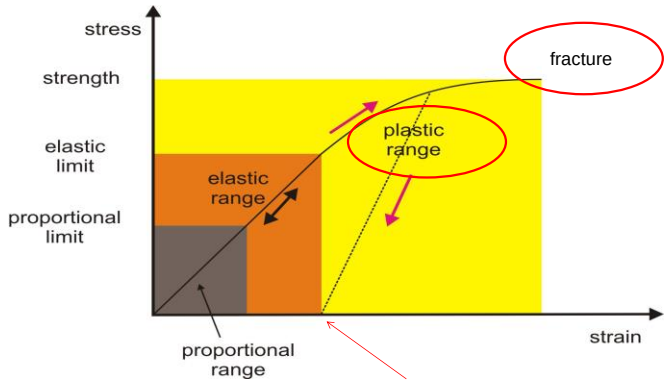
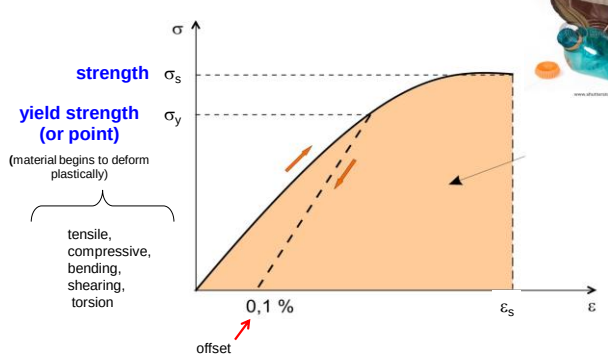
Physical basis of dental material science
8.

Mechanical properties 2.

Stress-strain diagram



Plastic deformation: deformation of a material, non-reversible changes of shape



offset yield point: if there is no well-defined yield point. (offset may be: 0.1, or 0,2% …)

Plastic deformation: deformation of a material, non-reversible changes of shape

Definitions

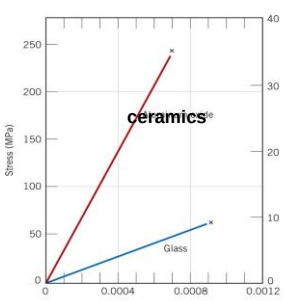
Plasticity is the propensity of a material to undergo permanent deformation.

Ductility is a solid material's ability to deform under tensile stress.

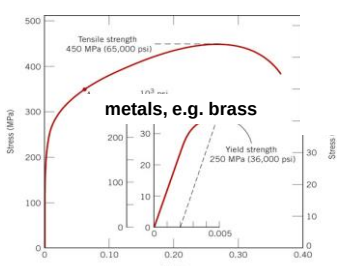
The complementary concept of the stiffness is **flexibility**.

A material is **brittle** if, it breaks without significant deformation.
(brittlenes is opposite of plasticity)

brittle material

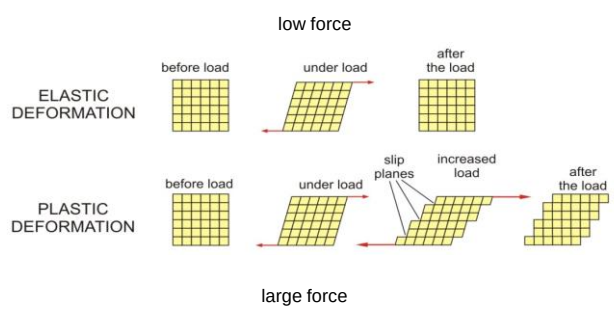


ductile material



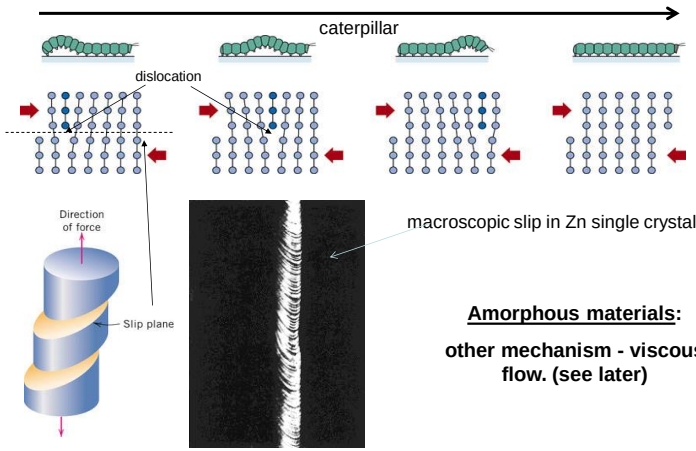
very small strain ⟷ large strain

Mechanism of the deformation in crystals



Plastic deformation: planes are shifted due to the reformed bonds.

Crystals (slip): Slip: plastic deformation due to the dislocation motion.



macroscopic slip in Zn single crystal

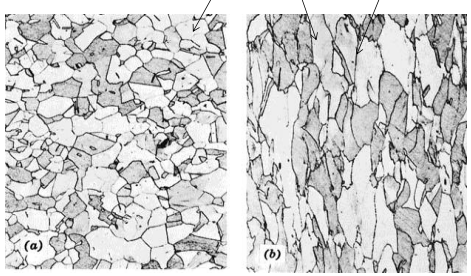
Amorphous materials:

other mechanism - viscous flow. (see later)

9

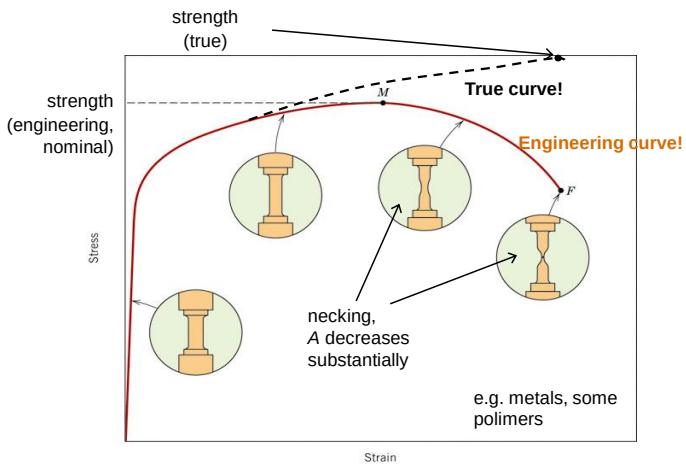
10

Policrystallic materials



11

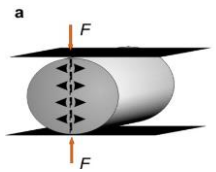
Engineering system vs. „real system”

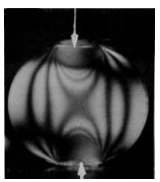


12

Strength measurements

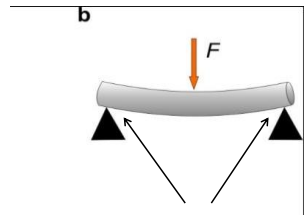
Diametral compressive test





Visualisation of the stress.
(remember:
polarization microscope)

3-point bending test



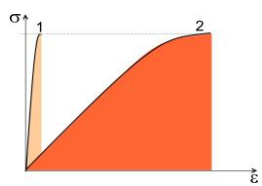
supporting point

Gauge to measure the deflection.

Tensile and compressive strength of some dental materials:

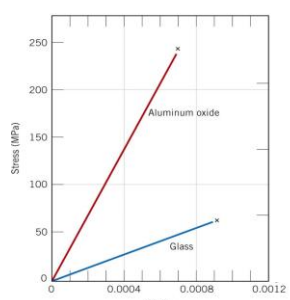
material	$\sigma_{s,\ tensile}$ (MPa)	$\sigma_{s,\ comp}$ (MPa)
Enamel	≈ 10	≈ 400
dentine	≈ 110	≈ 300
Amalgam	30-55	200-450
gold	108	
Gold alloys	300-900	
Pd-Ag alloys	400-700	
Co-Cr alloys	600-800	
Ni-Cr alloys	400-900	
Glass	≈ 70	≈ 700
Ceramics	5-400	20-5000
Porcelain	≈ 25	≈ 300
PMMA (polimethyl methacrylate)	≈ 50	≈ 80

Strength ↔ toughness:

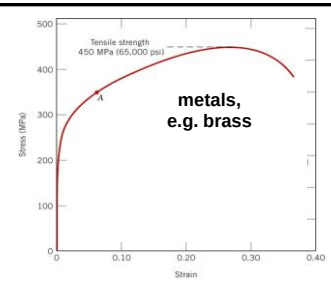


Plastic material more tough
if the strength are same.

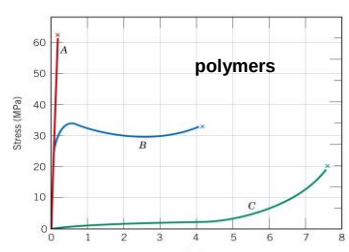
examples:



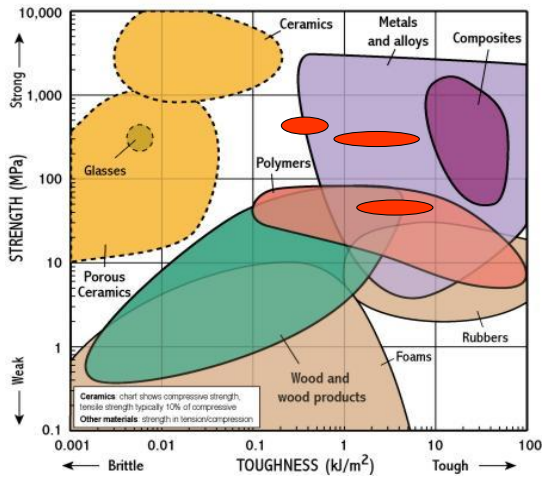
ceramics



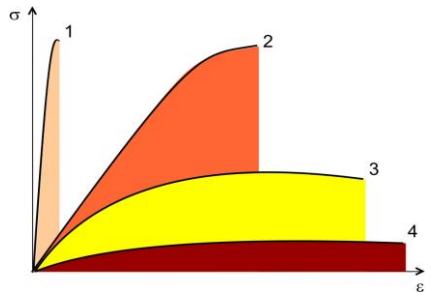
metals,
e.g. brass



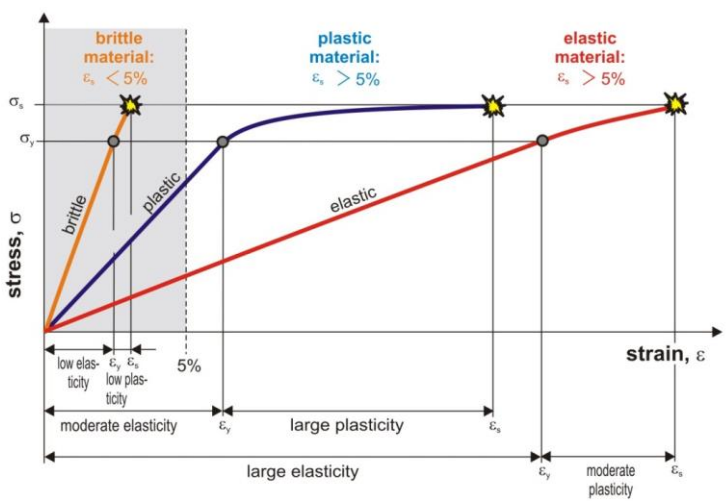
polymers



Summary of different properties

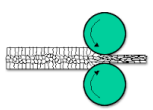


1) *rigid (brittle), strength (strong), small toughness, brittle*
2) *flexible, stiff (strong), tough*
3) *ductile, medium strength, tough*
4) *ductile, small strength(weak), small toughness*



Modifying mechanical properties

Cold working
(work-hardening)



Effect:
increase of dislocations

Alloying

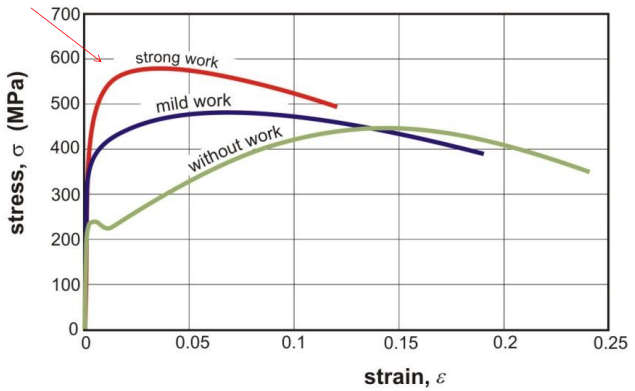
Alloy	Composition
Brass	Copper, Zinc
Bronze	Copper, Zinc, Tin
Steel	Iron, Carbon (plus small amounts of other elements)
Stainless Steel	Iron, Chromium, Nickel

Dentistry
(examples)

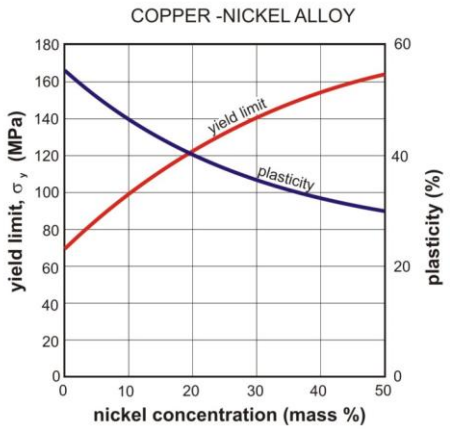
Titanium alloys
Nickel chromium
Cobalt chromium

Cold-working

higher yield strength



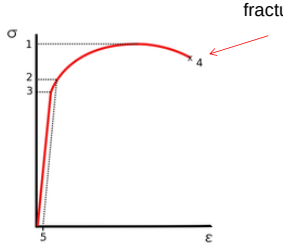
Alloying



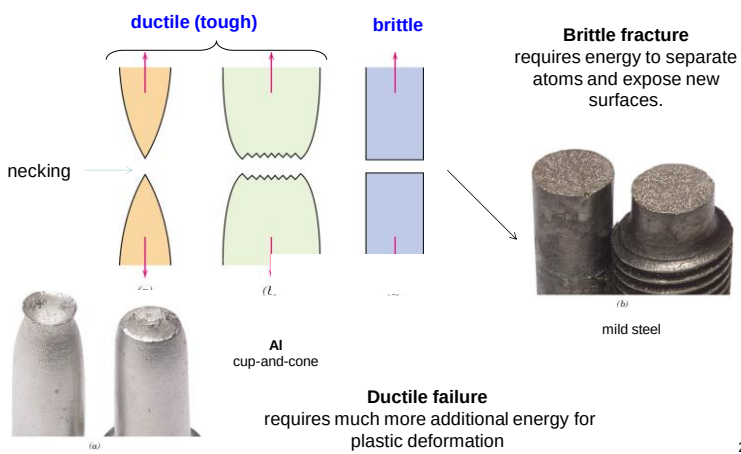
Fracture

A **fracture** is the separation of an object or material into two or more pieces.

fracture strength



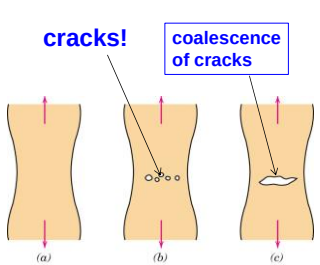
Fracture



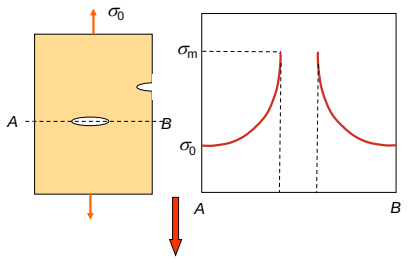
Brittle fracture
requires energy to separate atoms and expose new surfaces.

Ductile failure
requires much more additional energy for plastic deformation

ductile (tough)



propagation

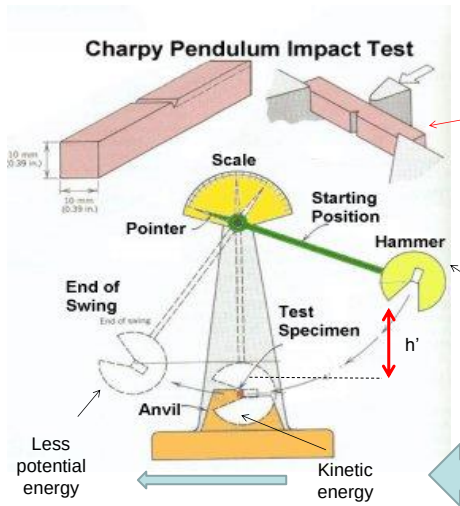


Increasing stress

elastic deformation — **ductile fracture**

No deformation — **brittle fracture**

Impact test



Quantities

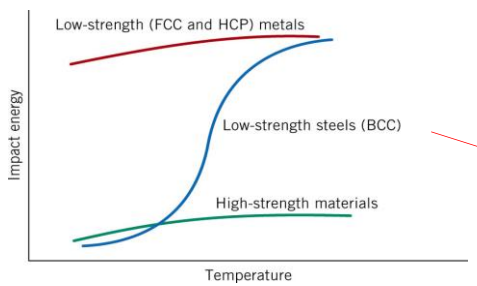
$E_{pot} = mgh'$

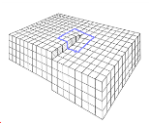
Impact energy:
the gravitational energy loss of the hammer (J)

Specific impact energy:
impact energy/cross-section of the specimen (J/m²)

ductile – brittle transition

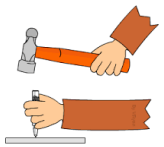
BCC: body-centered cubic
FCC: face-centered cubic
HCP: hexagonal closed packed





(screw dislocations are temperature sensitive)

Hardness of a material



Applying same force!

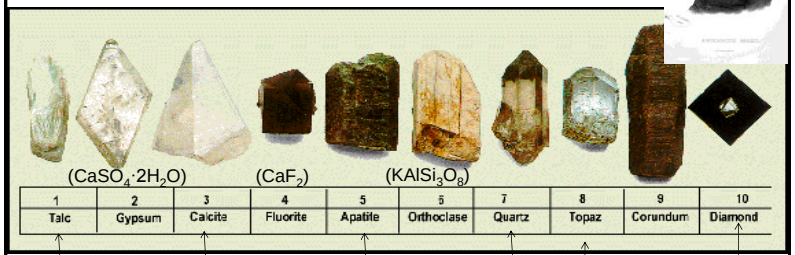
Compare metals and plastics!
How much is the size of the hole?

Practically there is no hole in steel!

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied.

Hardness

Mohs scale:



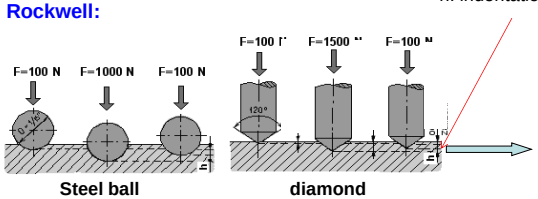
$(Mg_3Si_4O_{10}(OH)_2)$ $(CaCO_3)$ $(Ca_5(PO_4)_3(OH\text{-},Cl\text{-},F\text{-}))$ (SiO_2) $(Al_2SiO_4(OH\text{-},F\text{-})_2)$ (Al_2O_3) (C)

Several measuring method:

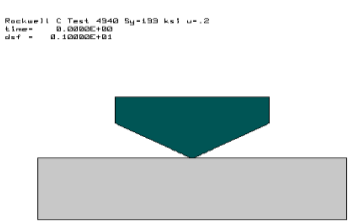
- Rockwell
- Brinell
- Vickers
- Knoop
- Barcol
- Shore

Rockwell:

h: indentation in the material

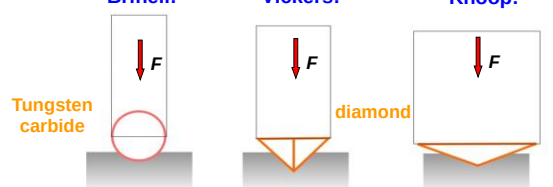


HR – Rockwell hardness



Microindentation hardness tests

Brinell: **Vickers:** **Knoop:**

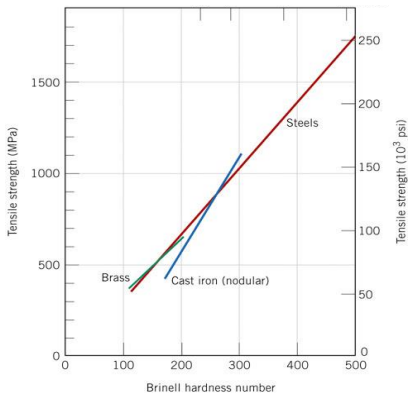


$H = \frac{F}{A}$ (Pa)

HB **HV** **HK**

33

Relationship to other quantites:



HB

hardness

Elastic limit

34

Hardness of some dental materials:

material	*HV* (MPa)	*HK* (MPa)
Enamel	≈ 3400	3400-4000
Dentin	≈ 600	≈ 700
Amalgam	≈ 1000	
Gold		60-70
gold alloys	600-250	≈ 2000
Pd-Ag alloys	1400-1900	
Co-Cr alloys	≈ 4000	3000-4500
Ni-Cr alloys	3000-4000	2000-3500
Glass		≈ 5000
Porcelain	4500-7000	≈ 6000
acrilate	≈ 200	≈ 200

35