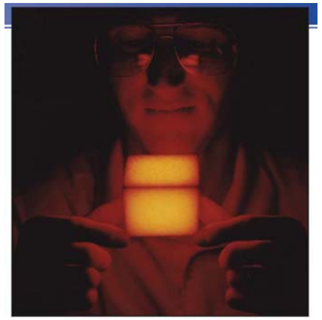
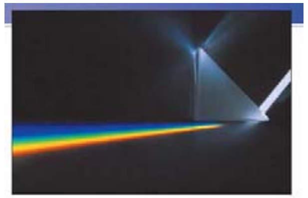


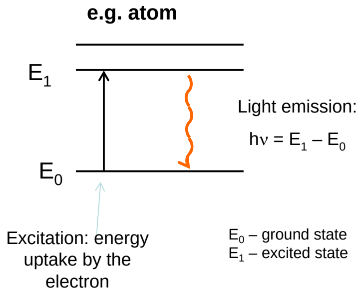


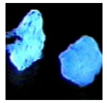
Physical basis of dental material science 11.

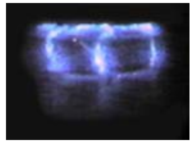
Optical and other properties. Summary

Luminescence

Light emission over the thermal radiation.
Light emission after excitation.





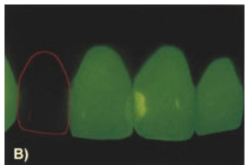


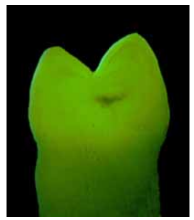
Application of luminescence

excitation	*name: -luminescence*	*example*
light	photo-	quinine-sulphate, phosphor, …
X-ray	X-ray	NaI(Tl)
radioactive radiation	radio-	NaI(Tl)
electric field	electro-	mercury-lamps
mechanical effect	tribo-	sugarcube
chemical raction	chemo- (bio-)	firebug
heat	thermo-	$CaSO_4$(Dy)

+ materials analysis, structure of biological macromolecules, fluorescence microscopy, sensors, monitors, radiation detectors, ...

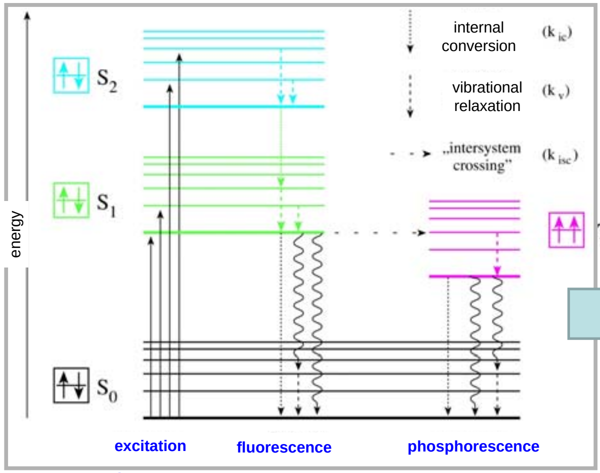
Dental application





Electronic states

Jablonski diagram:



(energy absorption)

light emission luminescence

S – energy state of electrons singlett states (S_0 ground state)
T – energy state of electrons triplett states

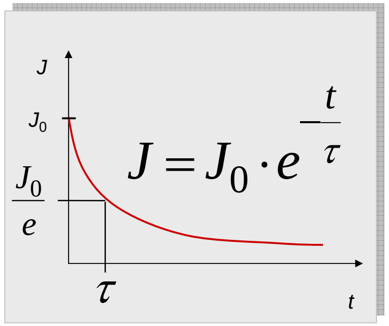
arrows - spin

- line/band spectrum
- Stokes's shift:

$$\bar{\varepsilon}_{phos} \le \bar{\varepsilon}_{fluo} \le \bar{\varepsilon}_{abs}$$

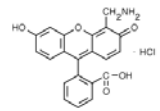
$$\bar{\lambda}_{abs} \le \bar{\lambda}_{fluo} \le \bar{\lambda}_{phos}$$

Life-time (τ): time while the intensity decreases by factor e.

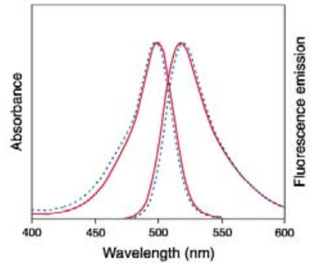


$$\bar{\tau}_{fluo} << \bar{\tau}_{phos}$$

emission spectrum: $J(\lambda)$ (Intensity of the emitted light versus wavelength)



fluorescein

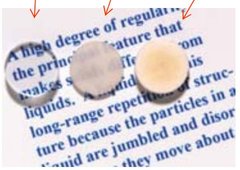


Quantum efficiency (Q):

$$Q = \frac{\text{no. of emitted photons}}{\text{no. of absorbed photons}}$$

Optical properties

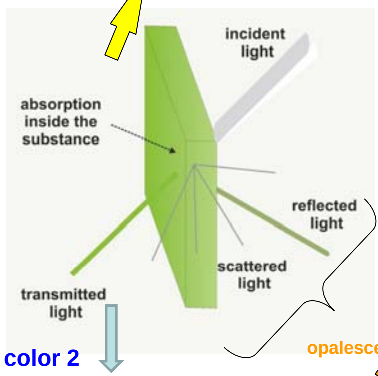
transparent - translucent - opaque



translucent: diffuse transparency

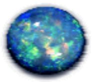
opaque: not transparent, diffuse reflection

fluorescence after absorption



color 3

Depends on the spectrum of the incident light!



opalescence

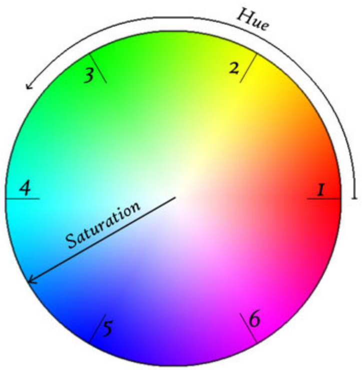
color 2

color 1

Color

„**color space**": **3 coordinates**

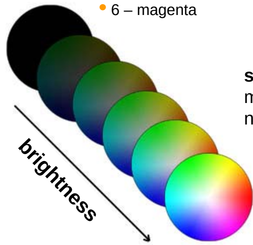
Hue: refers to a *pure* color
Saturation: perceived intensity of a specific color.



regular units:
hue: °
saturation: %

- color
  - chromatic color
    - primary color
      - additive: 1, 3, 5
      - substractive: 2, 4, 6
    - mixed color
  - achromatic color: white, gray, black

- 1 – red
- 2 – yellow
- 3 – green
- 4 – cyan
- 5 – blue
- 6 – magenta



primary color: sets of colors that can be combined to make a color.

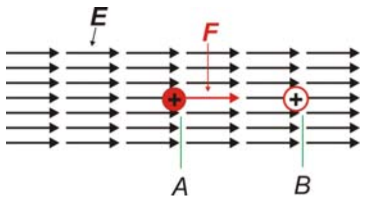
additive color model: involves light emitted directly from a source.

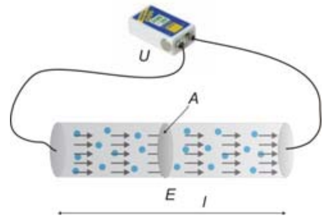
substractive color model : mixing of paints, dyes, inks, and natural colorants.

Electric properties

Electric charges in materials:
electrons, ions.

Q – charge, unit: C (coulomb)





Coulomb-force: attractive or repulsive
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)

Electric properties

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

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

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

Chemical properties

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

- Oxidation and corrosion of metals

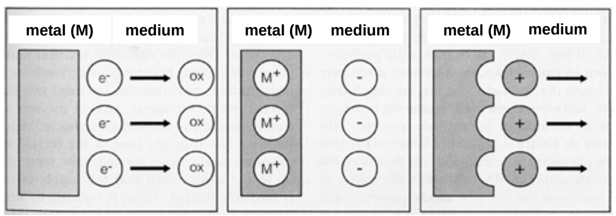
$$M \rightarrow M^{n+} + n \cdot e^-$$

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

neutral or alkaline medium $O_2 + 2H_2O + 4e^- \rightarrow 4(OH)^-$

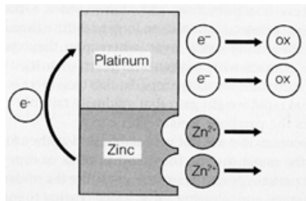
galvanic series of elements (in salt water)

Pt ↑ inert
Au
Ti
Ag
Cu
Ni
Sn
Pb
Al
Zn ↓ active



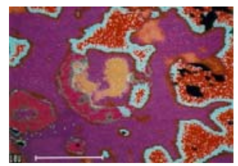
corrosion of the amalgam

Type of corrosion



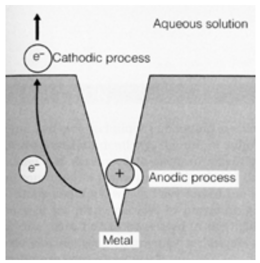
Galvanic corrosion:

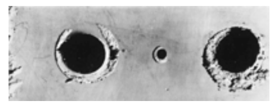
one metal corrodes to another when both metals are in electrical contact and immersed in an electrolyte.



crevice corrosion:

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





corrosion of the amalgam

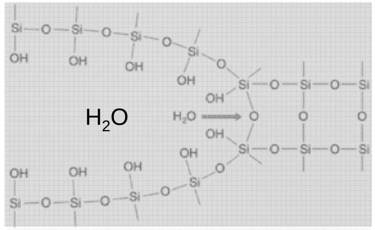
Typical amalgam

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

+ Hg

Corrosion of ceramics

They are highly immune to the corrosion.
Process is a simple dissolution

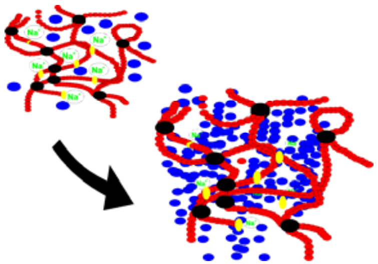


increasing crack

(„static fatigue")

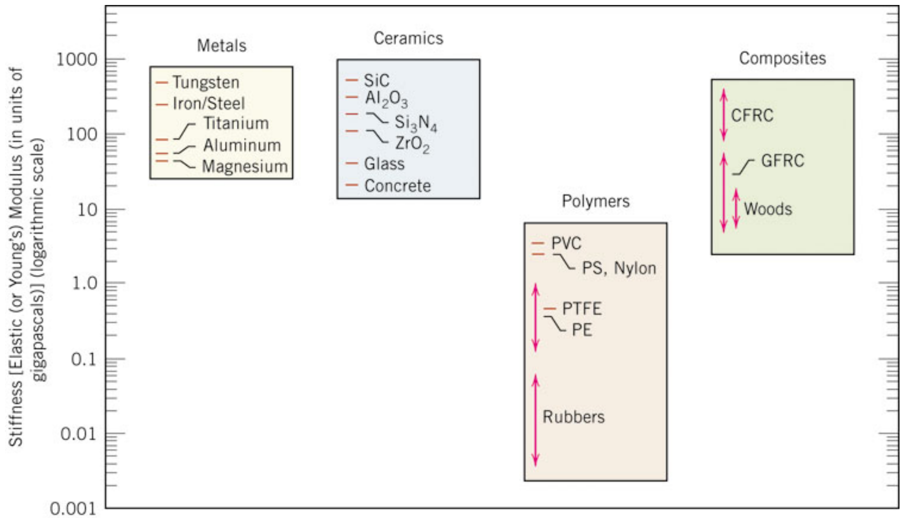
Degradation of the polimers

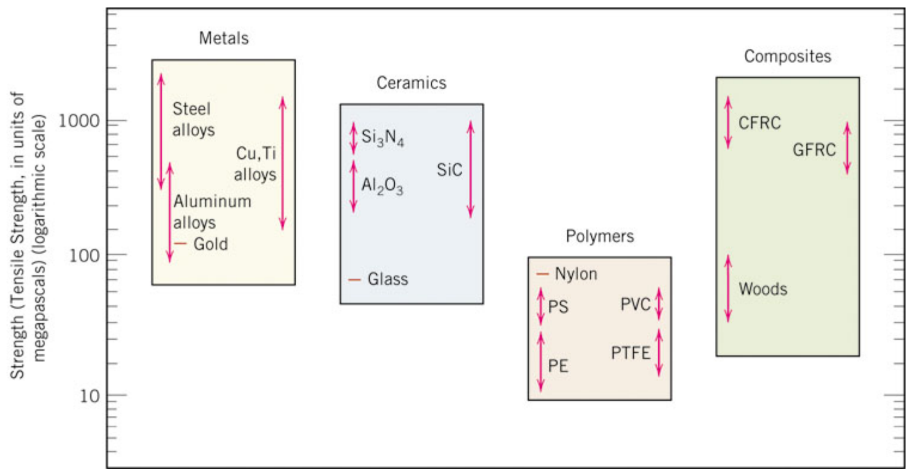
water uptake (alcohol) → swelling, dissolution → weaker bonds → changing mechanical and optical properties

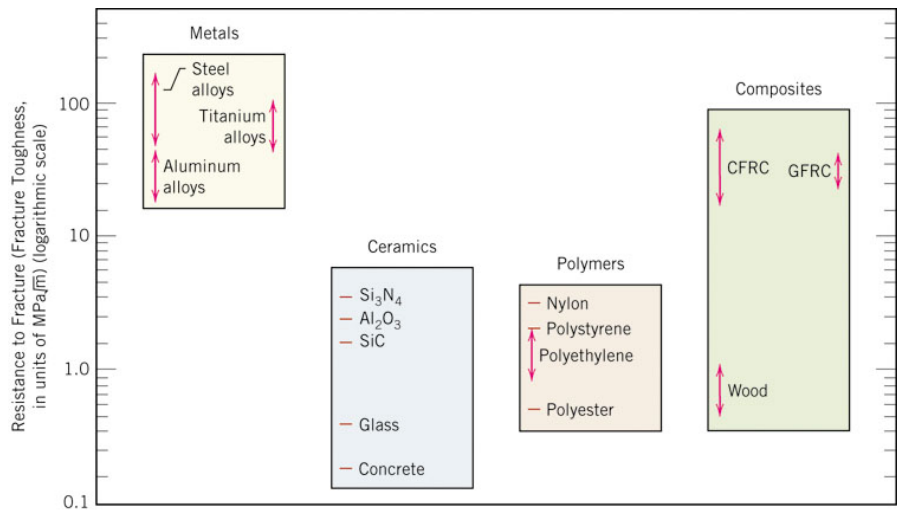


UV irradiation → ionization → breaking covalent bonds → strand breaks, crossing-over, ...

Comparison of the properties of the materials







Metals

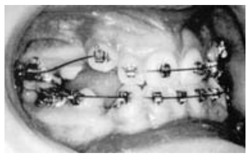
properties in general:

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



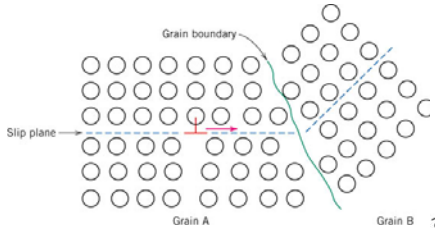




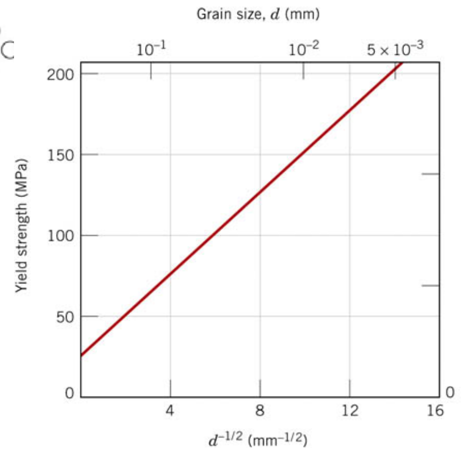
Increasing the strength of the metals (grain size reduction)

grain size (*d*) decreasing

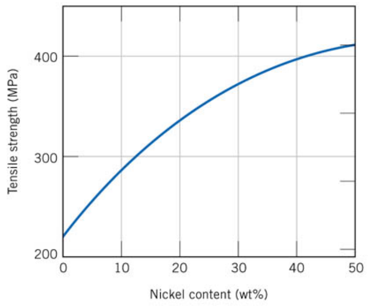


Slip planes change directions across the boundary.

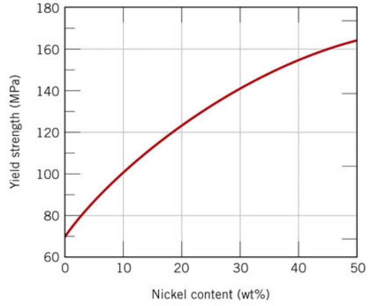
Motion of dislocations!



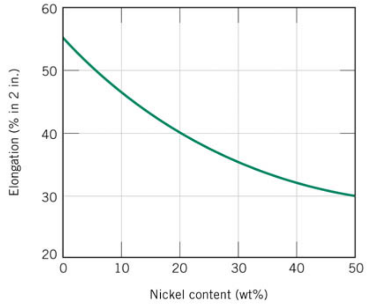
Brass alloy
(take care diameter decreases from left to the right!)



(a)



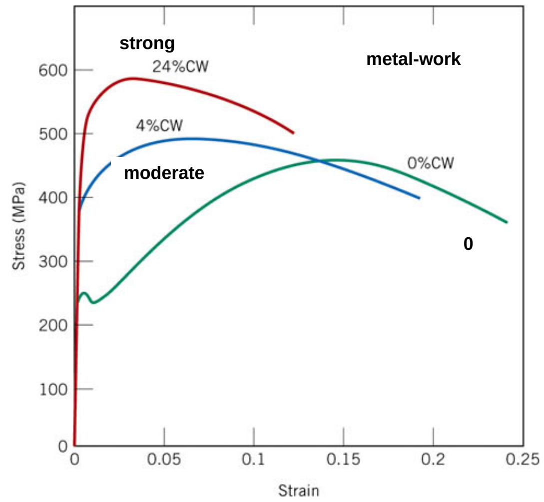
(b)



(c)

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

Cold metal-work



Ductile metal plastically is deformed and becomes harder and stronger.

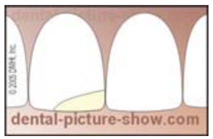
$$CW(\%) = \left(\frac{A_0 - A_d}{A_0}\right) \times 100$$

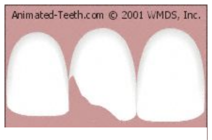
A_0 – original cross-section
A_d – cross-section after the deformation

Ceramics

properties in general:

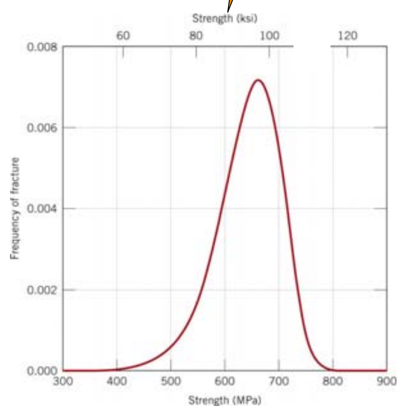
- medium density
- rigid
- strong
  (in rupture medium)
- not plastic
- brittle
  (brittle fracture)
- hard
- thermal insulator
- weak thermal shock toler
- electric insulator
- different optical properties
- low chemical corrosion

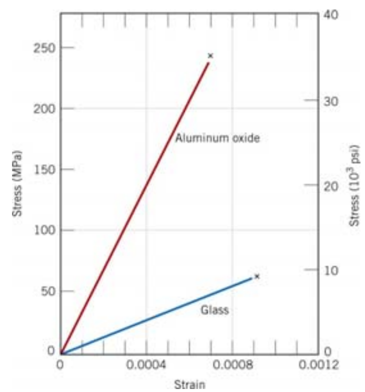




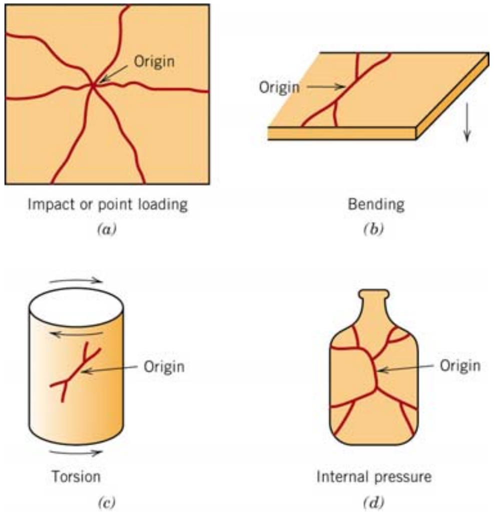
Crack sensitivity

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





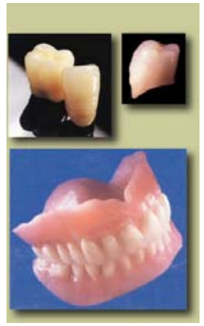
Crack types



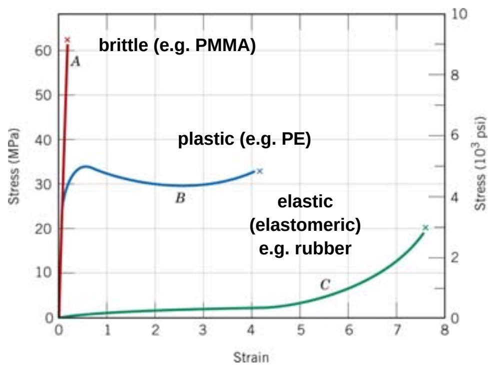
Polimers

properties in general:

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

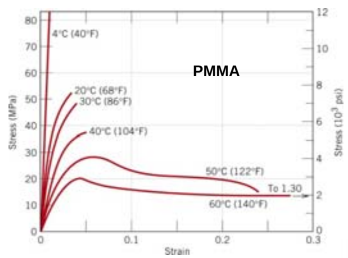


High variety of properties

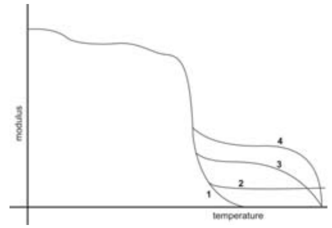


Important factors

temperature

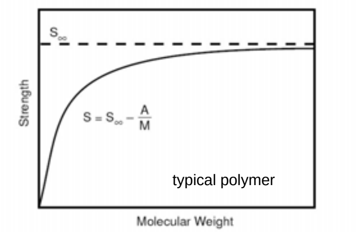


degree of crystallinity



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

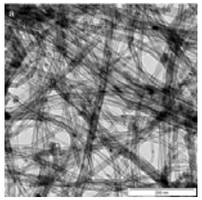
molecular weight



Composites in dentistry

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

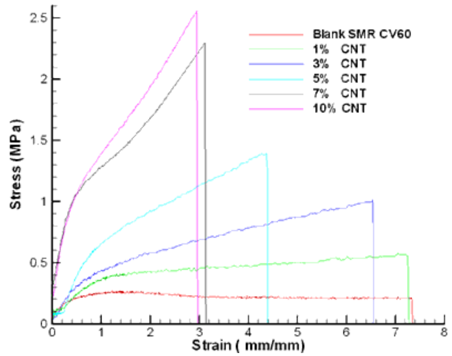


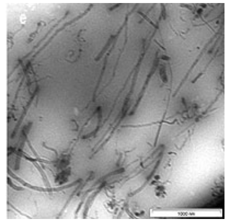
carbon nanotubes (CNT)

Combination of advantageous properties

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

rubber (SMR CV60)





Effect on properties