters 2,3 and 4