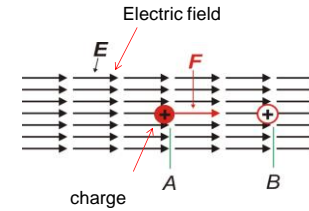


Physical basis of dental material science 11.

Other properties. Summary

1

Electric properties



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

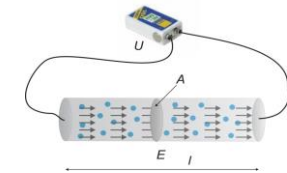
$$\text{Work: } W_{AB} = \sum \vec{F} \cdot \Delta \vec{s} = Q \cdot \sum \vec{E} \cdot \Delta \vec{s}$$

Voltage (V):
unit: volt (V)

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

Electric charges in materials: electrons, ions.

Q – charge, unit: C (coulomb)



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

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

Ohm's law:

$$R = \frac{U}{I}$$

R: resistance, unit: ohm (Ω)

2

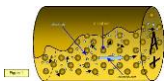
Mobility of charges

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

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

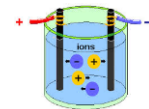
v: velocity of charges

electrons (in metals)



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

ions (in solutions)



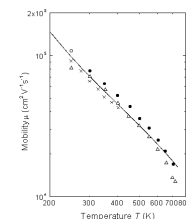
Ion	μ (cm^2/Vs)
H^+	0.0036
OH^-	0.00206
Na^+	0.000519
Cl^-	0.000791

3

What influences the mobility?

in metals

Temperature

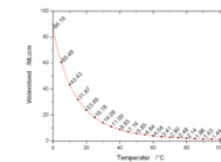


Main effect: Lattice scattering

Vibrating atoms and higher temperature
higher amplitude of oscillation.

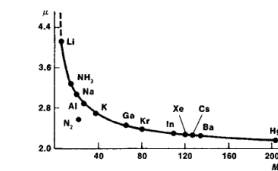
in solutions

Temperature



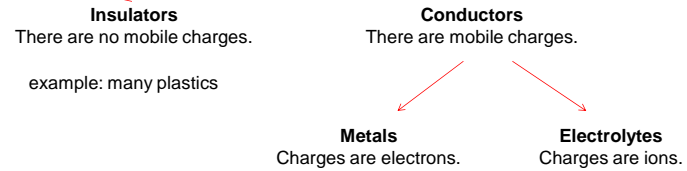
Viscosity

Mass



4

Type of materials



5

Electric properties: resistivity

Resistivity (ρ): -
(specific resistance)

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

R : resistance
 A : cross-section
 l : length

unit: Ωm

Conductivity (σ):

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

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

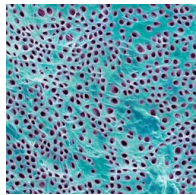
S: siemens, unit of conductance
conductance = $1/R$

material	$\sigma (\text{S/m})$	
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	$\sigma (\text{S/m})$
Enamel	$1.4 \cdot 10^{-7}$
Dentin	$2 \cdot 10^{-5}$

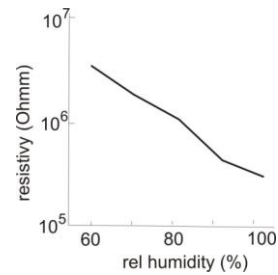
6

Role of channels in tooth



diameters. a few μm .

Water and ions in channels.



Enamel. Dependency on humidity

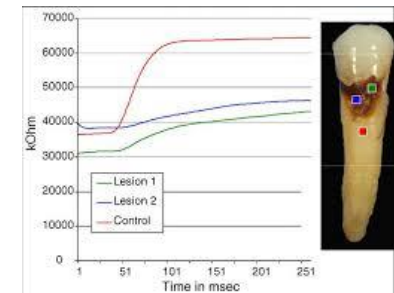
7

Resistivity of the enamel

intact enamel

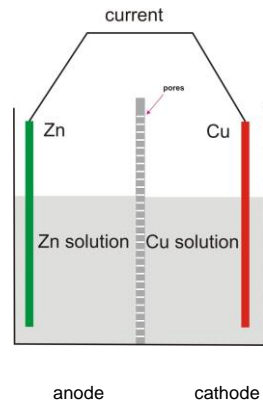


degraded enamel



8

Galvanic cell



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

9

In the mouth

Saliva

electrolyte
(ions)

pH: 6.2-.74

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?

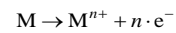
see later.

10

Chemical properties

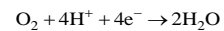
Corrosion is the disintegration of a material into its constituent atoms due to chemical reactions.

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

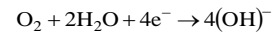


e^-

in acidic medium



neutral or alkaline medium



11

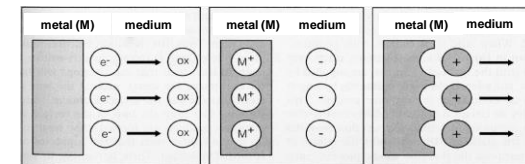
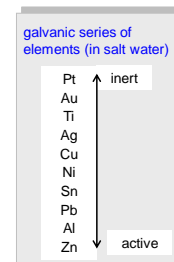
Galvanic series

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

Corrosion rate (speed)

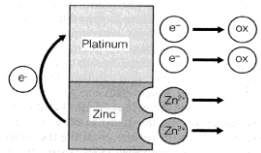
Determine by the electrolyte and the difference in
voltage potential of elements.
(see galvanic cell)

corrosion of the amalgam (steps)



12

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., oxygen etc.)
- diffusion rate



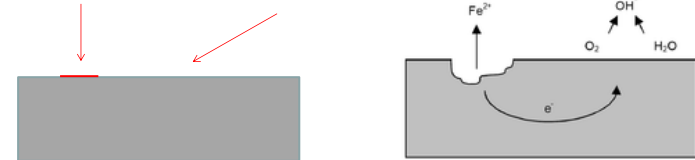
13

Pitting corrosion

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

Smooth, polished surface
has high resistance!

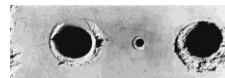
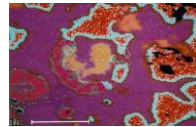
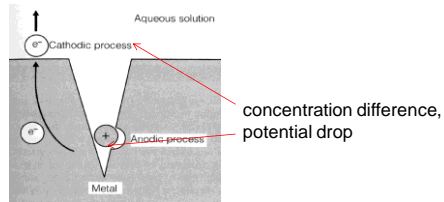
Depassivation of the surface
(becomes anodic) vast area
(becomes cathodic)



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Crevice corrosion

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



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

p. 643 corrosion of the amalgam

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Typical amalgam

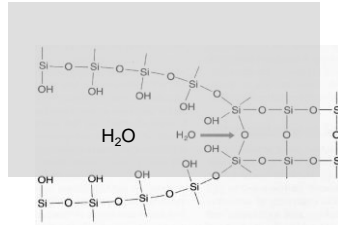
typical constitution	
metal	weight%
Ag	67-74
Sn	25-28
Cu	0-6
Zn	0-2
Hg	0-3

+ Hg

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Corrosion of ceramics

dissolution



increasing crack
(„static fatigue“)

17

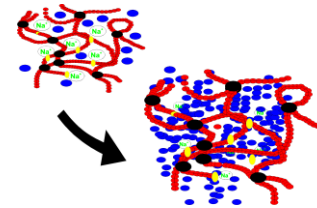
Degradation of the polymers

water uptake
(e.g. alcohol)

swelling,
dissolution

weaker bonds

changing mechanical and optical properties



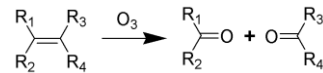
UV irradiation → ionization → breaking covalent bonds → strand breaks, crossing-over, ...

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Ozone cracking (in elastomers)

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

Chemical background:
Attack on double bonds.



Ozone crack in rubber.

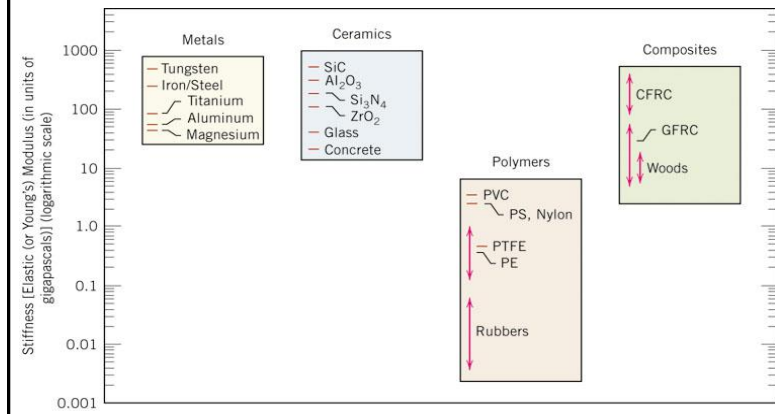


(microscopic size)

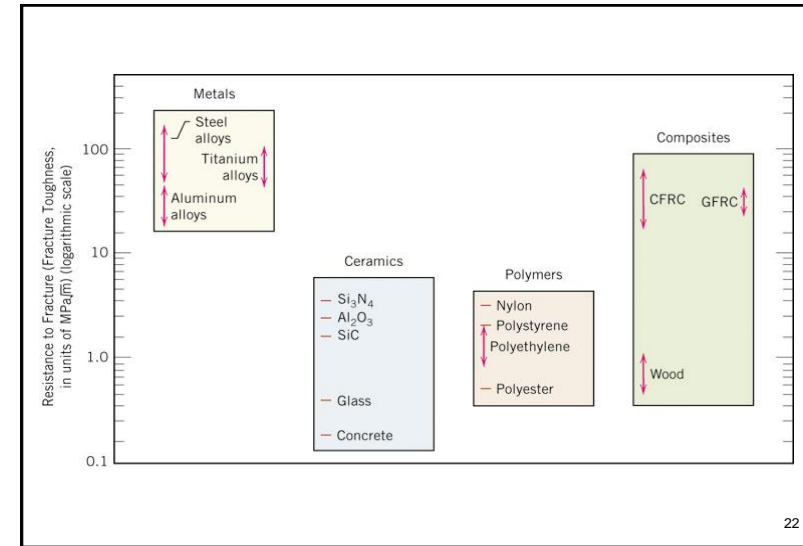
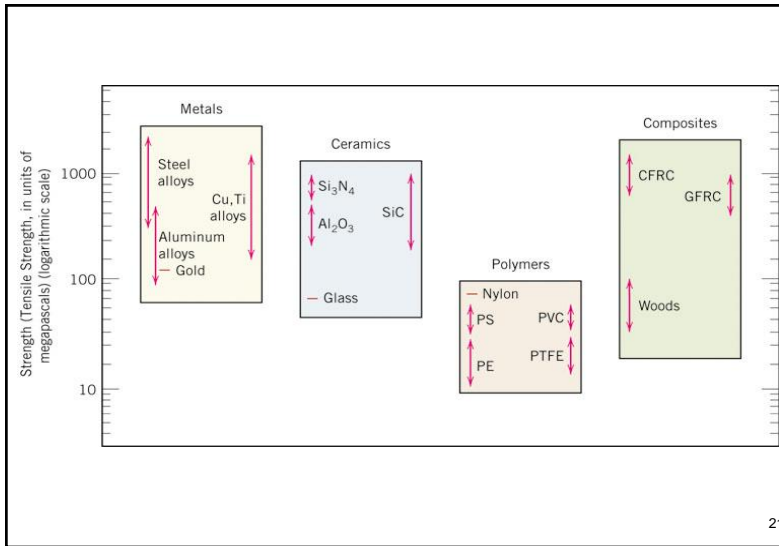
- Smaller chain length.
- Less degree of polymerisation.
- Decrease in tensile strength.

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Comparison of the properties of the materials



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Metals

properties in general:

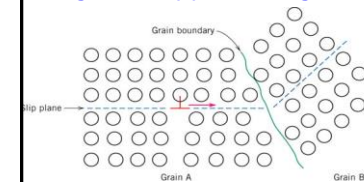
- high density
- stiff
- strong
- ductile (plastic)
- tough (tough fracture)
- hard
- thermal conductor
- electric conductor
- opaque, metal color
- corrosive



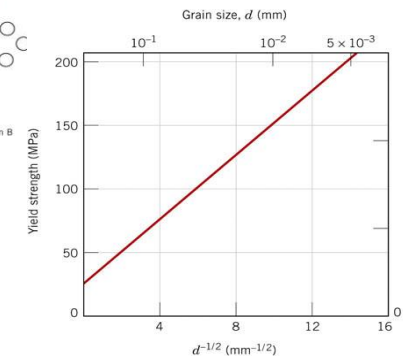
23

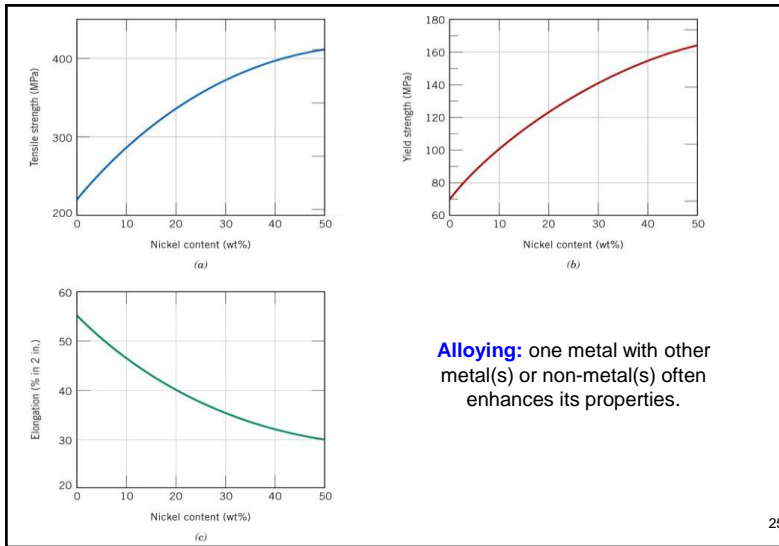
Increasing the strength of the metals

grain size (d) decreasing

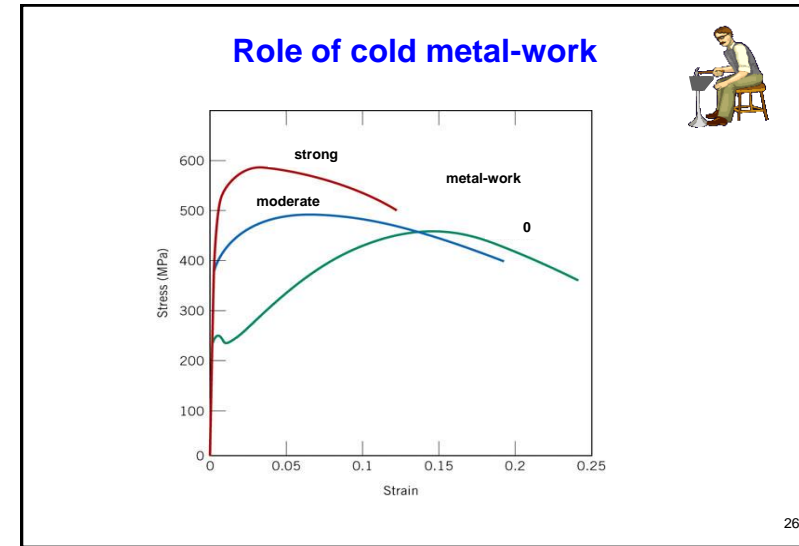


Motion of dislocations!





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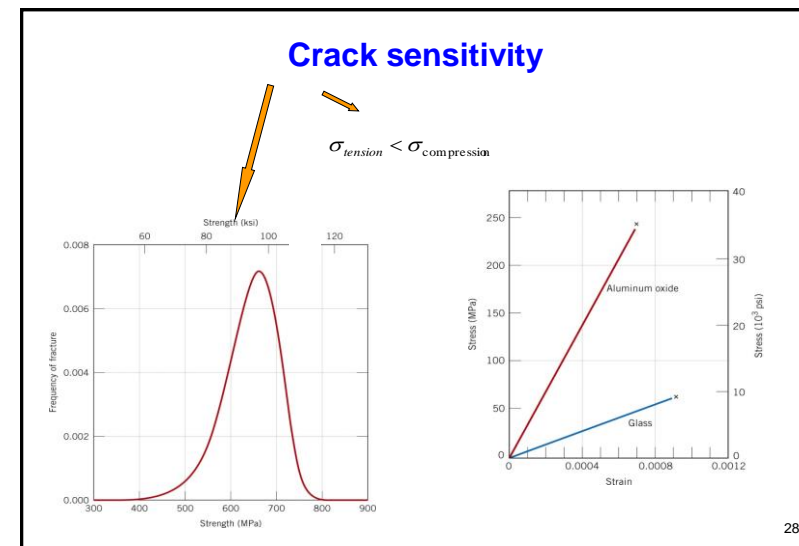
26

Ceramics

properties in general:

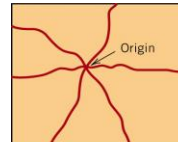
- medium density
- rigid
- strong (in rupture medium)
- not plastic
- brittle (brittle fracture)
- hard
- thermal insulator
- weak thermal shock tolerance
- electric insulator
- different optical properties
- low chemical corrosion

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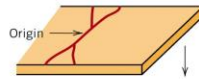


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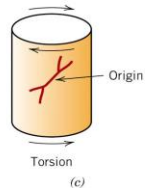
Crack types



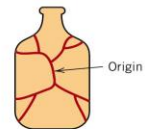
Impact or point loading
(a)



Bending
(b)



Torsion
(c)



Internal pressure
(d)

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Polimers

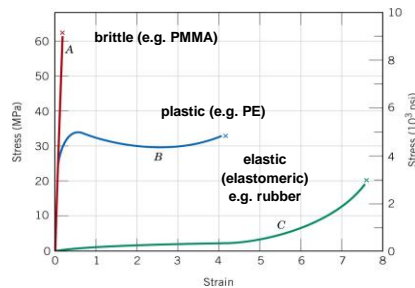
properties in general:

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



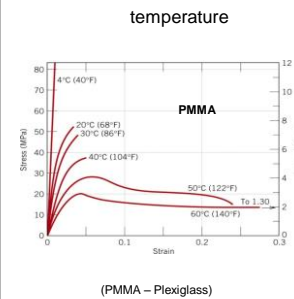
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High variety of properties

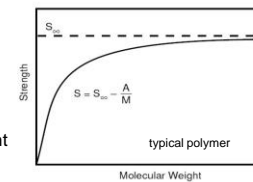


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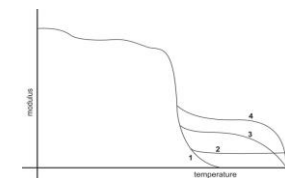
Important factors



molecular weight



degree of crystallinity



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

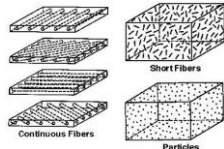
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Composites

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

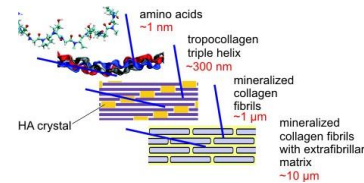
reinforcement

- fiber
 - aggregates
 - bars
 - etc.
- bone
concrete
concrete

33

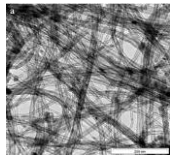
Biological example

Bone: hydroxyapatite reinforced with collagen fibres.



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Combination of advantageous properties

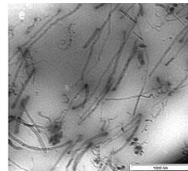
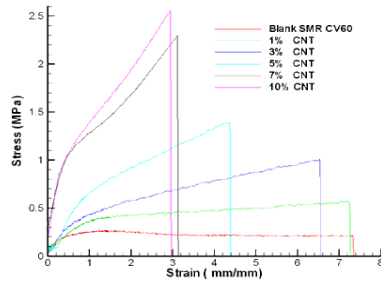


carbon nanotubes (CNT)

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

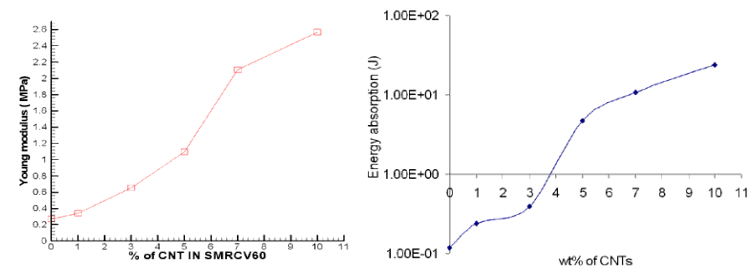


rubber (SMR CV60)



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Effect on properties



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In dentistry

Dental composite resin

matrix: GMA, TEGMA etc.
reinforcement: silica



UV polymerization

Ceramic brace:

made of composite material



Fiber reinforced composite

application in bridge

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