

# Recycling of Rubber Products:

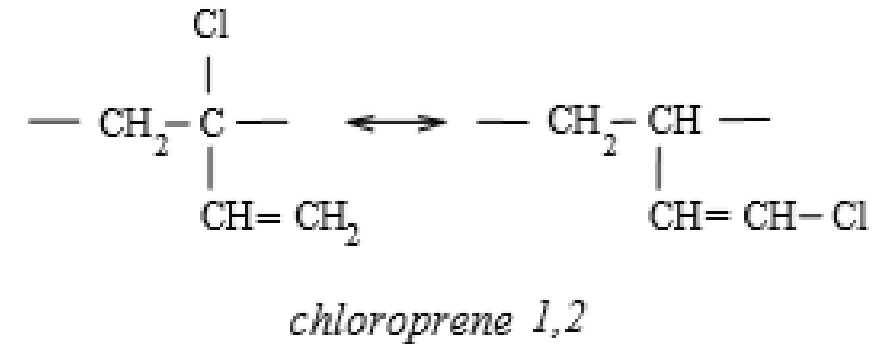
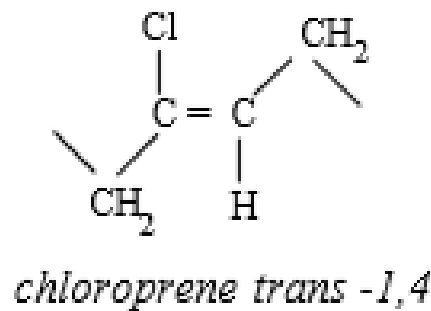
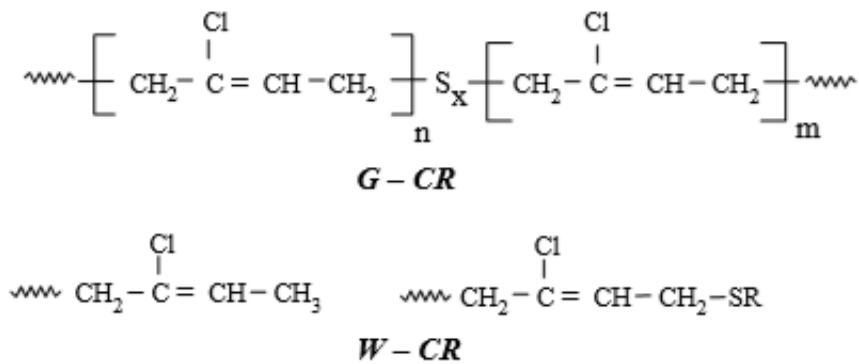
Acrylic elastomers (ACM) are copolymers of various alkyl acrylates differing in the nature of their alkyl group. They contain the strongly polar ester group. Acrylate elastomers are saturated.

Chloroprene rubber (CR) is prepared by emulsion polymerization of chloroprene. It resists hydrocarbon solvents and shows improved flame resistance due to the incorporated chlorine. In addition, it is also more resistant to oxidation than NR owing to the electron-withdrawing effect of the chlorine groups, which makes the unsaturation less subject to ambient oxidation.

Saturated chlorinated synthetic elastomers such as chlorinated polyethylene (CPE) are made by reacting polyethylene with chlorine. Chlorosulfonated polyethylene (CSM) is made similarly by reacting polyethylene with both chlorine and sulfur dioxide.

# Chloroprene rubbers

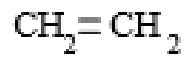
Chloroprene rubbers (CR) belong to the oldest types of synthetic rubbers. They are produced by radical emulsion polymerization of chloroprene (2chlorbutadiene 1.3).



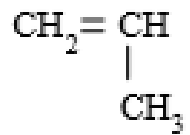
*Structural units of CR rubbers*

# Ethylene-propylene rubbers

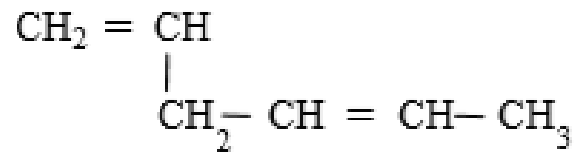
The important special rubbers are ethylene and propylene copolymers (EPM) and terpolymers of ethylene, propylene and suitable diene monomer (EPDM), the most often ethylidene norbornene, eventually 1.4-hexadiene or dicyclopentadiene:



*ethylene*



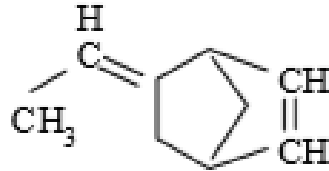
*propylene*



*1,4-hexadiene*



*dicyclopentadiene*



*ethylidene  
norbornene*

Their typical properties are related mainly to absence of unsaturated bonds in their polymer backbones. EPM rubbers do not have any unsaturated bonds and those are resistant to oxygen, ozone and to several types of chemicals. EPDM have unsaturated bonds only in the side groups.

EPM rubbers with approximately same content of ethylene and propylene (45-60 %wt. ethylene) are randomly copolymers. Although they can contain short segments of individual monomers they are amorphous and they have low mechanical strengths.

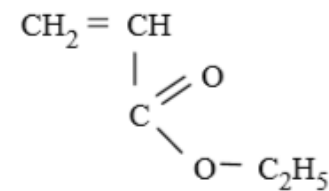


# Acrylic rubbers

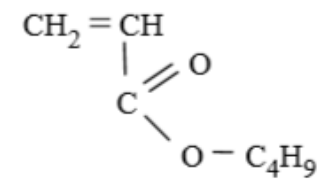
Acrylic rubbers (ACM) are unsaturated polar rubbers that are characterized with very good swelling resistance in non-polar oils and also in oils containing sulfur substances.

ACM are produced by emulsion (exceptionally by suspension) radical polymerization. For its initiation peroxides, azo-compounds or oxidation-reduction initiation systems are used.

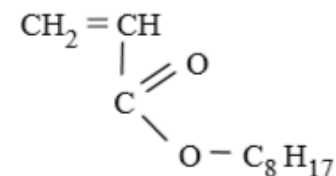
Acrylic rubbers are used mainly for production of materials resistant to oils applicable in automotive motors and other mechanical equipments, in form of latexes for impregnation of textile and paper and in form of solutions as adhesive agents and coating compositions



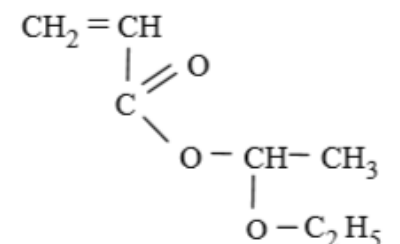
*ethyl acrylate*



*butyl acrylate*



*octyl acrylate*



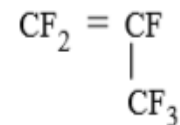
*ethylethoxy ethyl acrylate*

*Examples of the acrylic monomers used during production of ACM*

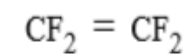
# Fluorocarbon rubbers

The special properties of fluorocarbon rubbers (FKM) are determined by their chemical structure. Polymer chains of these rubbers are saturated and they are created by structural units of different fluorohydrocarbons of ethylene and propylene type.

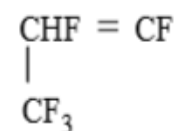
FKM are produced during the radical copolymerization or terpolymerization of fluorinated hydrocarbons mainly vinylidene fluoride, hexafluoro propylene and tetrafluoro propylene. They are usually combined with small amounts of monomers with reactive groups (e.g. bromine, iodine, perfluorated aromatic rings, and nitrile groups) which are able to take part in cross-linking. FKM are too



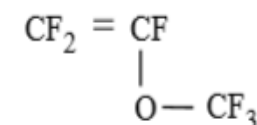
*hexafluoro propylene*



*tetrafluoro ethylene*



*1-hydropentafluoro propylene*



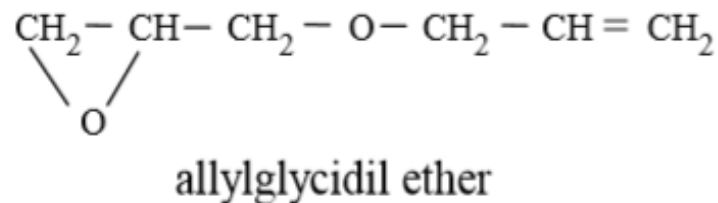
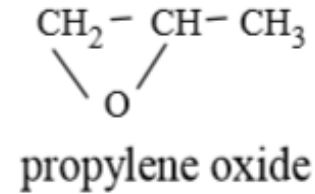
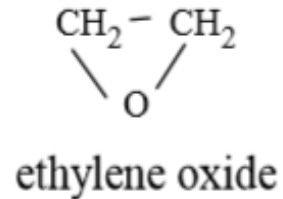
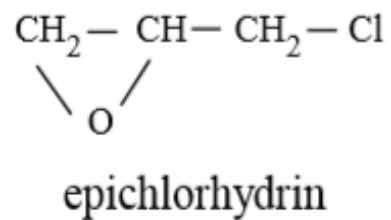
*perfluoro(methylvinyl ether)*

*Examples of monomers used during FKM production*

They are used mainly as sealing components in car engines, aircraft engines and rockets.

# Epichlorhydrin rubbers

Epichlorhydrin rubbers (O) are special rubbers with saturated polymer backbone, in which the ether C-O-C bonds and in form of pendant groups also chloromethyl substituents are present. They are produced through ring-opening polymerization of epichlorhydrin (CO rubbers) and by its copolymerization with ethylene oxide (ECO rubbers),



Opening of epoxide ring in present monomers is primary act of polymerization process.

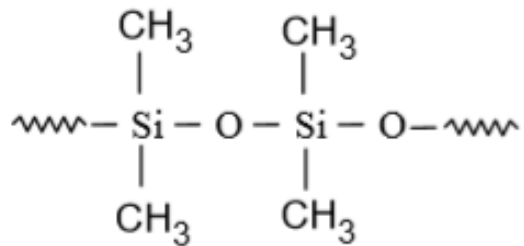
unsaturated residues in pendant groups and saturated backbones. Similar type of rubbers may be produced also by polymerization of polypropylene oxide or its copolymerization with

allylglycidyl ether (PO, GPO

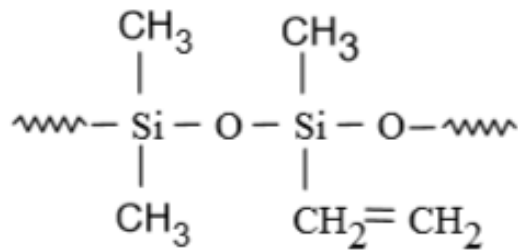


# Silicone rubbers

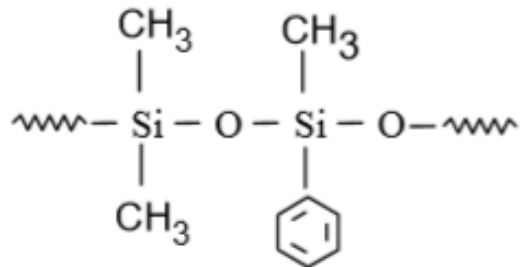
Polymer backbones of silicone rubbers (Q) don't have hydrocarbon character. Oxygen and silicon atoms to which the hydrocarbon substituents, the most often methyl (MQ) or combination of methyl and vinyl (VMQ) or phenyl substituents (PMQ) are joined create them:



*methyl silicone rubbers*



*vinyl methyl silicone rubber*

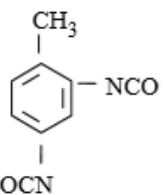


*phenyl methyl silicone rubbers*

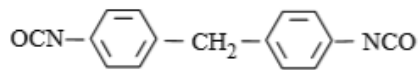
Si - O - Si bond angles in rubbers Q are bigger than bond angles of C - C or C - H bonds therefore their polymer chains are elastic and flexible also at low temperatures. In consequence of spiral organization of polymer chains (polar backbone is covered by non-polar substituents) cohesive energy density

# Polyurethane rubbers

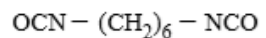
Polyurethane rubbers (U) are produced by polyaddition of diisocyanates and diols. Possible usage of different types of monomers and also combination of diisocyanate monomers and pre-polymer diols, their mutual ratio content and selection of reaction conditions allow creating polyurethanes with different chemical structure and various properties.



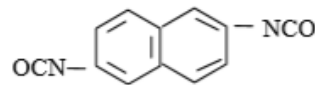
Toluene diisocyanate



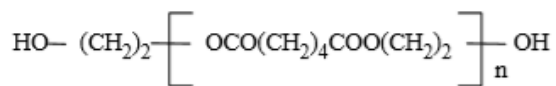
Diphenylmethane 4,4'-diisocyanate



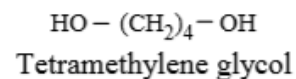
Hexamethylene diisocyanate



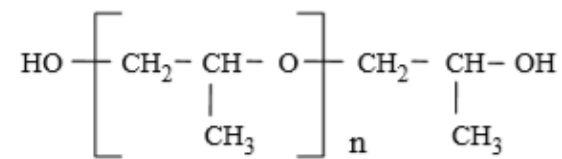
Naphthalene 1,5-diisocyanate



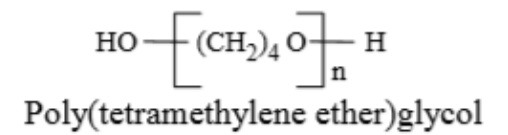
Polyethylene adipate



Tetramethylene glycol



Poly(propylene)glycol



Poly(tetramethylene ether)glycol

*Some monomers used by polyurethane rubber production*

Polyurethane elastomers are usually prepared in excess of diols. Those are polyurethane-polyester (AU) or polyurethane-polyether (EU) copolymers.



## Polysulfide rubbers

Polysulfide rubbers (TM) are special rubbers. Their vulcanizates are characterized by extraordinary swelling resistance in ketones, aromatic and halogenated hydrocarbons.

They are produced by polycondensation of aliphatic dihalides  $X - R - X$  and sodium polysulfide  $Na_2S_x$  ( $x \geq 2$ ) in water phase:



Created polymer is insoluble in reaction medium and under presence of suitable dispersion agents it precipitated. It has mostly -OH end groups (these are created by hydrolysis of halogen groups). The oldest type of polysulfide rubbers is Thiokol A produced by polycondensation of 1,2-dichloro-ethane and sodium polysulfide. Liquid polysulfide rubber with end -SH groups may be prepared from it by reduction splitting of the -S-S- bonds in its polymer chain under influence of NaHS,  $Na_2SO_3$  or other suitable agents.