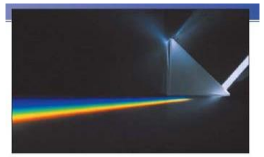




Physical basis of dental material science 11.

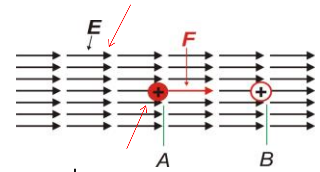
Other properties. Summary

Electric properties

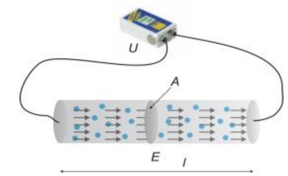
Electric charges in materials: electrons, ions.

Q – charge, unit: C (coulomb)

Electric field



charge



Coulomb-force: may be attractive or repulsive one.
E: strength of the electric field = F/Q

Work: $W_{AB} = \sum \vec{F} \cdot \vec{\Delta s} = Q \cdot \sum \vec{E} \cdot \vec{\Delta s}$

current (I): flow of charges.
(due to the electric field)
unit: amper (A)

$I = \frac{\Delta Q}{\Delta t}$

Voltage (*V*):
unit: volt (V)

$V_{AB} = \frac{W_{AB}}{Q}$

Ohm's law: $R = \frac{U}{I}$

R: resistance, unit: ohm (Ω)

Mobility of charges

Resistance depends on the mobility of charges and the charge densities.

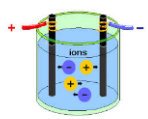
Mobility: $\mu = v / E$ unit: cm^2 /Vs

v: velocity of charges

electrons (in metals)

Metal	μ (cm^2/Vs)
Gold	6120
Aluminum	2600
Copper	5770

ions (in solutions)

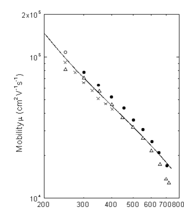


Ion	μ (cm^2/Vs)
H^+	0.0036
OH^-	0.00206
Na^+	0.000519
Cl^-	0.000791

What influences the mobility?

in metals

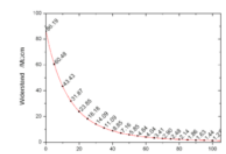
Temperature



Main effect: Lattice scattering

Vibrating atoms and higher temperature higher amplitude of oscillation.

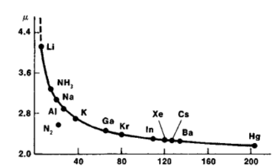
in solutions



Temperature

Viscosity

Mass



Type of materials

Insulators
There are no mobile charges.

example: many plastics

Conductors
There are mobile charges.

Metals
Charges are electrons.

Electrolytes
Charges are ions.

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Electric properties: resistivity

Resistivity (ρ): -
(specific resistance)

$$\rho = \frac{R \cdot A}{l}$$

unit: Ωm

R: resistance
A: cross-section
l: length

Conductivity (σ):

$$\sigma = \frac{1}{\rho}$$

unit: $(\Omega\text{m})^{-1}$ = S/m

S: siemens, unit of conductance
conductance = 1/R

material	σ (S/m)	
silver	$6.8 \cdot 10^{7}$	conductors
gold	$4.3 \cdot 10^{7}$	
platinum	$0.94 \cdot 10^{7}$	
germanium	2.2	semi-conductors
silicon	$4 \cdot 10^{-4}$	
hyacinth	$\approx 10^{-10}$	insulators
porcelain	$\approx 10^{-11}$	
glass	$\approx 10^{-13}$	
PMMA	$\approx 10^{-12}$	
PE	$\approx 10^{-16}$	

material	σ (S/m)
Enamel	$1\text{-}4 \cdot 10^{-7}$
Dentin	$2\text{-}10 \cdot 10^{-5}$

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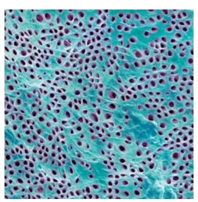
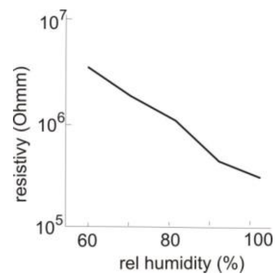
Role of channels in tooth



diameters. a few μm.

Water and ions in channels.



Enamel. Dependency on humidity

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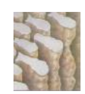
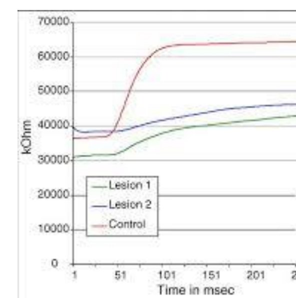
Resistivity of the enamel

intact enamel

degradated enamel





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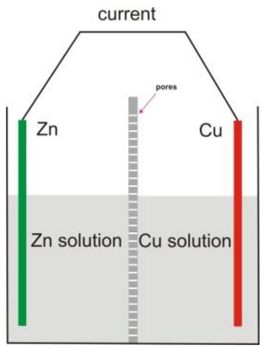
Galvanic cell



anode cathode

Zn oxidation and Cu reduction.
(energetically more favourable!)

Result: electric current, potential difference (voltage).

half cell

half cell potentials (V)

element	E_0
Cu	+0.337
Zn	-0.7618
Hg	+0.8

In the mouth

Saliva

electrolyte
(ions)

pH: 6.2-.74

Two different metals

Galvanic pain:

2 different metals and saliva form galvanic cell.
Voltage -> current to the pulp.

Galvanic corrosion:

Oxidation of the anode material.
Reduction of the cathode material.

Bone destruction?

see later.

Chemical properties

Corrosion is the disintegration of a material into its constituent atoms due to chemical reactions.

- Oxidation and corrosion of metals (see: galvanic cell)

$$M \rightarrow M^{n+} + n \cdot e^{-}$$

e^-

in acidic medium

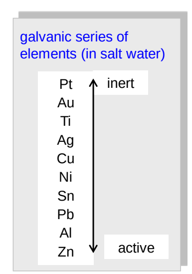
$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

neutral or alkaline medium

$$O_2 + 2H_2O + 4e^- \rightarrow 4(OH)^-$$

Galvanic series

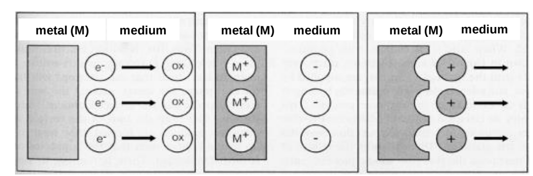
Determines the nobility of metals
(ability to take part in chemical reactions)



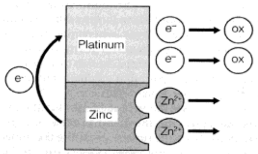
Corrosion rate (speed)

Determinde by the electrolyte and the difference in voltage potential of elements.
(see galvanic cell)

corrosion of the amalgam (steps)



Galvanic corrosion



One metal corrodes to another when both metals are in electrical contact and immersed in an electrolyte.

Many factors influence the rate e.g.:

- potentials
- electrode areas
- galvanic current (resistance)
- components of saliva (pH., oxigen etc.)
- diffusion rate

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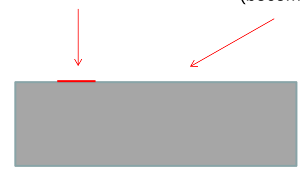
Pitting corrosion

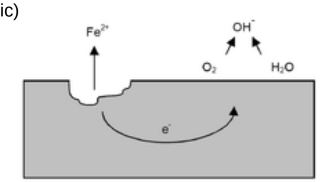
Extremely lokalized, initiated by a surface defect.
(e.g. scratching, other damage.)

Smooth, polished surface
has high resistance!)

Depassivation of the surface
(becomes anodic)

vast area
(becomes cathodic)





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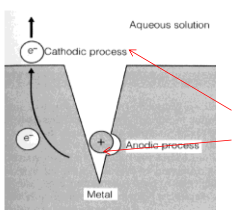
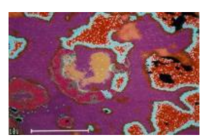
Crevice corrosion

Corrosion occurring in spaces to which the access of the working fluid from the environment is limited.



concentration difference,
potential drop



Small gap (a few micrometers)
and there is no fluid circulation.

p. 643 **corrosion of the amalgam**

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Typical amalgam

typical constitution	
metal	**weight%**
Ag	67-74
Sn	25-28
Cu	0-6
Zn	0-2
Hg	0-3

+ Hg

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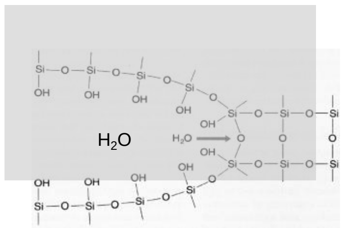
Corrosion of ceramics

dissolution



increasing
crack

(„static fatigue")

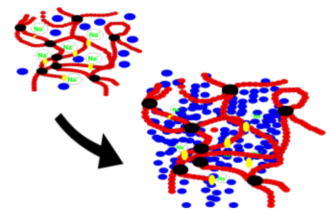
Degradation of the polimers

water uptake → swelling, dissolution → weaker bonds

(e.g. alcohol)

↓

changing mechanical and optical properties

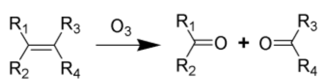


UV irradiation → ionization → breaking covalent bonds → strand breaks, crossing-over, ...

Ozone cracking (in elastomers)

A small tension is required.
Not too high is enaugh.

Chemical background:
Attack on double bonds.

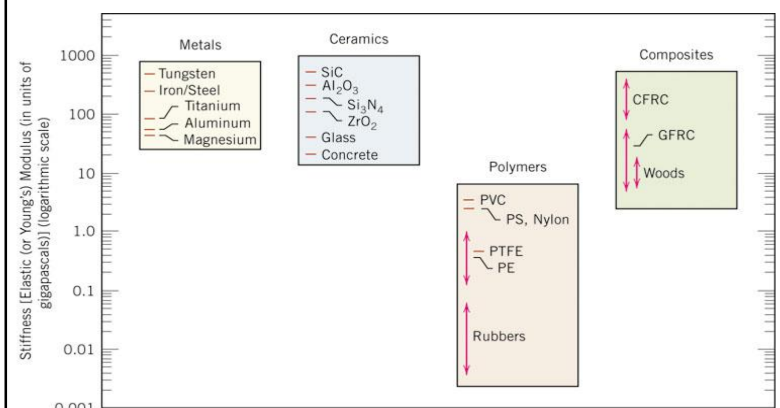


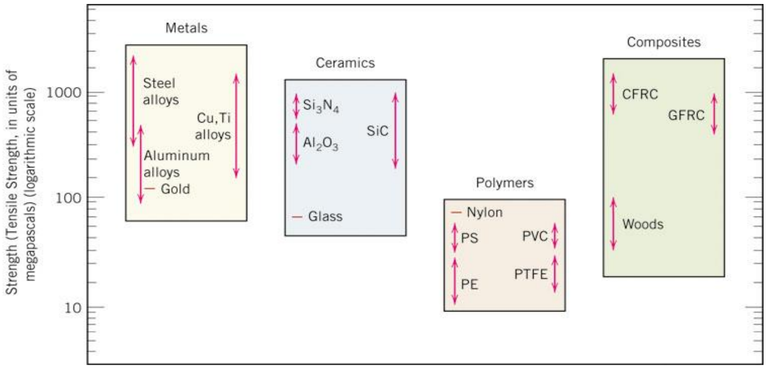
Ozone crack in rubber.

(microscopic size)

- Smaller chain length.
- Less degree of polymerisation.
- Decrease in tensil strength.

Comparison of the properties of the materials





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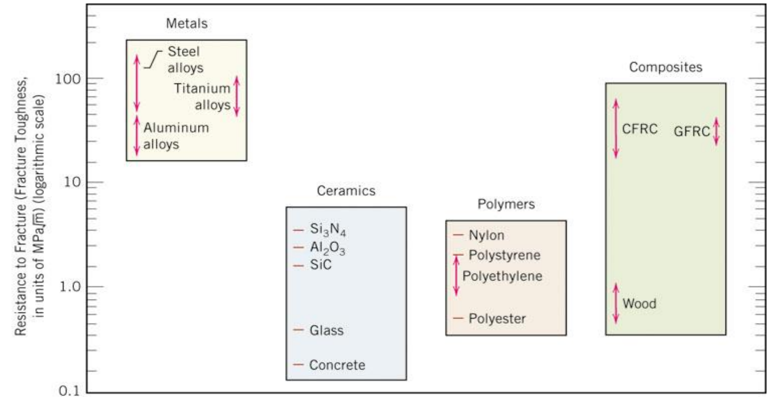

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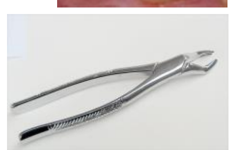
Metals

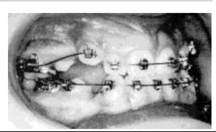
properties in general:

- high density
- stiff
- strong
- ductile
  (plastic)
- tough
  (tough fracture)
- hard
- thermal conductor
- electric conductor
- opaque, metal color
- corrosive







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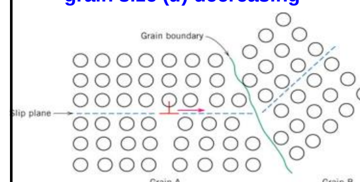
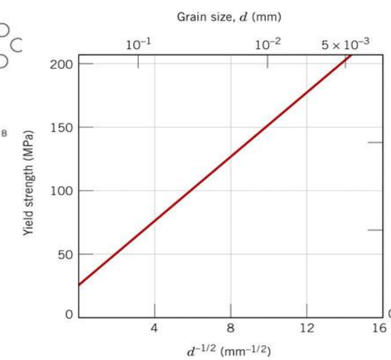
Increasing the strength of the metals

grain size (*d*) decreasing



Motion of dislocations!



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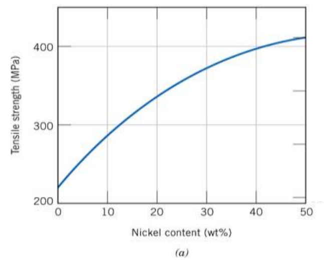
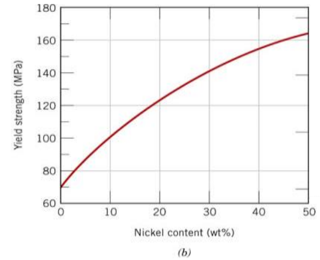
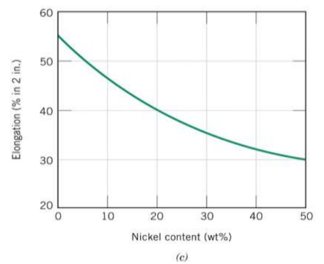
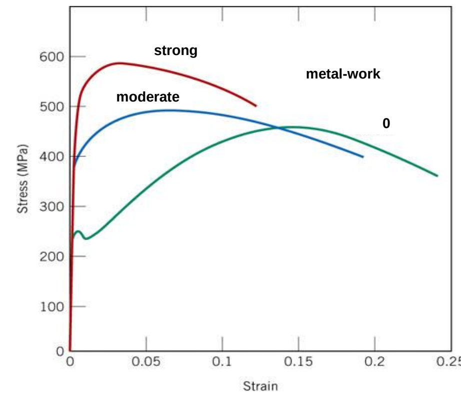






Alloying: one metal with other metal(s) or non-metal(s) often enhances its properties.

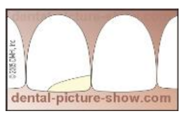
Role of cold metal-work

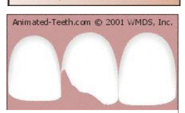


Ceramics

properties in general:

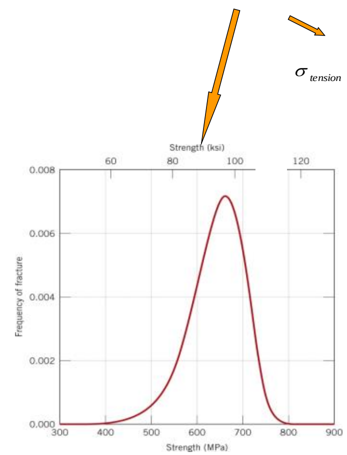
- medium density
- rigid
- strong
(in rupture medium)
- not plastic
- brittle
(brittle fracture)
- hard
- thermal insulator
- weak thermal shock tolerancy
- electric insulator
- different optical properties
- low chemical corrosion

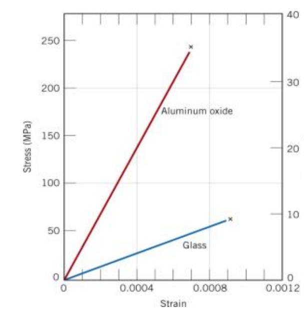




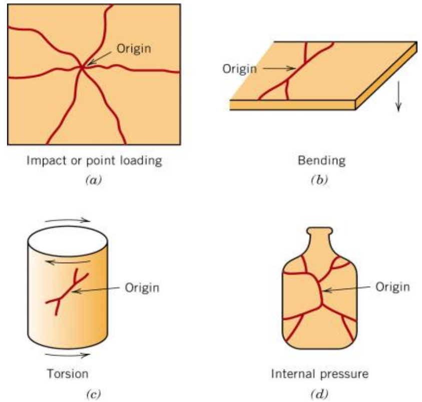
Crack sensitivity

$\sigma_{tension} < \sigma_{compression}$





Crack types



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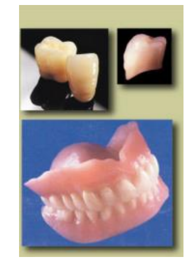
Polimers

properties in general:

- low density
- elastic
- weak
- ductile
- medium tough - brittle
- soft
- viscoelastic
- thermal insulator
- electric insulator
- different optical properties
- degradation



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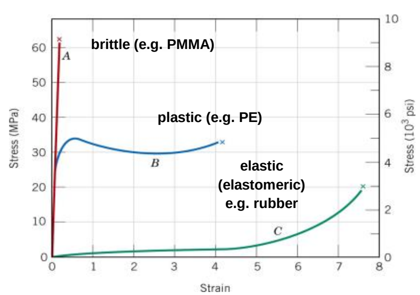
High variety of properties



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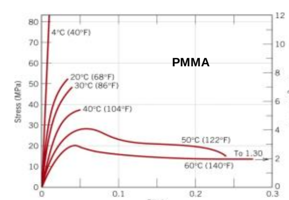
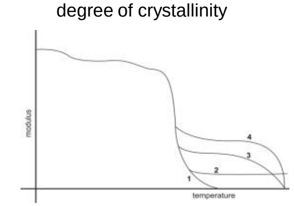
Important factors

temperature



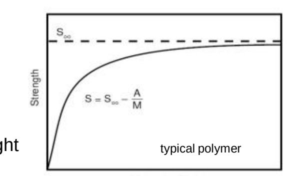
(PMMA – Plexiglass)

degree of crystallinity



1 = amorphous polymer
2 = amorphous polymer, high molecular weight
3 = crystalline polyme
4 = crystalline polymer, higher degree of crystallinity

molecular weight



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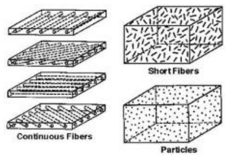
Composites

materials made from two or more constituent materials with different physical and chemical properties to combine them.

properties in general:

- low and medium density
- medium stiff - elastic
- strong
- ductile
- tough
- hard – medium hard
- thermal insulator
- electric insulator
- different optical properties
- small degradation



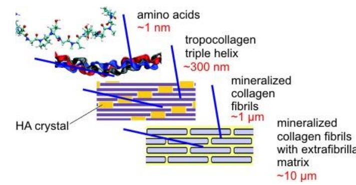
matrix material

reinforcement

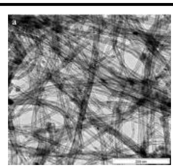
• fiber	bone
• aggregates	concrete
• bars	concrete
• etc.	

Biological example

Bone: hydroxyapatite
reinforced with collagen fibres.



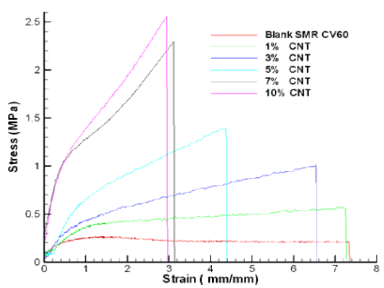
Combination of advantageous properties

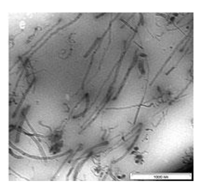


carbon nanotubes (CNT)

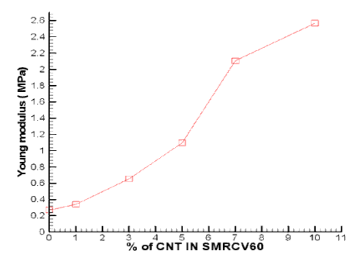
Composite:
rubber (SMR)
+
carbon nanotubes (CNT)

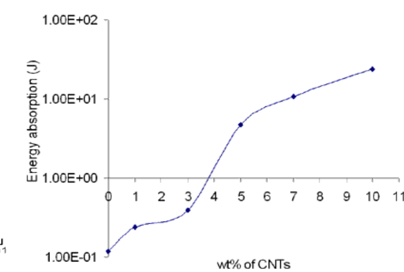
rubber (SMR CV60)





Effect on properties

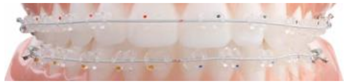




In dentistry

Ceramic brace:

made of composite material



Dental composite resin

matrix: GMA, TEGMA etc.
reinforcment: silica

UV polimerization

Fiber reinforced composite

application in bridge

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