Condensed Matter Physics

- Dr. Baris Emre

- Solid State Physics: An Introduction, by Philip Hofmann (2nd edition 2015, **ISBN-10:** 3527412824, **ISBN-13:** 978-3527412822, Wiley-VCH Berlin.
- (Advanced Texts in Physics) Harald Ibach, Hans Lüth (auth.) - Solid-State Physics_ An Introduction to Principles of Materials Science-Springer-Verlag Berlin Heidelberg (2009)-2

Ingredients for solid state physics

- The electromagnetic interaction
- Quantum Mechanics
- Many particles
- Symmetry to handle it all

and what we get out

- Microscopic picture for a zoo of different phenomena: conductivity, superconductivity, mechanical properties, magnetism, optical properties.
- Funny new “quasi” particles: ‘electrons’ with unusual mass and charge, phonons, Cooper pairs, particles which are neither bosons or fermions, magnetic monopoles,....

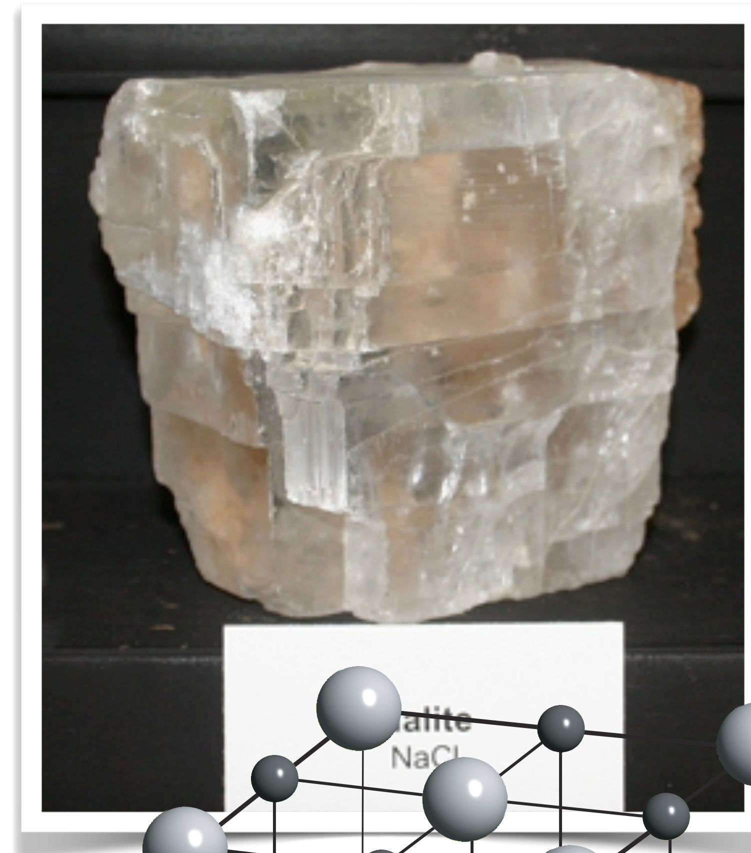
Crystal Structures

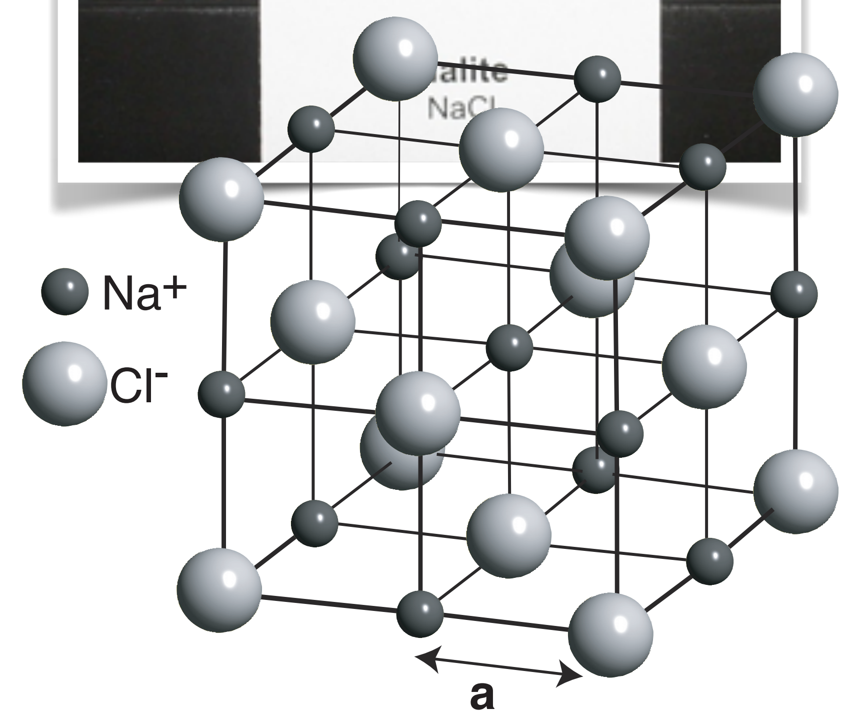
In this course we are concerned with perfectly crystalline solids, with the atoms arranged on a perfect lattice without any defects, impurities, or boundaries. It turns out that the perfect periodicity and translational symmetry allow us to develop very good models for the solid state despite the very many ($\approx N_A$) particles involved. It may seem that such perfect crystals are not particularly relevant for real materials but this is not the case. Many solids are actually composed of small crystalline grains. The fact that these grains are three dimensional means that the number of atoms on the grain boundary is quite small compared to the number of atoms in the grain. For instance, for a grain size in the order of 1000^3 atomic distances, only about 0.1% of the atoms are at the grain boundaries, the rest find themselves in a perfectly crystalline environment. There are, however, some solids that are not crystalline. These are called amorphous solids. The amorphous state is characterized by the absence of any long-range order. There may, however, be some short-range order between the atoms.

Perfect Crystalline Solids

bismuth

NaCl





$$G = U + PV - TS$$

- solid made from small, identical building blocks (unit cells) which also show in the macroscopic shape

Crystals and crystalline solids: contents

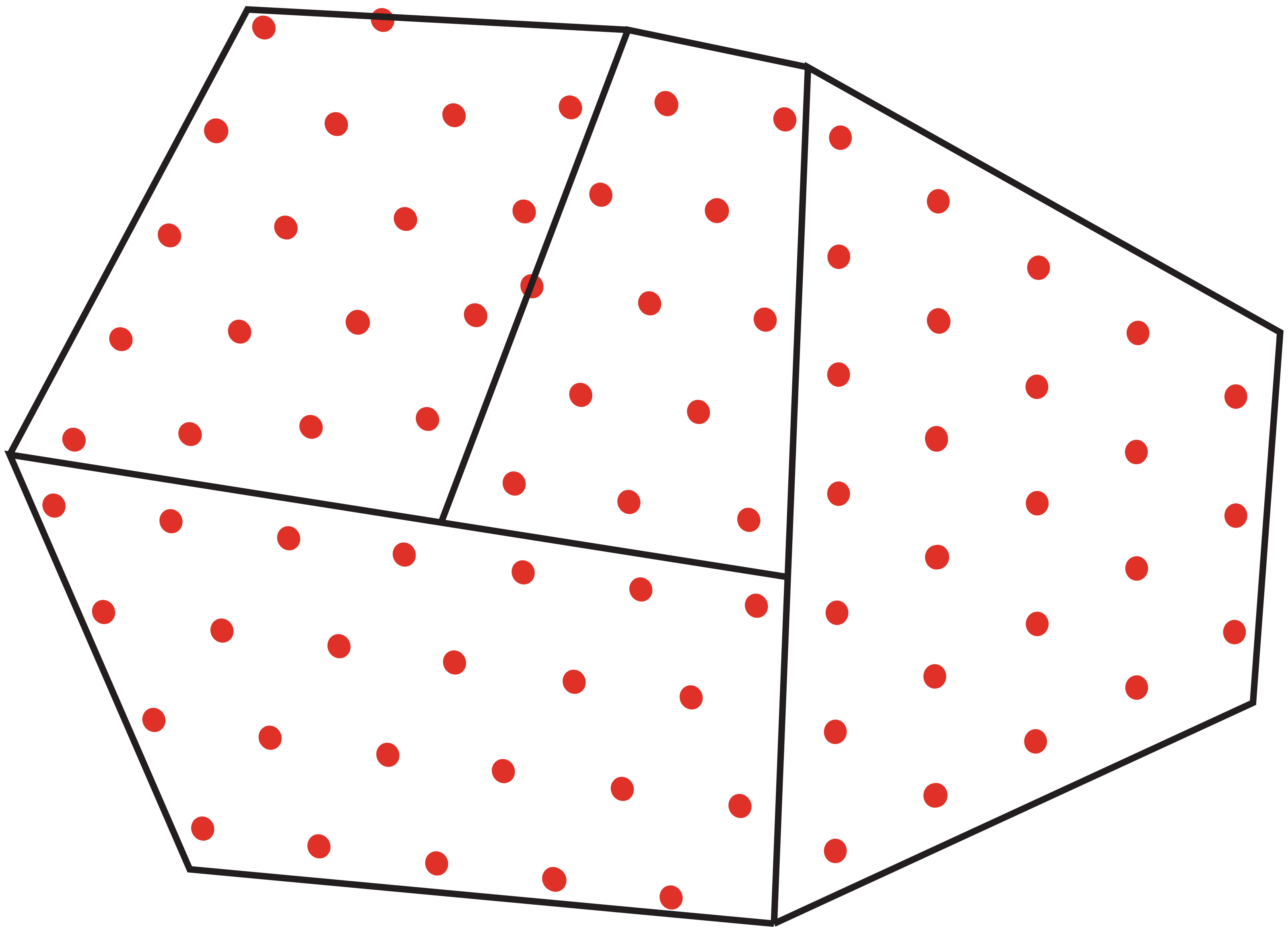
at the end of this lecture you should understand....

- Bravais lattice, unit cell and basis
- Miller indices
- Real crystal structures
- X-ray diffraction: Laue and Bragg conditions, Ewald construction
- The reciprocal lattice
- Electron microscopy and diffraction

Crystals and crystalline solids

- The total energy gain when forming crystals most be very big because the ordered states exists also at elevated temperatures, despite its low entropy.
- The high symmetry greatly facilitates the solution of the Schrödinger equation for the solid because the solutions also have to be highly symmetric.

Crystals and crystalline solids



- most real solids are polycrystalline
- still, even if the grains are small, only a very small fraction of the atoms is close to the grain boundary
- the solids could also be amorphous (with no crystalline order)

Crystal Structures

This chapter is divided into three parts.

- In the first part, we define some basic mathematical concepts needed to describe crystals. We keep things simple and mostly use two-dimensional examples to illustrate the ideas.
- In the second part, we discuss common crystal structures.
- Finally, we go into a somewhat more detailed discussion of X-ray diffraction. The reason is that this technique is widely used, also in the fields of microbiology and nanotechnology, and you will probably encounter it again many times.

The crystal lattice: Bravais lattice (2D)

A Bravias lattice is a lattice of points, defined by

$$\mathbf{R}_{mn} = m\mathbf{a_1} + n\mathbf{a_2}$$

- Fig 2.1, Solid State Physics: An Introduction, by Philip Hofmann, Wiley-VCH Berlin.

The lattice looks exactly the same from every point

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The lattice looks exactly the same from every point

The crystal lattice: Bravais lattice (2D)

Not every lattice of points is a Bravais lattice

$$\mathbf{R}_{mn} = m\mathbf{a_1} + n\mathbf{a_2}$$

- Fig 2.1, Solid State Physics: An Introduction, by Philip Hofmann, Wiley-VCH Berlin.