Introcudtion to materials

Materials Engineering
(BMEGEMTAMM1)
25th February, 2026

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MT épület 061.

Administration

Metals

Dr. Dorina Kovács

Classes:

week 2-7.

Polymers

Dr. Ákos Pomázi

Classes:

week 8.

(week 9. – dean holiday)

week 10-14.

The subject has a written exam, but it is possible to get a recommended grade.

Test 1:

1st, April (week 7)

Test 2:

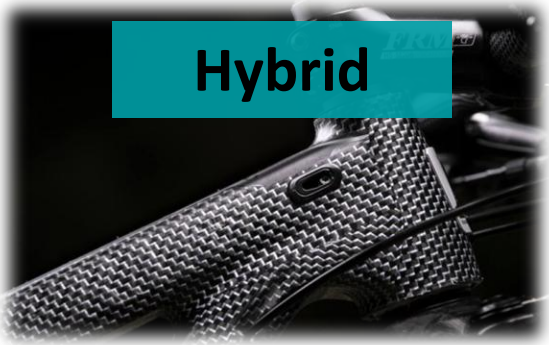
27th, May (week 14)

If you are not satisfied with your grade, you must take an exam in the exam period. There is no retake from the tests.

Materials

Ceramics

Glasses



Hybrid

Metals

Polymers

Elastomers

Definitions

Materials science

connection between materials' properties and structure

- Mechanical (effect of load and deformation)
- Electric (effect of electric field)
- Thermal (effect of temperature field)
- Magnetic (effect of magnetic field)
- Optical (effect of electromagnetic field)
- Corrosion (effect of chemical reactivity)

Materials testing

Testing methods to measure the properties of materials

Materials engineering

Design and production of engineering structures

How can we look inside the materials?

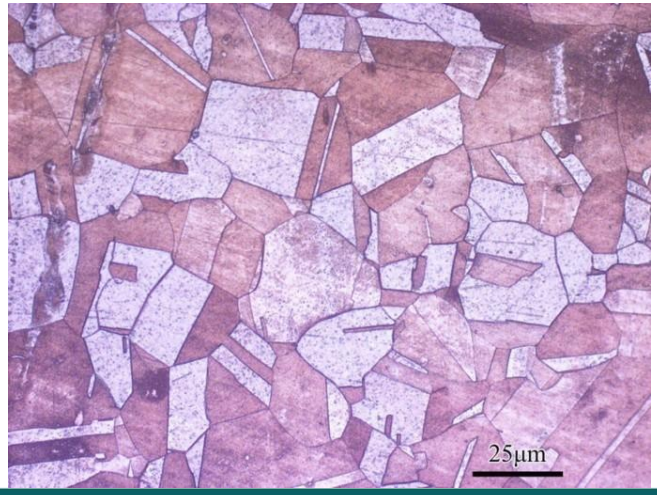
Camera

- too far
- visual observation
- documentation of initial problem

Microscopy

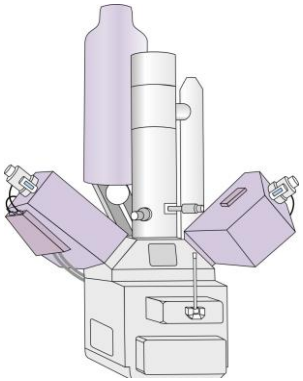
Optical microscope

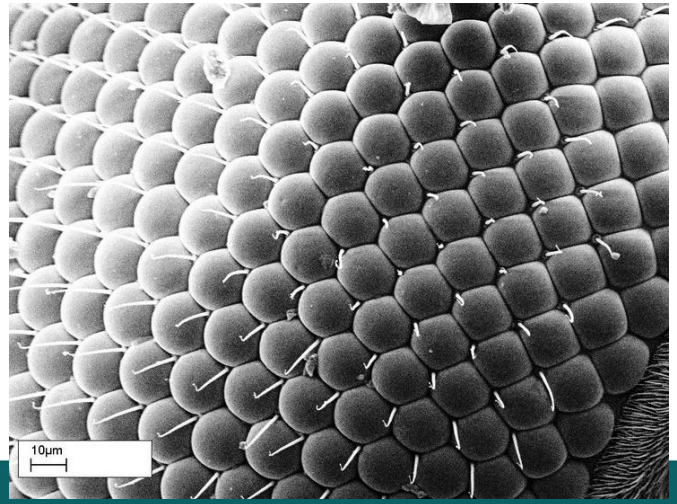
- the light microscope is used to study the microstructure
- meticulous surface preparations are necessary to reveal the important details of the microstructure
- specimen surface must first be ground and polished to a smooth and mirror-like finish
- etching can show the microstructure by chemical reaction between the surface and the reagent



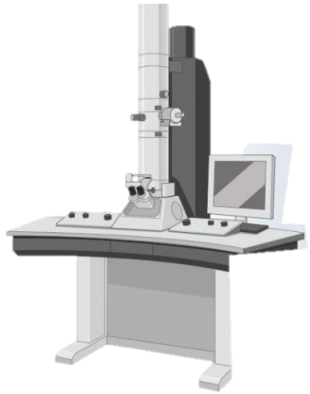
Scanning electron microscope

- The surface of a specimen to be examined is scanned with an electron beam, and the reflected (or back-scattered) beam of electrons is collected by a detector
- The sample must be electrically conductive
- The equipment permits qualitative and semiquantitative analysis of the elemental composition

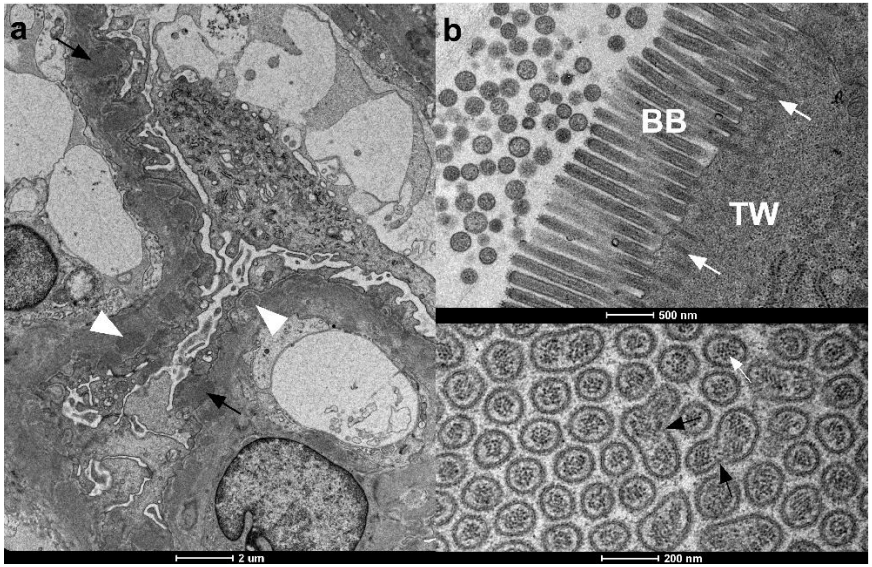




Transmission electron microscope



- The image is formed by an electron beam that passes through the specimen
- specimen to be examined must be prepared in the form of a very thin foil
- Magnifications approaching 1,000,000X

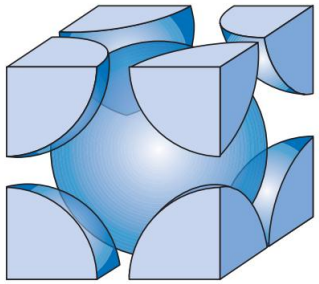


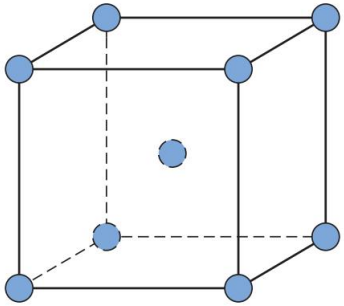
Go to microstructure

A **crystalline** material is one in which the atoms are situated in a repeating or periodic array over large atomic distances

- solid material
- crystallic structure (lattice)

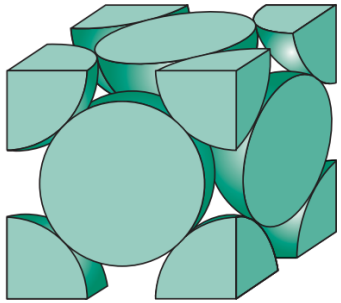
Body-centered-cubic (BCC)

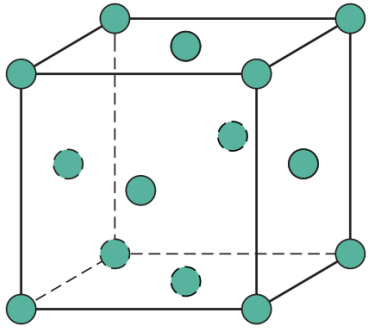




Fe
Cr
Mo

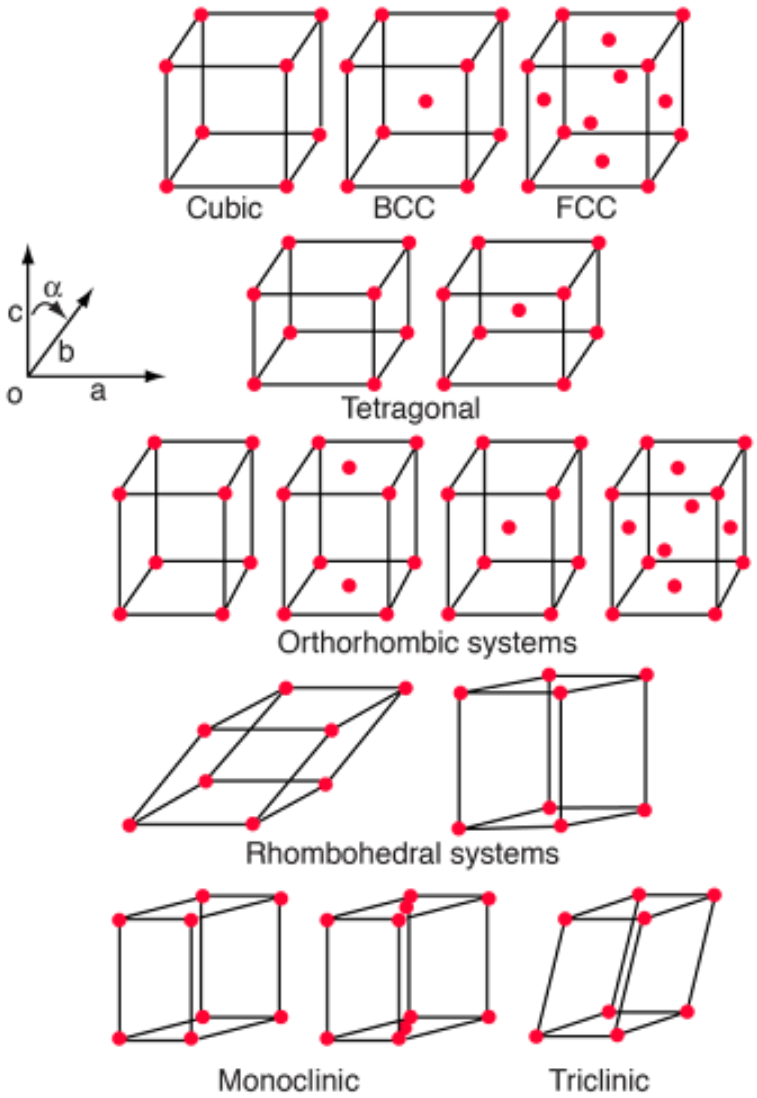
Face-centered-cubic (FCC)





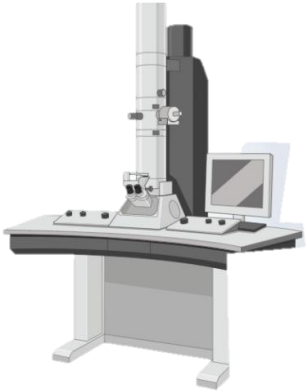
Al
Cu
Ni

Go to microstructure

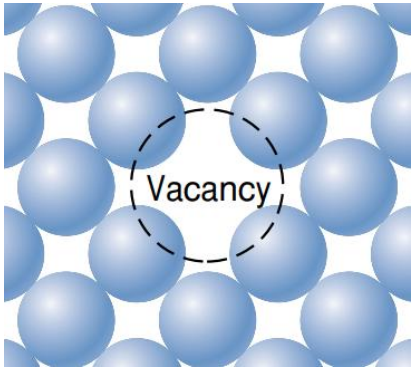


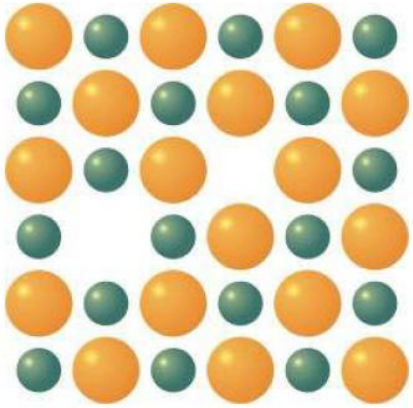
1D

Vacancy



an atom is missing from the crystal structure



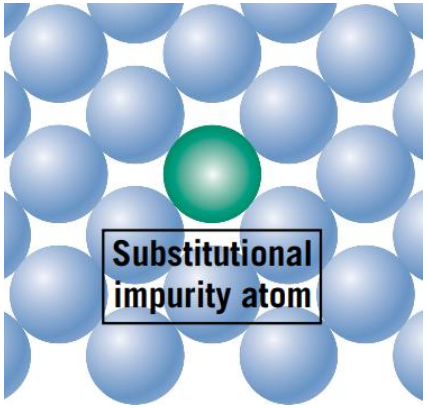


All crystalline solids contain vacancies, and, in fact, it is not possible to create such a material that is free of these defects.

1D

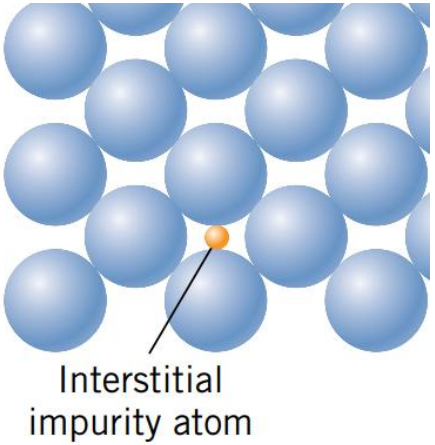
Additional atoms

Substitutional



Solid solution:
the solute atoms are added to the host material, the crystal structure is maintained and no new structures are formed

Interstitial



Impurity point defects are found in solid solutions, of which there are two types: **substitutional and interstitial**. For the substitutional type, solute or impurity atoms replace or substitute for the host atoms. An interstitial site—a small void space that under ordinary circumstances is not occupied, and a small atom is going into this space.

2D

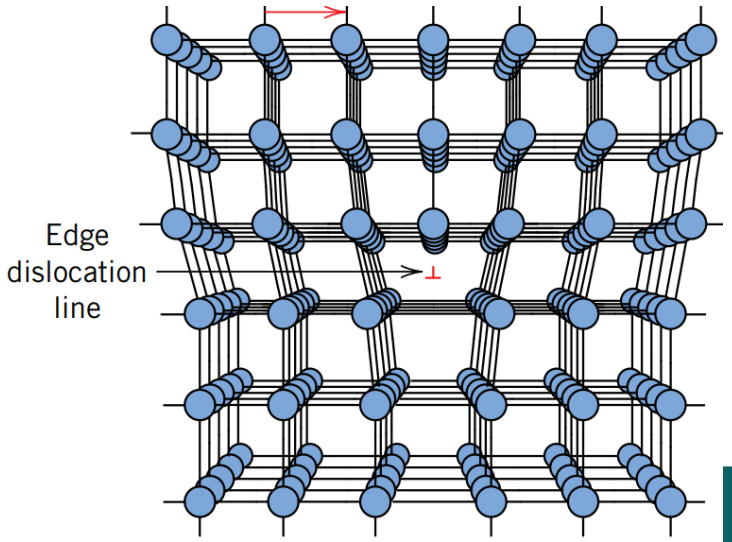
Dislocation

A dislocation is a linear or one-dimensional defect around which some of the atoms are misaligned.

Edge dislocation

is an extra portion of a plane of atoms, or half-plane, the edge of which terminates within the crystal. Within the region around the dislocation line there is some localized lattice distortion.

- represented by the symbol ⊥, which also indicates the position of the dislocation line



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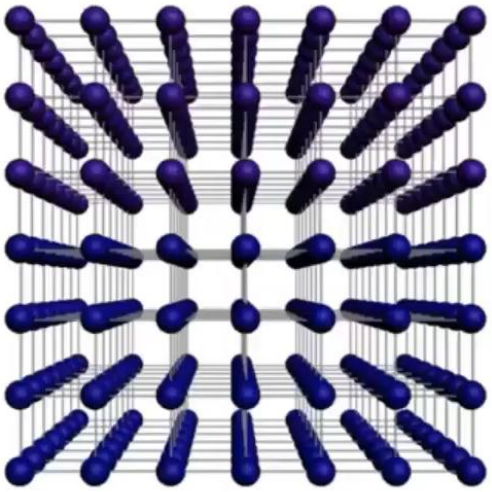


https://www.youtube.com/watch?v=Upcc70OZ8Z4

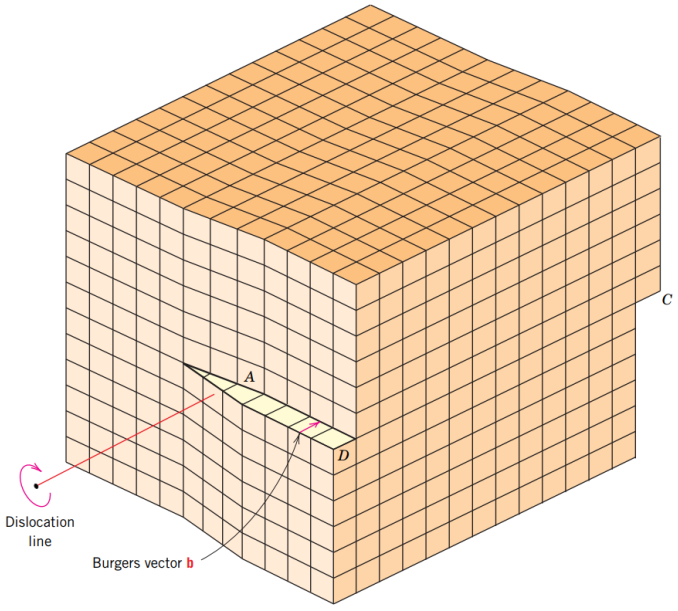
2D

Dislocation

A dislocation is a linear or one-dimensional defect around which some of the atoms are misaligned.

Screw dislocation

formed by a shear stress that is applied to produce the distortion. The screw dislocation derives its name from the spiral or helical path or ramp that is traced around the dislocation line by the atomic planes of atoms.



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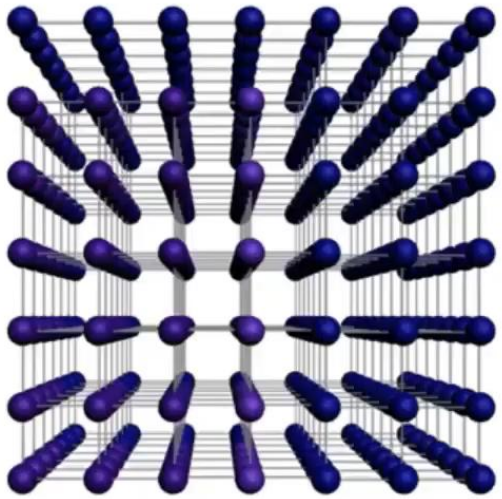
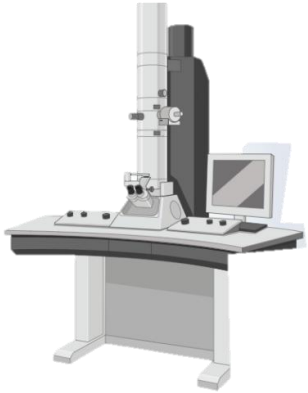


SCREW DISLOCATION

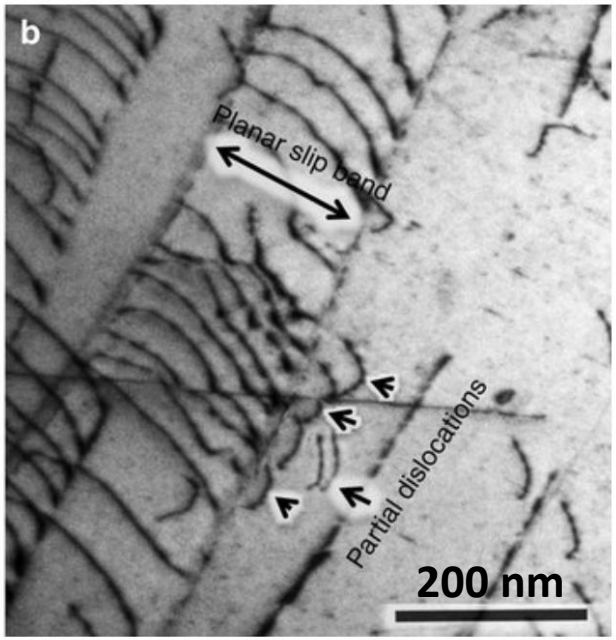
https://www.youtube.com/watch?v=RD40OtchSVg

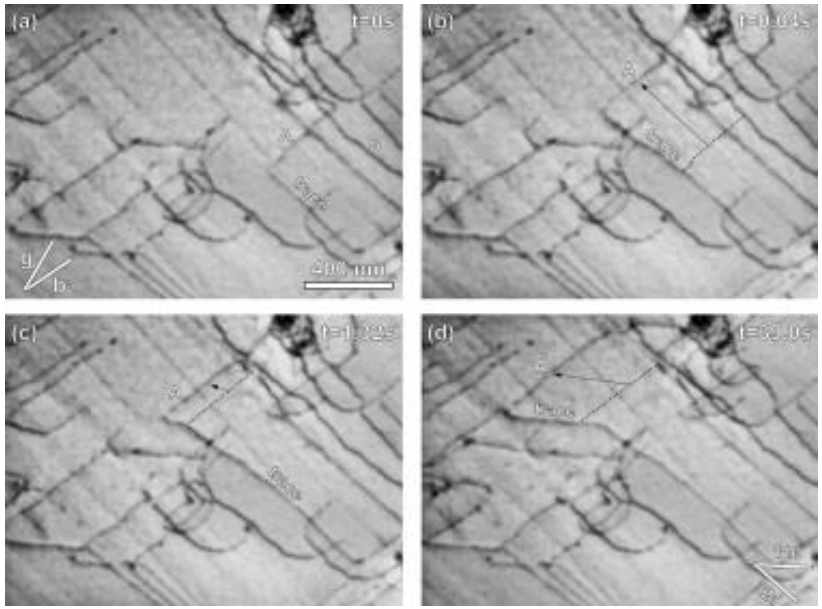
2D

Dislocation



Most dislocations found in crystalline materials are probably neither pure edge nor pure screw but exhibit components of both types; these are termed: **mixed dislocations.**





Real lattice – Interfacial defects

2D

Interfacial defects are boundaries that have two dimensions and normally separate regions of the materials that have different crystal structures and/or crystallographic orientations.

External surface

Surface atoms are not bonded to the maximum number of nearest neighbors and are therefore in a higher energy state than the atoms at interior positions. (For example, liquids assume a shape having a minimum area—the droplets become spherical.)

Grain boundaries

A boundary is separating two small grains or crystals having different crystallographic orientations in polycrystalline materials. Within the boundary region, which is probably just several atom distances wide, there is some atomic mismatch in a transition from the crystalline orientation of one grain to that of an adjacent one

2D

Grain boundaries

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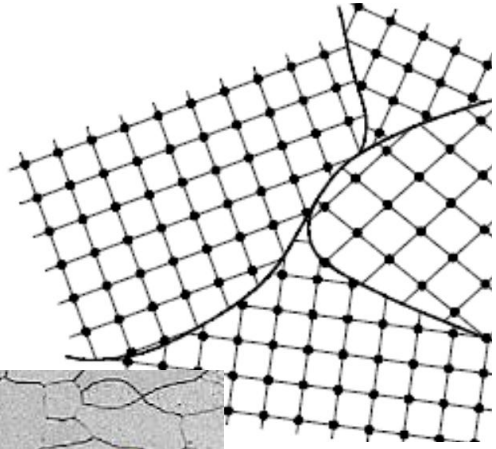
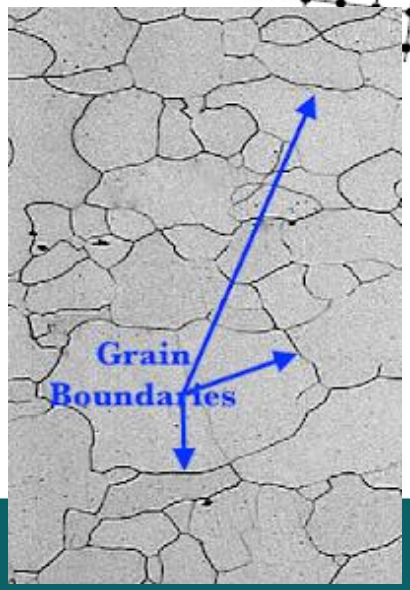
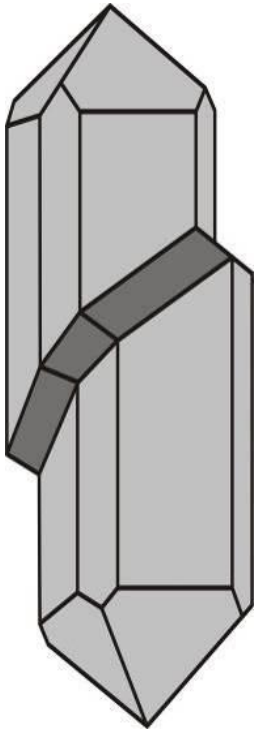
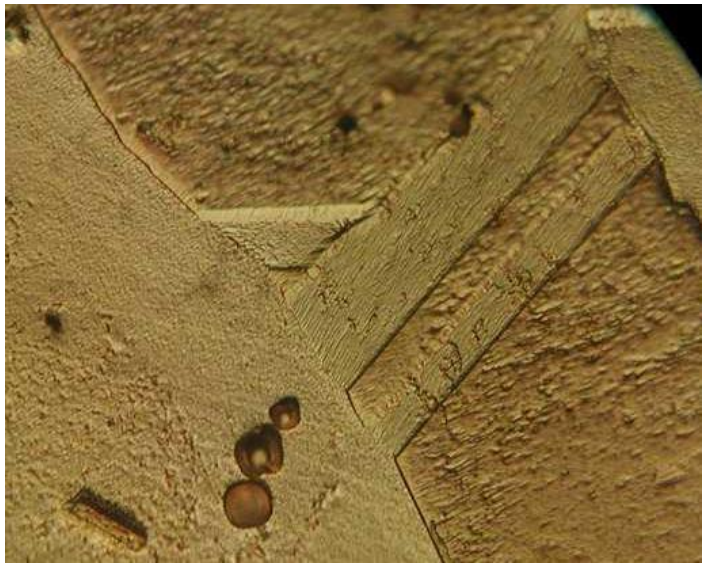






Twin boundaries

there is a specific mirror lattice symmetry

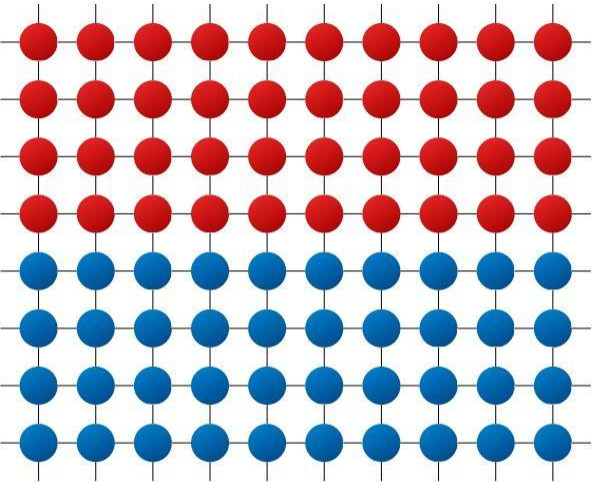


2D

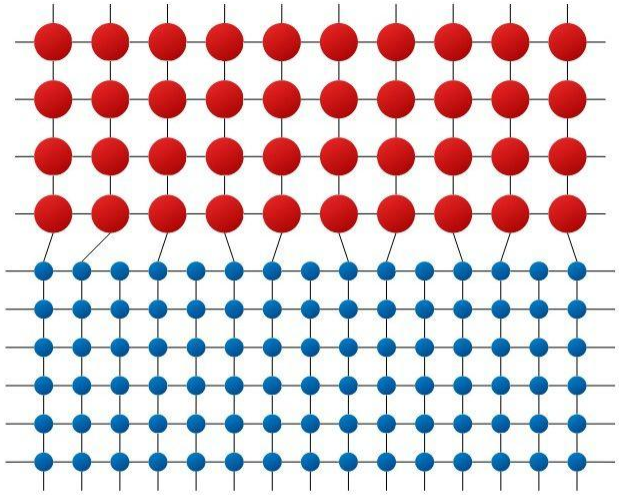
Phase boundaries

A different phase exists on each side of the boundary; furthermore, each of the constituent phases has its own distinctive physical and/or chemical characteristics.

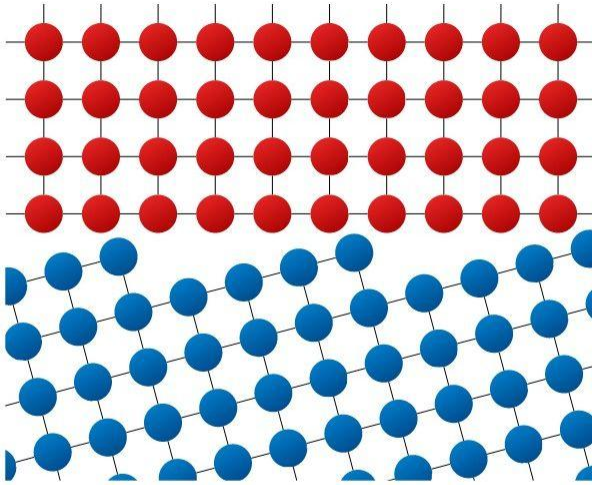
coherent phase boundary



partially coherent phase boundary



incoherent phase boundary



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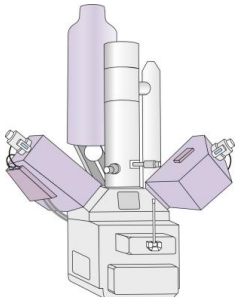
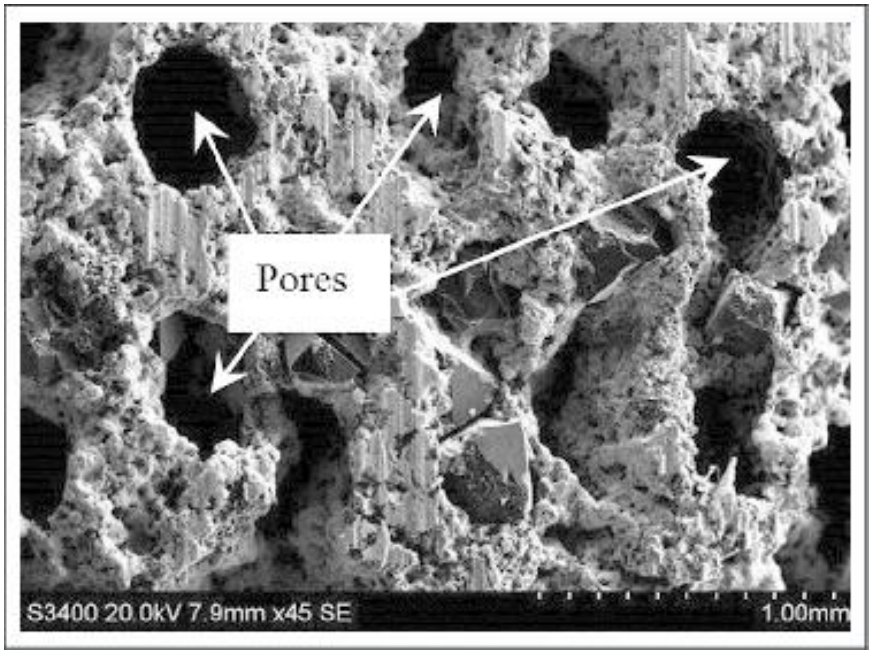
Real lattice – Volume defects

3D

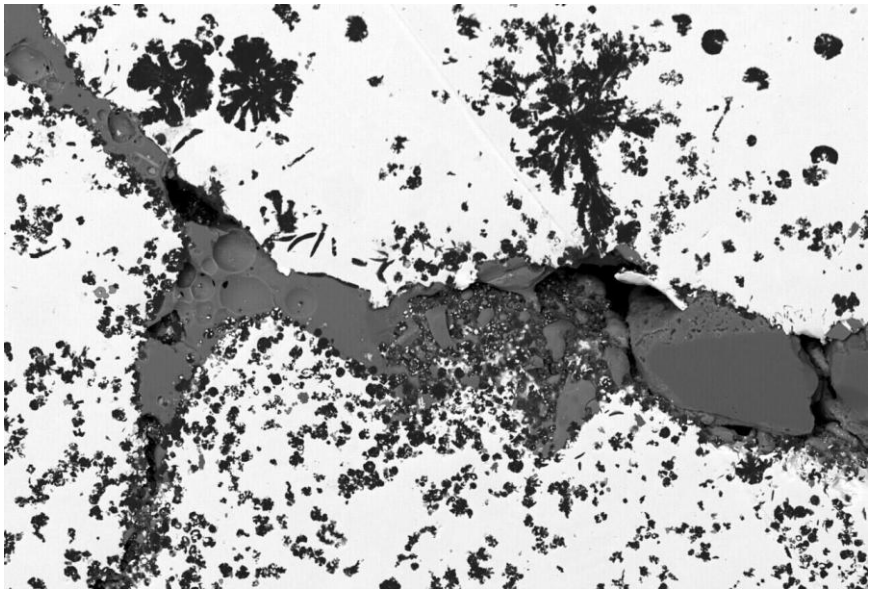
It exists in all solid materials that are much larger than those heretofore discussed.



Pores



Inclusion



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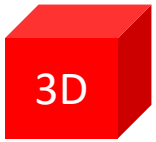

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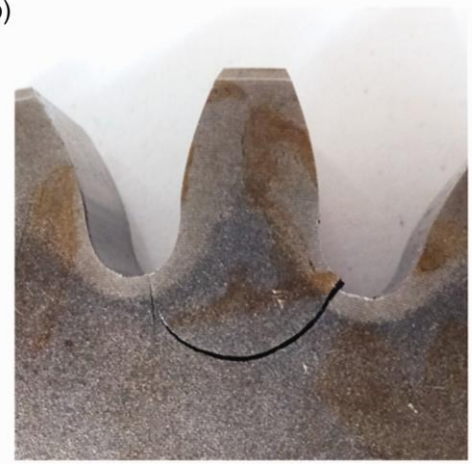
Crack

(a)

(b)

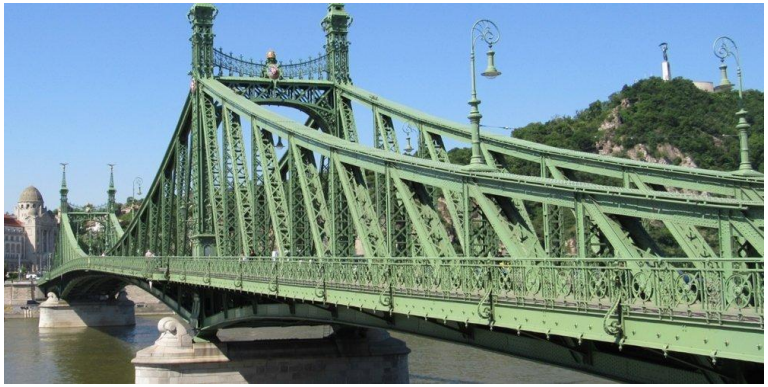


(c)

Mechanical properties

Hardness ↔ Softness

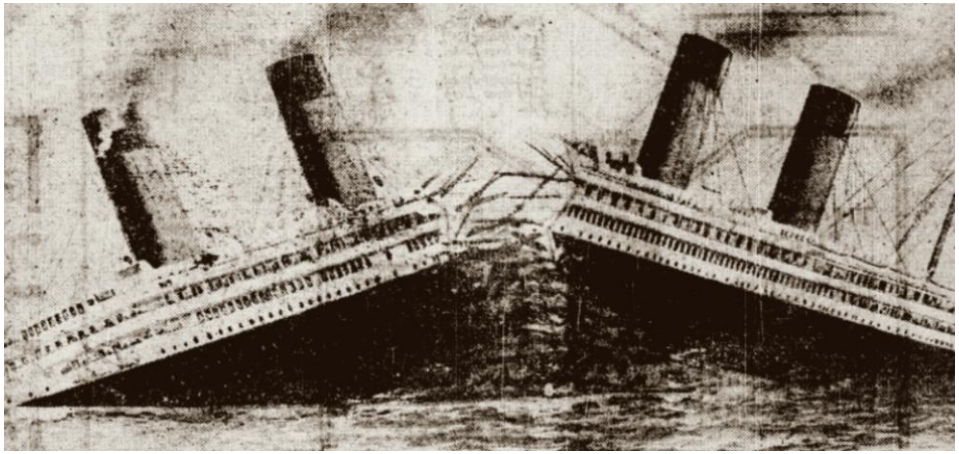
Strength ↔ Plasticity



Mechanical properties

Stiffness ↔ Elasticity

Brittle ↔ Ductile

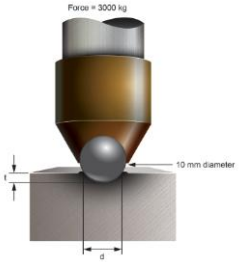


Mechanical testing methods

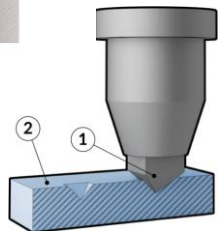
Hardness gives the material's resistance to localized plastic deformation

Static

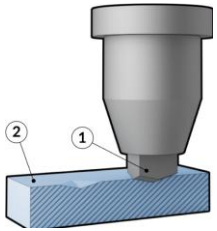
- **Brinell**



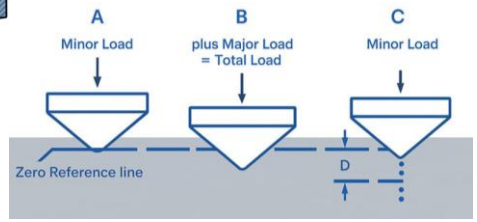
- **Vickers**



- **Knoop**

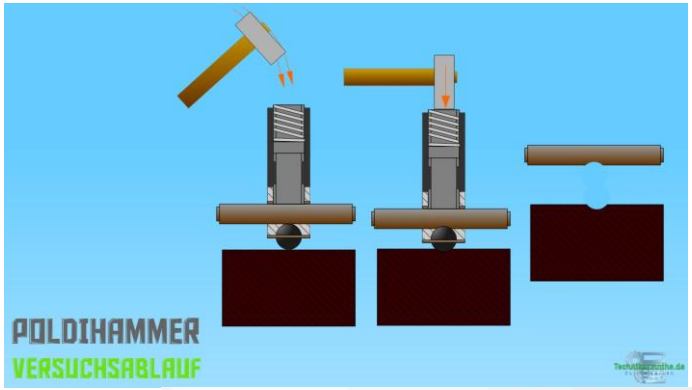


- **Rockwell**



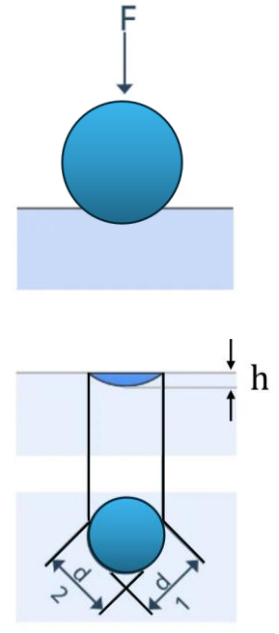
Dynamic

- **Poldi**



- **Leeb**

Brinell



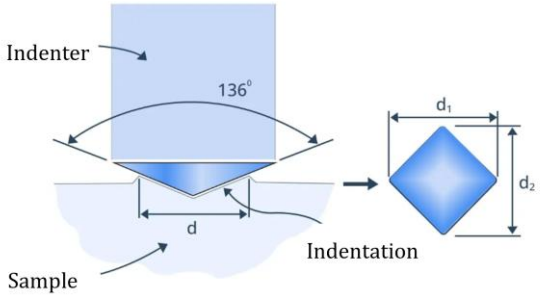
HB/D/F/t

Brinell hardness / ball diameter (mm) / load (kp) / load time (s)

Example: 200 HB / 1 / 30 / 20

It is typically used for:
cast irons
non-ferrous and light metals
mild steels

Vickers



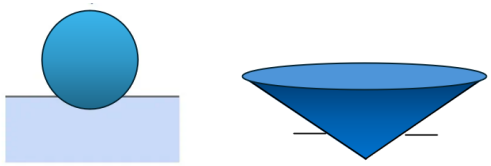
HV/F/t

Vickers hardness / load (kg)/load time (s)

Example: 60 HV/5/12

It is typically used for:
all material

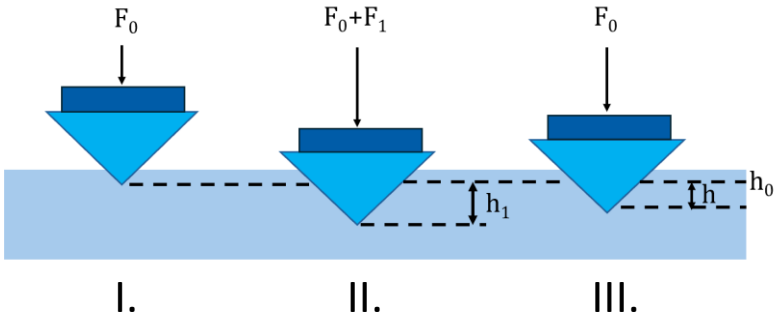
Vickers



It is typically used for:
HRC - Steels, carburized steels, titanium alloys, cast alloys

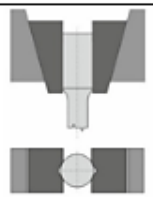
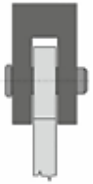
HRB - Mild steels, copper and aluminum alloys

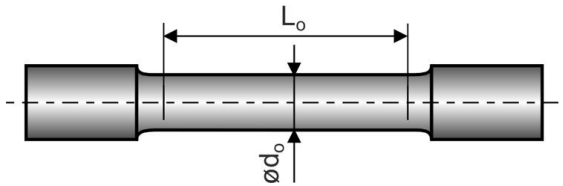
(I) applying the preload (F_0) to seat the indenter,
(II) applying the main load (F_1) causing further penetration
(III) Removing the main load allows elastic recovery
(IV) The hardness value is read directly from a calibrated dial



Tensile testing

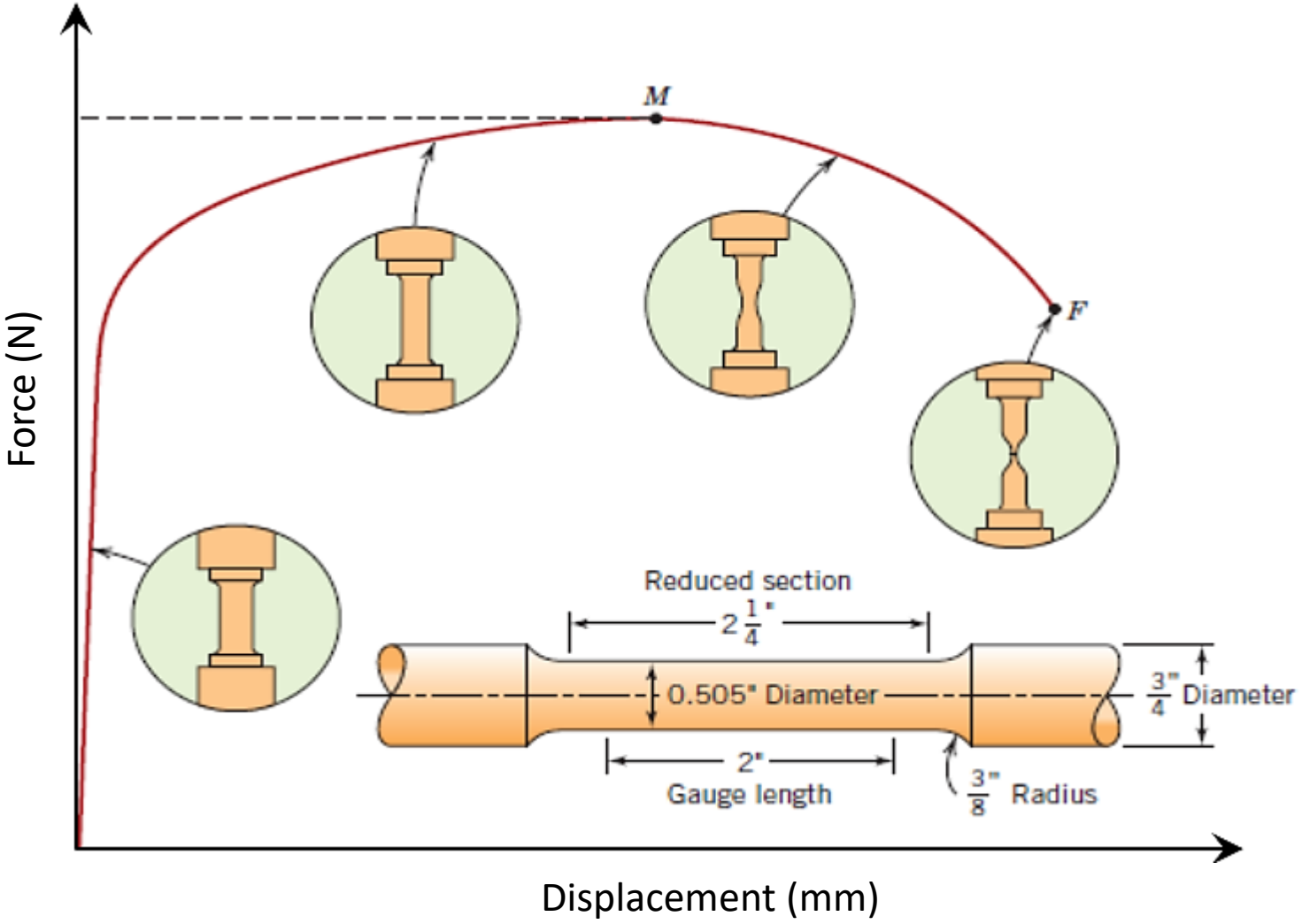
The **aim of tensile testing** is to determine the **load-bearing capacity, deformability, and toughness of structural materials, as well as to determine material characteristics.**

Type	Cylindrical	Cylindrical	Cylindrical	Plate	Plate
Clamping	Mechanical	Threaded	Hook	Mechanical	Rivet
Geometry					
Clamping					



Tensile testing

Tensile testing



Tensile testing

I. **Elastic deformation phase** (points 0–e)

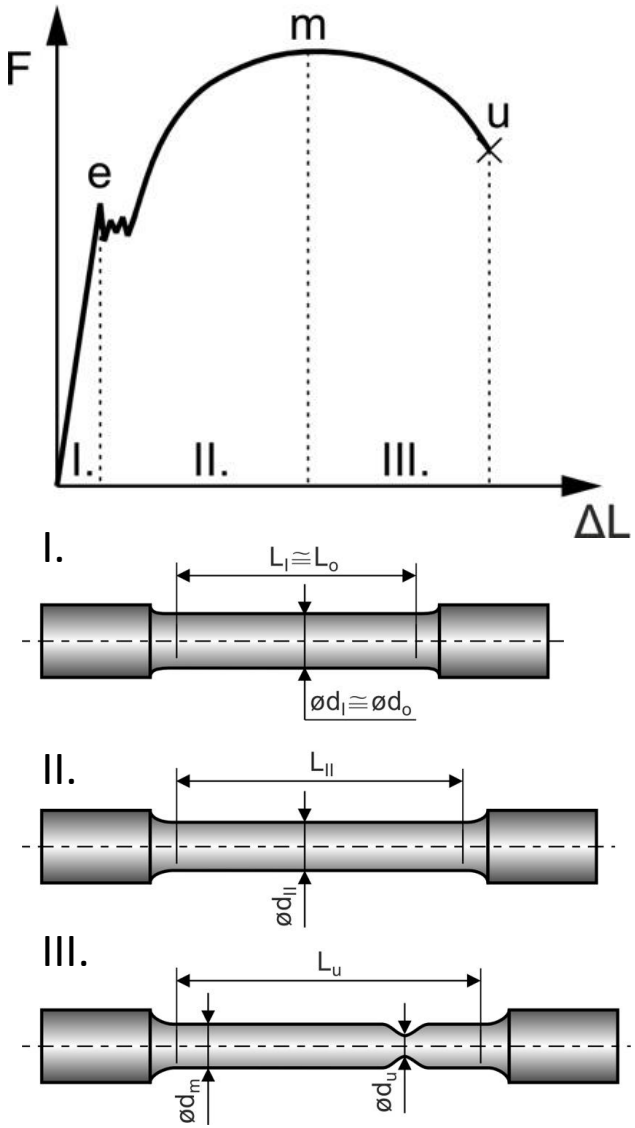
The deformation is completely elastic, meaning that after the load is removed, the piece returns to its original shape.

I. **Uniform plastic deformation phase** (points e–m)

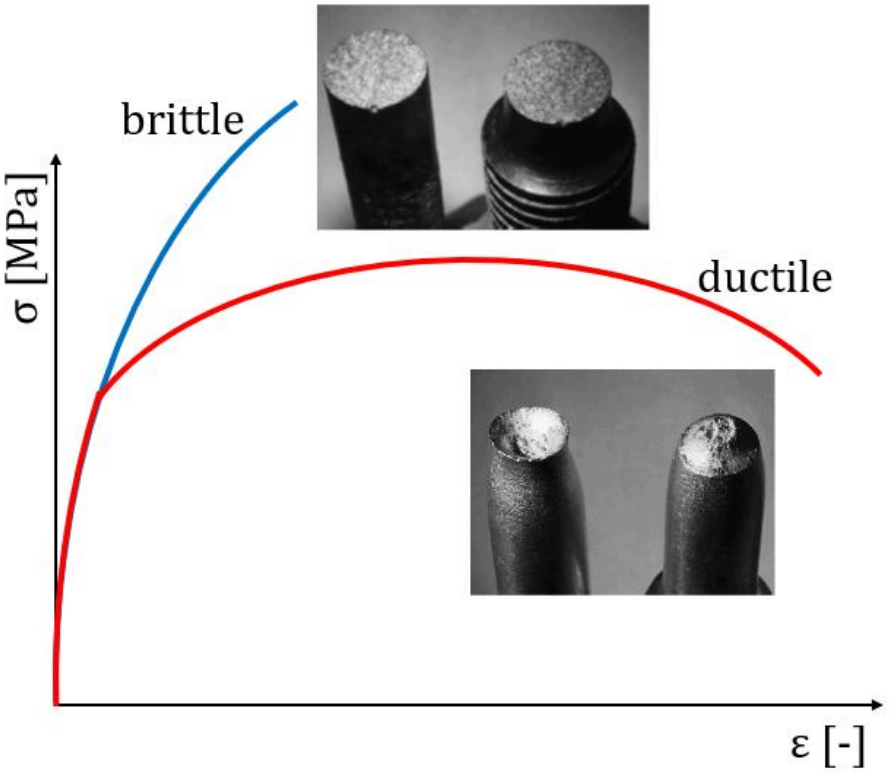
The specimen undergoes plastic (permanent) deformation, but it is uniform over the entire measuring length.

I. **Necking phase** (points m–u)

The plastic deformation becomes localized, while the rest of the test piece no longer deforms, thus initiating neck formation. The fracture occurs at the smallest cross-section of the neck.



Impact testing

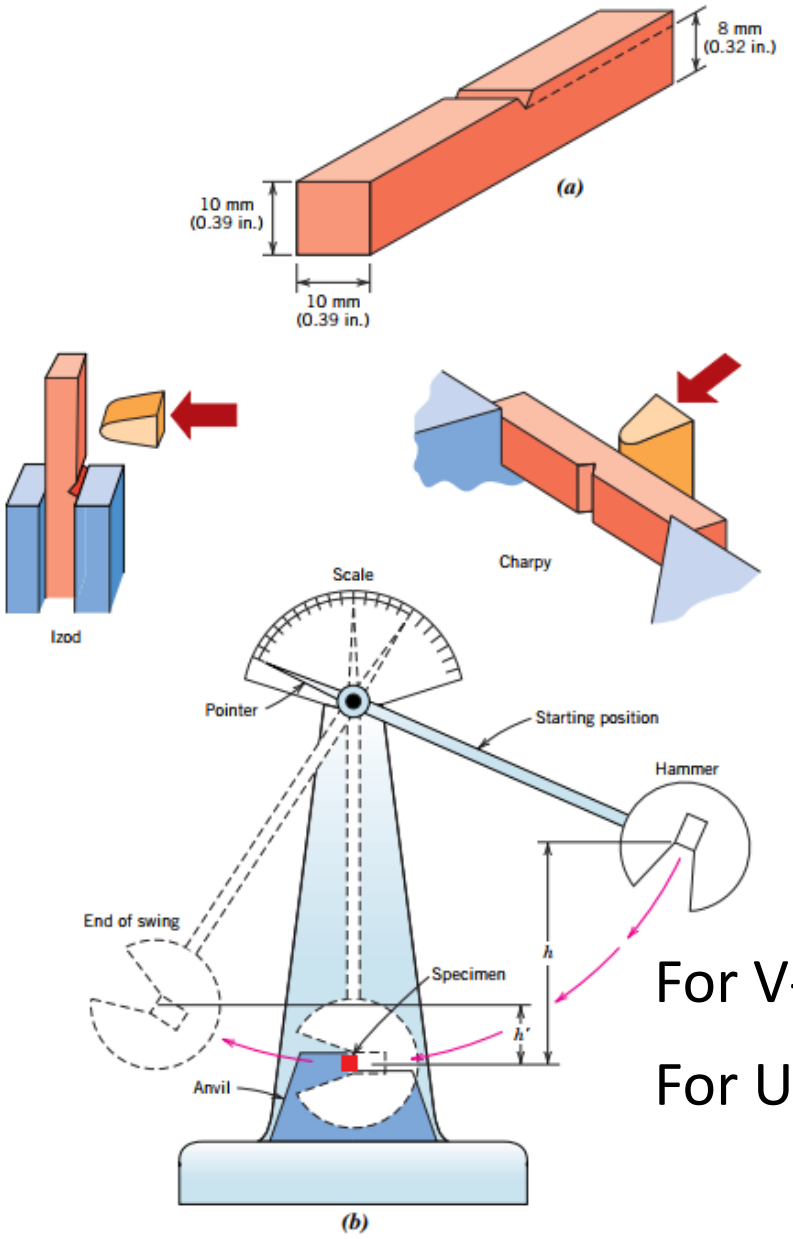


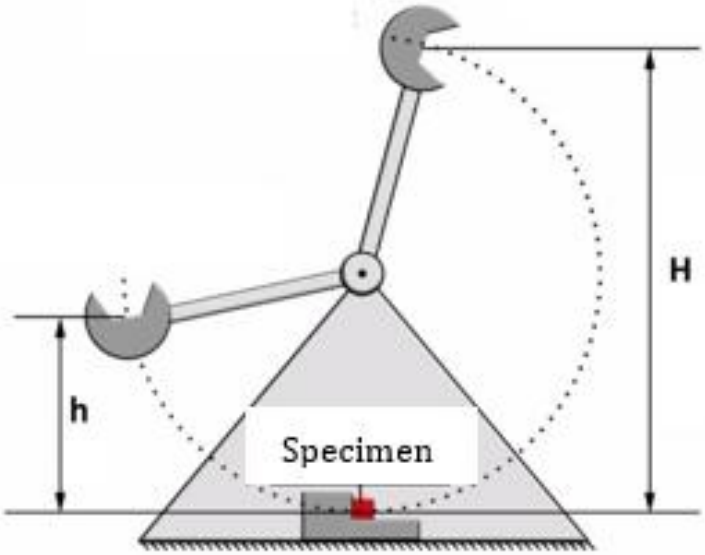
One of the primary functions of the Charpy is to determine whether a material experiences a **ductile-to-brittle transition** with decreasing temperature and, if so, the range of temperatures over which it occurs

Brittle fractures can occur very suddenly as cracks spread rapidly; crack propagation is normally much slower in ductile materials, and the eventual fracture takes longer.

Ductile metals fail after relatively large degrees of permanent deformation - For ductile fracture, this surface appears fibrous or dull (or of shear character),

Impact test



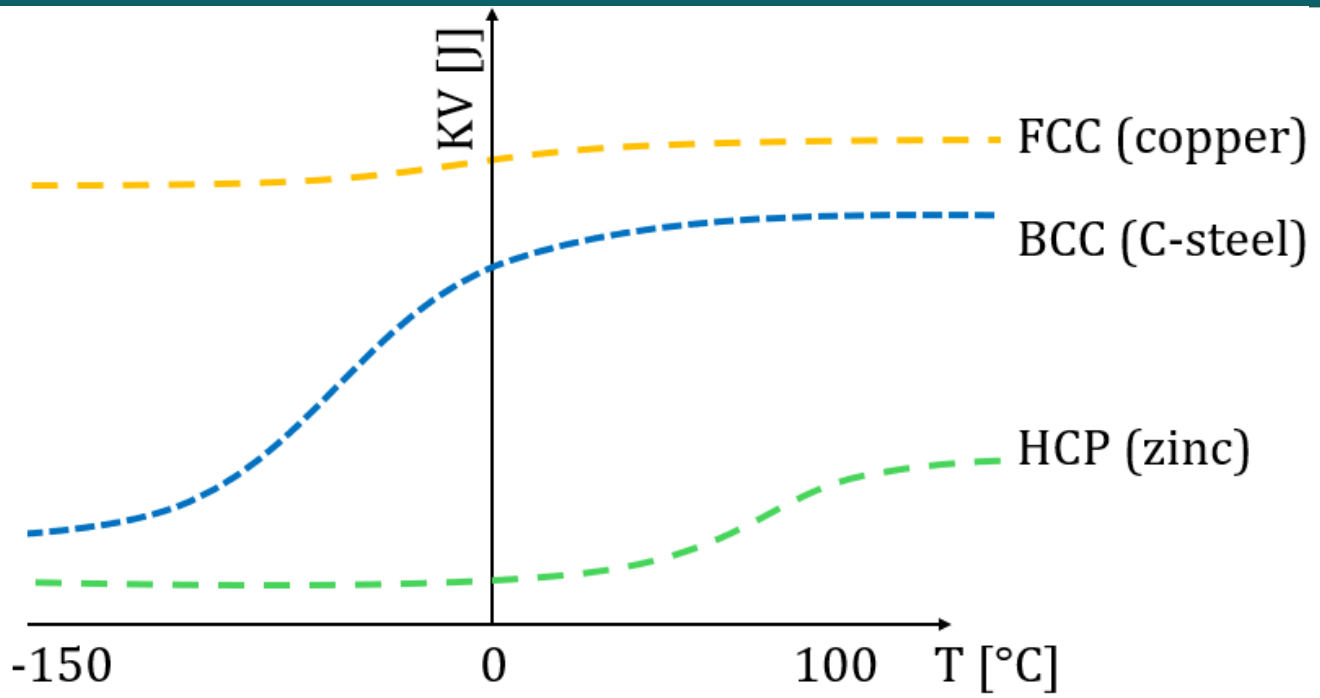


Unit: Joule (J)

For V-notched specimen: $KV = mg(H - h)$

For U-notched specimen: $KU = mg(H - h)$

Impact test

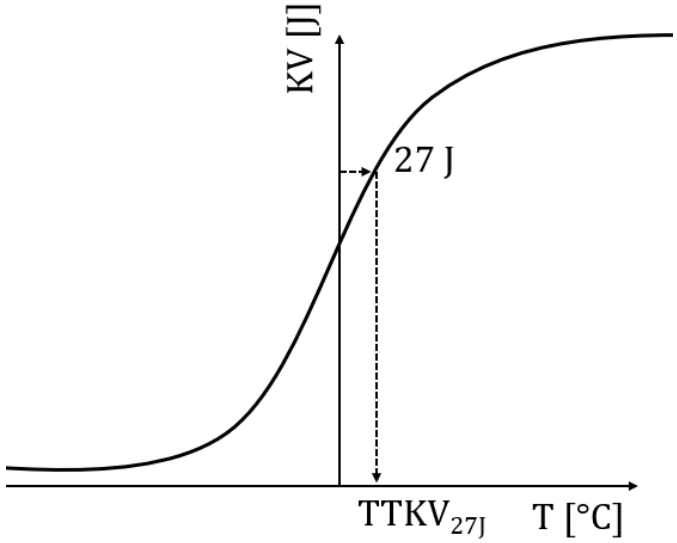


Several methods are used to quantify DBTT:

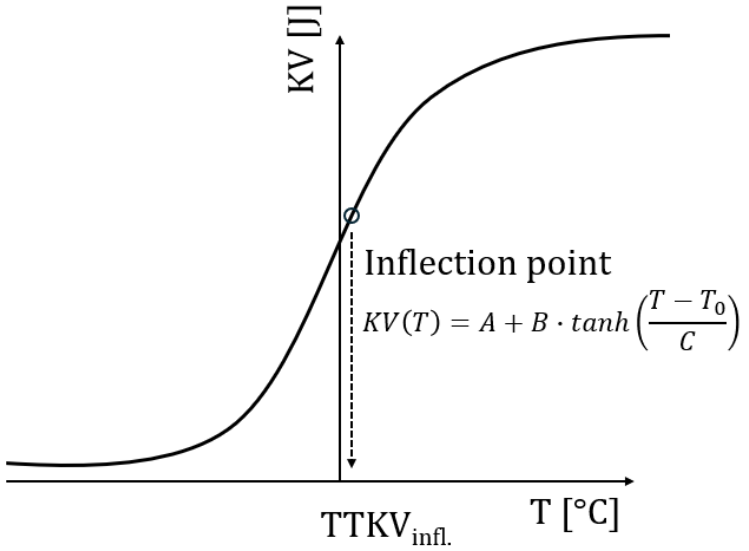
- (I) based on a specified impact energy,
- (II) based on the inflection point,
- (III) based on fracture surface appearance,
- (IV) based on linear expansion.

Impact test

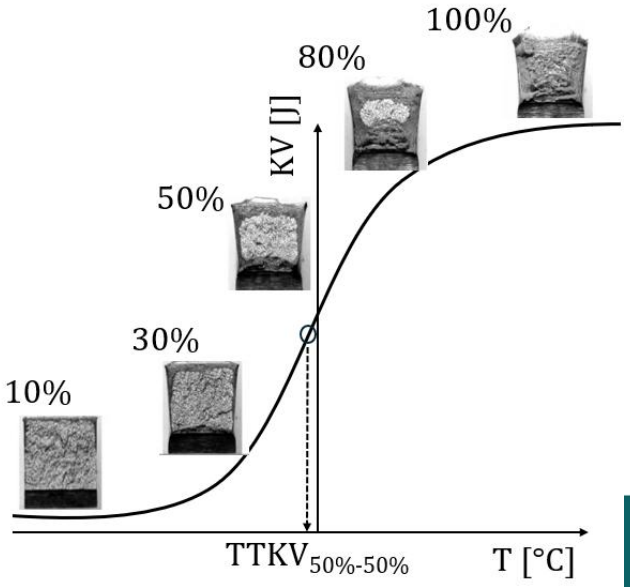
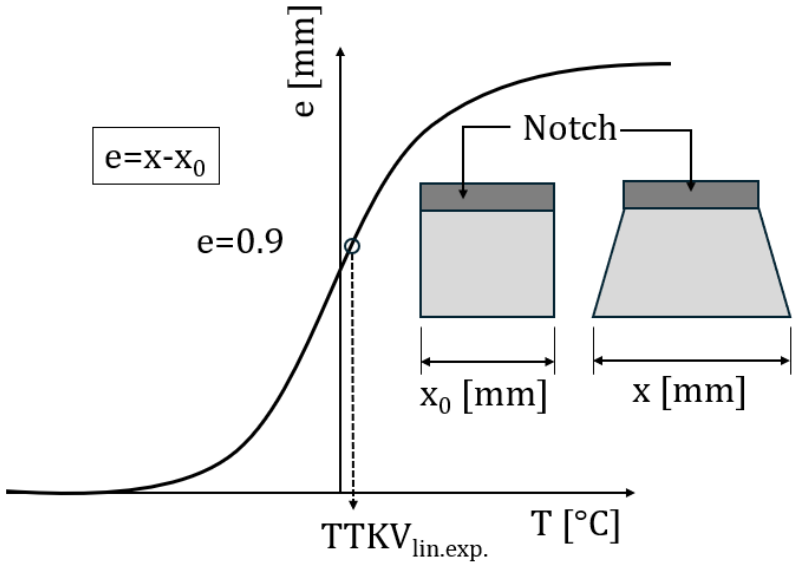
based on a specified impact energy,



based on a infelction point



based on a fracture surface appearance



based on a linear expansion