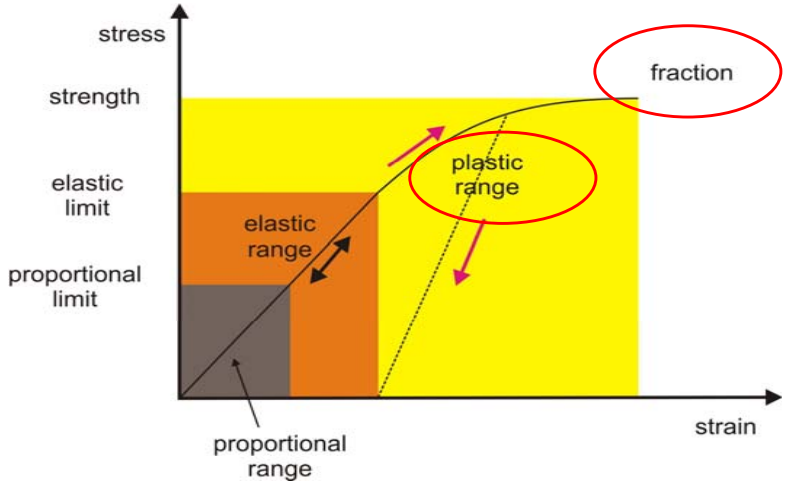
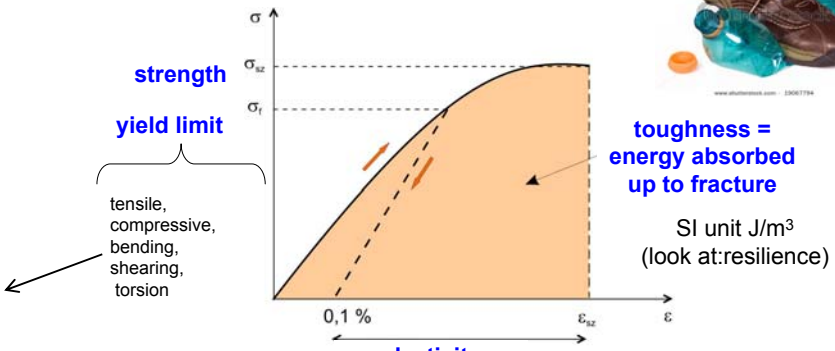
Physical basis of dental material science 8.

Mechanical properties 2.

Stress-strain diagram



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



toughness = energy absorbed up to fracture

SI unit J/m³
(look at:resilience)

Ductility: the extent in which solid materials can be plastically deformed without fracture.

Compressibility: measure of the relative volume change of a solid as a response to a stress change .

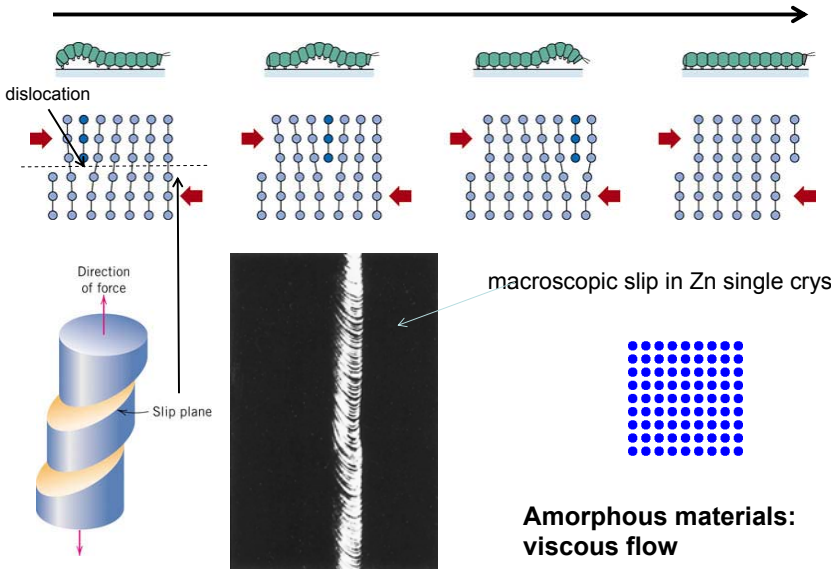
flexibility:

...

brittleness

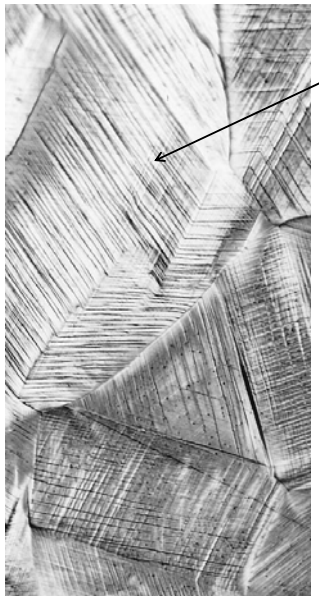
(the quality of being brittle)

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



macroscopic slip in Zn single crystal

Amorphous materials: viscous flow

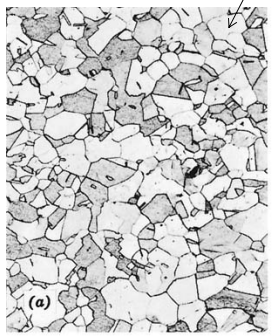


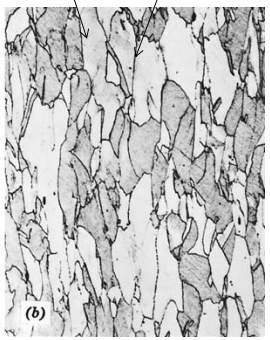
Slip lines
(copper policrystal)

Policrystallic
materials

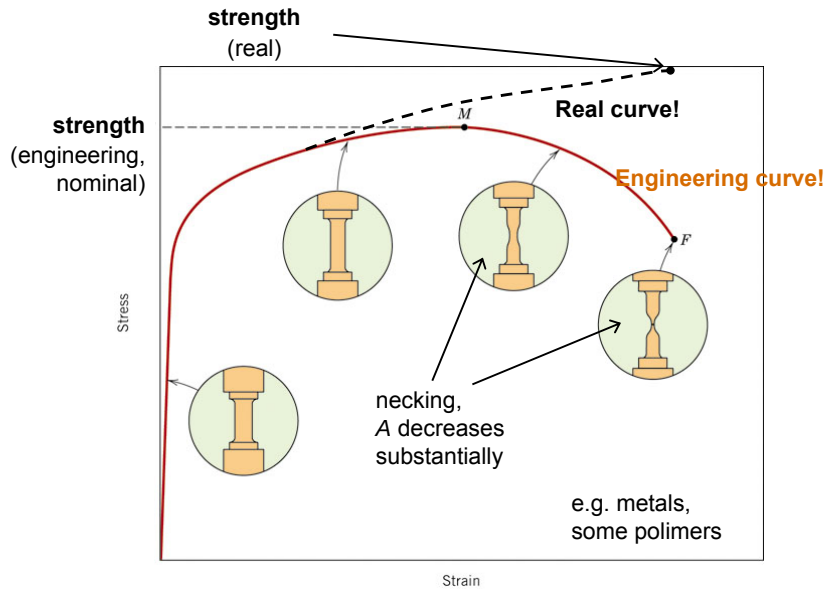
grains

grain boundary



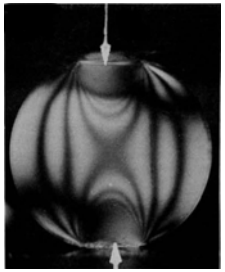


Engineering system vs. „real system”

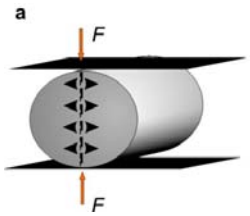


Strength measurements

Optical observation of stresses

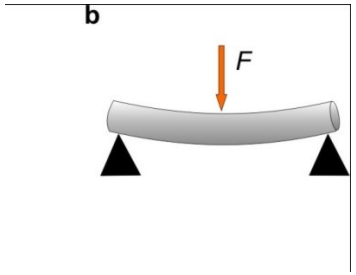


Diametral compressive test



3-point bending test

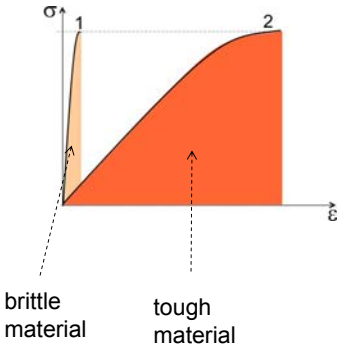
(provides values for the modulus of elasticity in bending)



Tensile and compressive strength of some dental materials:

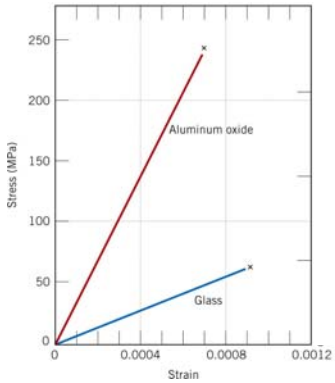
material	$\sigma_{s,\ tensile}$ (MPa)	$\sigma_{s,\ comp}$ (MPa)
Enamel	≈ 10	≈ 400
dentine	≈ 110	≈ 300
Amalgam	30-55	200-450
gold	108	
Gold alloys	300-900	
Pd-Ag alloys	400-700	
Co-Cr alloys	600-800	
Ni-Cr alloys	400-900	
Glass	≈ 70	≈ 700
Ceramics	5-400	20-5000
Porcelain	≈ 25	≈ 300
PMMA (polimethyl methacrylate)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

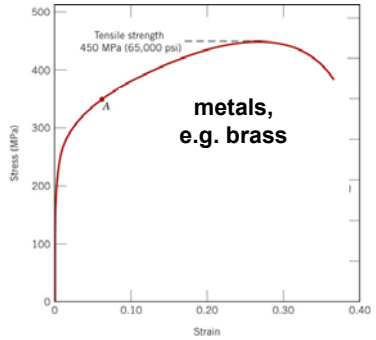
Strength ↔ toughness:



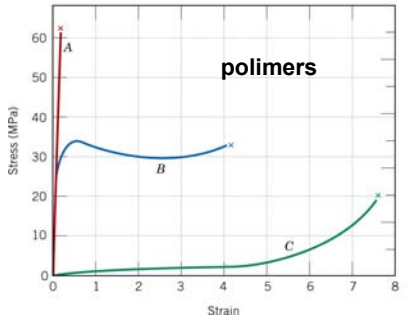
examples:

ceramics



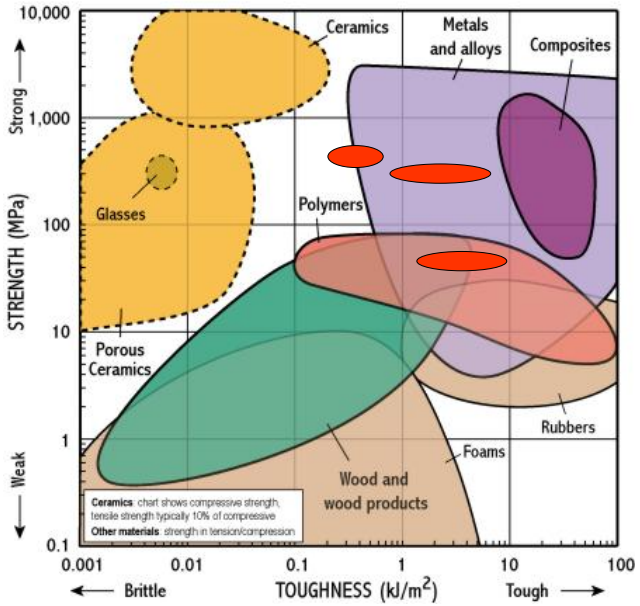


metals, e.g. brass

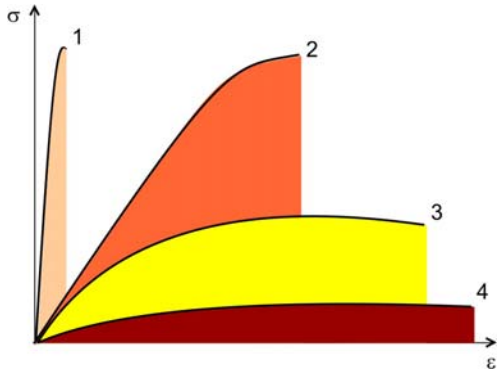


polimers

A: brittle
B: plastic
C: highly elastic



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*

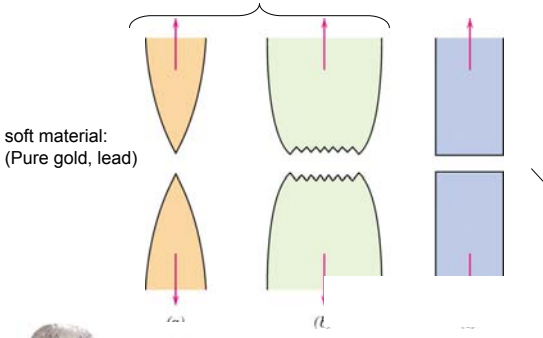
Fracture

ductile (tough)

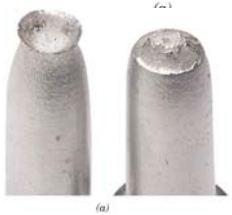
before fracture plastic deformation

Brittle
(no plastic deformation)

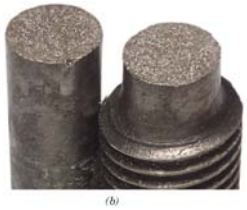
soft material:
(Pure gold, lead)



Al
cup-and-cone



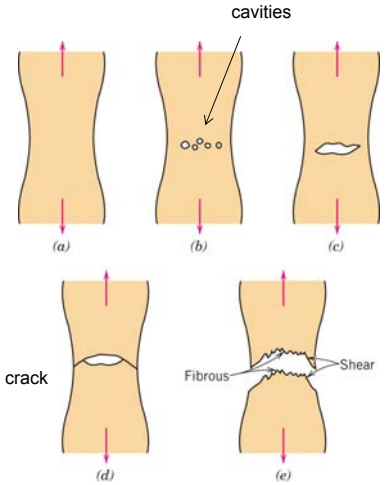
Brittle fracture requires energy to separate atoms and expose new surfaces.



mild steel

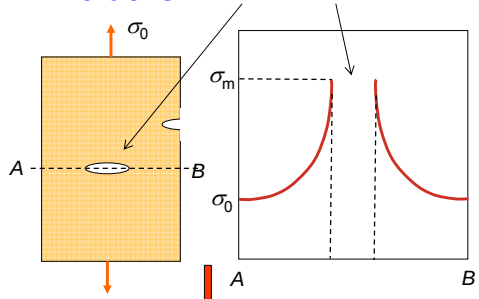
Ductile failure requires much more additional energy for plastic deformation.

ductile (tough)



cracks!

Stress concentrated here



Increasing stress

elastic deformation

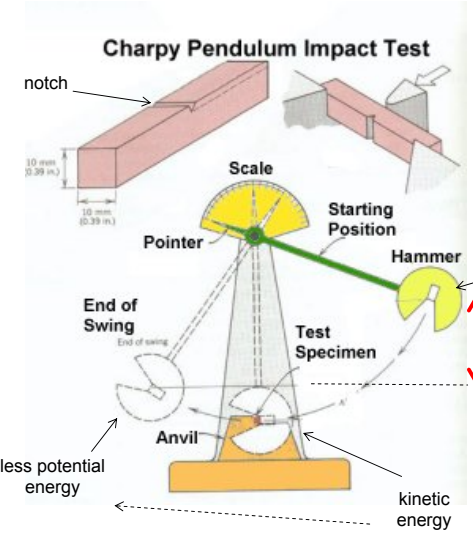
ductile fracture

No deformation

brittle fracture

Impact test

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

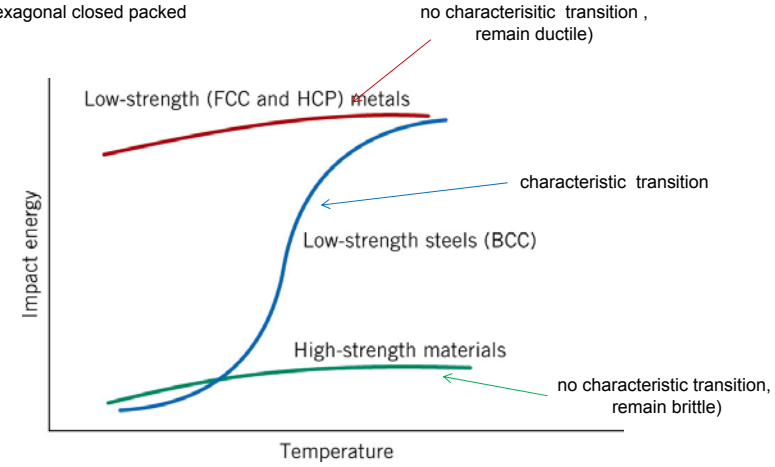


Specific impact energy:

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

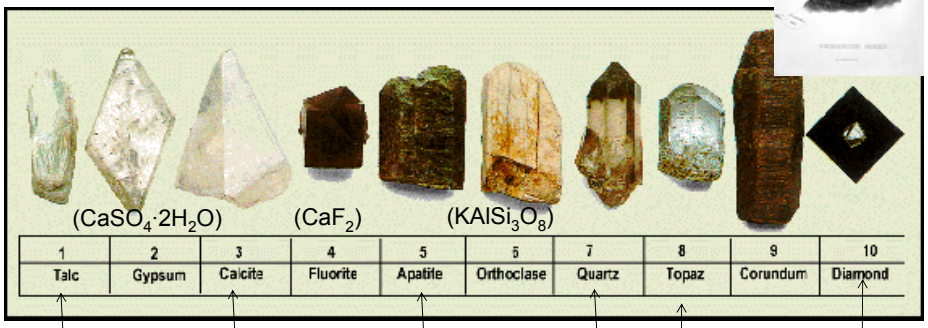
ductile – brittle transition

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



Hardness (the measure of how resistant solid matter is to various kinds of permanent shape change)

Mohs scale: (characterizes the scratch resistance of various minerals)

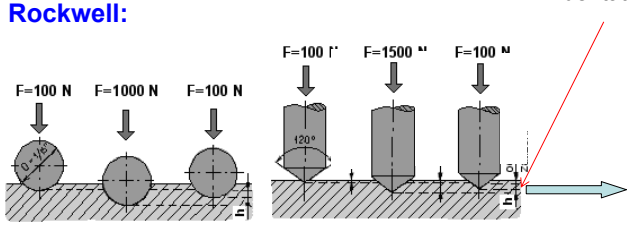


Several measuring method:

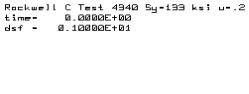
- Rockwell
- Brinell
- Vickers
- Knoop
- Barcol
- Shore

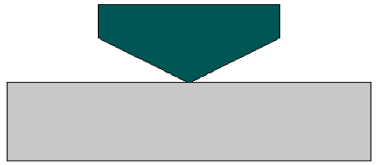
h: indentation in the material

Rockwell:



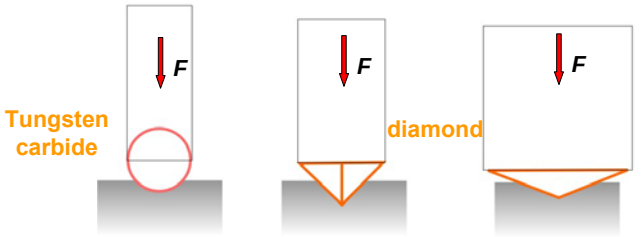
HR – Rockwell hardness



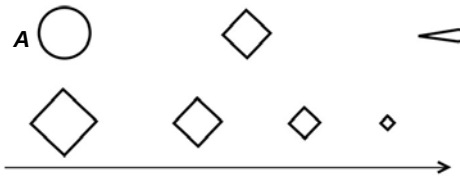


Microindentation hardness tests

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



Tip (pyramid shape)



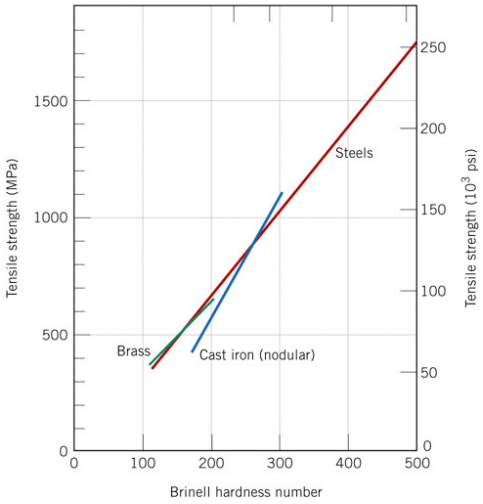
intender

Increasing Vickers-hardness (HV)

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

HB **HV** **HK**

Relationship to other quantites:



HB

hardness

Elastic limit

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