

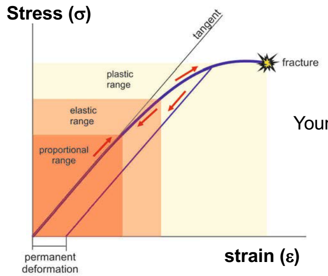

Physical Foundations of Dental Materials Science 8.

Mechanical properties of materials 2.
Plasticity

Kiemelt témák:
- *Strength*, plasticity and tougness
- Mechanism of plastic deformation in crystals
- Fractures
- Hardness

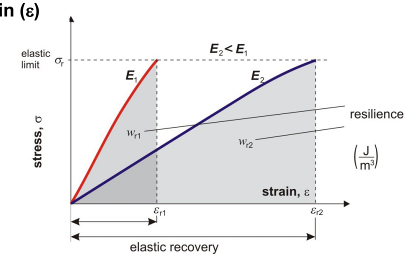
E-book chapter 16, 17.

Problems: Chapter 4.: 26, 27, 29, 30, 32, 33, 34, 36

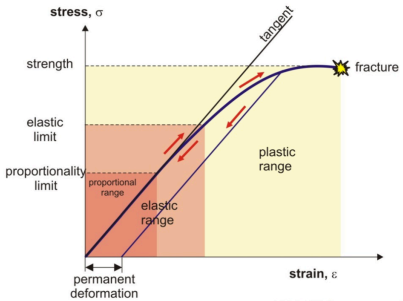


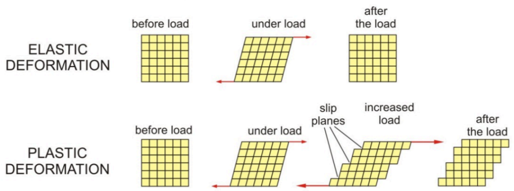
Young's modulus

Resilience

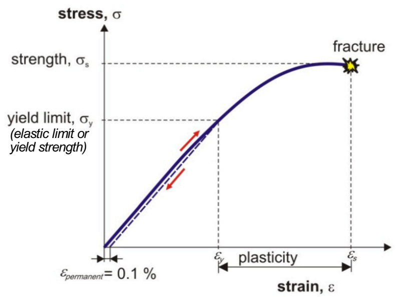


Stress - strain diagram





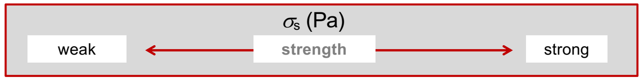
Plastic behavior



yield limit, σ_y (Pa)

strength, σ_s (Pa)
- tensile,
- compressive,
- bending,
- shear,
- torsional

plasticity, $\varepsilon_s - \varepsilon_y$ (%)

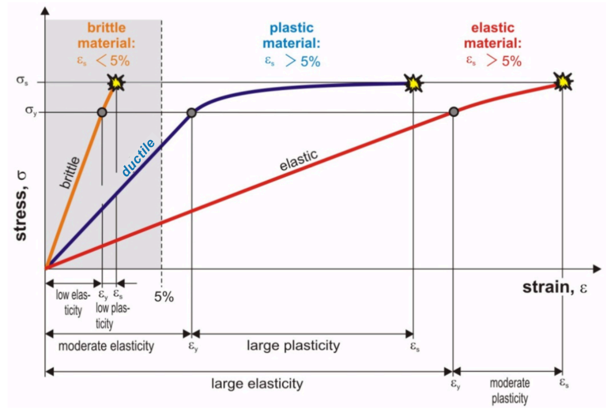


Strength of some dental materials

material	$\sigma_{tensile}$ (MPa)	$\sigma_{comp.}$ (MPa)
enamel	≈ 10	≈ 400
dentine	≈ 110	≈ 300
ceramics	5-400	20-5000
porcelain	≈ 25	≈ 300
polyethylene (high density)	≈ 30	
amalgam	30-55	200-450
PMMA	≈ 50	≈ 80
glass	≈ 50-70	≈ 700
gold	108	
aluminum oxide	≈ 170	≈ 2100
zirconium dioxide	≈ 250	≈ 2500
gold alloys	300-900	
Pd-Ag alloys	400-700	
Ni-Cr alloys	400-900	
Co-Cr alloys	600-800	
Ti alloys	900-1100	
carbon-fiber (61%) reinforced epoxy	≈ 1700	

5

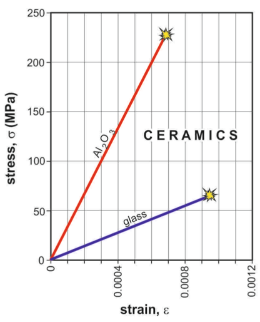
5

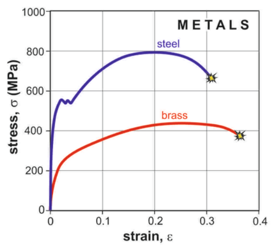


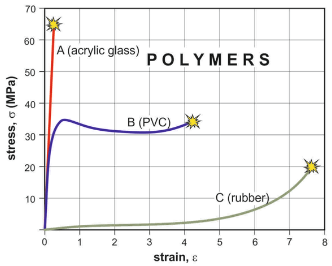
6

6

Examples:



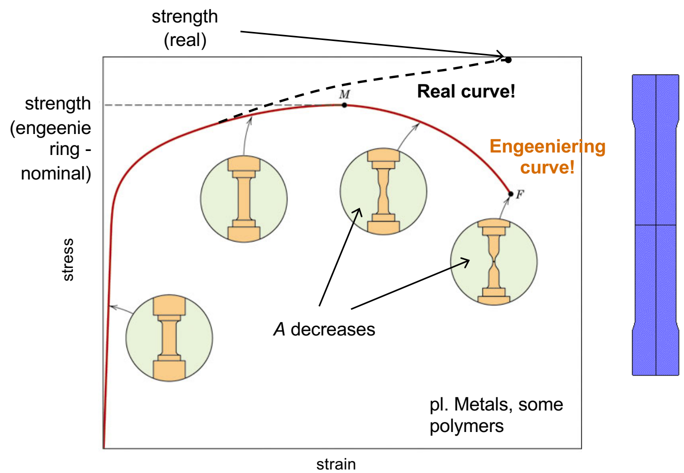




7

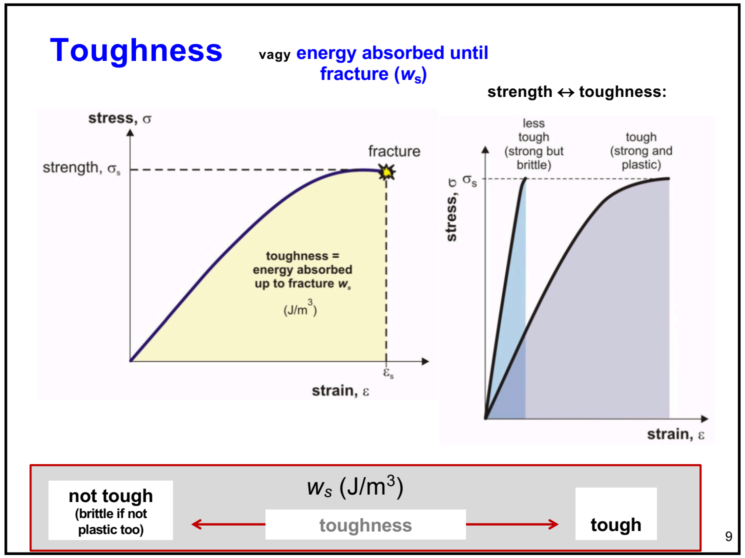
7

Engenieering vs. „real” system

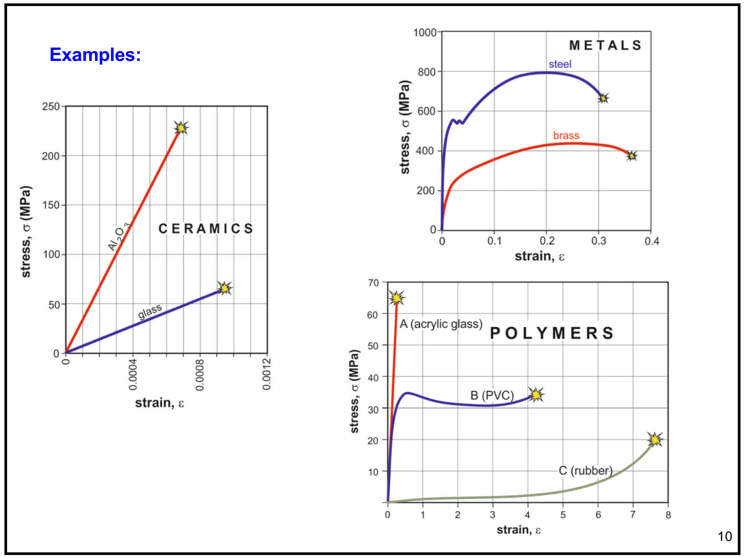


8

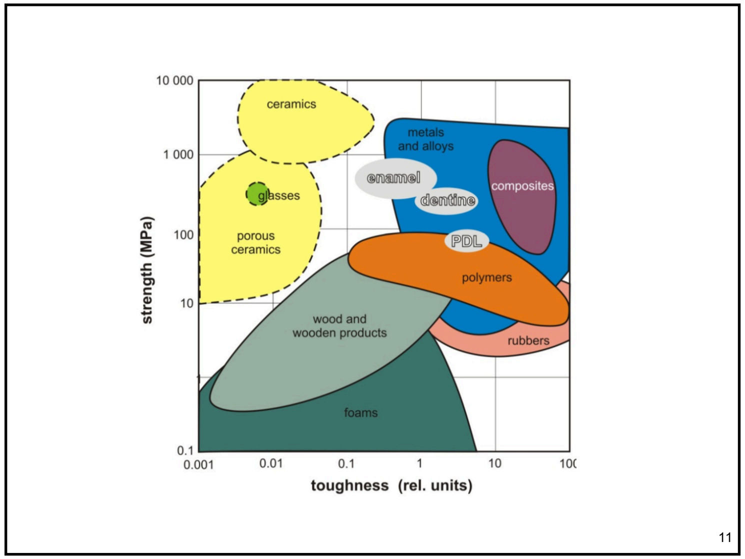
8


Toughness
vagy energy absorbed until fracture (w_s)
strength ↔ toughness:
stress, σ
strength, σ_s
fracture
toughness = energy absorbed up to fracture w_s
(J/m^3)
ε_s
strain, ε
less tough (strong but brittle)
tough (strong and plastic)
stress, σ
σ_s
strain, ε
not tough
(brittle if not plastic too)
w_S (J/m^3)
toughness
tough
9

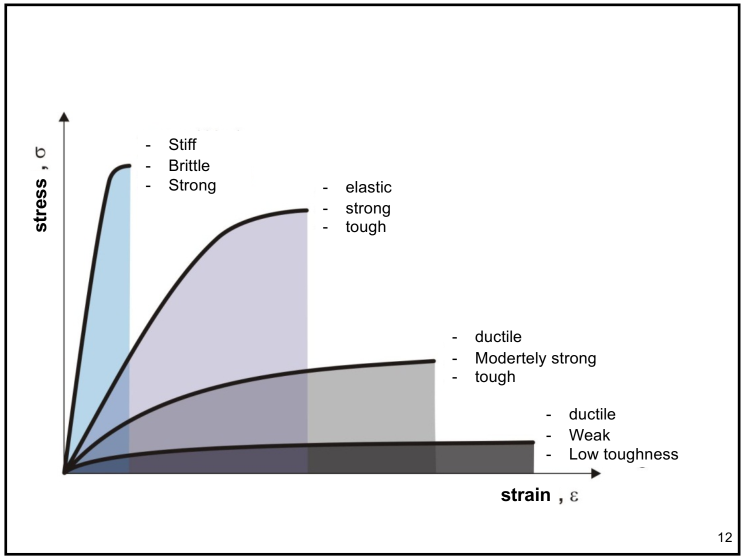
9


Examples:
stress, σ (MPa)
250
200
150
100
50
0
Al_2O_3
glass
CERAMICS
0
0.0004
0.0008
0.0012
strain, ε
1000
800
600
400
200
0
METALS
steel
brass
stress, σ (MPa)
0
0.1
0.2
0.3
0.4
strain, ε
70
60
50
40
30
20
10
A (acrylic glass)
POLYMERS
B (PVC)
C (rubber)
stress, σ (MPa)
0
1
2
3
4
5
6
7
8
strain, ε
10

10

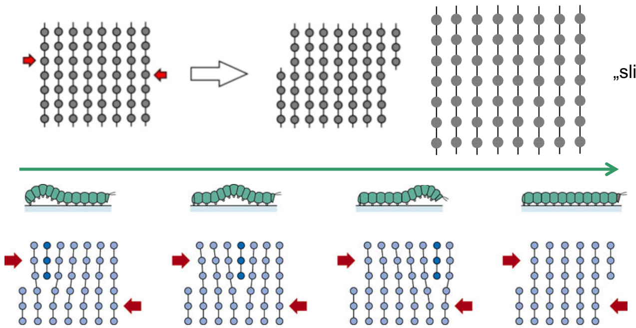

10 000
1 000
100
10
0.1
strength (MPa)
ceramics
metals and alloys
enamel
dentine
composites
glasses
porous ceramics
PDL
polymers
wood and wooden products
rubbers
foams
0.001
0.01
0.1
1
10
100
toughness (rel. units)
11

11


stress , σ
- Stiff
- Brittle
- Strong
- elastic
- strong
- tough
- ductile
- Modertely strong
- tough
- ductile
- Weak
- Low toughness
strain , ε
12

12

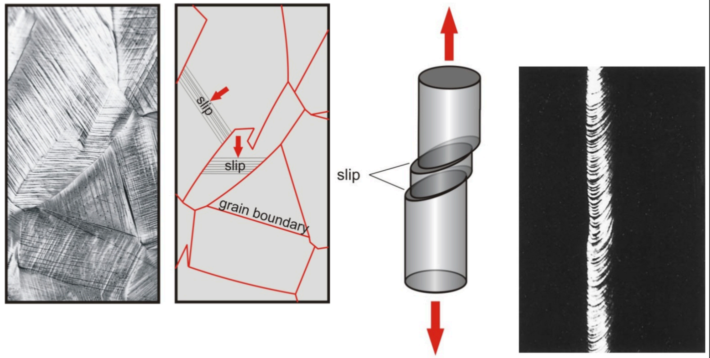
Mechanism of plastic deformation in crystals:

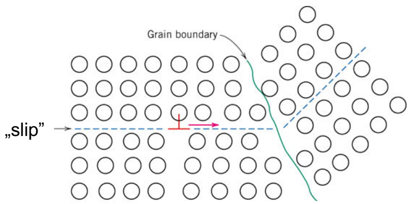


Moving a rug by moving a wrinkle in the rug

In case of amorphous materials: viscous flow only!

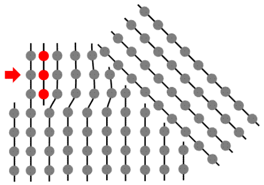
Movement of disclocations





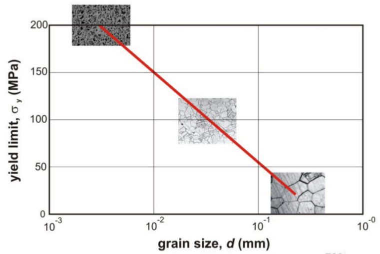
Quantities of plastic range (σ_y, ε_s, σ_s, w_s), and hardness

Are very sensitive to lattice defects.



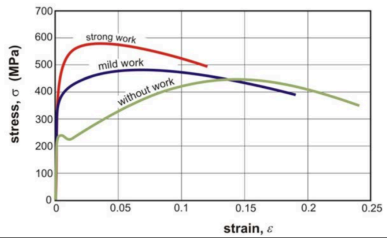
Similar reason: Brittleness of ceramics

Changening the strength and plastic properties of metals

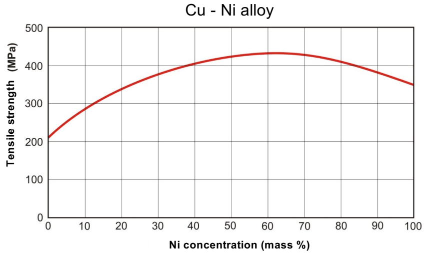


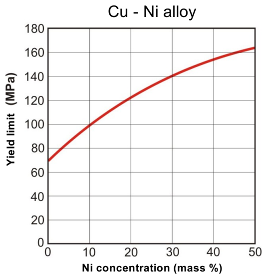
decreasing grain size (*d*)

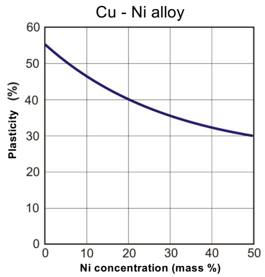
Cold-work



Alloying





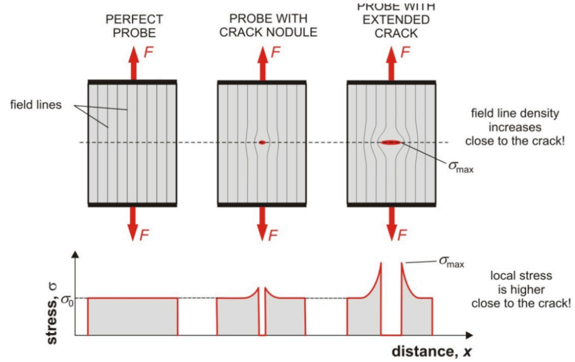


17

17

Fracture

Mechanism:

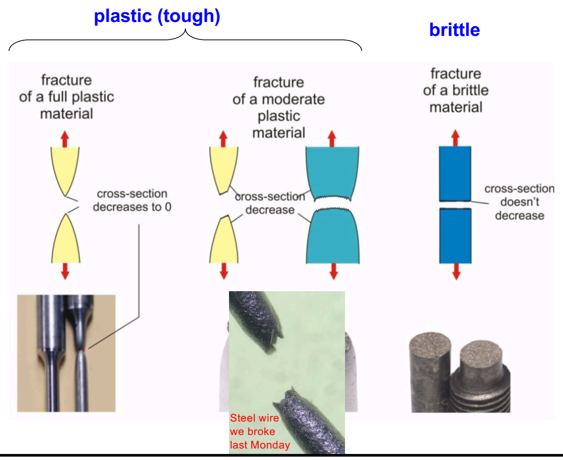


Increasing stress
- Brittle material: no plastic deformation **britle fracture**
- Plastic deformation **plastic fracture**

18

18

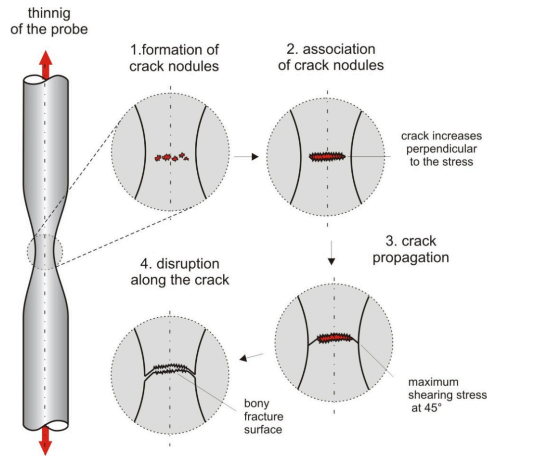
Fracture types



19

19

Phases of fracture in a ductile material



20

20

Fatigue, *fatigue fracture*

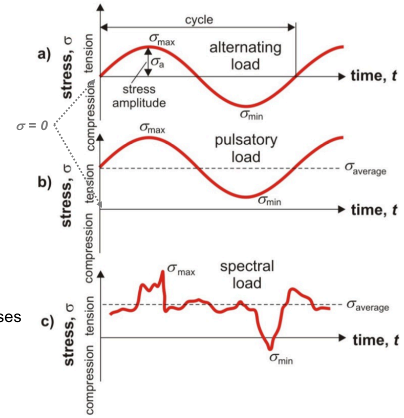
Persistant, repetitive load (stress)

→ structursl changes

→ strength decreases

Crack formation!

Types of loads:



21

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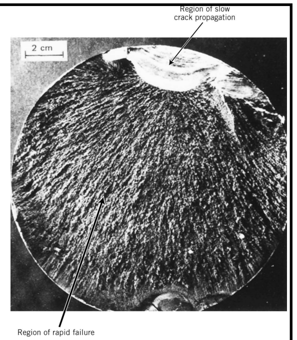
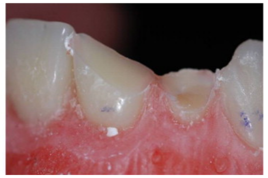
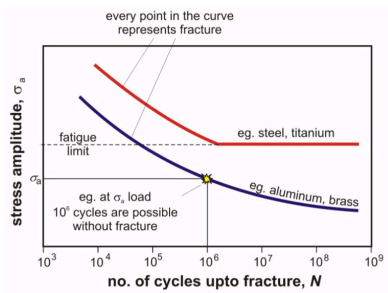


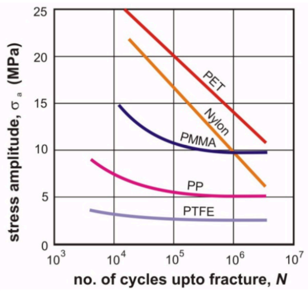


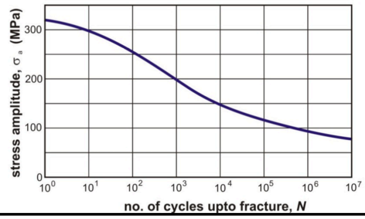
22

22

Fatigue curve:







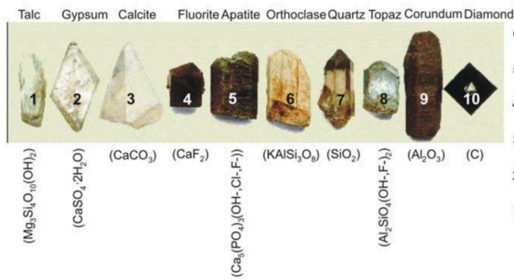
23

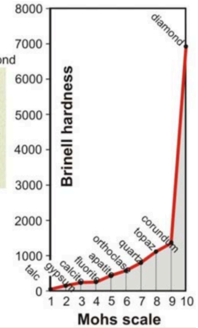
23

Hardness

Resistance against plastic deformation

Mohs-scale:

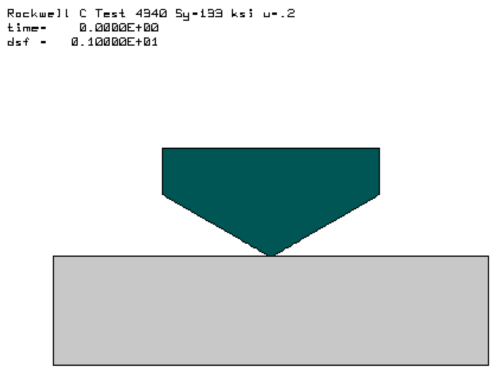




24

24

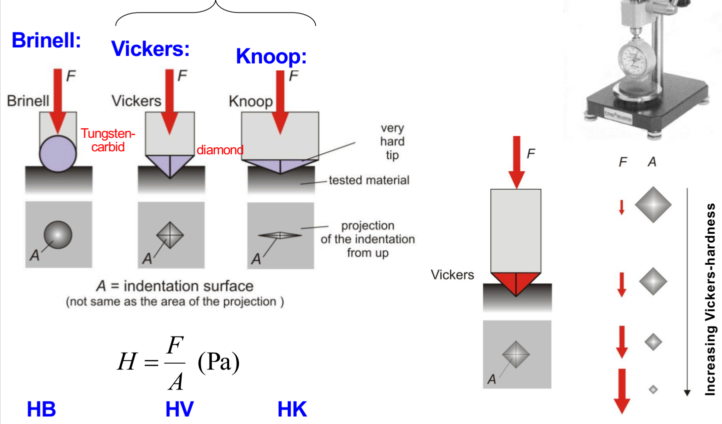
Hardness measurement



25

25

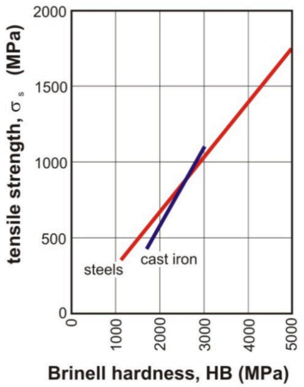
Hardness measurement



26

26

Connections with strength:



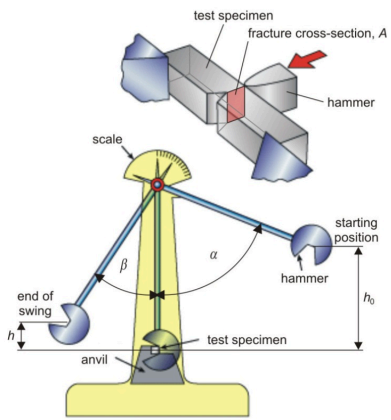
Hardness of dental materials:

material	HV (MPa)	HK (MPa)
dentine	≈ 600	≈ 700
enamel	≈ 3400	3400-4000
gold		60-70
acrylate	≈ 200	≈ 200
gold alloys	600-2500	≈ 2000
amalgam	≈ 1000	
Pd-Ag alloys	1400-1900	
Ni-Cr alloys	3000-4000	2000-3500
Co-Cr alloys	≈ 4000	3000-4500
glass		≈ 5000
porcelain	4500-7000	≈ 6000

27

27

Charpy test



Impact energy = The loss of the hammer's potential energy (J)

Specific impact energy= impact energy / cross sectional area of test specimen (J/m^2)

28

28

5. A piece of zirconia with a fracture cross-sectional area of 1 cm^2 is tested in a Charpy. The drawing shows the hammer's start and end positions. The hammer has a mass of 2 kg. Calculate the specific impact energy of zirconia!