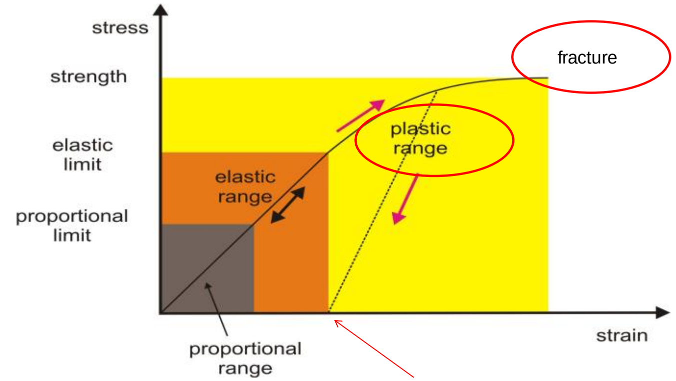
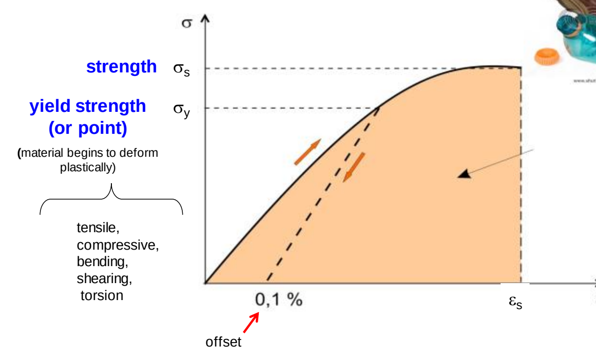
Physical basis of dental material science 8.

Mechanical properties 2.

Stress-strain diagram

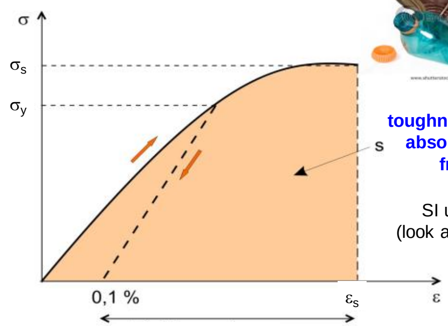


Plastic deformation: deformation of a material, non-reversible changes of shape



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



toughness = energy absorbed up to fracture

SI unit J/m^3
(look at:resilience)

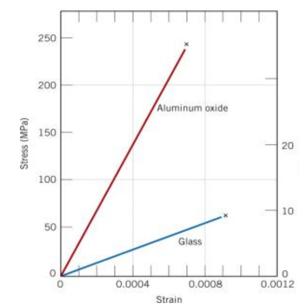
plasticity

ductility, compressibility, flexibility, ...

brittleness

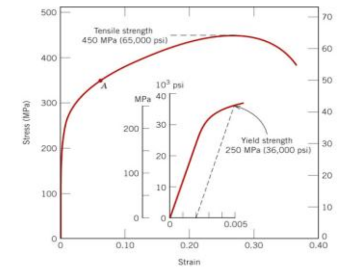
brittle material

ceramics

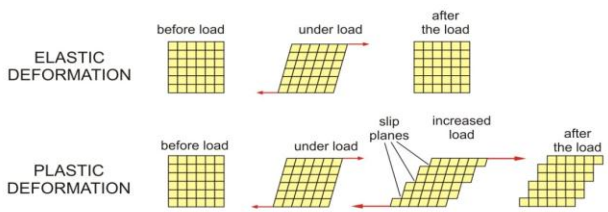


ductile material

metals, e.g. brass



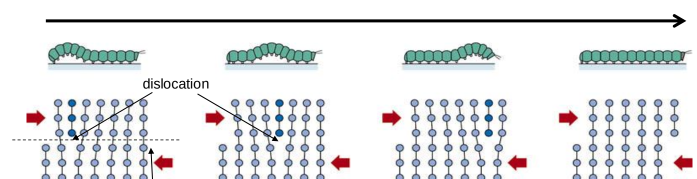
Mechanism of the deformation in crystals

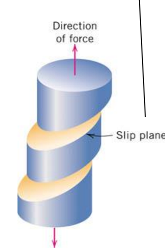


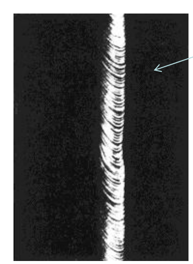
Plastic deformation: planes are shifted due to the reformed bonds.

Crystals (slip):

Slip: plastic deformation due to the dislocation motion.



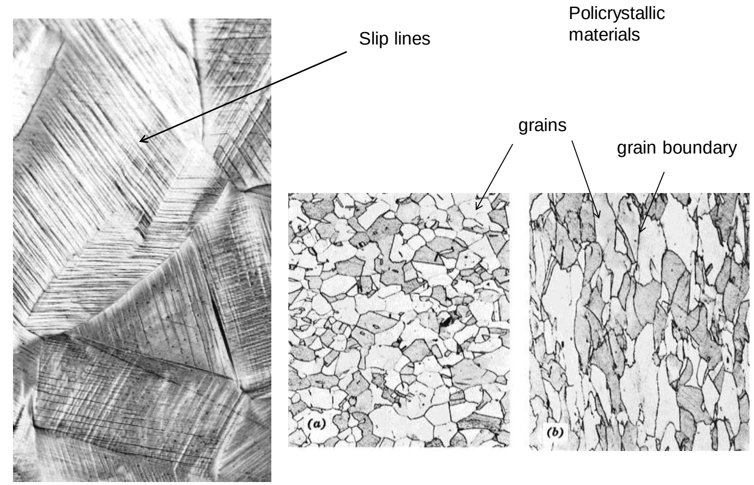




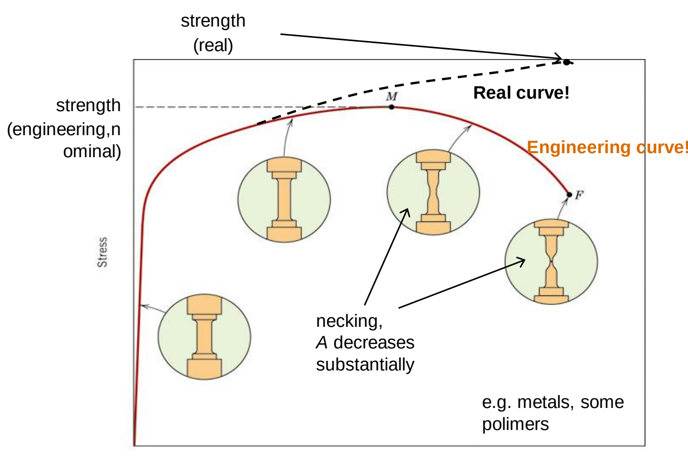
macroscopic slip in Zn single crystal

Amorphous materials:

other mechanism - viscous flow. (see later)

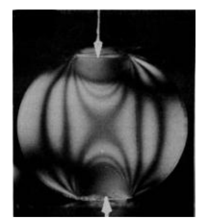


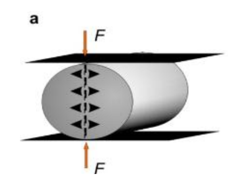
Engineering system vs. „real system”



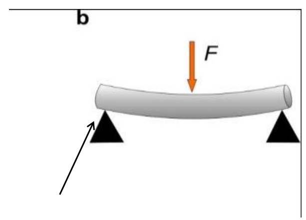
Strength measurements

Diametral compressive test





3-point bending test

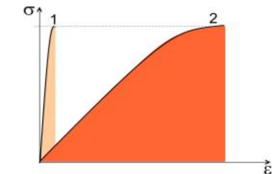


support point

Tensile and compressive strength of some dental materials:

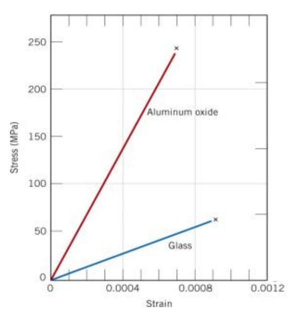
material	$\sigma_{s,\,tensile}$ (MPa)	$\sigma_{s,\,comp}$ (MPa)
Enamel	≈ 10	≈ 400
dentine	≈ 110	≈ 300
Amalgam	30-55	200-450
gold	108	
Gold alloys	300-900	
Pd-Ag alloys	400-700	
Co-Cr alloys	600-800	
Ni-Cr alloys	400-900	
Glass	≈ 70	≈ 700
Ceramics	5-400	20-5000
Porcelain	≈ 25	≈ 300
PMMA (polimethyl methacrylate)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

Strength ↔ toughness:

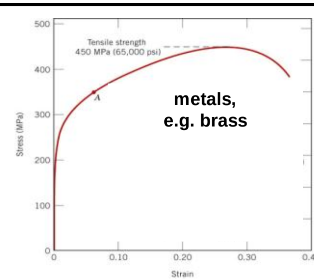


Plastic material more tough if the strength are same.

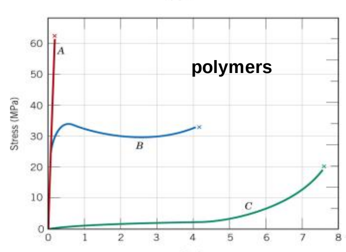
examples:



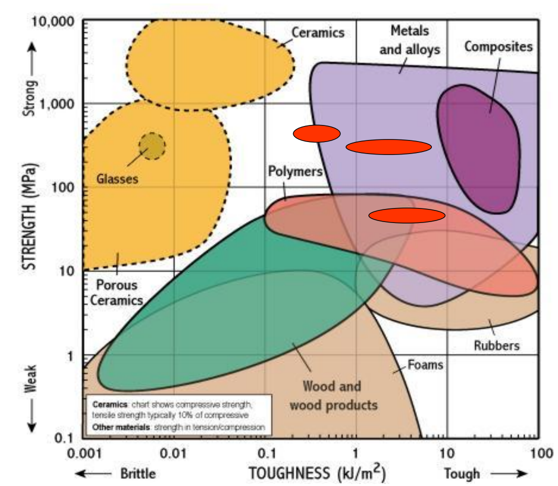
ceramics



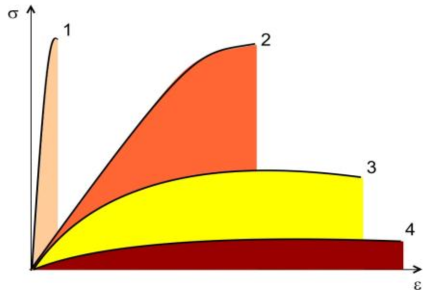
metals, e.g. brass



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*

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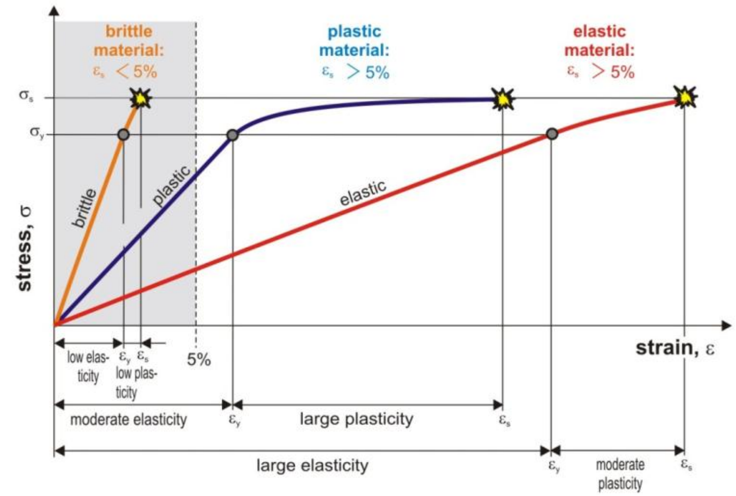
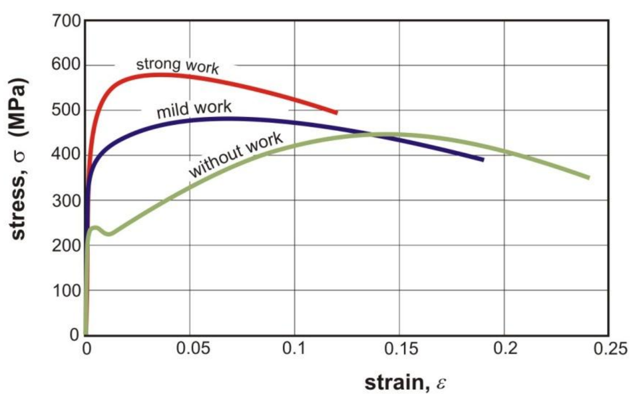


Cold-work



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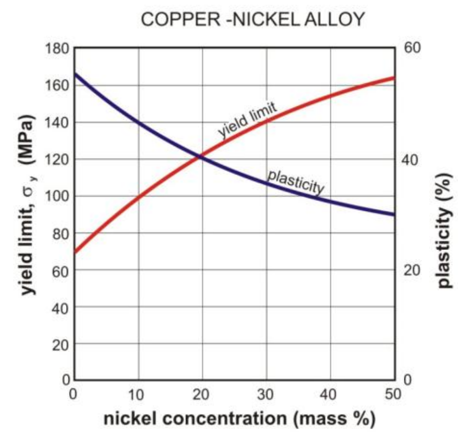
Alloying



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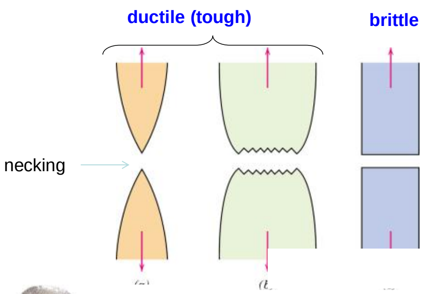
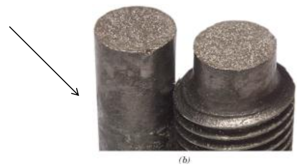
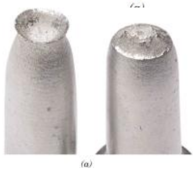
Fracture



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



mild steel



Al
cup-and-cone

Ductile failure
requires much more additional energy for plastic deformation

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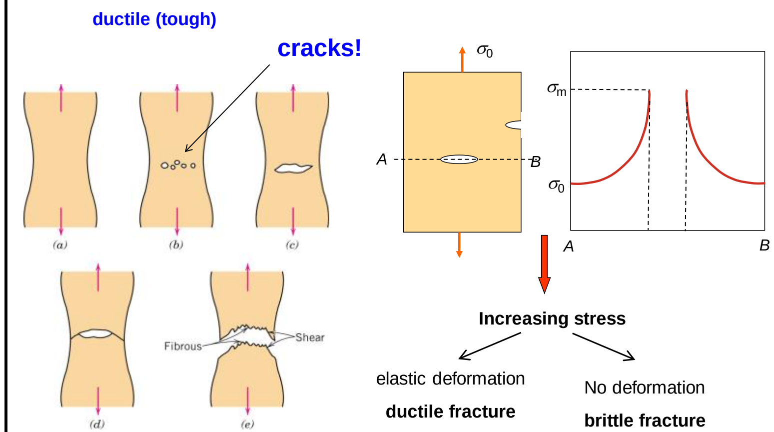

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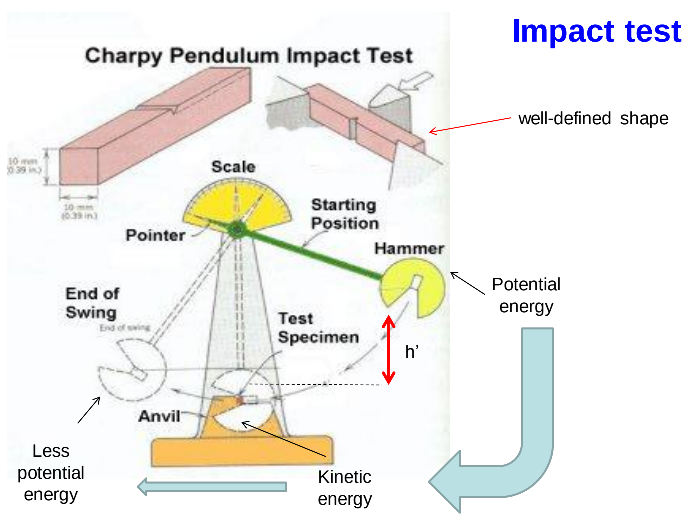
Impact test



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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/m^2)

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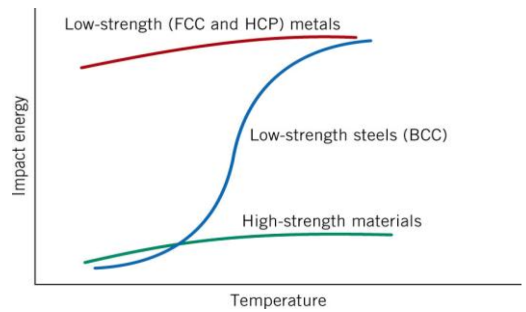
ductile – brittle transition

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



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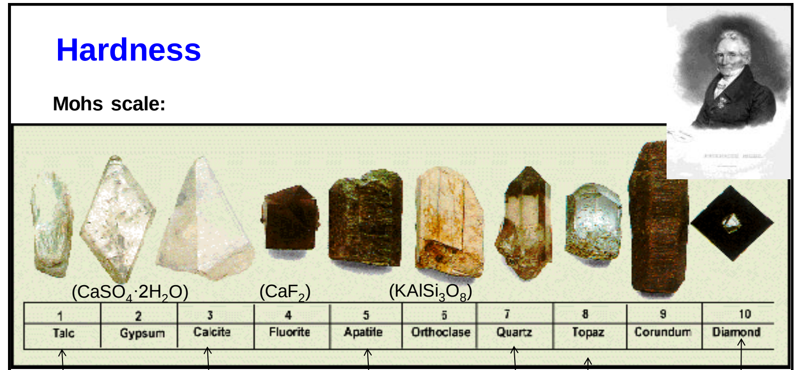
Hardness

Mohs scale:



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

Several measuring method:

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

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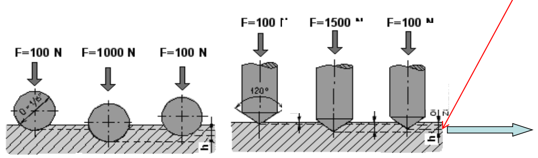
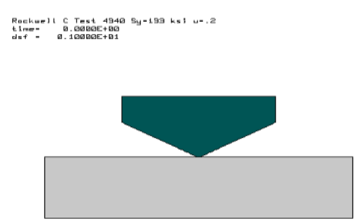
Rockwell:

h: indentation in the material



Steel ball diamond

HR – Rockwell hardness



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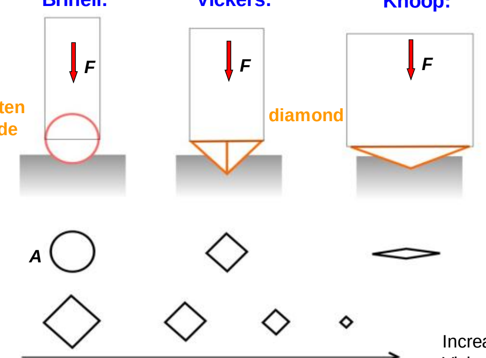
Microindentation hardness tests

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



Increasing Vickers-hardness (HV)

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

HB **HV** **HK**

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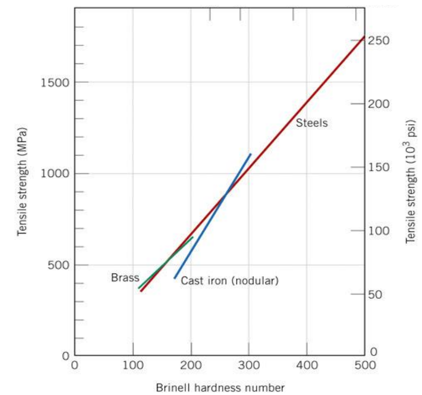
Relationship to other quantites:



HB

hardness

↕

Elastic limit

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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

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