Textile Chemistry

2 Polymers II - synthesis and applications

Jakub Wiener

Classification of polymers

- inorganic - e.g. diamond, graphite, various carbides, silica (SiO2)x

- organic - natural (= biopolymers)
  - synthetic

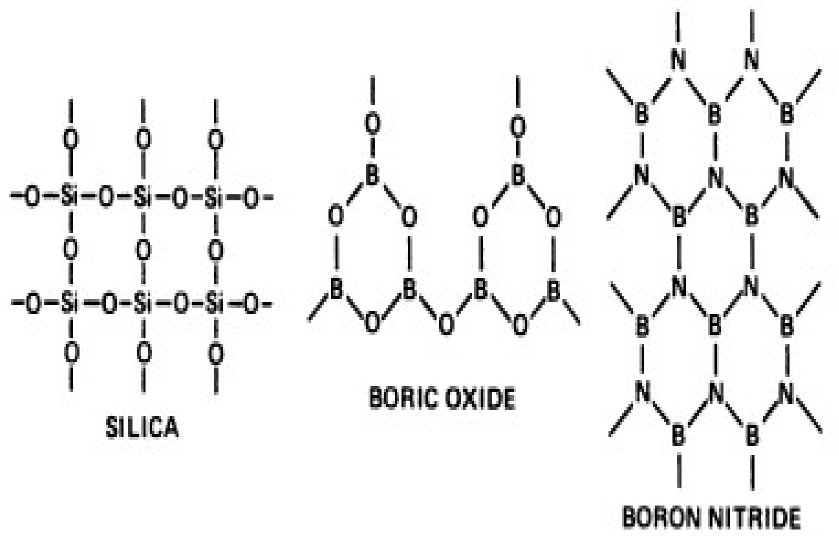
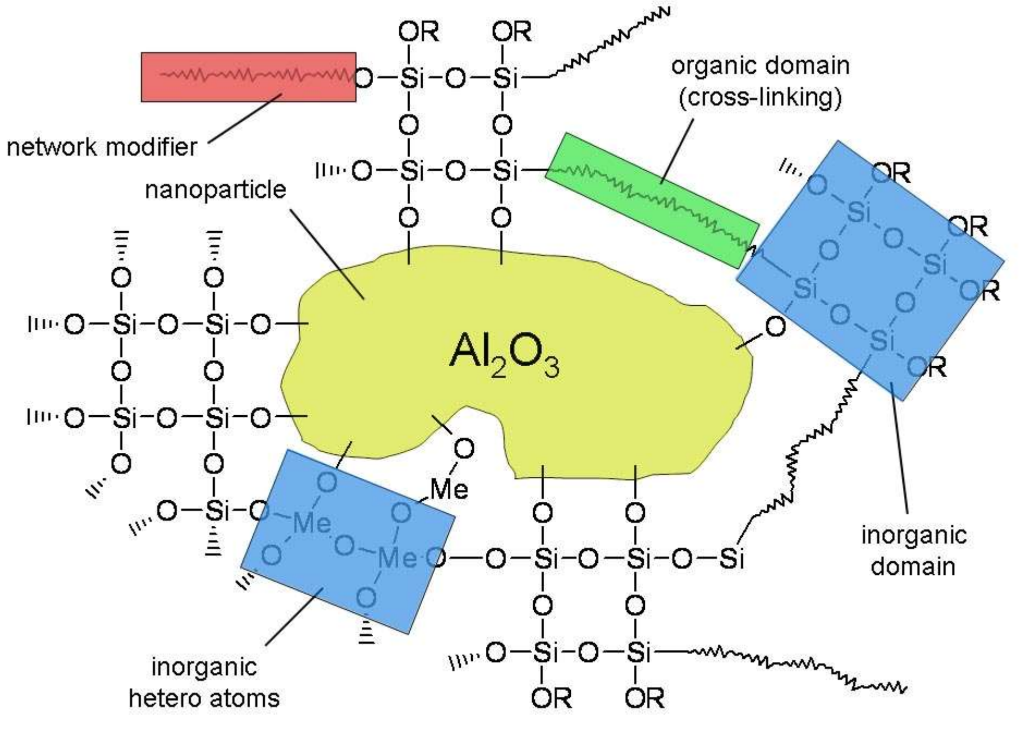


Figure 1.– *Some inorganic polymers.*



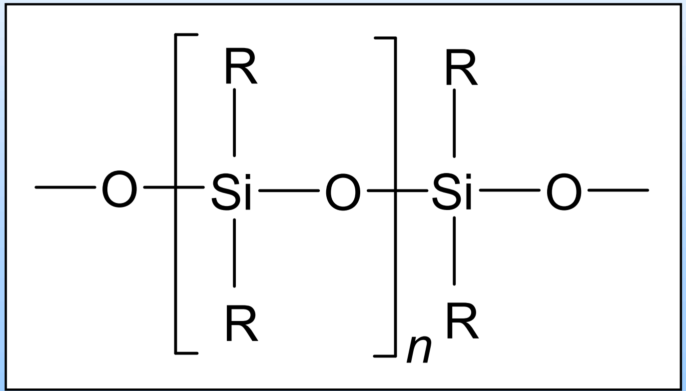
Hybrid (organic-inorganic polymers)

Silicones

If the bonds between the atoms in the macromolecule chain are strong, the energy of these chemical bonds will be high and the polymer will be stable.

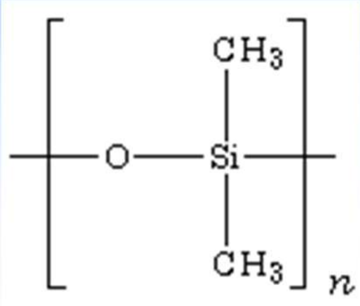
Chemical bond energies - if they are high, the bonds between the atoms in the macromolecule chain are strong and the polymer is stable.

(e.g. in silicones, the Si-O bond energy is much higher than the C-C bond energy in carbon polymers)



Si-O (444.1 kJ/mol) > C-C (347.8 kJ/mol)

Silicones $(R_2SiO)_n$



contain siloxane bonds - O - Si -

Inorganic-organic polymers

The long-term heat resistance of silicone rubbers ranges from -60 to +180 °C (special types -100 to +260 °C, short-term up to +320 °C).

Inert to living organisms. Other properties include relative fire resistance, good electrical insulation properties, long-term resistance to UV radiation and weather conditions, water repellency (hydrophobicity) and vapour permeability

Production: They are prepared by hydrolysis of alkyl or aryl-chlorosilanes

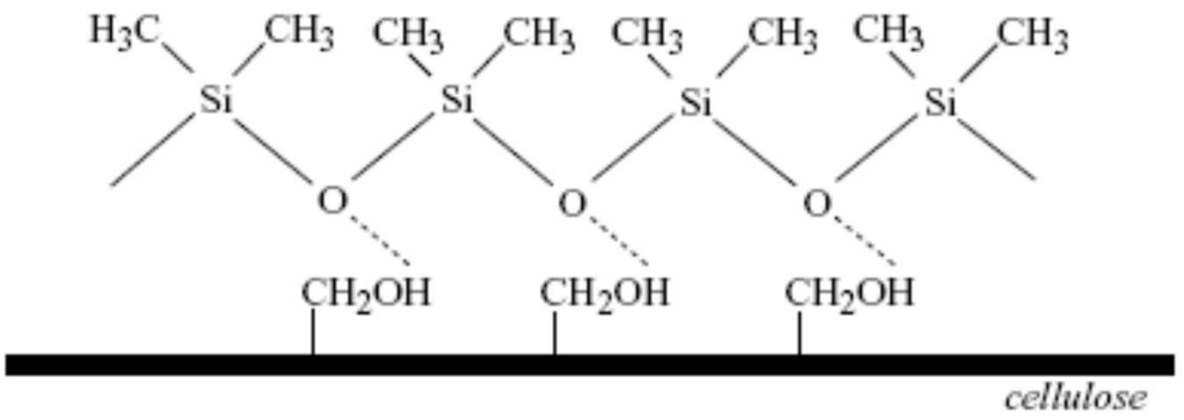
These are prepared by direct synthesis of alkyl or aryl chlorides and elemental °C (Cu catalysis, 400°C)

Silicones $(R_2SiO)_n$

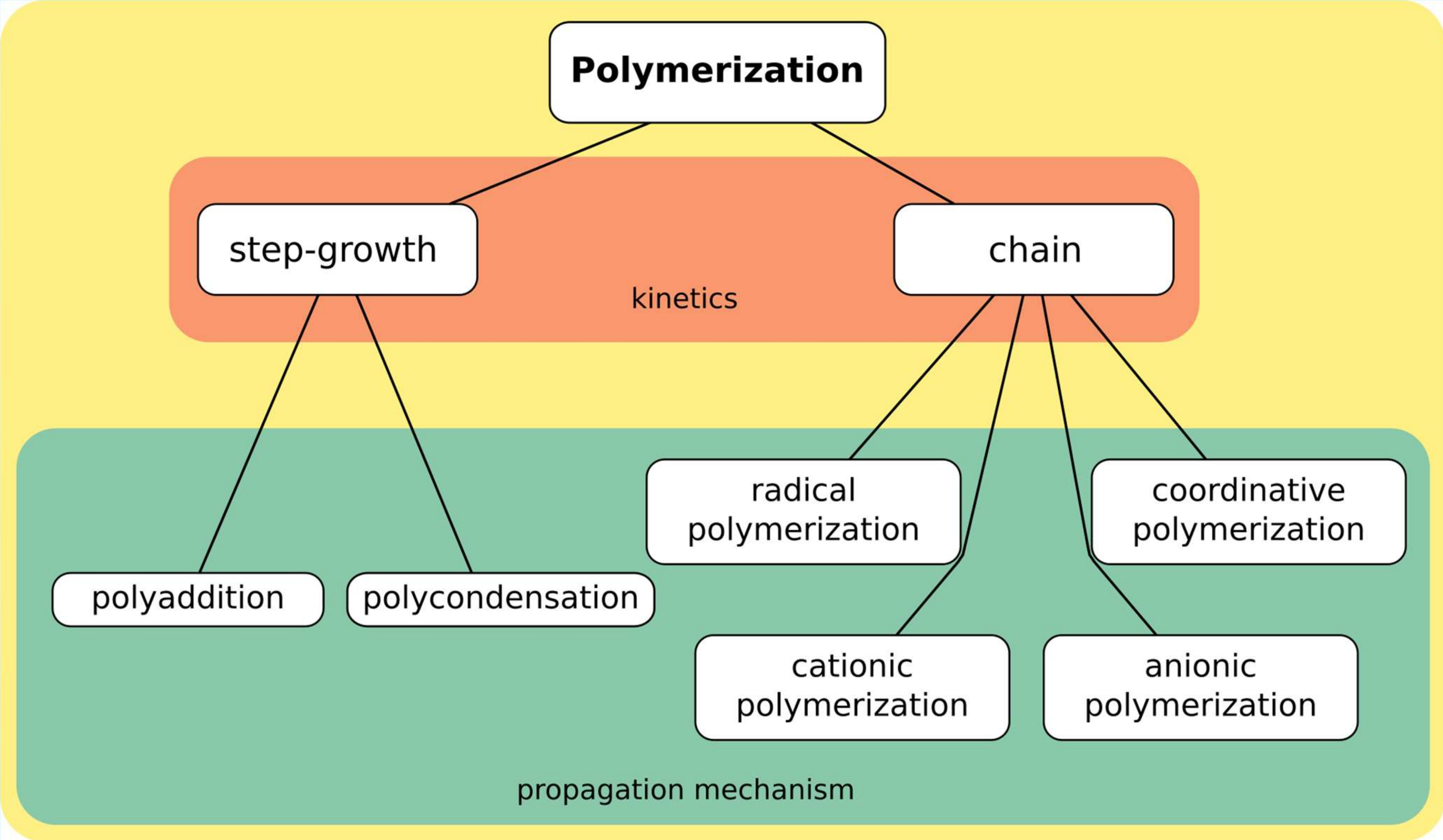
Silicones - They tolerate high temperatures well, are chemically less reactive, and are hydrophobic.

Use of silicones:

- as lubricants for heat-stressed machine parts
- plasticizers
- as hydrophobicity agents (water repellent)



Mechanisms of polymer formation



Mechanisms of polymer formation

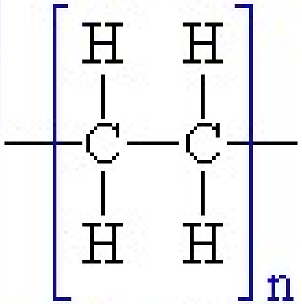
- Chain Polymerization: double bond required in the starting monomer A-A-A-A-A..
- Polycondensation: a small molecule is released during synthesis (e.g. water, methanol...) ..A-B-A-B-A-

A + B ► macromolecule + e.g. water

- Polyaddition: monomers have reactive groups, no low molecular weight substance is released ..A-B-A-B-A-B-A
- A + B ► macromolecule

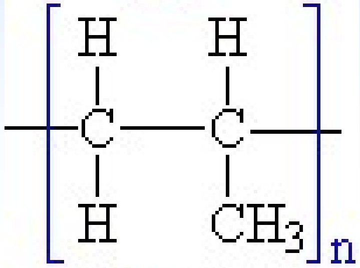
Polymerization

PE



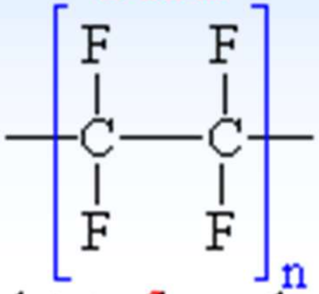
polyethylen

PP



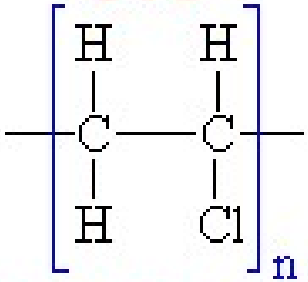
polypropylen

PTFE



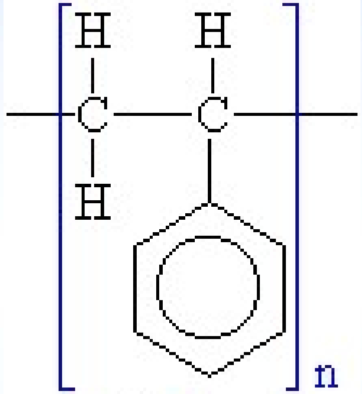
polytetrafluorethylen

PVC



polyvinylchlorid

PS



polystyren

Polyethylene

abbreviation: PE

HDPE (High Density PE)
LDPE (low density PE)

- properties: white, semi-transparent, flexible and tough to the touch;
has excellent electrical insulating properties; thermoplastic substance that can be moulded into desired products,
- applications: food packaging, foil, crockery, toys, chemical bottles, hoses, electrical cable insulation, in the medical sector for the manufacture of artificial blood vessels, etc,
- monomer: ethene (ethylene).

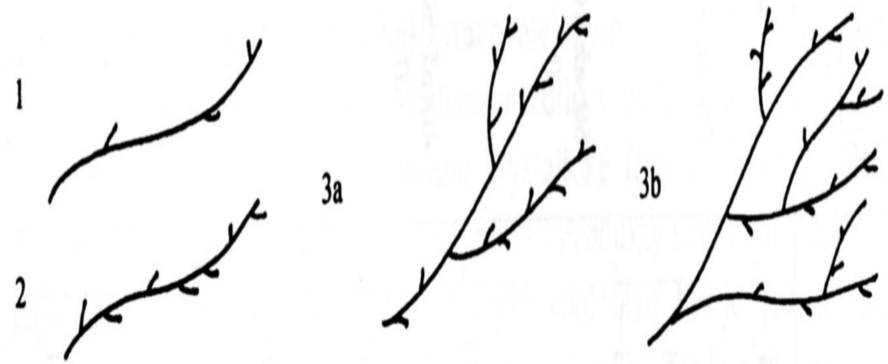
$$-\!\!\left[CH_2 - CH_2 \right]_n\!\!-$$

Polyethylene

Zkratka	Hustota (g/cm³)
ULDPE (Ultra-Low Density)	0,888–0,915
LDPE (Low Density)	0,910–0,955
LLDPE (Linear Low Density)	0,918–0,955
MDPE (Medium Density)	0,925–0,940
HDPE (High Density)	0,941–0,954
HMW-HDPE (High Molecular Weight HDPE)	0,944–0,954 MH = 200 000–500 000
UHMW-HDPE (Ultra-High Molecular Weight HDPE	0,955–0,957 MH = 3 000 000–6 000 000

$$n\ H_2C{=}CH_2 \xrightarrow{\text{polymerace}} -[CH_2-CH_2]_n-$$

ethylen → polyethylen



Obr. 2.1. Struktura makromolekul různých typů PE: *1* – HDPE, 2 – LLDPE (krátké větvení), 3 – LDPE (dlouhé a krátké větvení, *a* – trubkový reaktor, *b* – autokláv)

HDPE (vysokohustotní PE)

LDPE (nízkokohustotní PE)

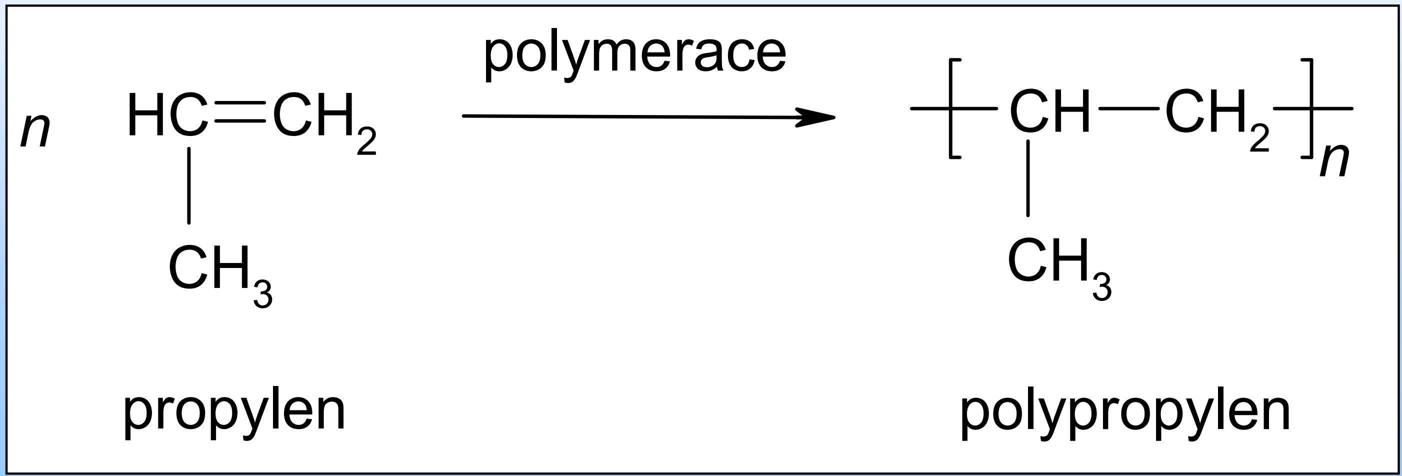
Polypropylene

abbreviation: PP,

- properties: similar to PE, but stronger; resistant to temperatures up to 160°C,

- use: packaging material, utensils, insulation of electrical cables, in the medical sector for the production of syringes and items that can be sterilised (free of germs) at temperatures above 60°C, for the production of fibres, ropes

- monomer: propene (propylene)



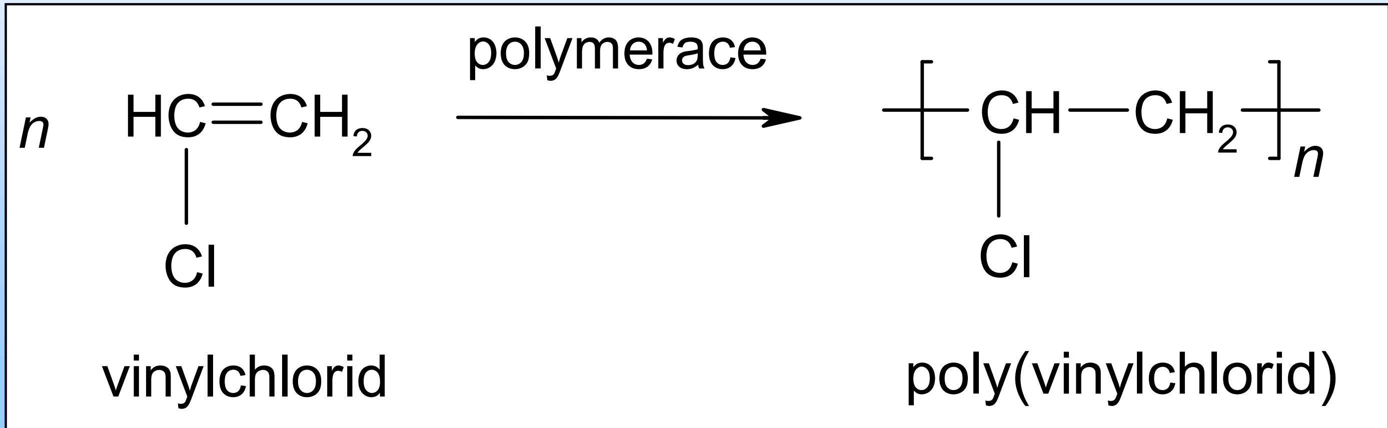
Polyvinylchloride

- abbreviation: PVC,

- properties: thermoplastic substance that can be well thermoformed (softens at 80°C); resistant to acids and hydroxides, use:

- **non-plasticized PVC is used for the production of water pipes, rods or plates;**
- **softened PVC for the production of plastic, foils, jackets raincoats, toys, films, tablecloths, bottles, artificial fur, etc,**

monomer: vinyl chloride.



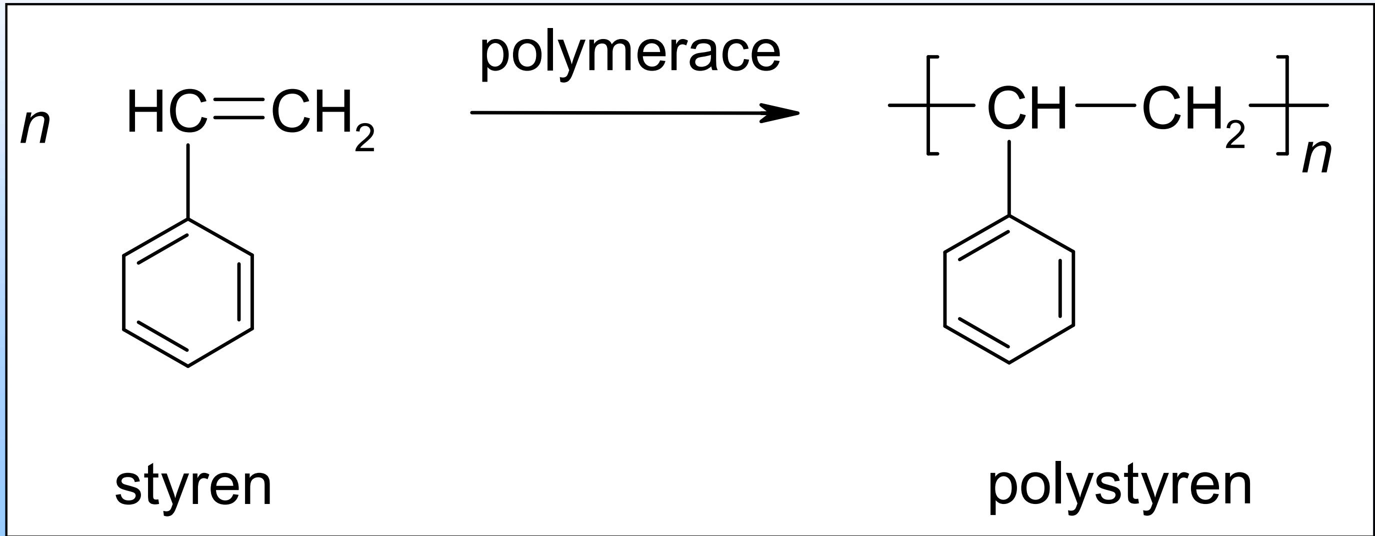
Polystyrene

- PS,

- Properties: hard, strong but brittle; acid and alkali resistant, thermoplastic, soluble in organic solvents (aldehydes, ketones, gasoline), acoustic and low-temperature insulator,

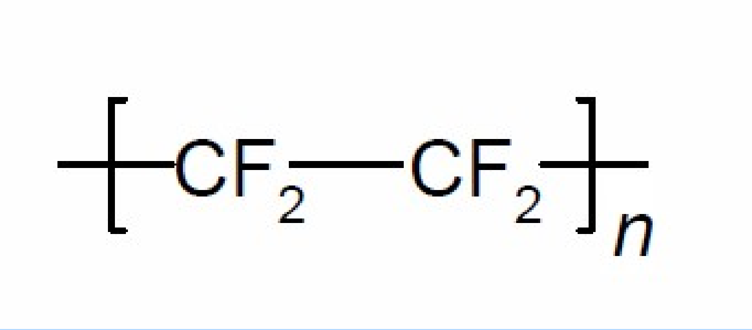
use: for the production of consumer goods, packaging, combs, bowls, spoons, yoghurt cups; foam PS as thermal or insulating material in the construction and refrigeration industry, etc,

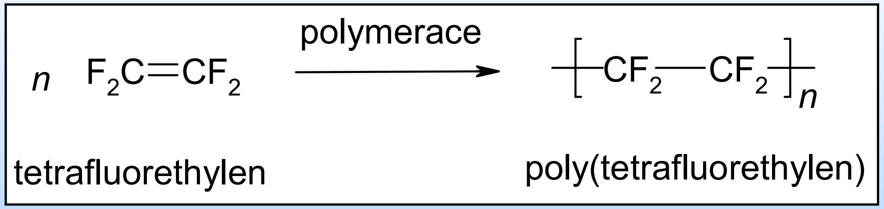
- monomer: styrene (vinylbenzene).



Polytetrafluoretylene

- abbreviation: PTFE,
- trade name: Teflon,
- Properties: non-flammable, non-toxic thermoplastic, chemically very resistant (can withstand even hot Arctic Charcoal),
- use: special laboratory equipment, bone substitutes in surgery, kitchen utensils, etc,
- monomer: tetrafluoroethylene (tetrafluoroethylene).

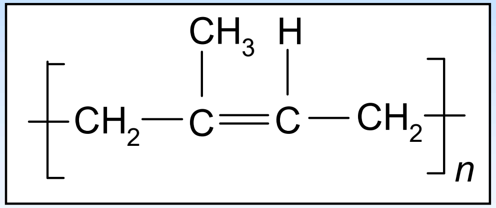




Elastomers

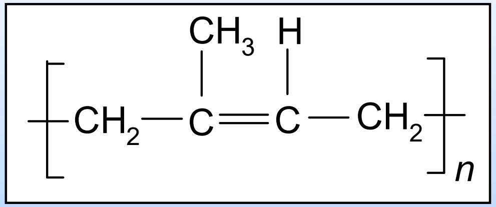
Natural rubber

latex milk from rubber tree

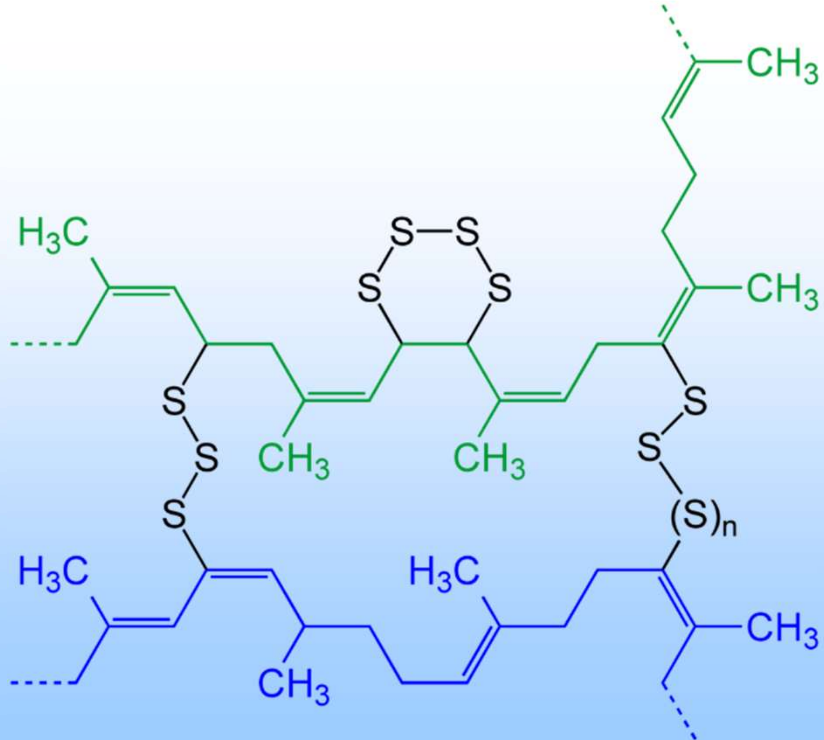


structural unit of natural rubber

Natural rubber



Vulcanisation of rubber



Elastomere

Elastomers

Polybutadiene rubber

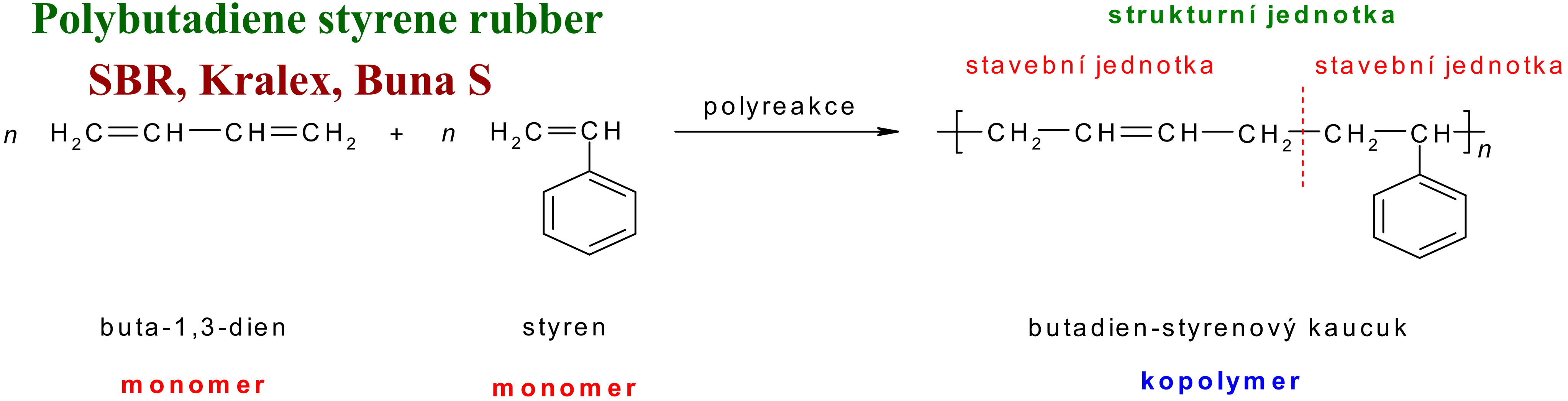
BR, Buna

$$n\ H_2C{=}CH{-}CH{=}CH_2 \xrightarrow{\text{polymerace}} {+}CH_2{-}CH{=}CH{-}CH_2{+}_n$$

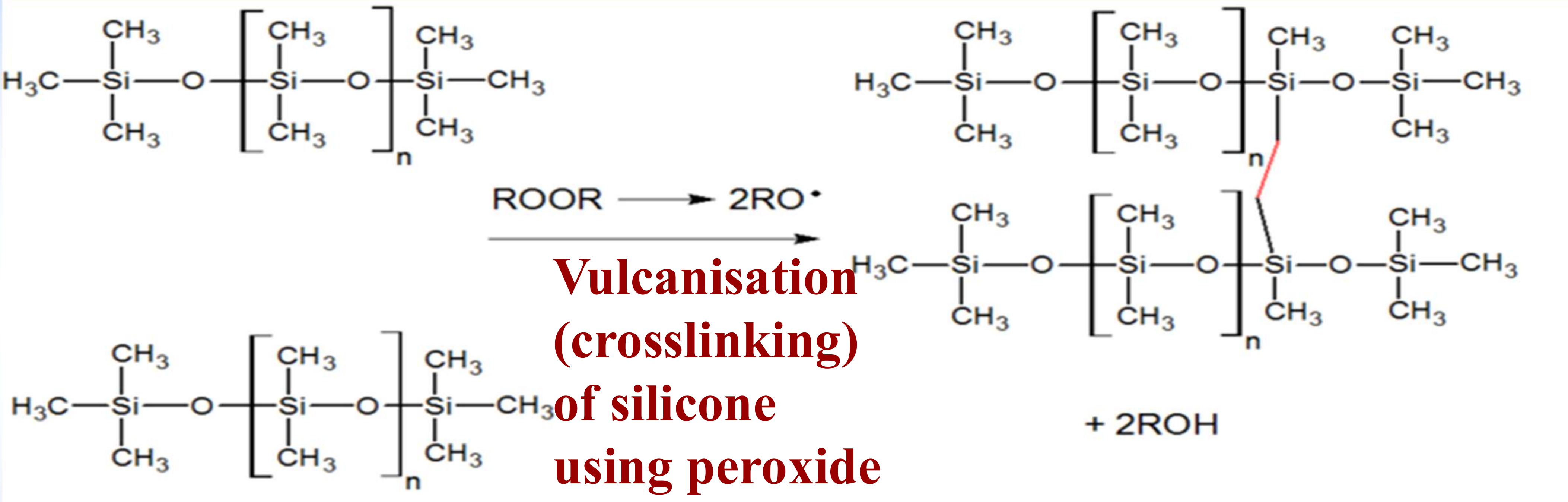
buta-1,3-dien — polybutadienový kaucuk

Polybutadiene styrene rubber

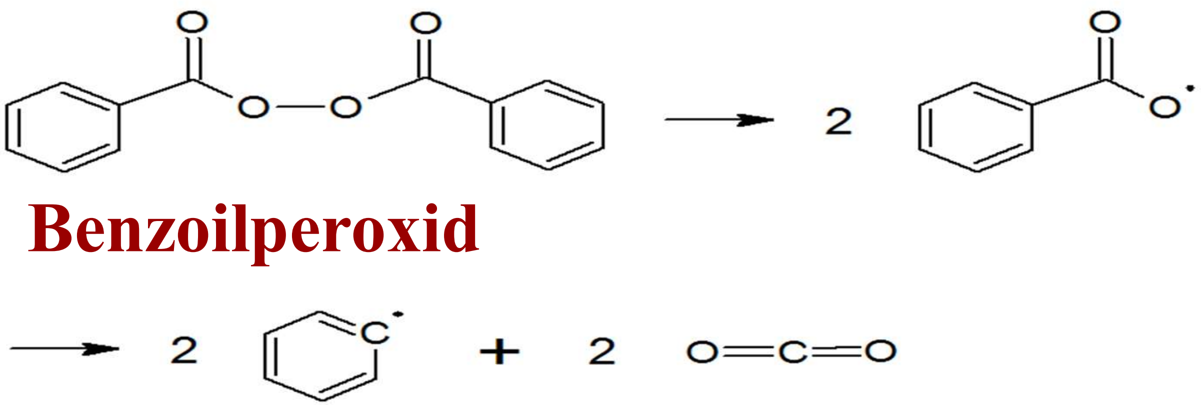
SBR, Kralex, Buna S



Elastomers



Vulcanisation (crosslinking) of silicone using peroxide



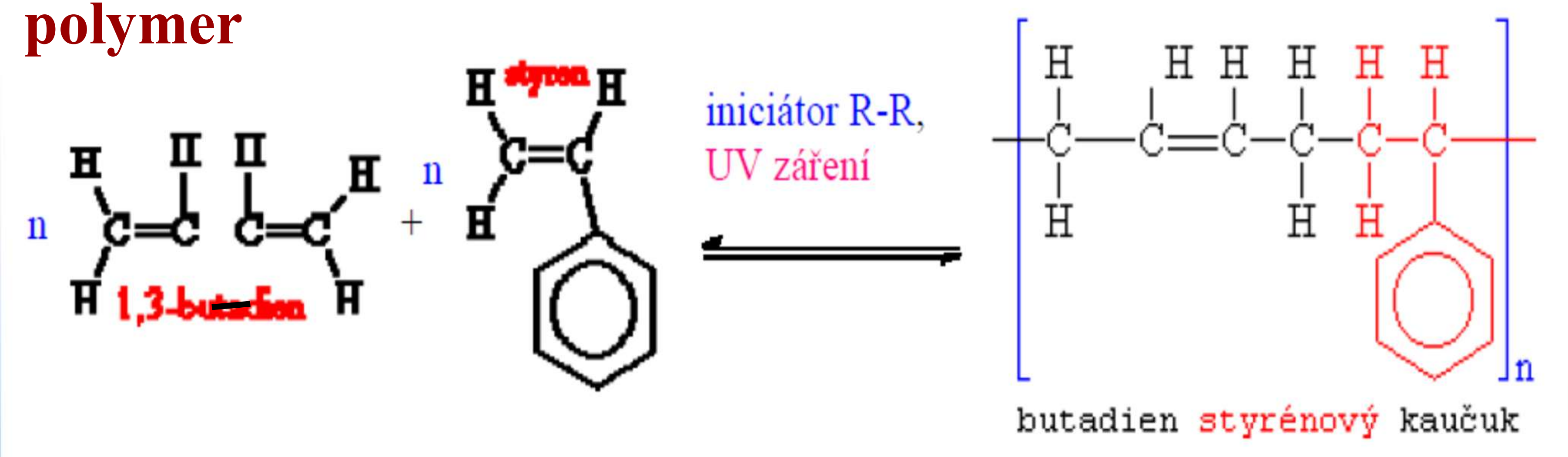
Benzoilperoxid

https://en.wikipedia.org/wiki/Benzoyl_peroxide

Copolymers

Homopolymer - a polymer formed from a single monomer having (usually) identical structural and structural units, the name is usually formed by prefixing poly- before the monomer name

Copolymers - polymers purposefully prepared from 2 or more monomers, the order of the units is not as important as DNA, but determines the properties of the resulting polymer



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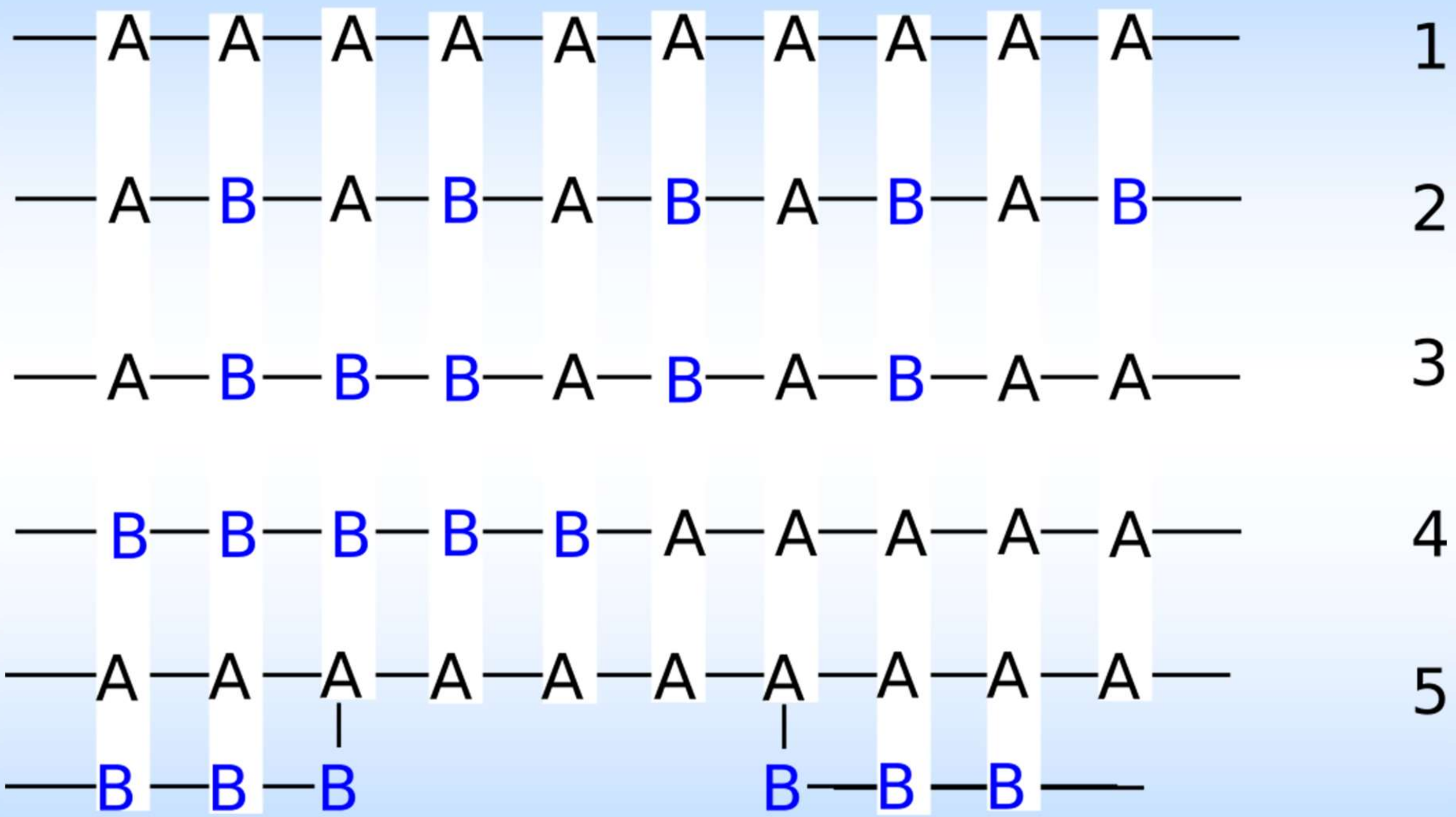
Copolymers



Different types of polymers:

1) homopolymer 2) alternating copolymer 3) random copolymer 4) block copolymer 5) graft copolymer.

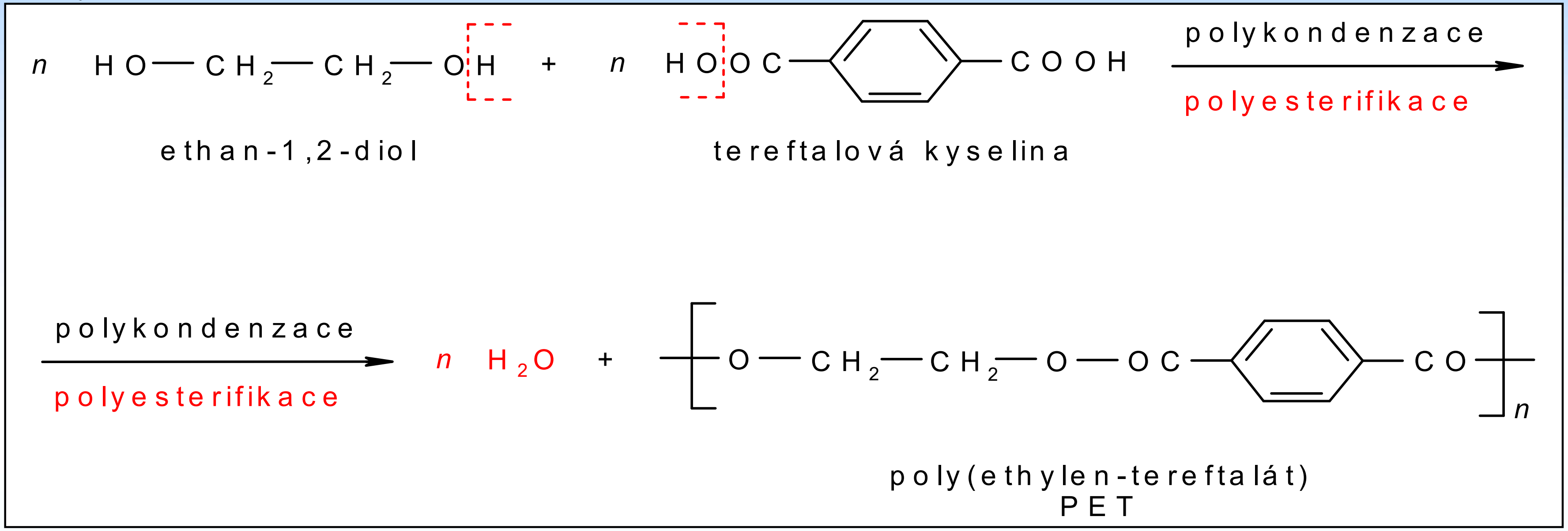
Polycondensation

Reaction of 2 different (or identical monomers) - at least two functional groups on each monomer

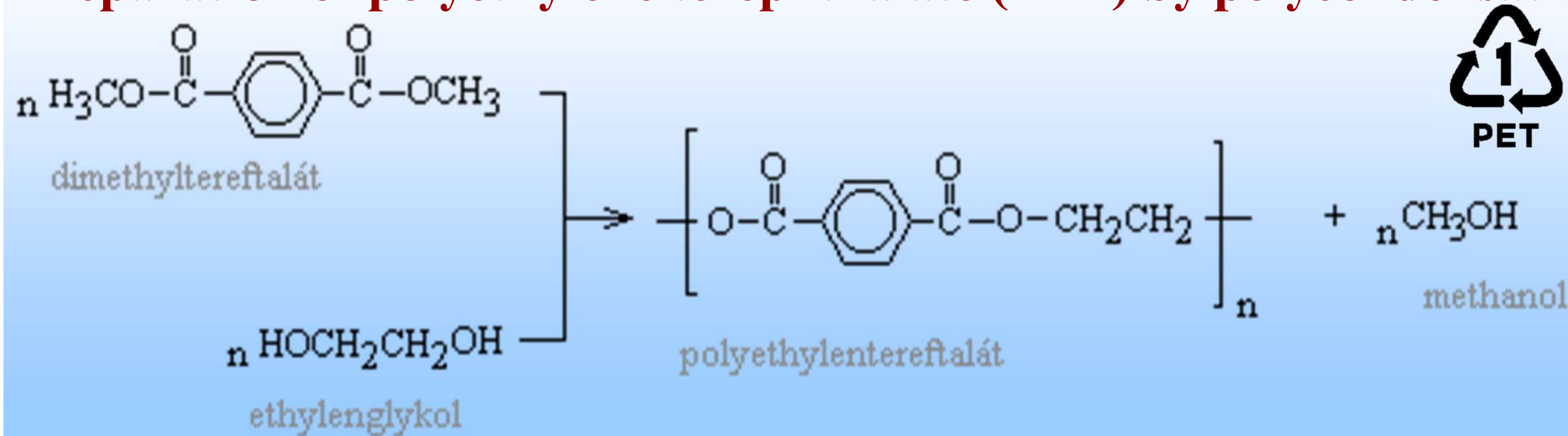
Reaction of functional groups brings molecules together - macromolecule is formed, simultaneously low molecular weight product is released (e.g. water, methanol...)

This is how polyamides and polyesters are formed

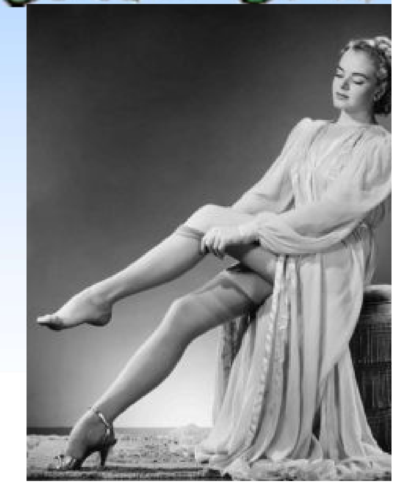
Polycondensation



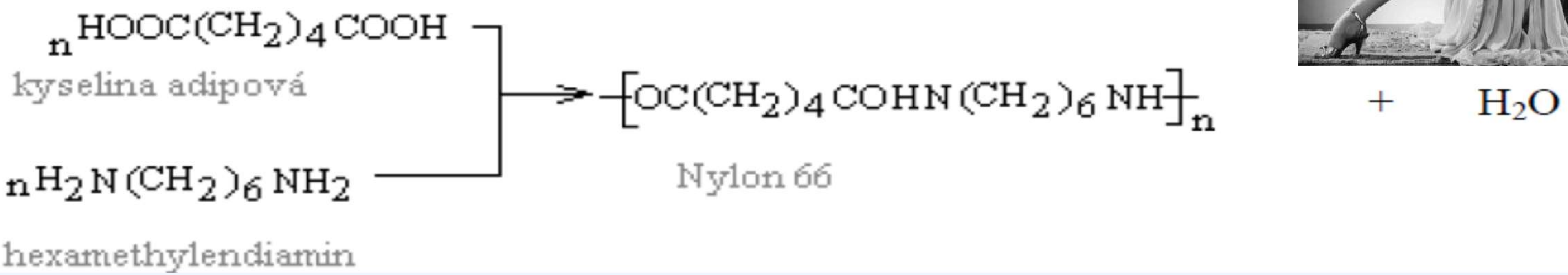
Preparation of polyethylene terephthalate (PET) by polycondensation

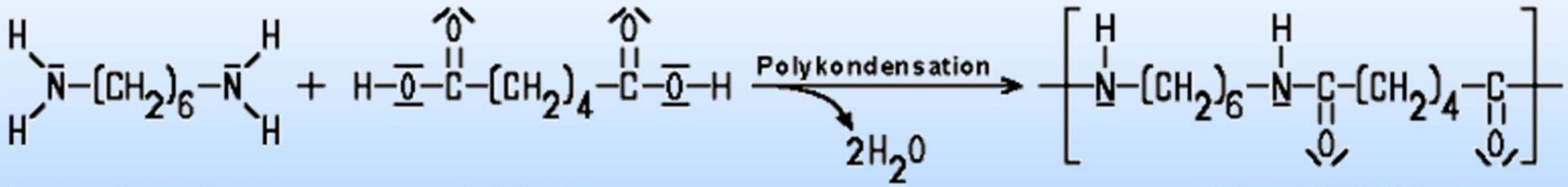


Polycondensation



Polyamide 6.6 is formed by the reaction of adipic acid and hexamethylene diamine
(The by-product of the reaction is water)





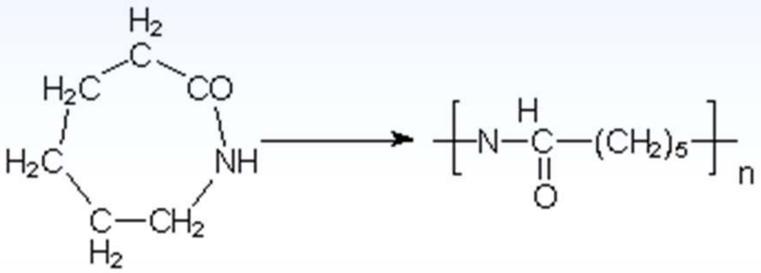
Hexamethylendiamin   Adipinsäure   Polyamid 6.6 (Nylon)

Polyamides - prepared by polycondensation of diamines with dicarboxylic acids or polymerization of cyclic amides,

- polyamide macromolecules contain a peptide bond (-CO-NH-), which repeats regularly in the macromolecule chain.

Polycondensation

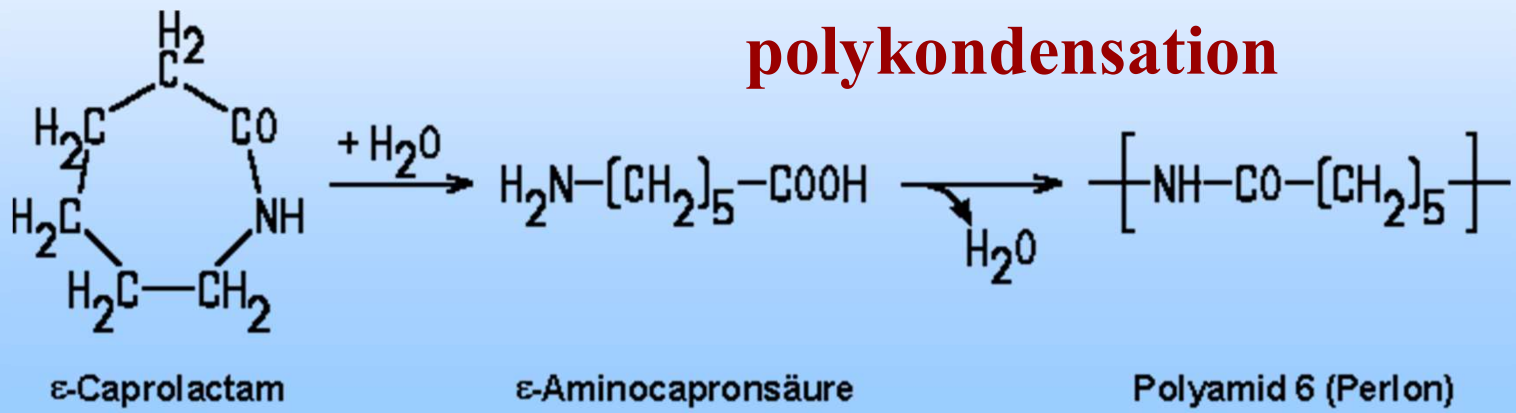
How polyamide 6 is formed from ε-caprolactam



polymerisation

Paul Schlack 1938 (Perlon), Otto Wichterle 1940 (Silon)

polykondensation

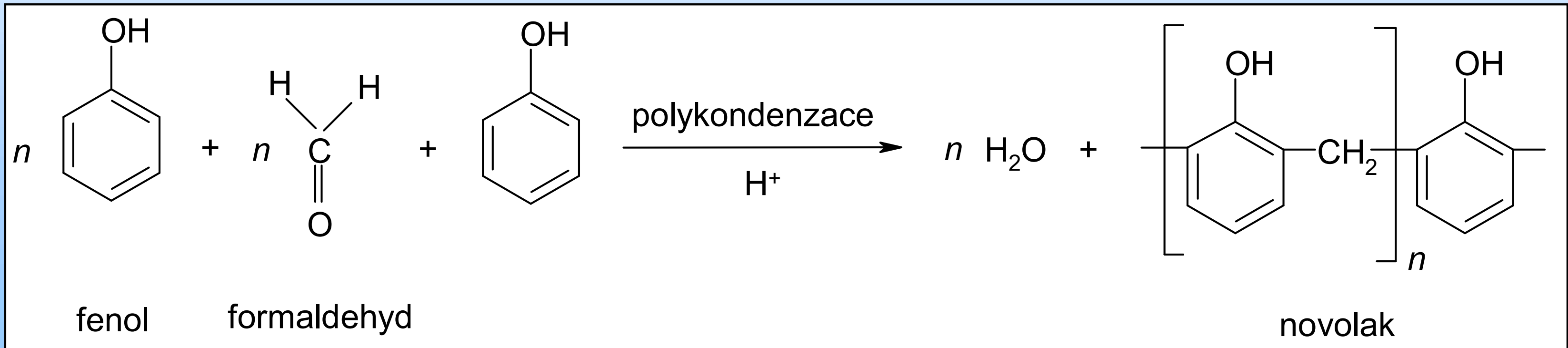


Polycondensation

Phenol formaldehyde resins (phenoplasts)

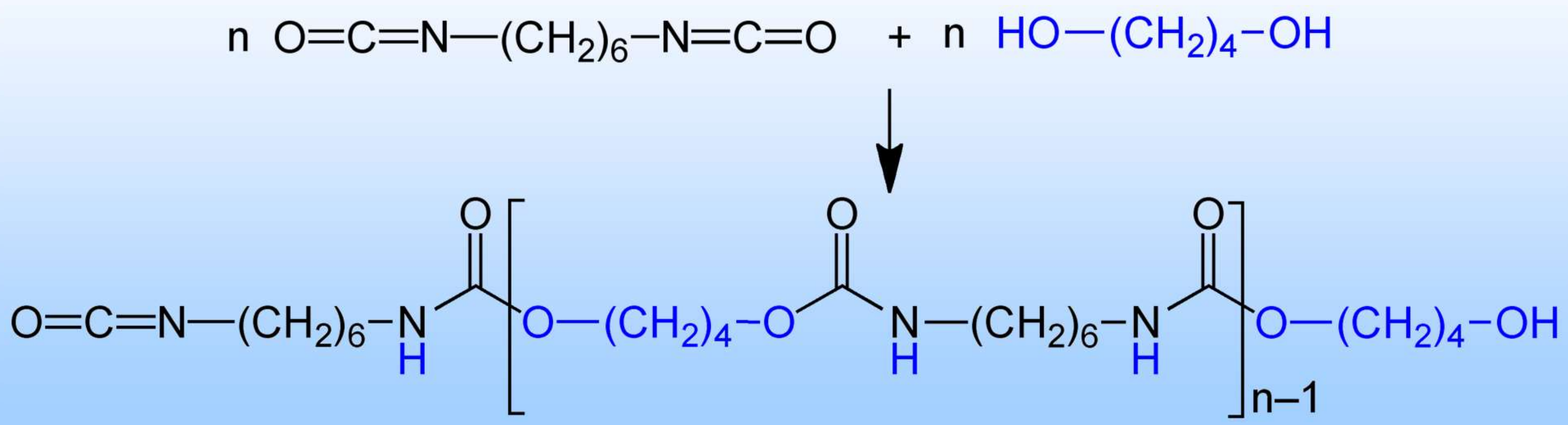
Leo Hendrik Baekeland (1863-1944)

- in 1907 he prepared the first phenoplast
- by polycondensation of phenol with formaldehyde,
- which can take place in both acidic and basic environments,
- in acidic environments, a linear
- polycondensate (Novolak),
- in alkaline media, a polycondensate is formed
- with a densely cross-linked structure (Bakelite).



Polyaddition

Polyaddition (or addition polymerisation) is a polymerization reaction that forms polymers via individual independent addition reactions. Polyaddition occurs as a reaction between functional groups on molecules with low degrees of polymerization, such as dimers, trimers and oligomers, to form species of higher molar mass. A typical polyaddition is the formation of a polyurethane.



Polyurethane = elastane, lycra ... elastic fibres

Polymer additives

For utility:

Lubricants (slip resistance)

Emollients

Antistatic

blowing agents (foams)

Fillers and binders

Pigments

PCM

For durability:

Antioxidants

Heat stabilizers

UV stabilisers

Flame retardants

Polymer additives - dosage

Influenced by particle size and effect required

Non-flammability: high doses

UV protection: low doses

Mechanical properties:

Large particles: approx. 10%

Nanoparticles: approx. 1 %

Polymer additives - pigments

Application via "Masterbatch"

(= pigment concentrate in polymer)

Pigment size: approx. 1micrometer

Organic and inorganic

Can also be used for fibre production, but it is an inflexible technology

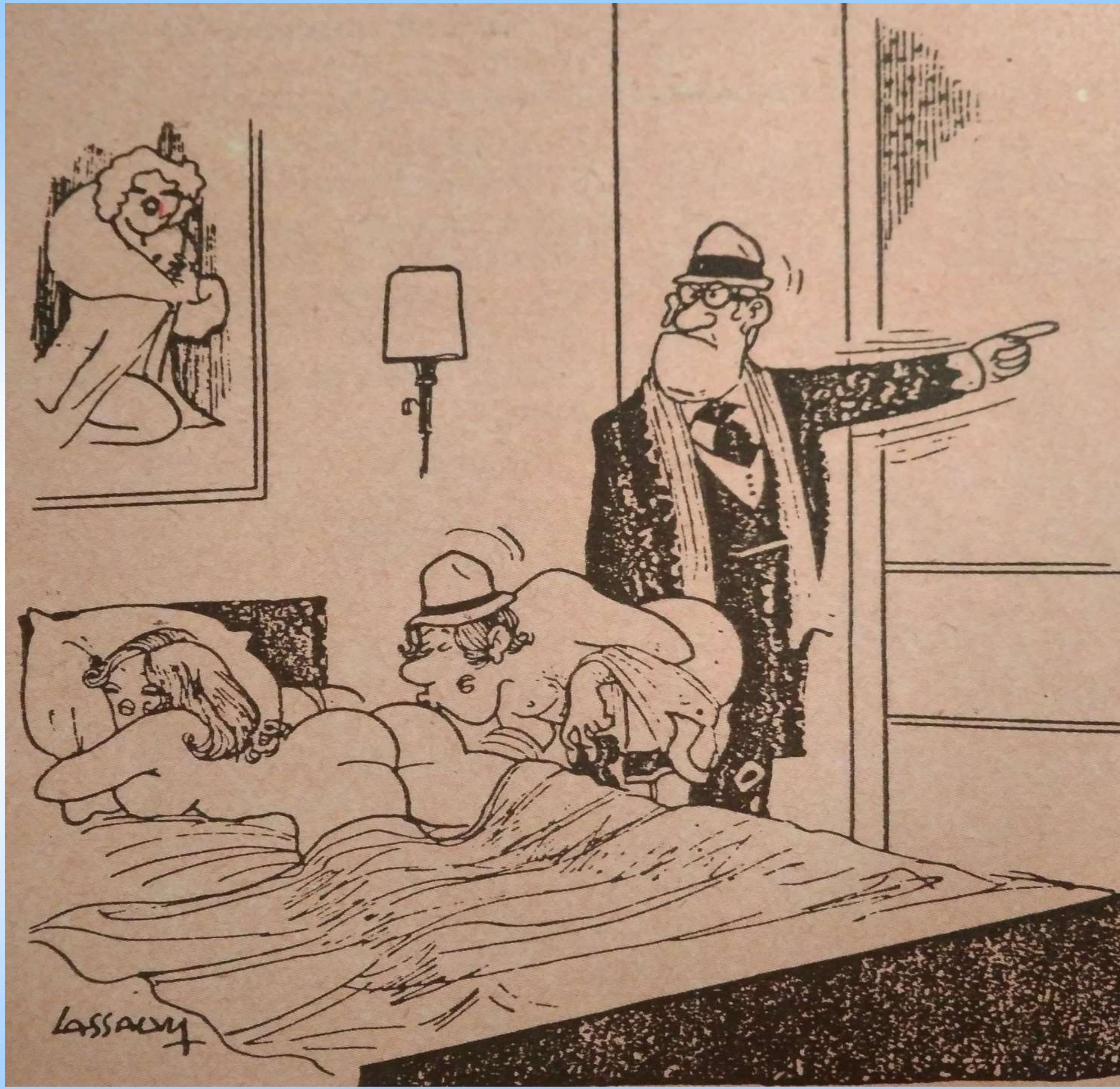
https://www.indiamart.com/proddetail/plastic-additives-masterbatches-15446607233.html

Delustring of fibres

- Chemical fibres: glossy, transparent ... =different from cotton and wool
- Need to increase light scattering - using tiny undyed particles in the fibre mass with high refractive index and stability
- Reality: only using TiO2 (titanium dioxide, approx. 0.5 micrometer)
- Delustrad fibres contain about 1% TiO2 (they are then matt, opaque, not shiny...)

Application of polymers

- Fibres (approx. 95%)
- Binders (nonwovens, coatings, pigment printing...)
- Thickeners (printing...)
- Layers (finishing...)
- Composites



Thank you for your attention!