

Solid State Physics I

Vorlesung / Lectures: Wednesday 13h00 – 15h45

Raum / Room: Y36-K-08

<http://www.physik.uzh.ch/lectures/fkp/>

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Übungen / Exercise class: Fridays 15h00 – 15h45

Raum / Room: Y36-K-08

Daniel Destraz

destraz@physik.uzh.ch

Stefan Holenstein

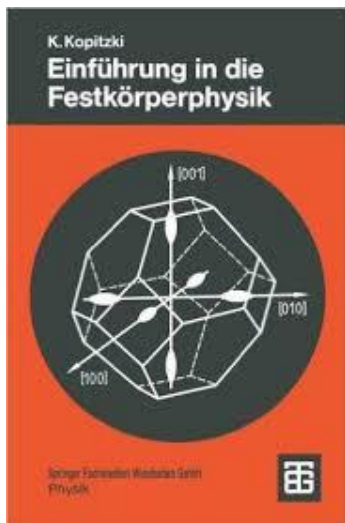
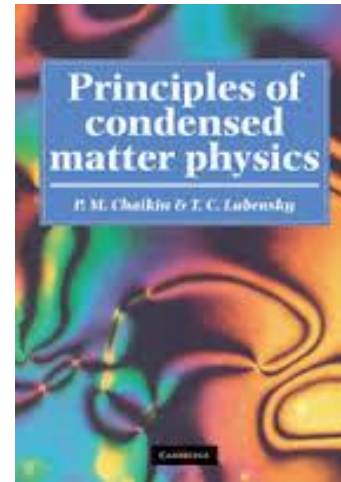
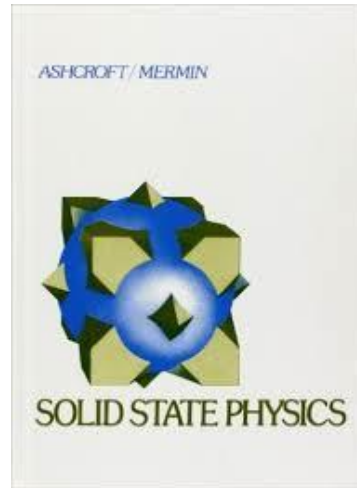
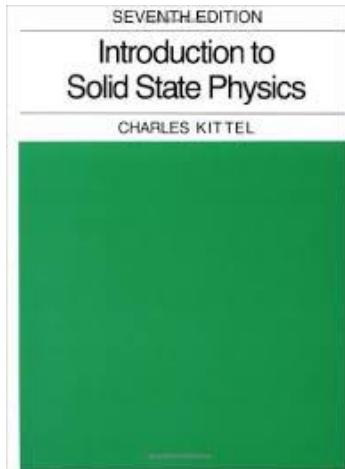
stefan.holenstein@psi.ch



Course Content

- I. Crystal structures
- II. Structures in reciprocal space
- III. Crystal bindings
- IV. Phonons – Crystal vibrations
- V. Thermal properties
- VI. Free electron gasses
- VII. Electronic band structure
- VIII. Semiconductors
- VIII. Magnetism

Literature



Today's Lectures

Lecture 1: Introduction

Motivation, Why solid state physics is important?

Lecture 2: Crystal structure

Vocabulary and definitions: Crystal lattice, unit & primitive cell, lattice parameter packing fraction.

Lecture 3: Crystal structure

Real examples from nature:

Historical periods

Bronze age



Iron age



Silicon age



Conducting Materials



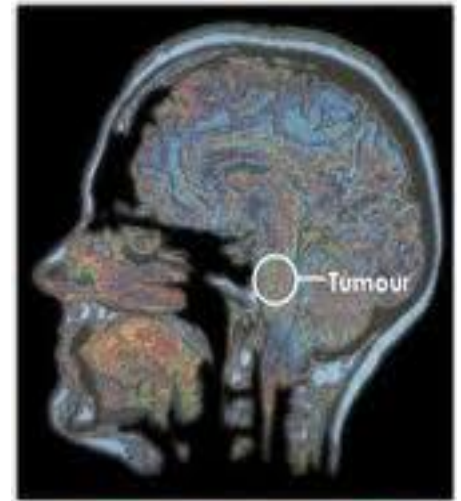
Conductors

Copper



Semi-conductors

Silicon



An MRI Scan of Human Brain

Super-conductors

Nb_3Sn

Examples of condensed matter

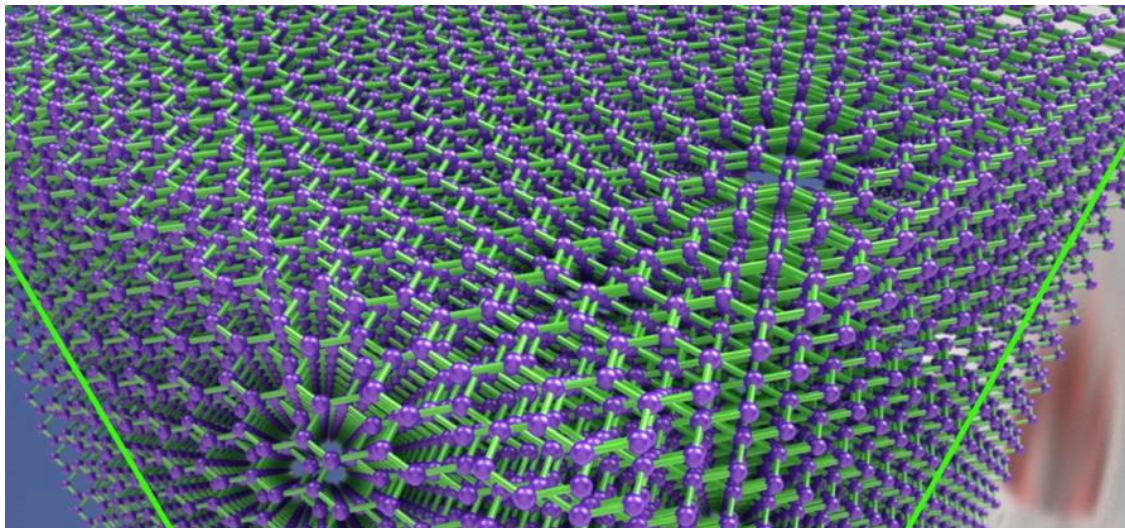


Material:		
Optical:		
Electrical:		
Heat:		

Many-Body Physics



<http://web.physics.ucsb.edu/~weld/>



<http://web.physics.ucsb.edu/~weld/>

Interesting Material Properties

Superconductivity



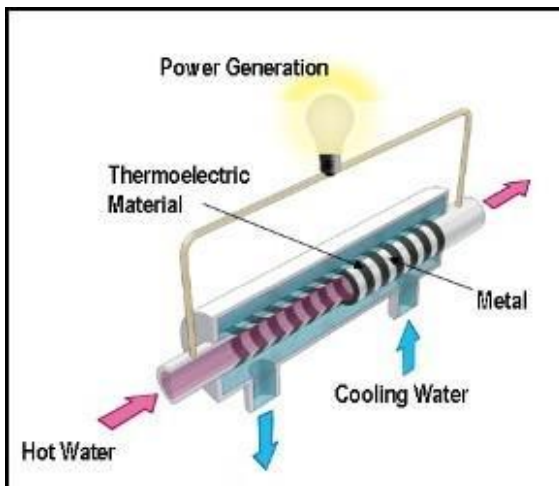
<http://www.ccas-web.org/superconductivity/renewableenergy/>

Smart Insulators



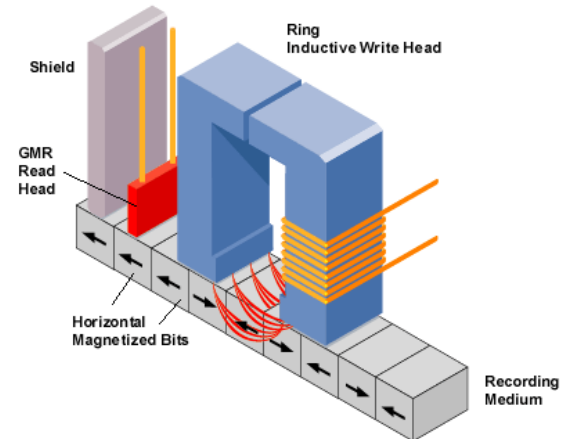
<http://phys.org/news/2012-09-intelligent-windows-future.html>

Thermoelectricity



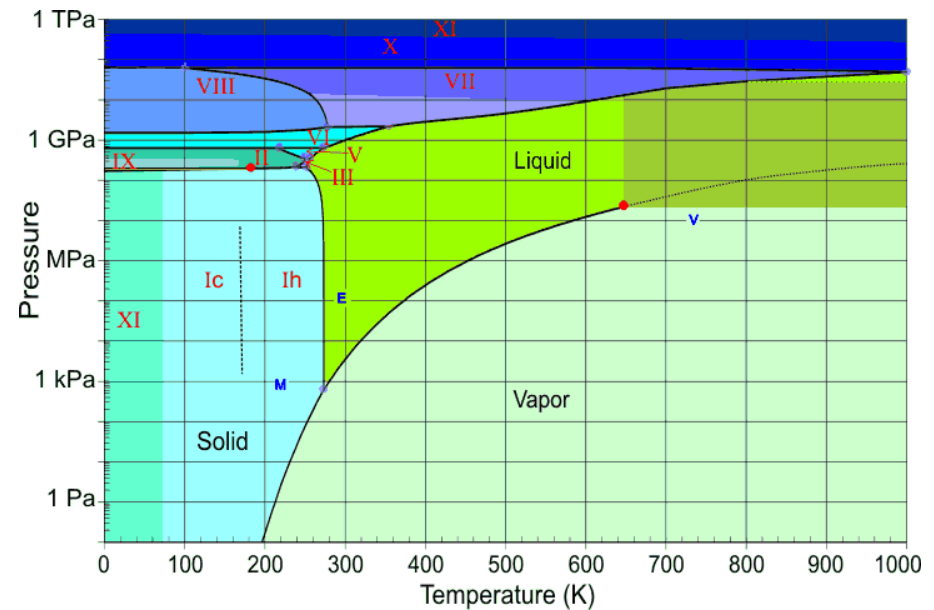
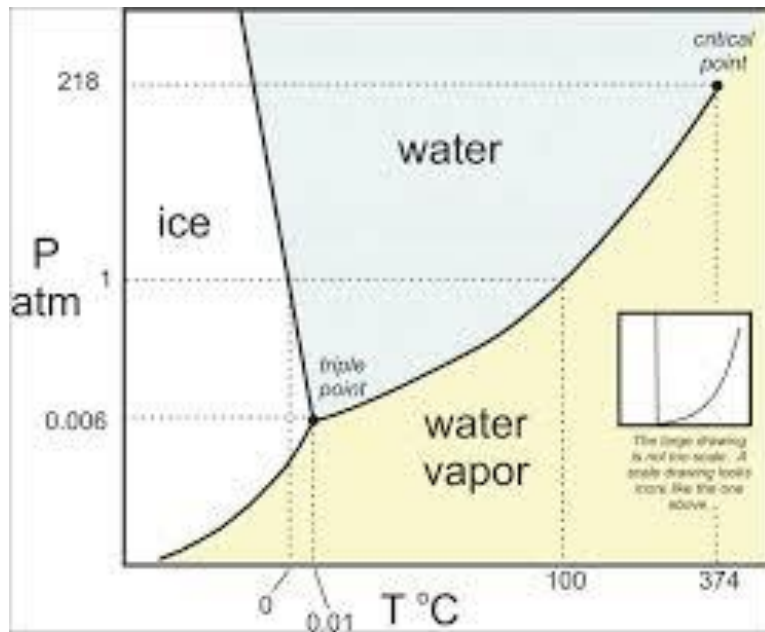
<http://www.green-energy-news.com/arch/nrgs2011/20110051.html>

Magneto-resistance



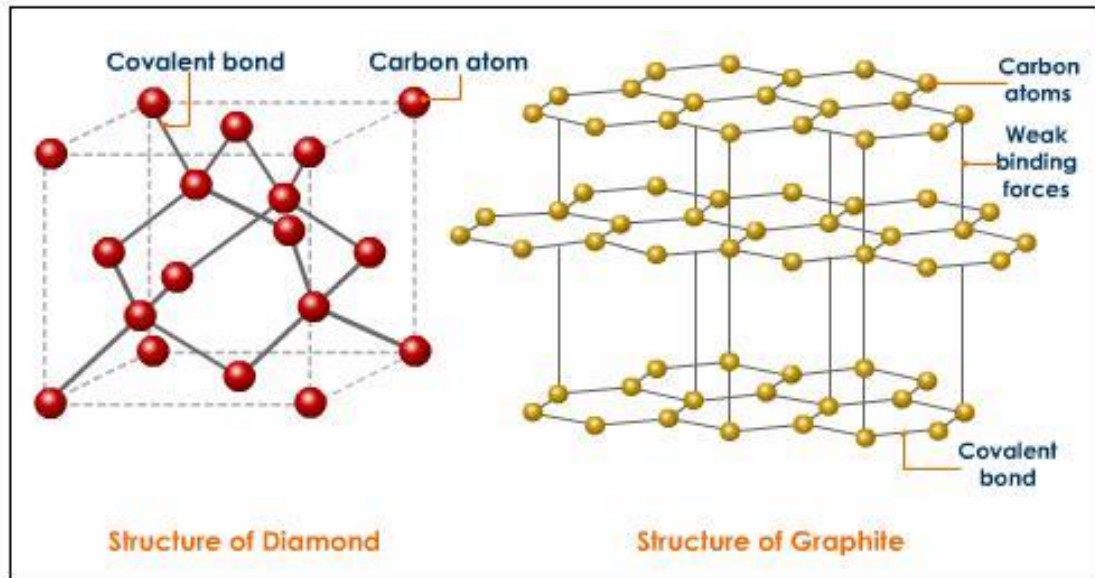
<http://www.yourdictionary.com/magneto-resistance>

Same material – Different crystal structures



<http://www.phy.duke.edu/~hsg/363/table-images/water-phase-diagram.html>

Same Material – Different crystal structures



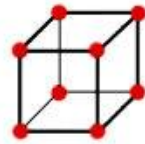
Outline

Complex structures

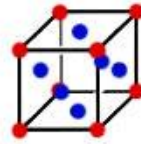
Crystal Defects and non-crystalline solids

Experimental Techniques to Map Crystal Structures
(Real Space)

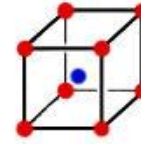
Crystal Structures



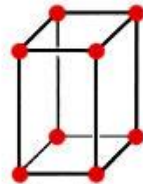
Simple cubic



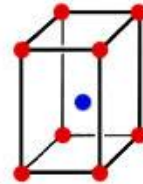
Face-centered cubic



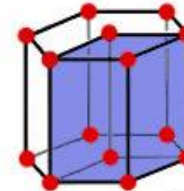
Body-centered cubic



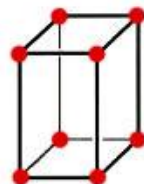
Simple tetragonal



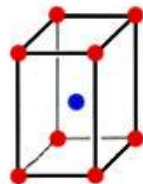
Body-centered tetragonal



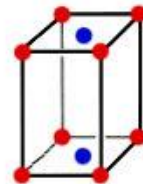
Hexagonal



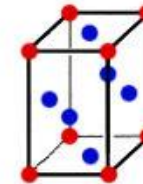
Simple orthorhombic



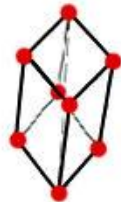
Body-centered orthorhombic



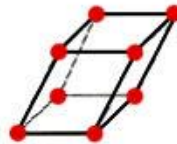
Base-centered orthorhombic



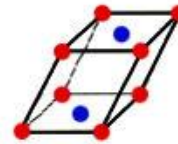
Face-centered orthorhombic



Rhombohedral



Simple Monoclinic



Base-centered monoclinic

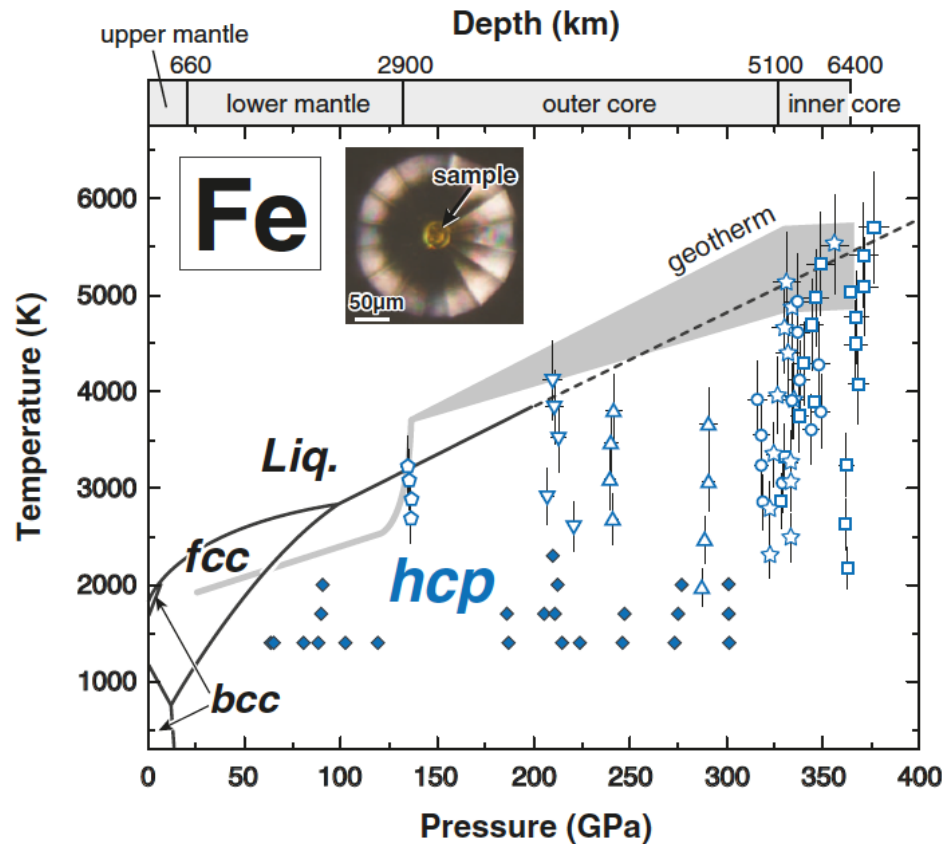


Triclinic

The Structure of Iron in Earth's Inner Core

Shigehiko Tateno,^{1,2*} Kei Hirose,^{1,2*} Yasuo Ohishi,³ Yoshiyuki Tatsumi²

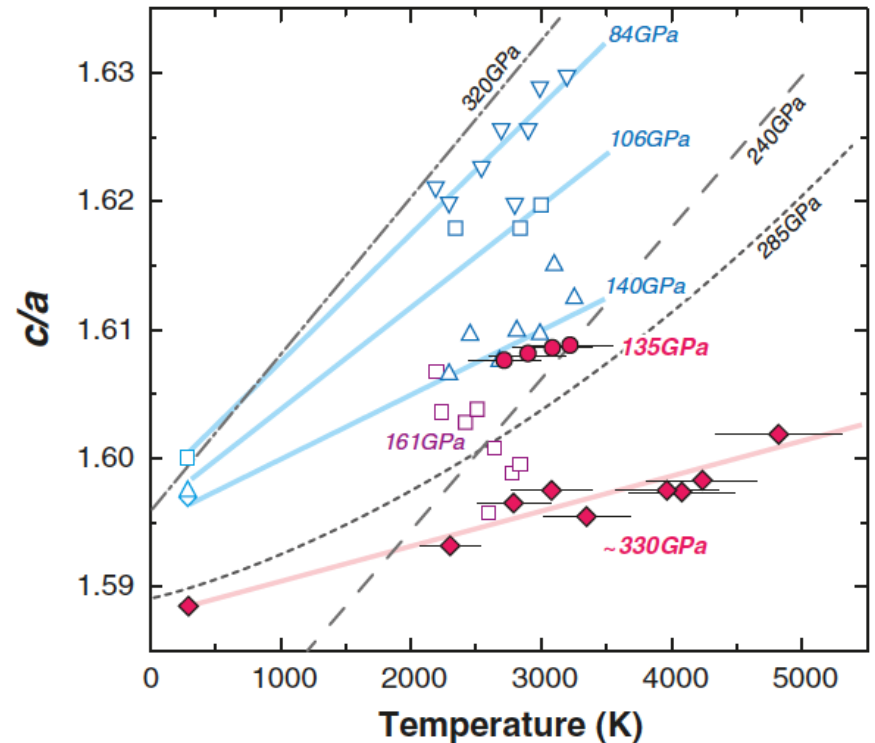
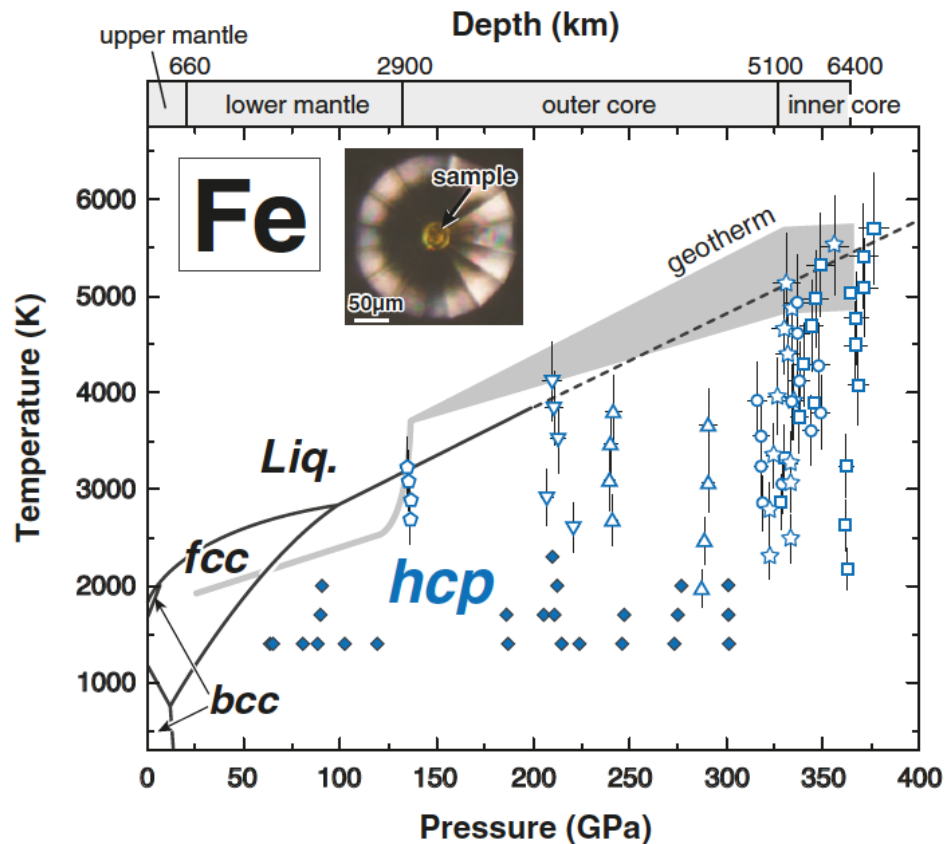
Science 330, 359 (2010)



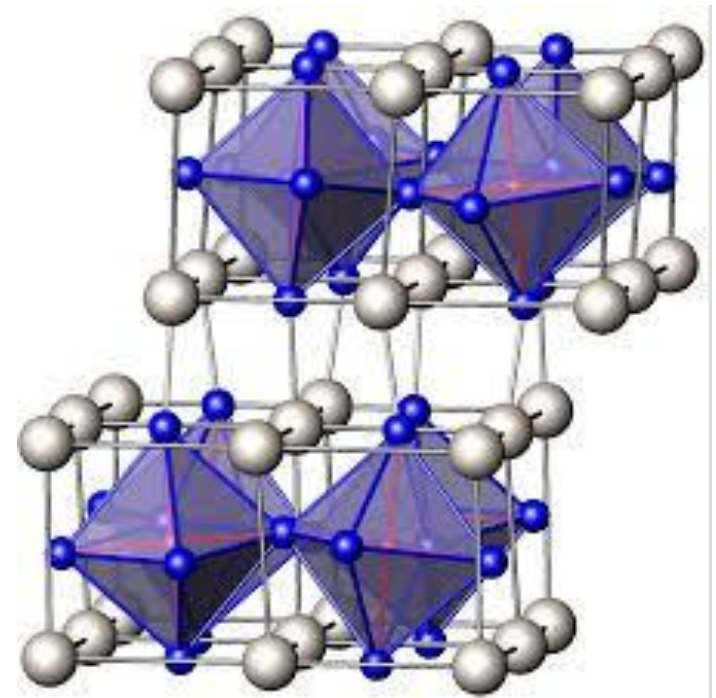
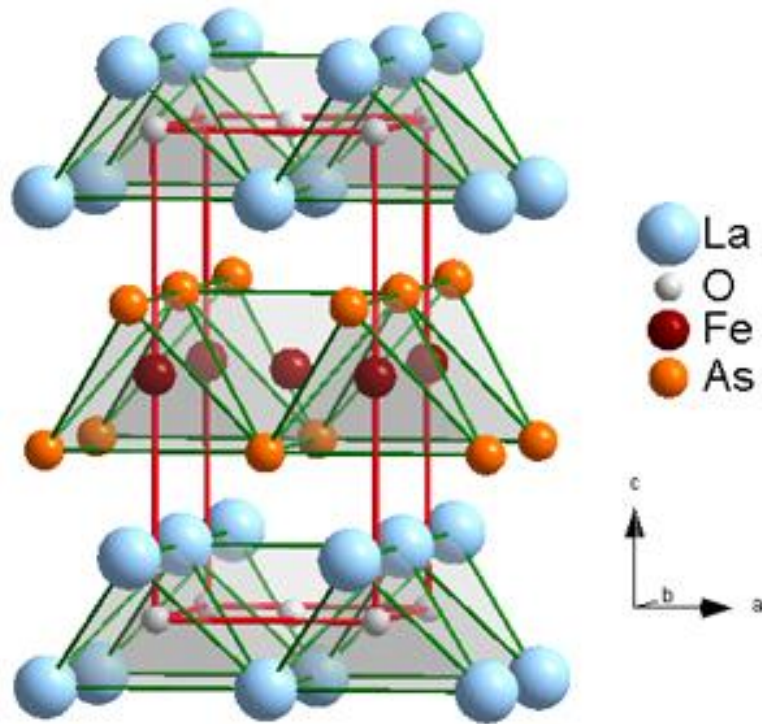
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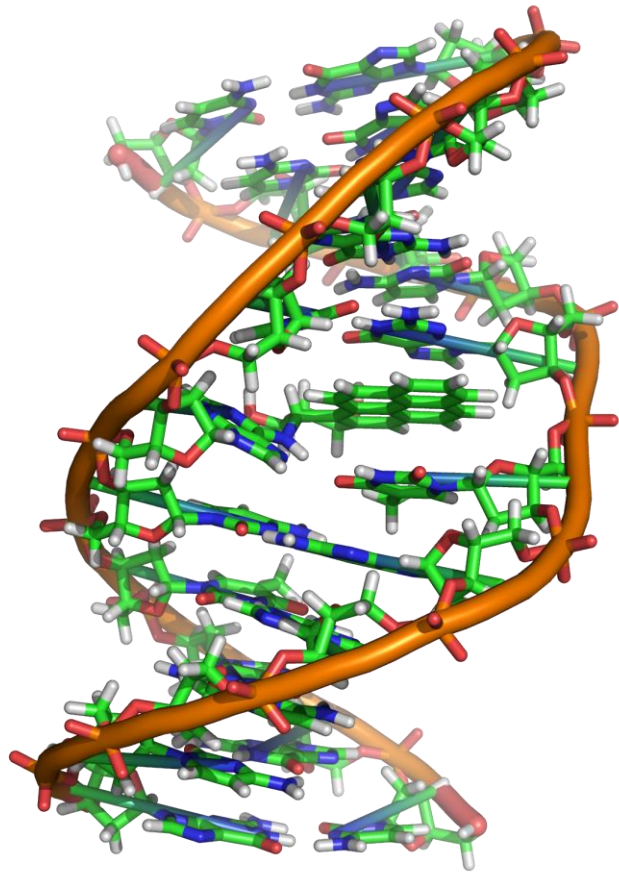
Complicated Crystal Structures



<http://www.wou.edu/~rmiller09/superconductivity/>

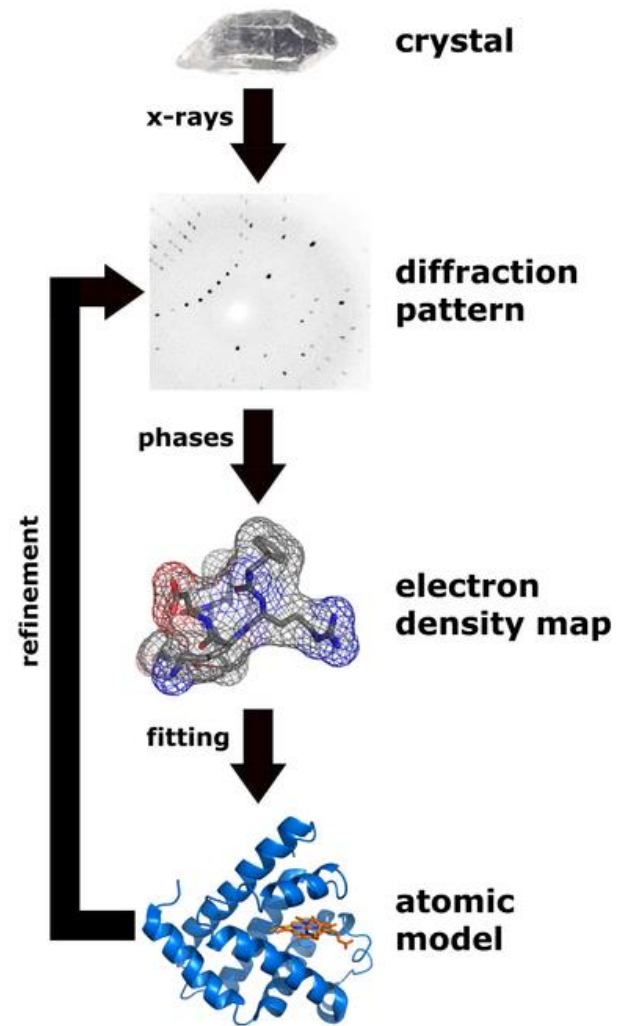
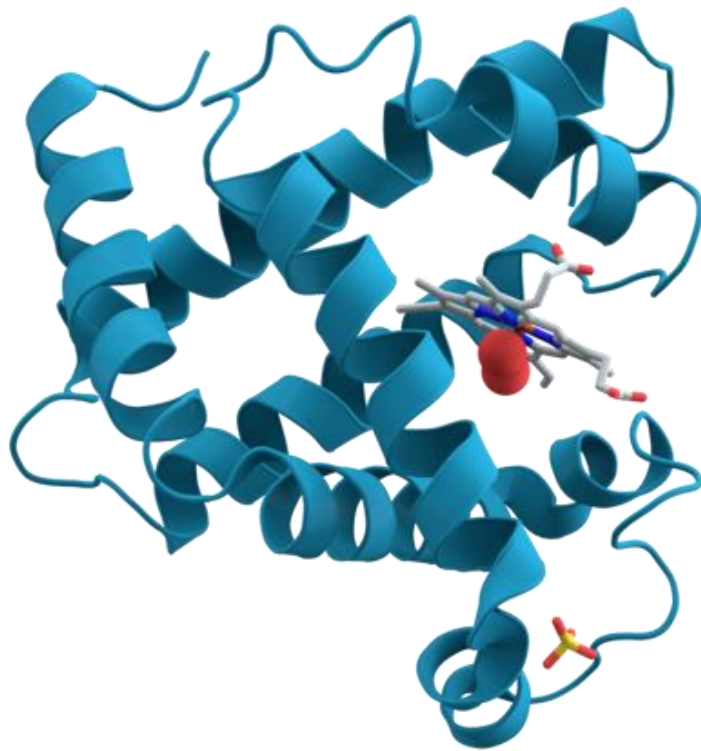
Phys. Rev. Lett. 104, 226401 (2010)

DNA Structure



<https://en.wikipedia.org/wiki/DNA>

Protein Structures



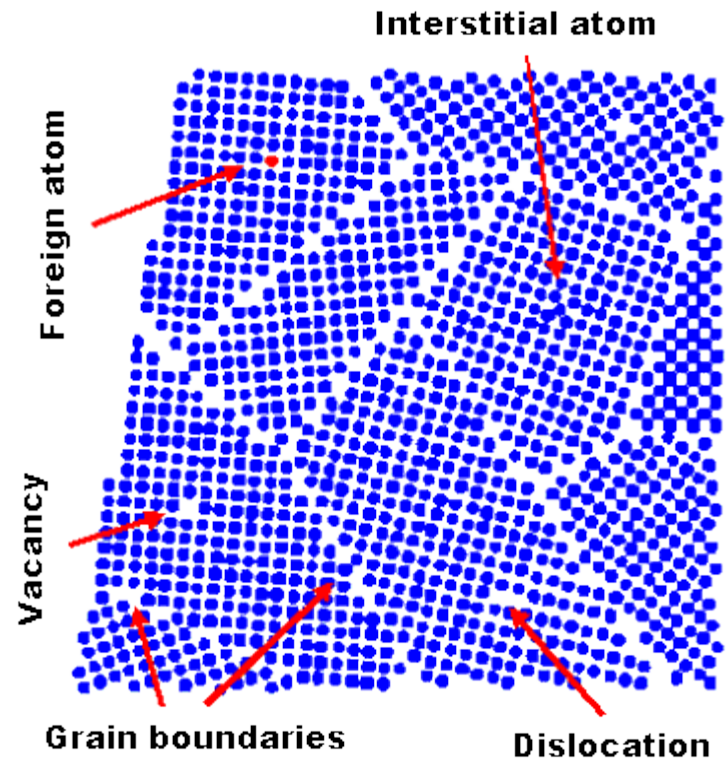
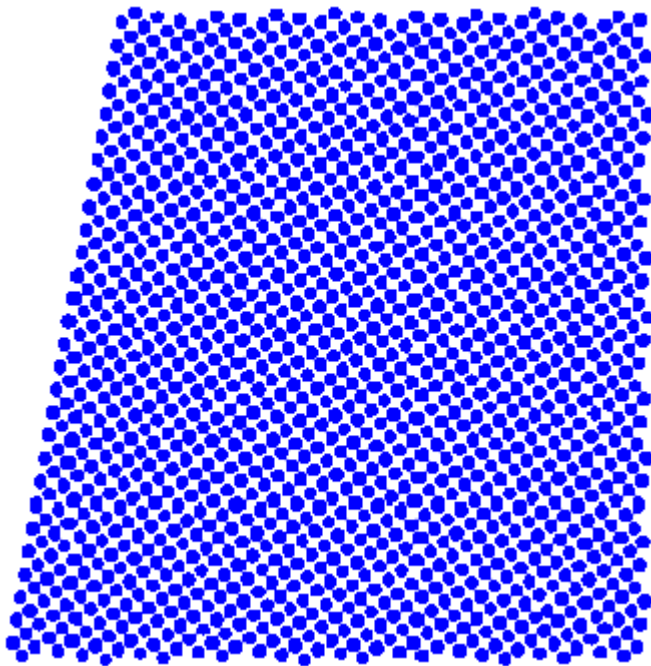
Outline

Complex structures

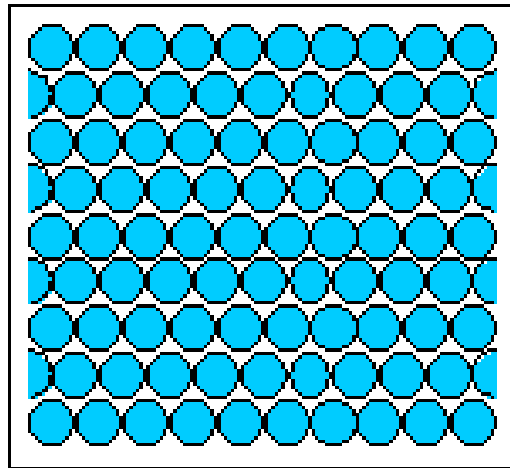
Crystal Defects and non-crystalline solids

Experimental Techniques to Map Crystal Structures
(Real Space)

Single crystal versus Polycrystal

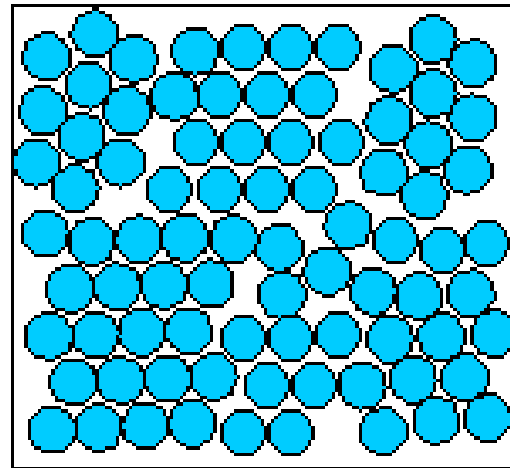


Amorphous solid



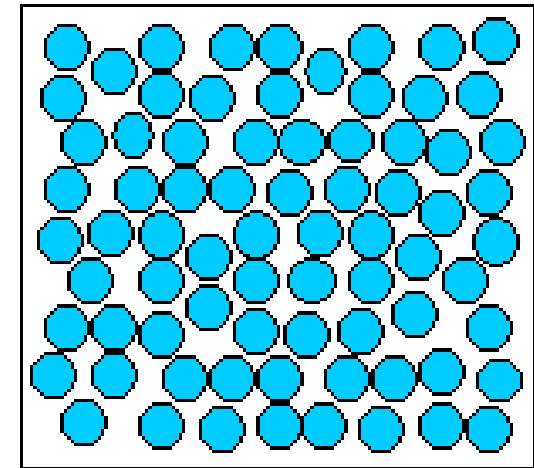
Single crystal

Periodic across the
whole volume.



Polycrystal

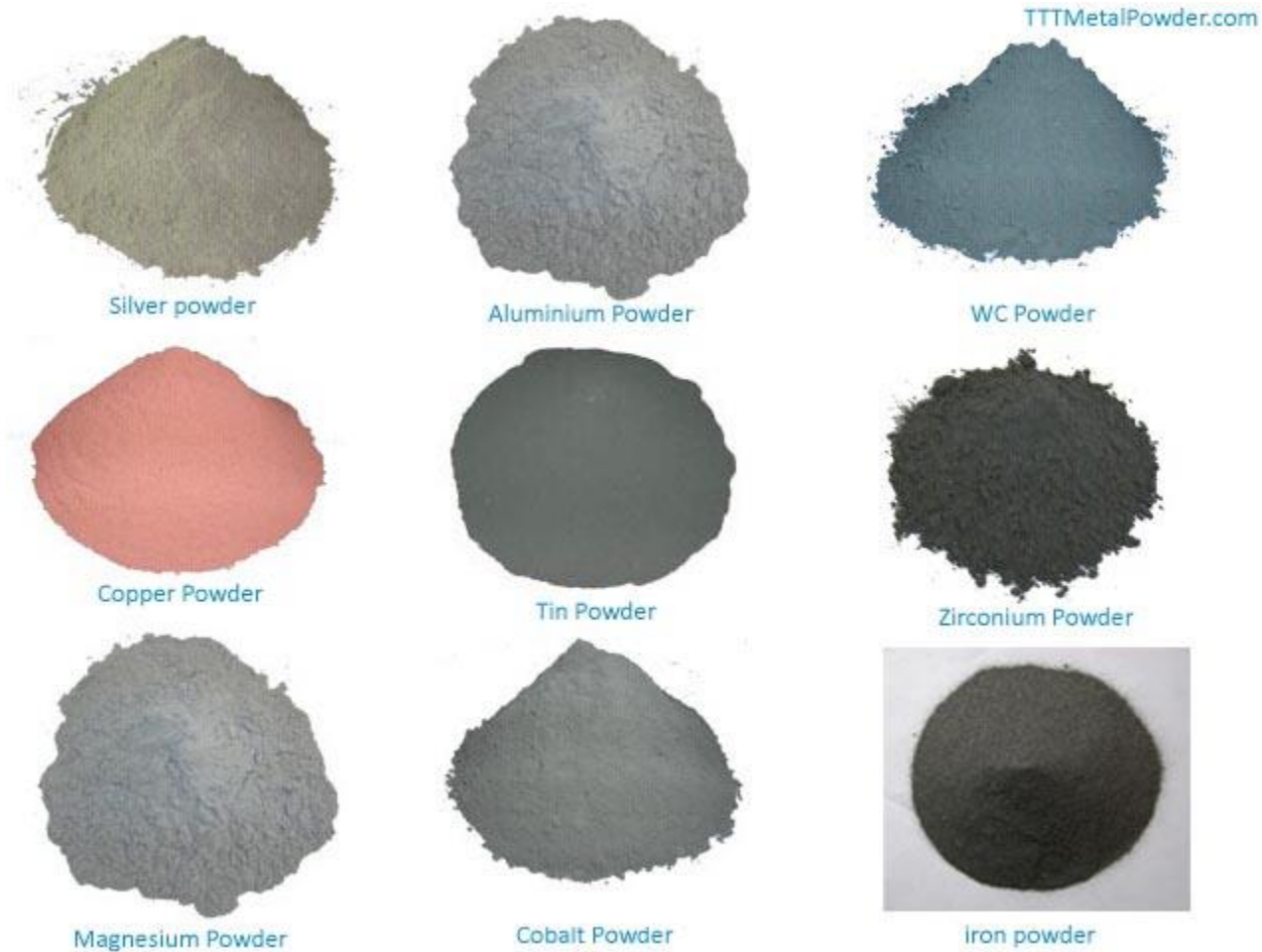
Periodic across
each grain.



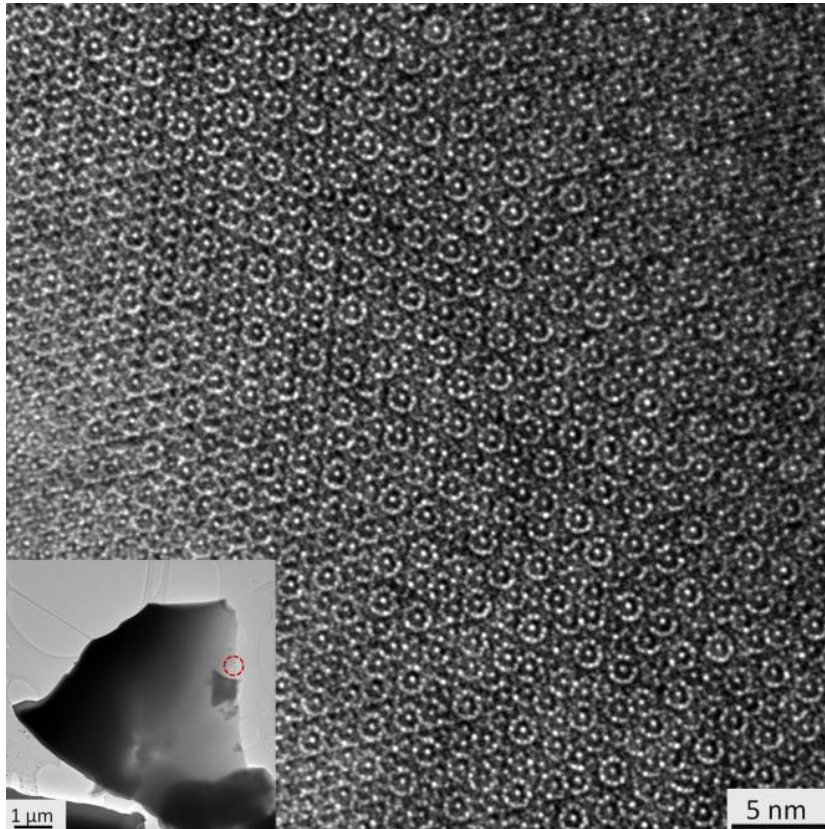
Amorphous solid

Not periodic.

Single crystal versus powder



Quasi-crystals



High-resolution transmission electron microscopy (HRTEM) image showing that the real space structure consists of a homogeneous, quasiperiodic and ten-fold symmetric pattern.

Sci Rep. 2015; 5: 9111

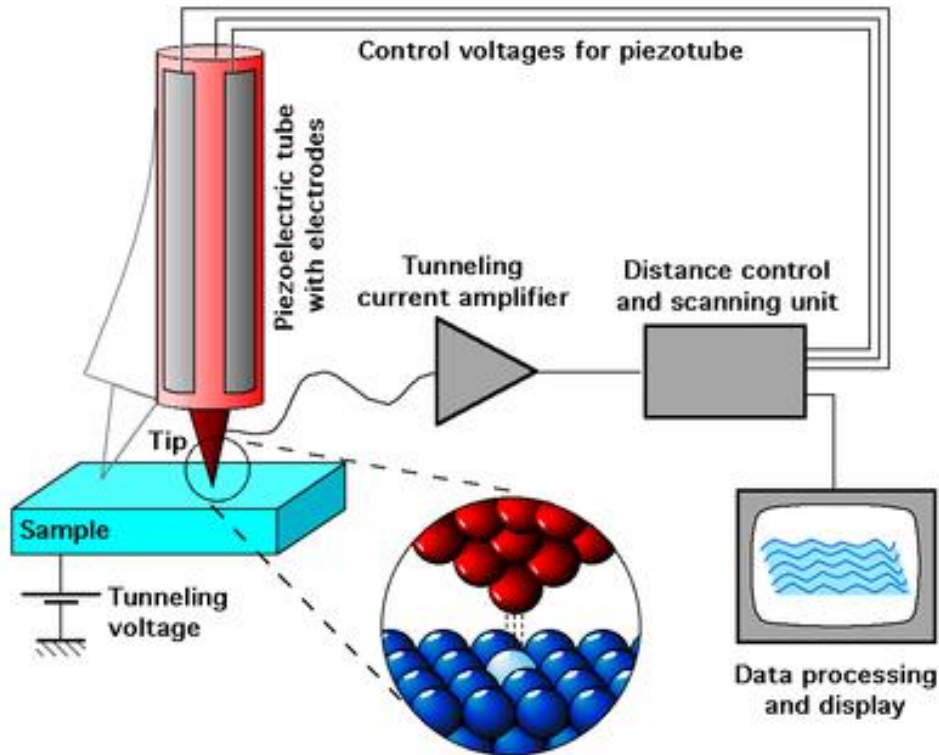
Outline

Complex structures

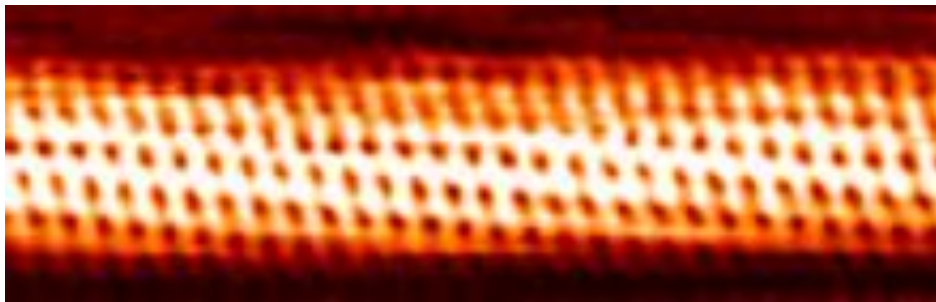
Crystal Defects and non-crystalline solids

Experimental Techniques to Map Crystal Structures
(Real Space)

Scanning tunneling microscope (STM)

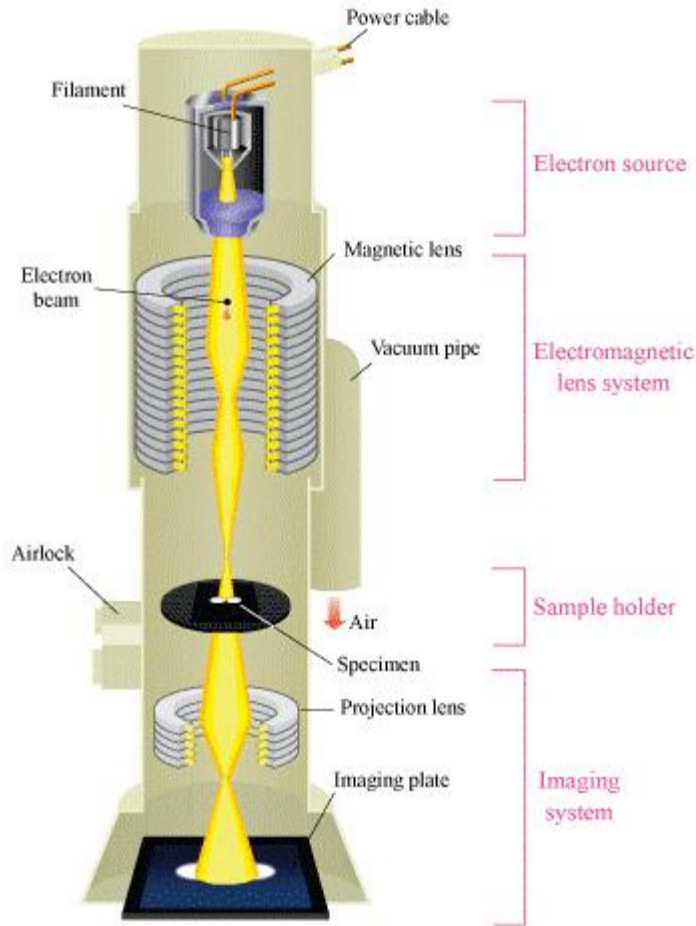


PRINCIPLES OF STM



Carbon Nano-type

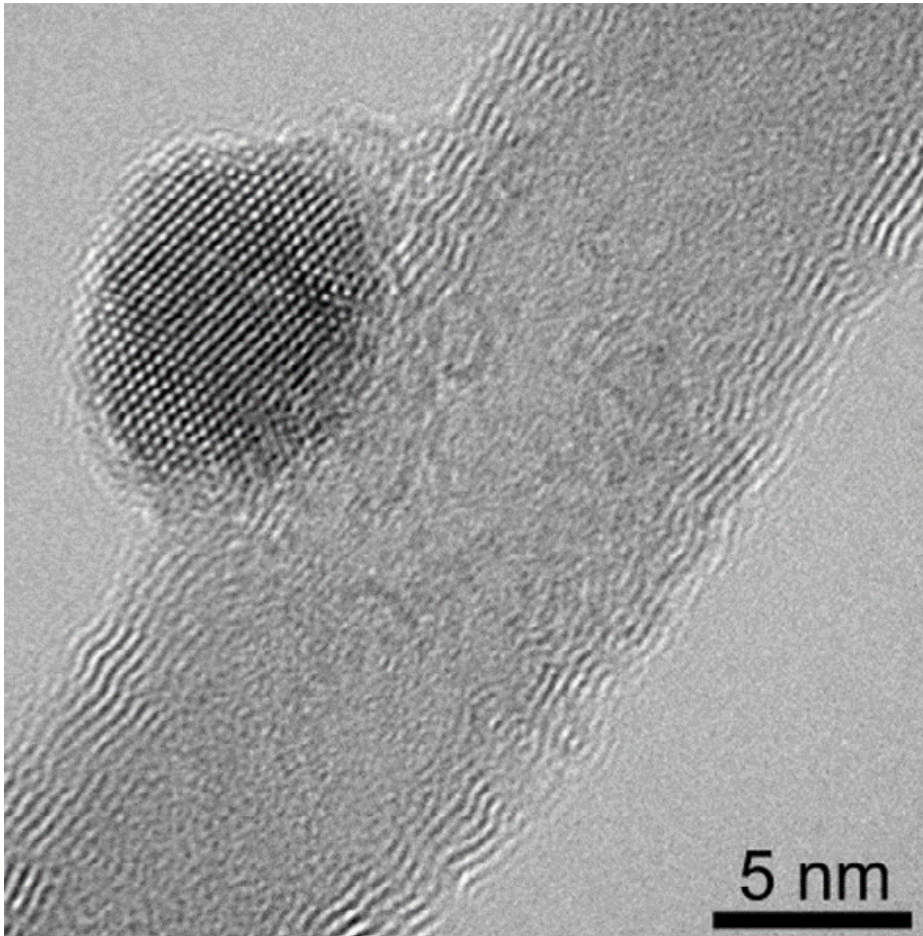
High-Resolution Transmission Electron Microscope (HRTEM)



http://www.hk-phy.org/atomic_world/tem/tem02_e.html

<http://www.dstuns.iitm.ac.in/microscopy-instruments.php>

High-Resolution Transmission Electron Microscope (HRTEM)



HRTEM image and focal series reconstruction of the MWCNTs with Fe₃O₄ nanoparticles attached.

<https://www.int.kit.edu/1745.php>