Dental composites

Chemistry, composition, properties

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Resin Composites

What are composites?

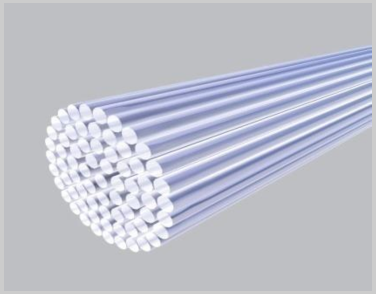
Heterogeneous materials *composed of a matrix (e.g. polymeric)* and particulate or fibrous *fillers/reinforcing particles*

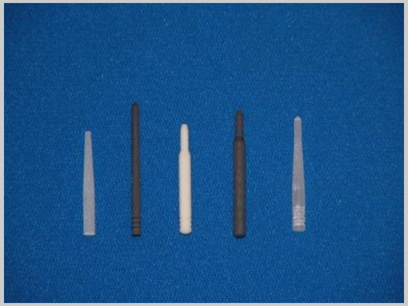
Main components:

- matrix
- fillers – treated with coupling agents (bonds, sizings)

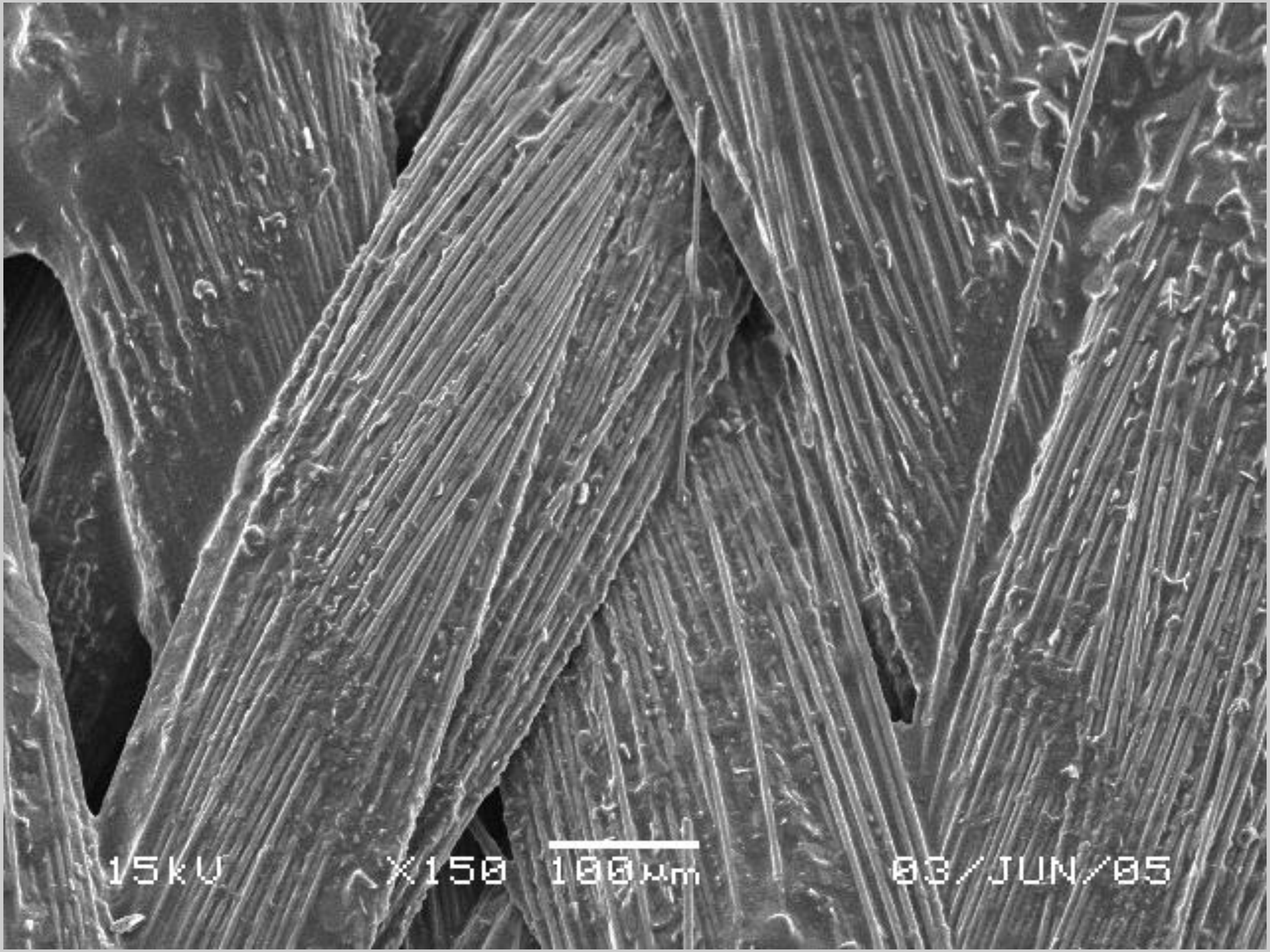
Types of composites

- Particulate composites – restorative composites, fillings, luting, build-ups material, temporary crown and bridge, sealers, etc.
- Fibrous composites „**F**ibre **R**einforced **C**omposites" (FRC) glass/carbon/ aramide posts, splints

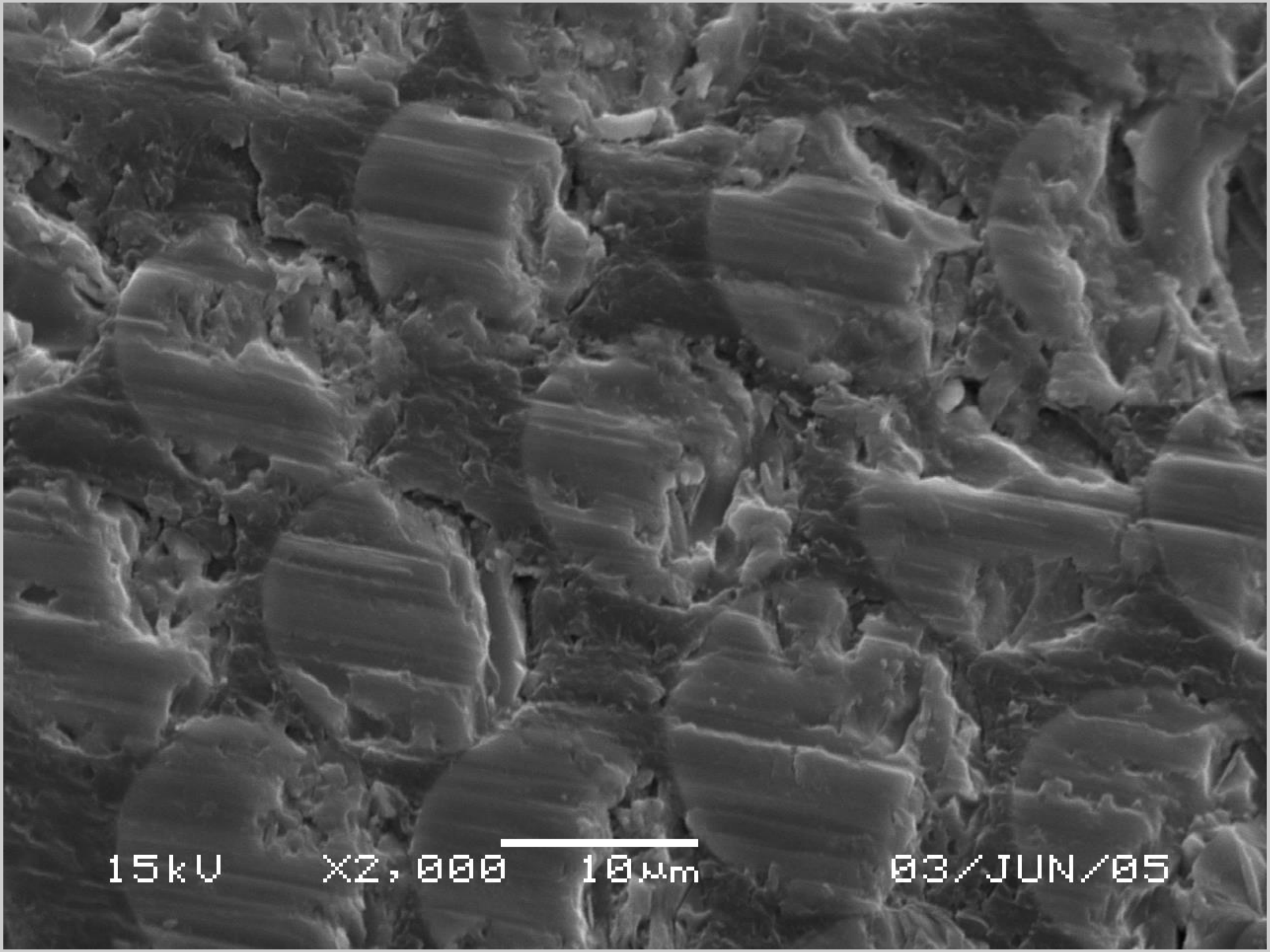




Example of longituidal fibre orientation



Example of transverse fibre orientation



Role of individual components:

Matrix (consists of monomers, initiators, inhibitors etc.)

- transfers mechanical load on reinforcing fillers,
- stabilizes distribution of fillers in matrix and protects them against environmental degradation.

Filler - act as a „load carrier"

Coupling agents – increases wetting of filler with a matrix,

- „conect" surface of filler particles with a matrix via chemical bond,
- enable stresses to be transferred on the fillers,
- facilitate particle dispersion in monomers – increases filler load.

Monomers

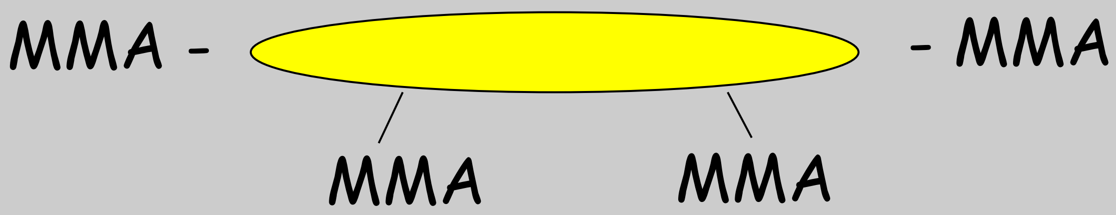
How to decrease polymerizatiom shrinkage???

1. To increase molecular mass of monomers

Less number of double bonds in the volume unit

2. To prepare monomers with a rigid structure

Less difference molar volume before and after polymerization

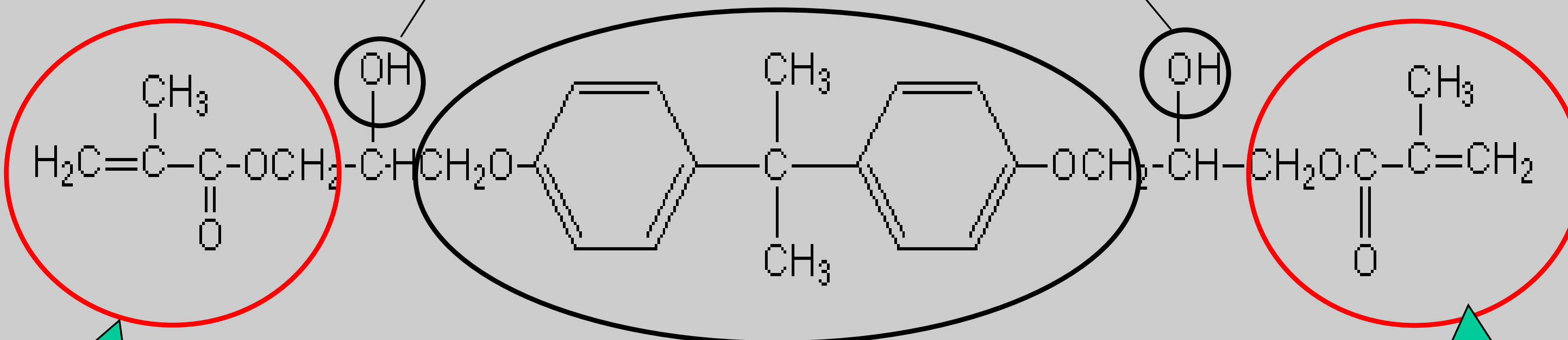


Similar principles of free radical polymerization as for monomers with a single MMA unit

Typical structure

$M_{BIS\text{-}GMA} = 512$
$M_{MMA} = 100$

Capable of H-bridge formation high viscosity



Meth. group

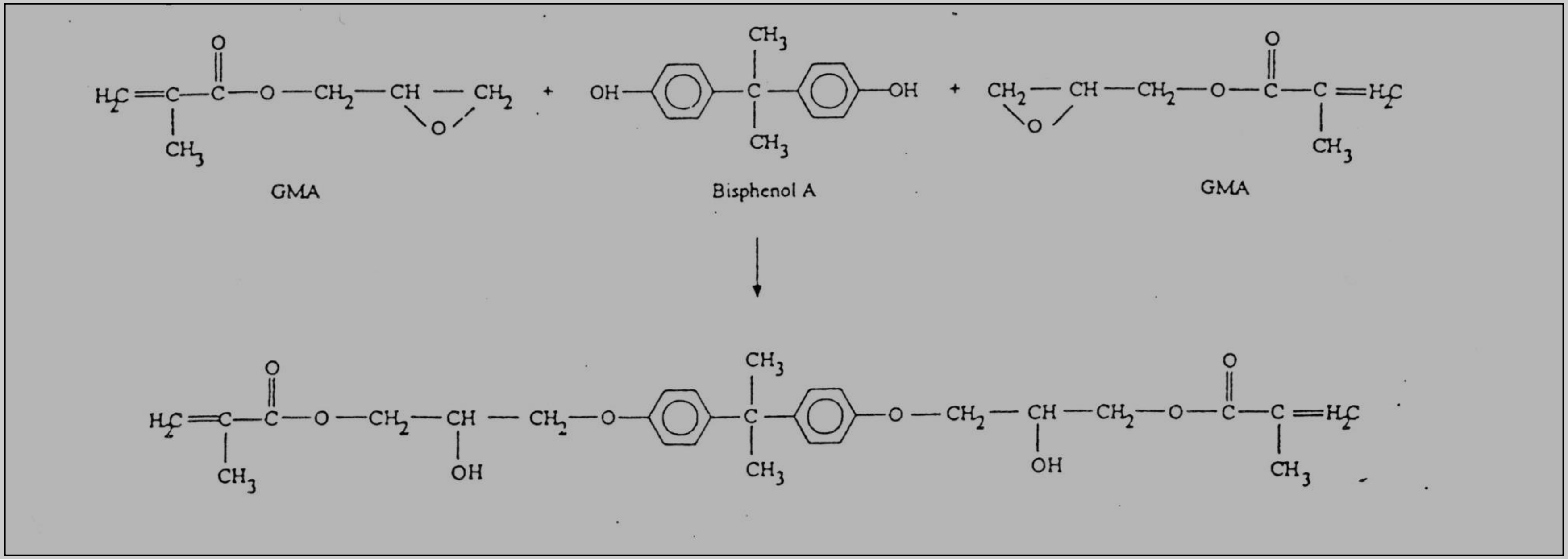
Meth. group

Composition of this spacer controls refractive index of the monomer which plays a key role in the composite´s optical/aesthetic properties

Increased molecular mass – reduces polymerization shrinkage app. to 5-6 vol %

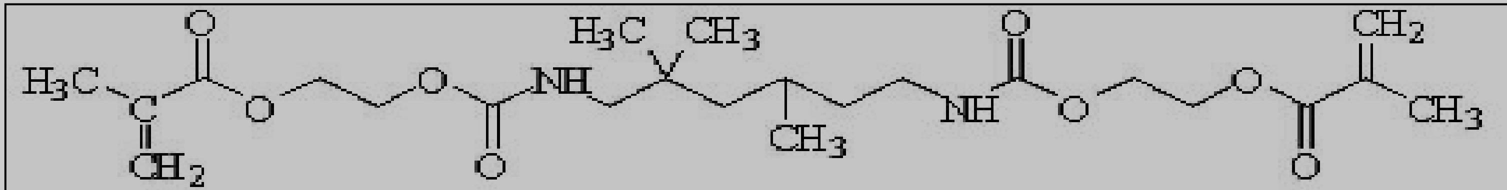
Typical dimethacrylate monomers (resins)

1. BIS-GMA 2,2-bis[4-(2-hydroxy-3-methacryloyloxypropoxy) phenyl]propane (Bowen monomer, 1955)



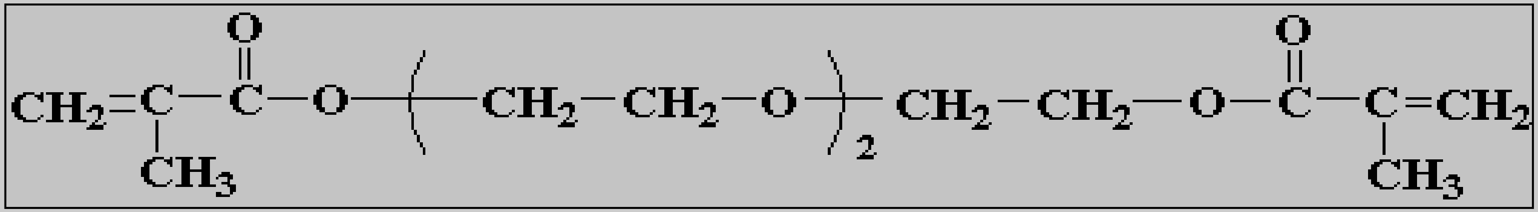
higher molecular weight – high boiling point, no odor

2. Urethane dimethacrylate (UDMA) (2,2,4-trimetylhexametyle-bis-(2-carbamoyl-oxyetyl)dimethacrylate)



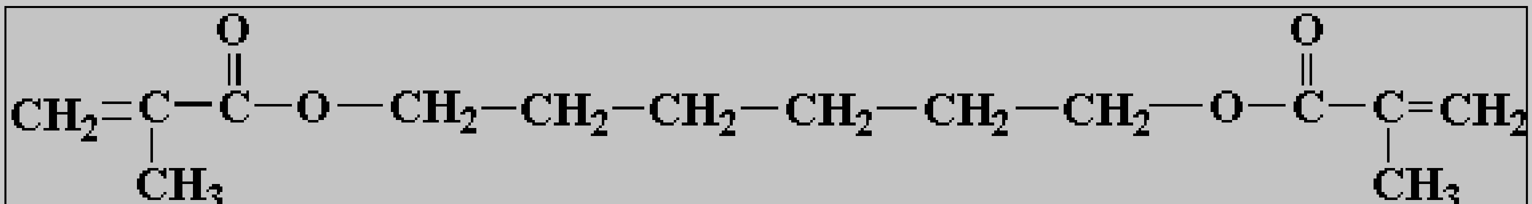
Also of high viscosity

3. Triethylene glycoldimethacrylate TEGDMA (low viscosity diluent)



n=1 ethylene glycoldimethacrylate (EGDMA)

4. 1,6 hexane dioldimethacrylate



Initiating systems and composite classification and according to initiation reactions

- **Light cured (LC)**

- Chemically cured

- **Dual cured – a combination of light and a chemical activation**

Note:

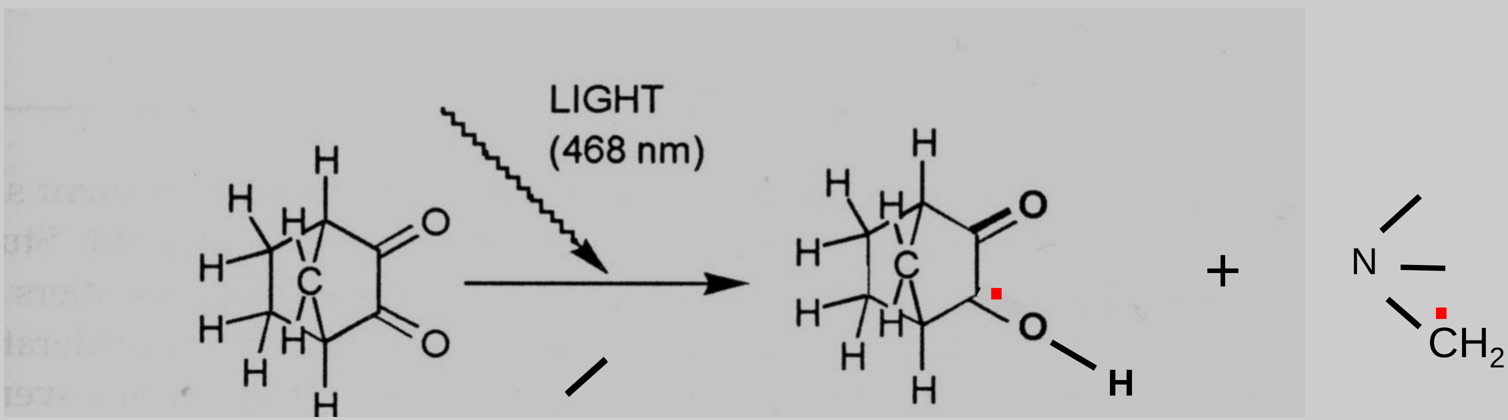
Heat cured - very rarely (microwave polymerization of some denture materials)

Light cured materials

(composite materials, adhesives)

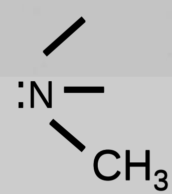
One component system

light initiating system: camphorquinone (CQ) max absorption app. 470 nm, **amine coinitiators**, inhibitors



CQ

yellow



Tertiary aromatic amine

Slowly reacting radical

Very active amine radical **starts polymerization**

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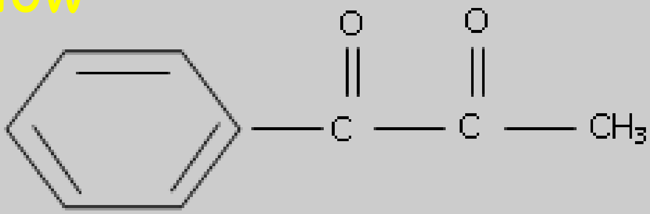
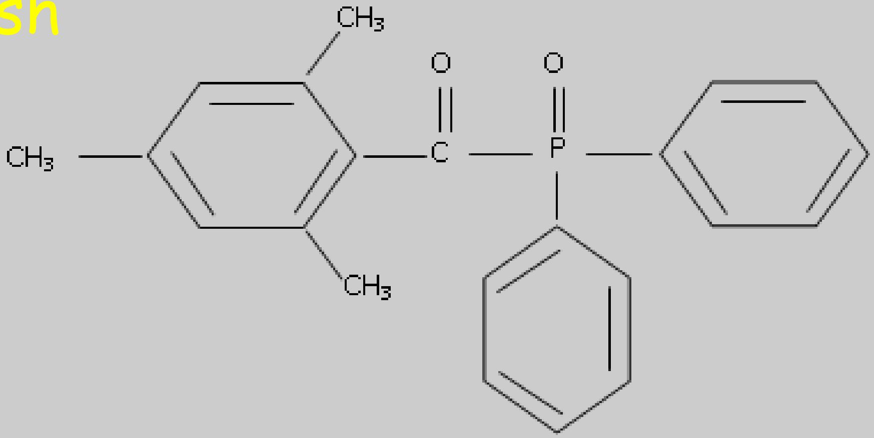
Other photoinitiators:

1-phenyl-1,2 propandion (PPD, absorption at app. 420 nm), yellow



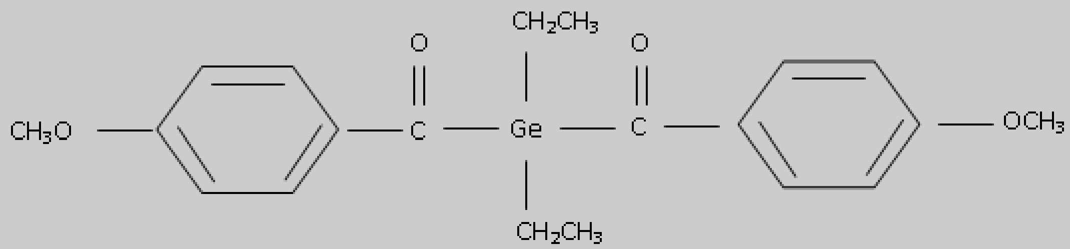
Only in combination with an amine coinitiator

Lucirin TPO: 2,4,6-trimethylbenzoyldiphenylphosphine oxide, absorption at app. 370-390 nm), slightly yellowish



Doesn´t need an amine coinitiator

Ivocerin: bis(4-methoxybenzoyl)diethyl german, absorption maximum at. 363 and 419 nm, slightly yellow



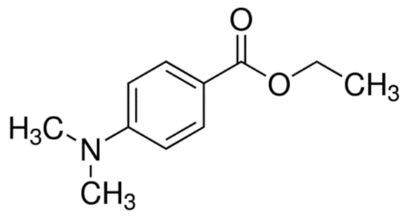
Doesn´t need an amine coinitiator

Due to enhanced efficacy of Lucirin TPO and Ivocerin their lower concentrations are used – less negative effect on composite color

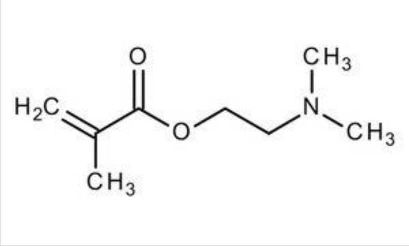
Modern materials contain usually a mixture of CQ, PPD, Lucirin TPO or Ivocerin

Amine coinitiators:

(N,N'-dimethylamino)ethylbenzoate (EDMAB)



(N,N'-dimethylamino)ethylmethacrylate (DMAEMA)



Phenolic inhibitors:

Hydroquinone (HQ), Methoxy Phenol 4-MP,

2,6-di-tertbutyl-4-methylphenol (Butylated Hydroxy-Toluene - BHT).

Chemically cured materials

composite materials, adhesives, resin cements, build-ups, temporary crown and bridge systems – **where sufficient light penetration can not be garanteed**

Two-component systems:

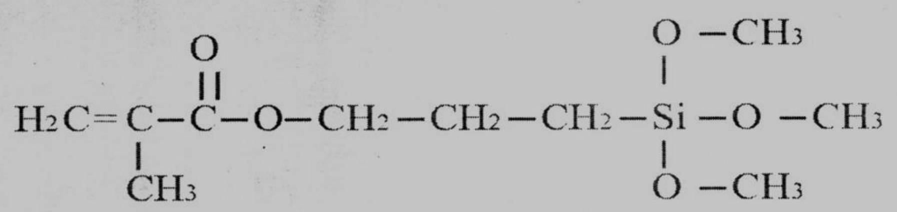
Paste – paste systems: base paste (amine) and catalyst paste (DBP),

Powder - liquid systems (old fashioned).

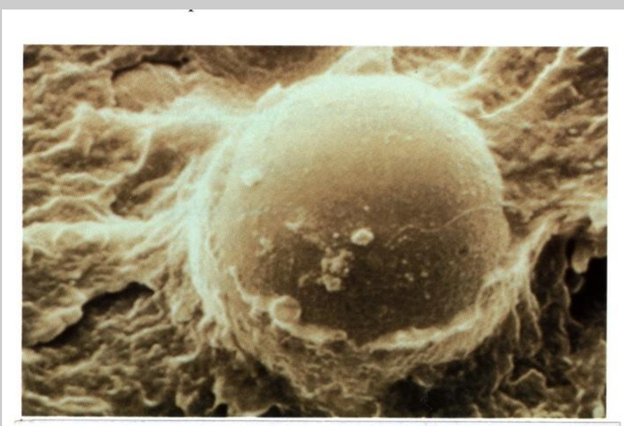
Fillers (particulate):

50 – 90 wt. % of silanated ground Ba-Sr glass, synthetic Zr glass (Zr-silica), pyrogenic silica SiO_2 (silica), pigments

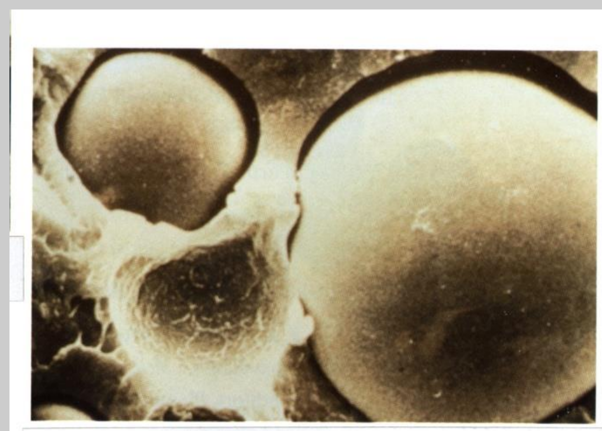
Coupling agents:



γ-methacryl-oxypropyltrimethoxysilane (A 174)



Treated surface



Untreated surface

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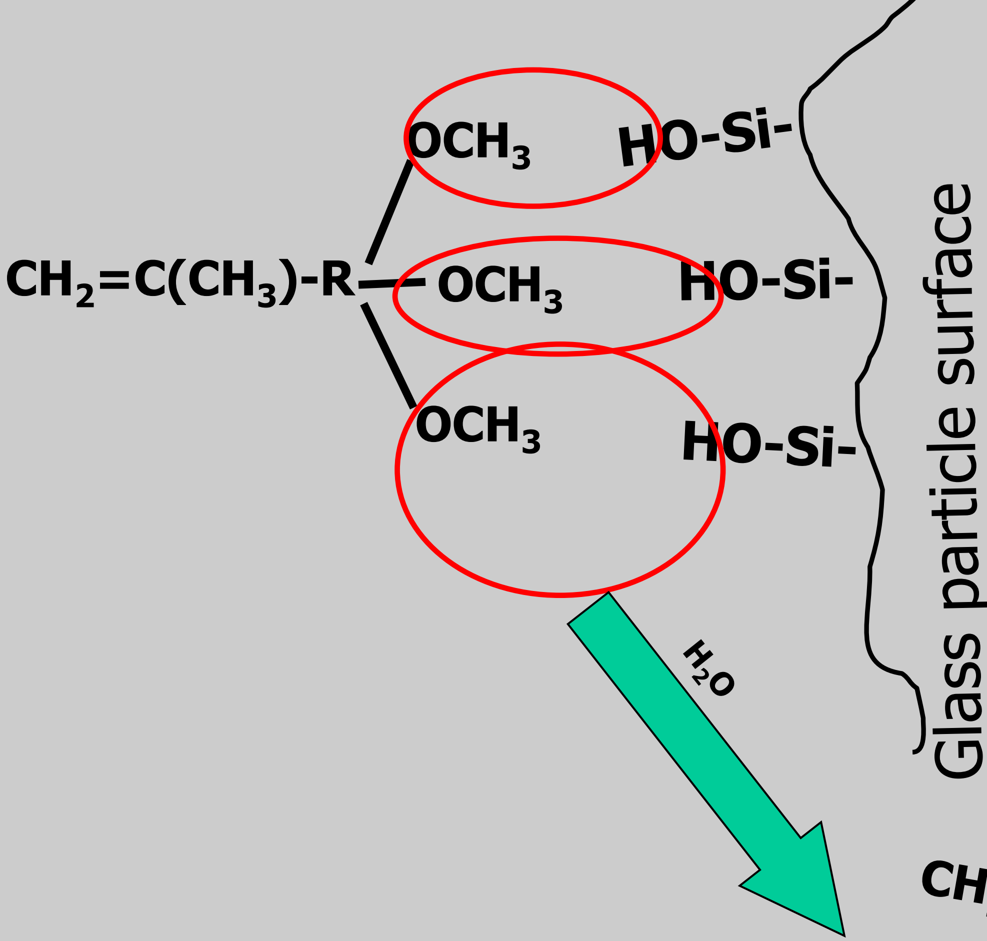
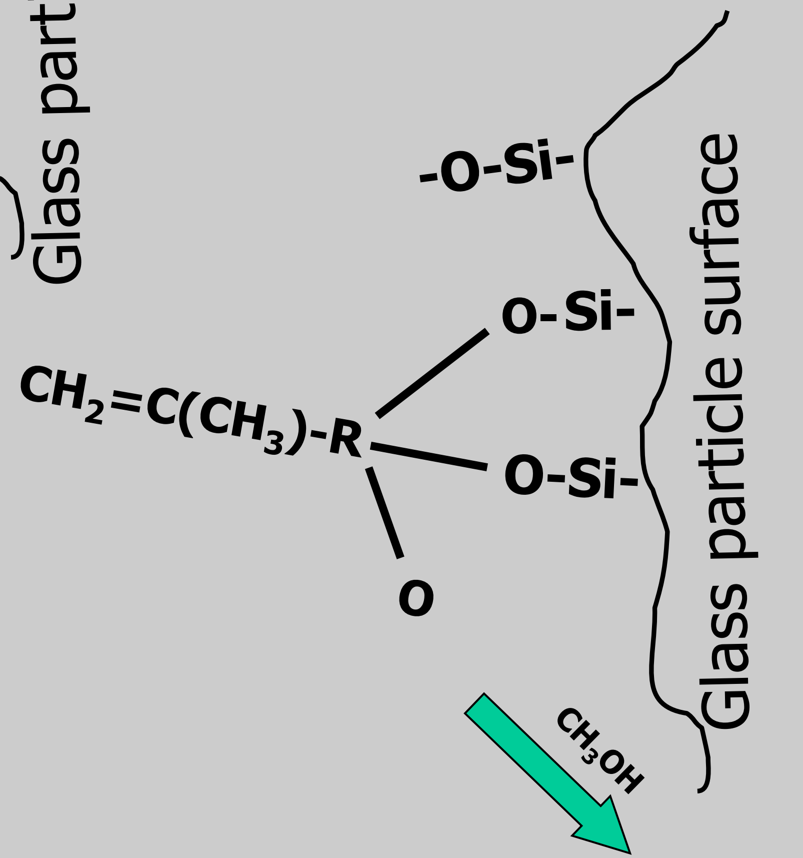


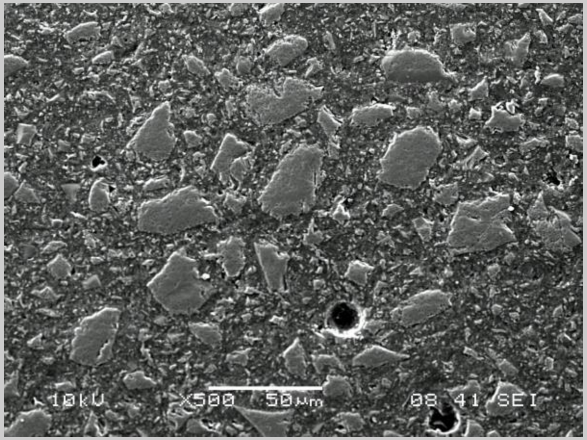
During manufacturing - hydrolysis of methoxy groups and their reaction with silanol groups on the glass particle surface (methanol is released)



During polymerization – double bond of silane molecules are copolymerised with monomers creating <u>covalent</u> bond between filler particles and a matrix

Classification according to the filler particle size

1. Conventional/traditional/**macrofilled** composites (quartz, glass, particle size 5 – 50 μm)

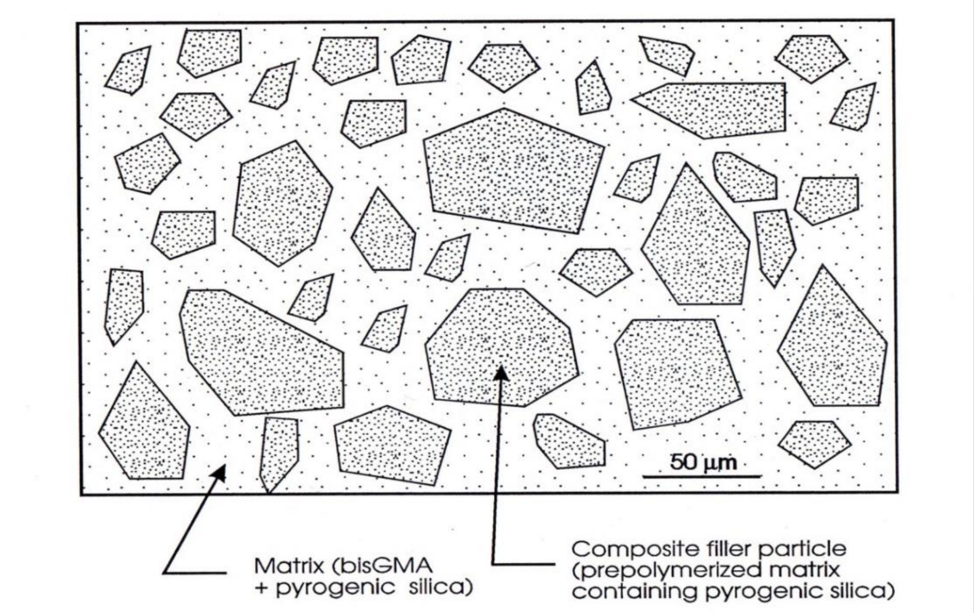


Quartz – extremely hard, **pronounced abrasion**, surface staining

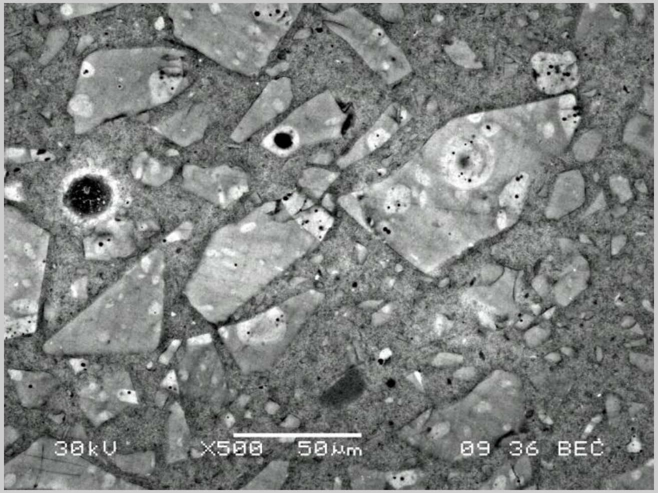
Filler load 50-65 wt. %

Polydisperse mixture of various particle size – to fill the whole volume with filler particles

2. Microfilled composites – a) heterogeneous: filled with 1–50 μm ground „prepolymer" (composite of ~0.04 μm pyrogenic SiO_2) in a matrix filled with similar SiO_2, b) homogeneous: filled with only SiO_2 particles ~0.04 μm.



App. 60 % of filler particles

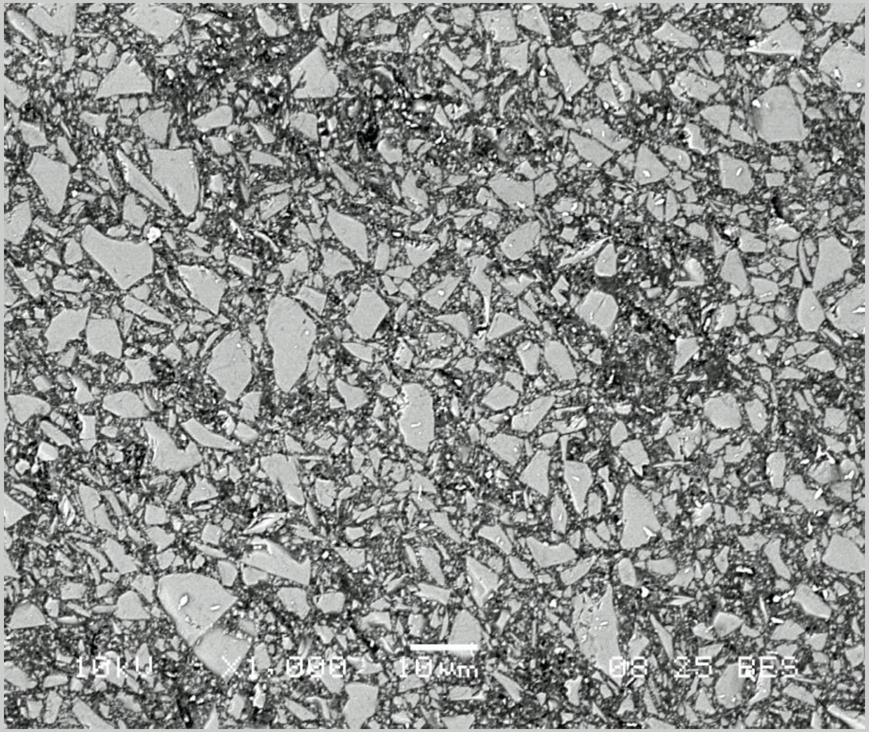


Advantages: highly aesthetic, easy to polish, high gloss

Disadvantages: low mechanical strength

3. Hybrid composites

- ground glass – „small" particle size 1 – 5 µm,
- pyrog. SiO_2 (0.04 µm) 0-3 wt. % (to adjust thixotropy and not stickening properties



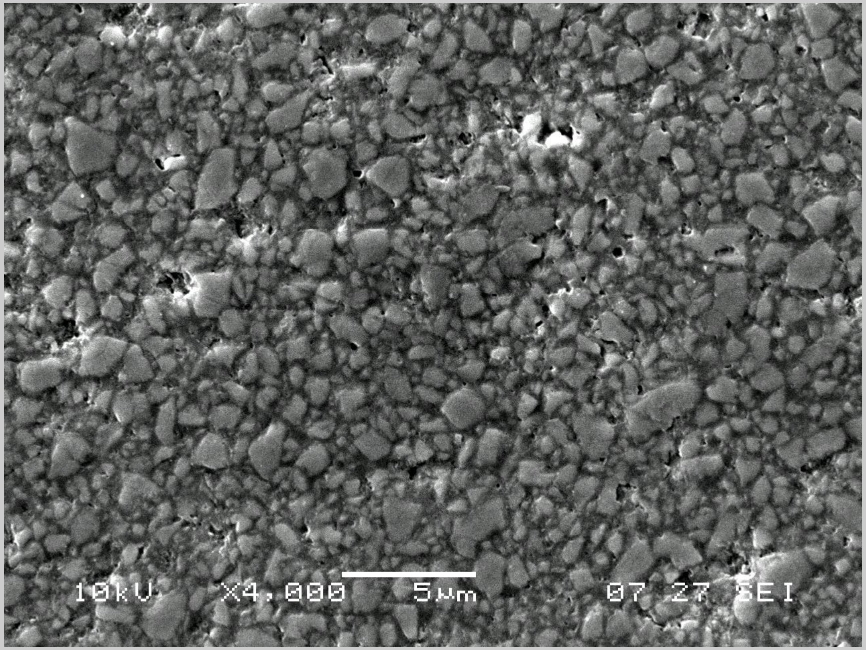
Filler load ~ 70 wt. %

Advantges: universal (high mechanical strength)

Disadvantages: not so aesthetic, poor polishability

4. Microhybrid composites

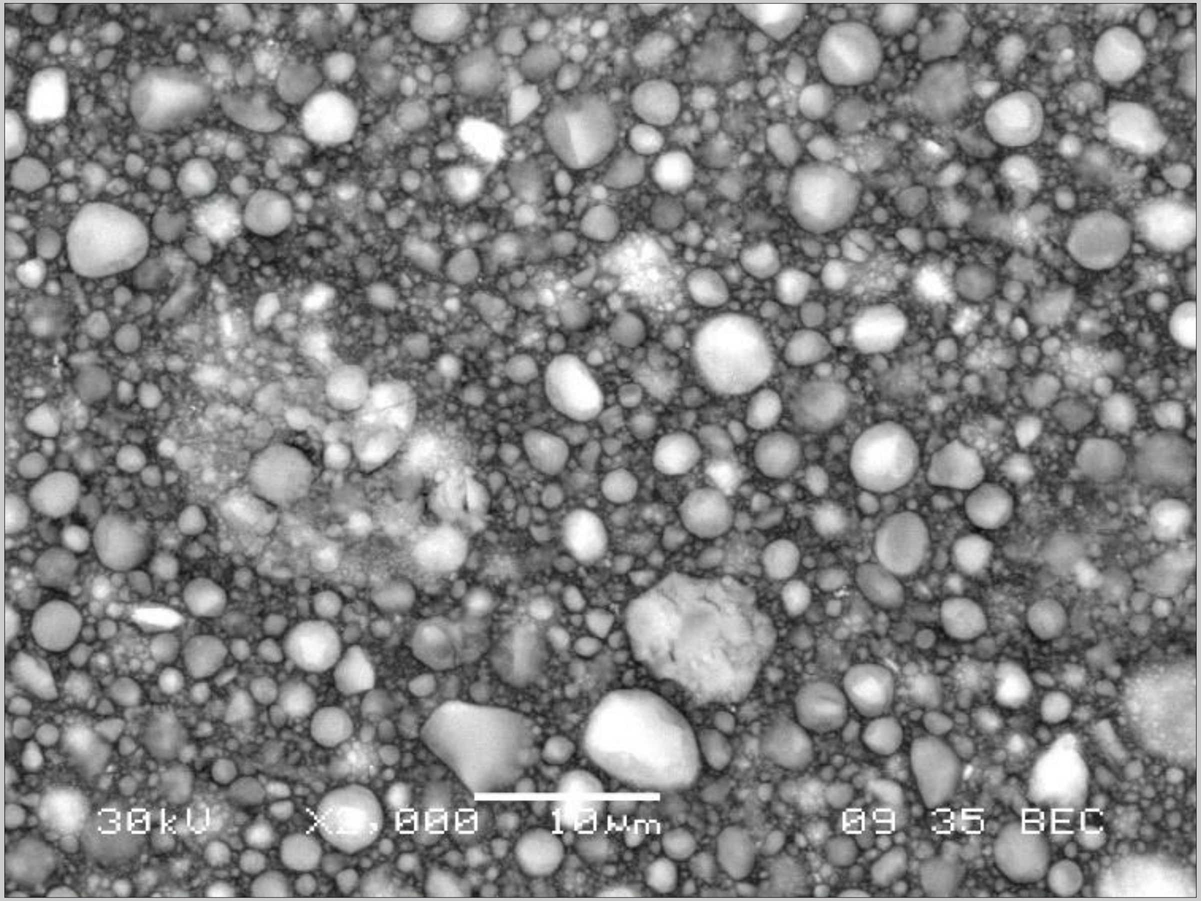
- ground glass, size below 1 μm
- amorphous SiO_2 5-10 wt. %



Filler load 70 – 75 wt. %

5. Nanocomposites/nanohybrid composites

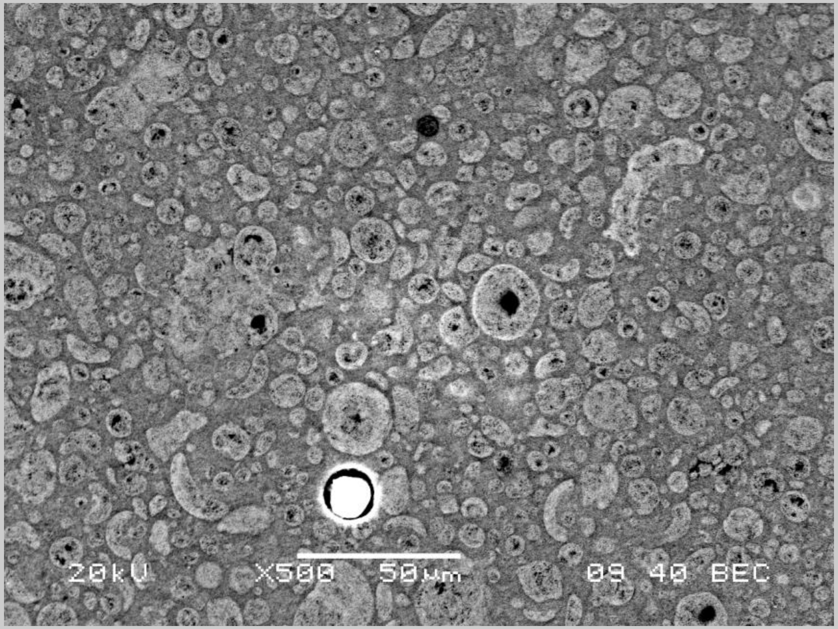
1. Spherical nanoparticles ~ 10 – 40 nm and their clusters (agglomerates) of particle size 1 – 3 µm

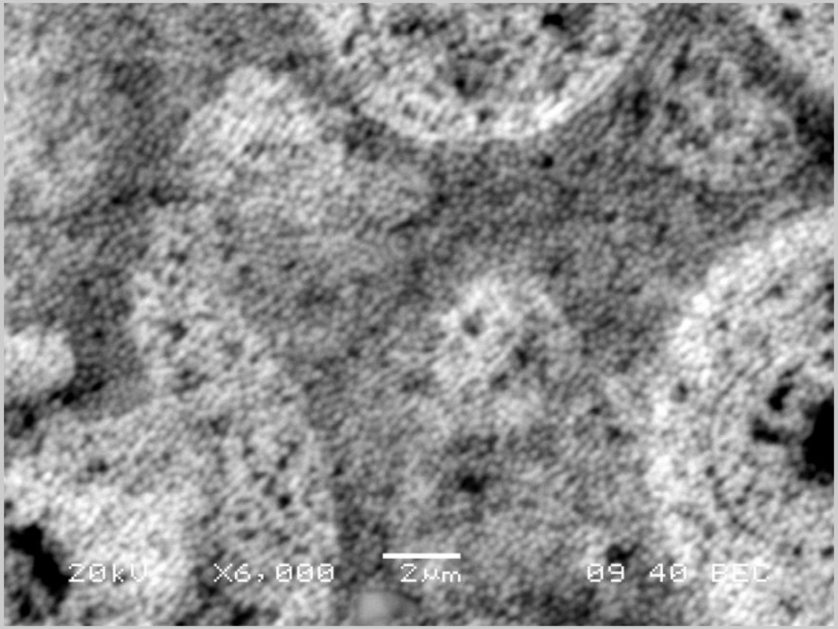


2000x

2. Another example: mixture of app. 200 nm particles and their agglomerates

500x





6000x

Advantages: Increased filler load (80 wt. %)

Decreased polymerization shrinkage

Excelent aesthetic properties, gloss and polishability

Low abrasion

Disadvantages: Higher price

Advantages of composite materials

- Tooth coloured
- High mechanical resistance
- Low solubility in the oral cavity
- Good biological properties

Disadvantages:

- Time consuming working protocol
- **Not adhering to the tooth tissues**
- **Polymerizatin shrinkage**
- **No self-protecting effect**
- High price

Classification of composites according to the particle size

composite	Filler	Particle size [μm]
Traditional/Conventional (macrofilled)	Ba-Sr glass, quarz	5 – 50
Microfilled • Heterogeneous (1+2) • Homogeneous (2)	1. Spliter" – prepolymerized ground with amorphous SiO_2 (d=0.04 μm) „organic filler" 2. amorphous SiO_2	1–50 0.04
Hybrid	1. Ba-Sr glass 2. amorphous SiO_2	1-5 0.02-0.04
Microhybrid	1. Ba-Sr glass, syntetic Zr-Si (zirconia-silica) 2. amorphous SiO_2	<1 0.02-0.04
Nanocomposites	1. nanoparticles 2. nanoclusters – nanoparticle agglomerates	~ 0.10 – 0.04 1 – 3

Filler load app. 55-85 wt %, amorphous $Si0_2$ app. **3-10 wt. % to control thixotropic properties**

Literature:

- Craig RG., Powers JM., Wataha JC: Dental Materials, Properties and Manipulation, Mosby
- Powers JM., Sakagushi RL: Craig´s Restorative Dental Materials, Mosby
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