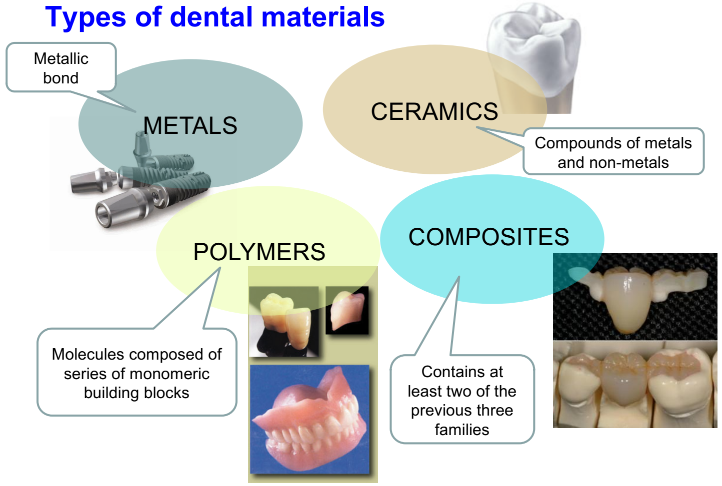
Physical Bases of Dental Material science 5.

Polymers, composites.

E-book Chapters: 12-13

Homework: Chapter 3.: 21, 24, 25, 27

Types of dental materials



Polymers

Macromolecule, that is a long chain of monomers

Properties:

- low density
- liquid or solid at room temperature
- low/medium stiffness and hardness, but easily malleable
- viscoelasticity
- relatively bad heat and corrosion resistance
- relatively bad electric and heat conduction
- diverse optical properties

Structure:

- covalent bonds between monomers in the chain, but usually weaker secondary bonds between chains
- semi-crystalline or amorphous

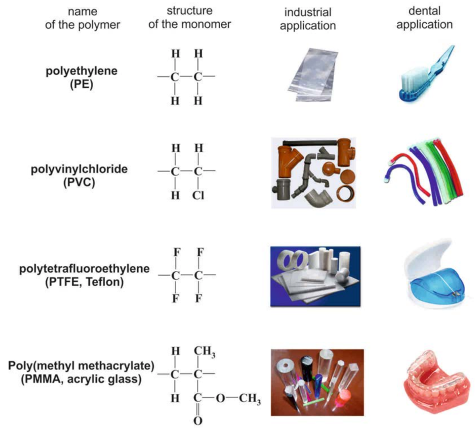
synthesis:

- addition
- condensation

Applications:

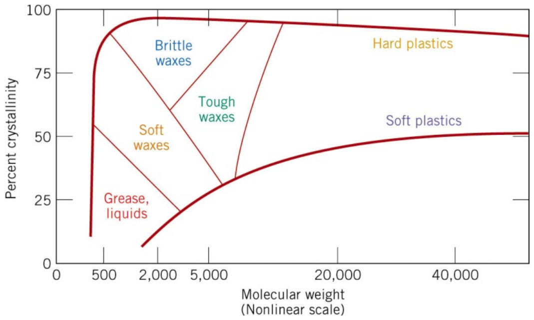
- denture
- filling
- impression materials

Monomer



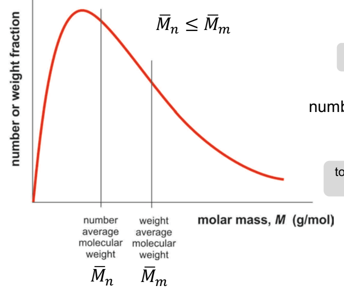
- **homopolymer:** one kind of monomer only
- **heteropolymer (copolymer):** two or more kinds of monomers

The length (molar mass) of polymer molecules and percent of crystallinity determines the physical properties:



Polymer composition

Statistics!



number... ...of molecules with given molecular weight mass...

number ratio: $\frac{n_i}{n}$ mass ratio: $\frac{m_i}{m}$

total number of molecules total mass of molecules

number average molecular weight ($\bar{M}_n$):

$$\bar{M}_n = \frac{n_1M_1 + n_2M_2 + \cdots + n_iM_i + \cdots + n_kM_k}{n_1 + n_2 + \cdots + n_i + \cdots + n_k} = \frac{\sum_{i=1}^{k} n_iM_i}{\sum_{i=1}^{k} n_i} .$$

weight average molecular weight ($\bar{M}_m$):

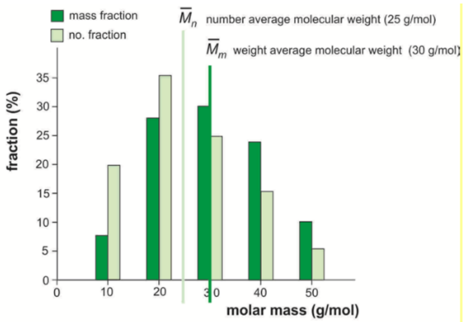
$$\bar{M}_m = \frac{m_1M_1 + m_2M_2 + \cdots + m_iM_i + \cdots + m_kM_k}{m_1 + m_2 + \cdots + m_i + \cdots + m_k} = \frac{\sum_{i=1}^{k} m_iM_i}{\sum_{i=1}^{k} m_i} .$$

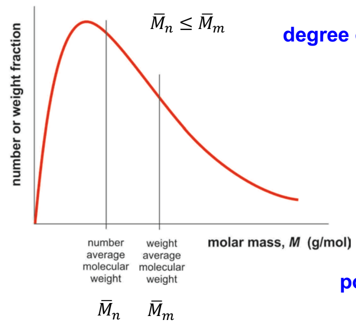
An example:

molar mass, M_i (g/mol)	n_i	no. fraction n_i/n (proportion)	$m_i = n_i \cdot M_i$ (g/mol)*	mass fraction m_i/m
$M_1 = 10$	$n_1 = 4$	4/20 = 0.20 = 20%	$m_1 = 4 \cdot 10 = 40$	40/500 = 0.08 = 8%
$M_2 = 20$	$n_2 = 7$	7/20 = 0.35 = 35%	$m_2 = 7 \cdot 20 = 140$	140/500 = 0.28 = 28%
$M_3 = 30$	$n_3 = 5$	5/20 = 0.25 = 25%	$m_3 = 5 \cdot 30 = 150$	150/500 = 0.30 = 30%
$M_4 = 40$	$n_4 = 3$	3/20 = 0.15 = 15%	$m_4 = 3 \cdot 40 = 120$	120/500 = 0.24 = 24%
$M_5 = 50$	$n_5 = 1$	1/20 = 0.05 = 5%	$m_5 = 1 \cdot 50 = 50$	50/500 = 0.10 = 10%
total	$n = 20$	1 = 100%	$m = 500$	1 = 100%

$$\bar{M}_n = \frac{\sum_{i=1}^{k} n_iM_i}{\sum_{i=1}^{k} n_i}$$

$$\bar{M}_m = \frac{\sum_{i=1}^{k} m_iM_i}{\sum_{i=1}^{k} m_i}$$





degree of polymerization: $\frac{\bar{M}_n}{M_{\text{monomer}}}$

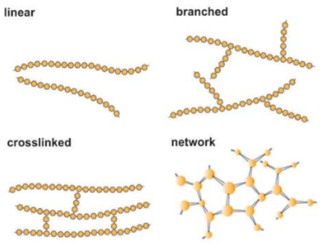
average length of polymer molecules

polydispersity index: $\frac{\bar{M}_m}{\bar{M}_n}$

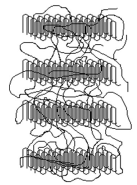
diversity of polymer molecules

= 1: monodisperse
1< : polydisperse

Structure of polymers

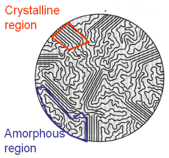


semi-crystalline



Degree of crystallinity (*x*):

amorphous 0% $x = \frac{m_{\text{kristály}}}{m_{\text{összes}}} (\cdot 100\%)$ crystalline 100%



- thermoplastics
- duroplasts
- elastomers

Composites

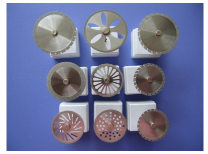
Materials of multiple, chemically different components with distinct phase boundaries

Properties:

- low density
- solid at room temperature
- combines the benefits of each of the phases
- strong, elastic and tough
- diverse optical properties

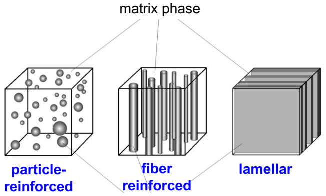
Applications:

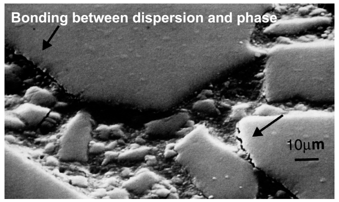
- filling
- dental tools



Structure of composites

Two-phase composite: **Matrix phase** **(polymer, metal, ceramics)**
+
dispersion phase **(ceramics, metal, ...)**



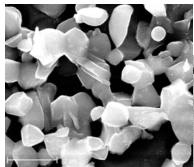


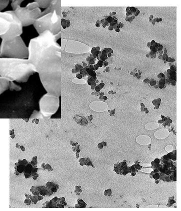
Hybrid composites: multiple dispersion phases

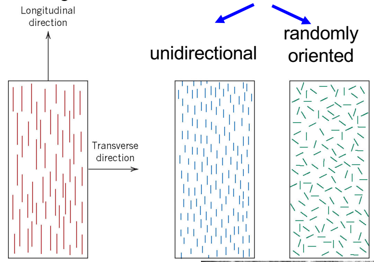
particle-reinforced → large particles, fine particles

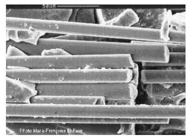
fiber-reinforced → long unidirectional, short fiber

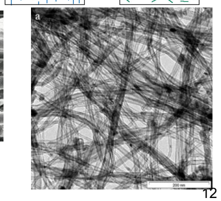
short fiber → unidirectional, randomly oriented





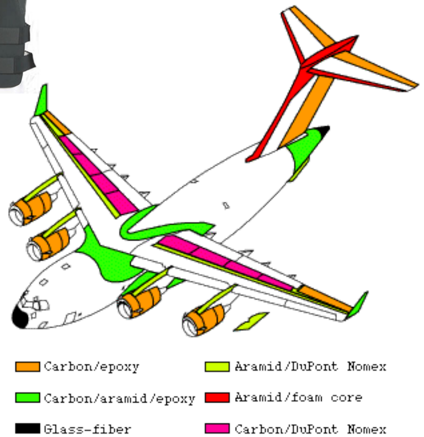






→ properties!

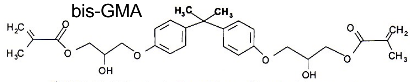
Applications



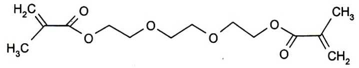
Dental composites

matrix: polymer (dimethacrylate)
dispersion material: glass (silica), ceramic crystal (i.e. quartz), polymer, + pigment, + UV absorbent (photoinitiator), ...

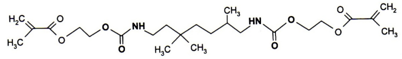
bis-GMA



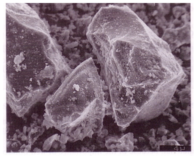
TEGDGMA



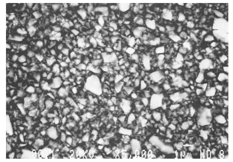
UDMA



large-grained
(0,1-100 μm)



micrograined
(≈ 40 nm)



shrinkage during polymerization
may cause secondary caries