FLUOROPOLYMERS

General properties of fluoropolymers

Fluoropolymers are semicrystalline thermoplastics consisting of fluorinated olefinic monomers.

Fluoropolymers contain fluorine (**F**) and their spesific properties result from the high energy bond **C-F** between the fluorine and carbon atoms.

The higher the content of fluorine atoms in a polymer molecule, the stronger the spesific properties of the material.

The properties of fluoropolymers:

- **Outstanding thermal stability**. Some fluoropolymers can work continuously at temperatures as high as 554ºF (290ºC) and as low as -454ºF (-270ºC).
- **Low coefficient of friction** varying from 0.02 to 0.2 (depending on the fluoropolymer type, load and the sliding speed).
- **Non-stick characteristics** - poor adherence to other substances.
- **Low surface energy (non-wetting)**. Fluoropolymers are hydrophobic and oleophobic - poorly wetable by both water and oils.
- **Chemical inertness**. Fluoropolymers are unaffected by most Solvents and other chemicals.
- **Excellent dielectric properties** such as electrical resistance, dielectric strength, low dissipation factor.
- **Cryogenic stability**.

Classification of fluoropolymers

There are two groups of fluoropolymers: homopolymers and copolymers

- **Homopolymers** are polymers a molecule of which consists of a cain composed of repeatedly joined monomers: -A-A-A-...-A-.
  - **Polytetrafluoroethylene (PTFE)** is a fully fluorinated polymer made by a polymerization of the monomer CF_2=CF_2 - tetrafluoroethylene (TFE). PTFE is one of the most widely used fluoropolymers due to its excellent properties: chemical inertness, low coefficient of friction (lower than 0.1), non-stick properties in a very wide temperature range. PTFE has a highest maximum

service temperature 554ºF (290ºC). The main disadvantage of PTFE is very high viscosity in a molten state. This property makes impossible using conventional Methods of polymers fabrication such as injection and extrusion. Sintering technology is commonly used for processing PTFE.

- **Polychlorotrifluoroethylene (PCTFE)** is a partially fluorinated polymer made by a polymerization of the monomer $CFCl=CF_2$ - chlorotrifluoroethylene (CTFE). The replacement of one fluorine atom with chlorine atom in the monomer molecule results in reduction of the properties: thermal resistance, chemical stability and electrical resistance. However PCTFE has better mechanical properties and lower viscosity in the molten state.
- **Polyvinylidene fluoride (PVDF)** is a partially fluorinated polymer made by a polymerization of the monomer $CF_2=CH_2$ - vinylidene fluoride (VDF). PVDF is not resistant to strong bases, esters, amines and ketons. It is stable in most organic Solvents. The mechanical properties and wear resistance of PVDF are better than of any other fluoropolymer. It can be processed and formed in molten state.

- **Copolymers** are polymers a molecule of which consists of a cain composed of alternating repeatedly joined two monomers monomers: -A-B-A-B-...-A-B-.
  - **Fluorinated ethylene propylene (FEP)** is a fully fluorinated polymer made by a polymerization of two monomers: $CF_2=CF_2$ - tetrafluoroethylene (TFE) and $CF_2=C_2F_4$ - hexafluoropropylene. FEP has a unique combination of high chemical resistance, thermal stability stability and mechanical properties (similar to those of PTFE) with the melt processability (low viscosity in the molten state).
  - **Ethylene tetrafluoroethylene (ETFE)** is a partially fluorinated polymer made by a polymerization of two monomers: $CF_2=CF_2$ - tetrafluoroethylene (TFE) and $CH_2=CH_2$ - ethylene. ETFE has the best of all fluoropolymers the wear resistance, the impact toughness and radiation resistance. ETFE is melt processable. The mechanical properties of ETFE are similar to those of fully fluorinated polymers.
  - **Ethylene chlorotrifluoroethylene (ECTFE)** is a partially fluorinated polymer made by a polymerization of two monomers: $CFCl=CF_2$ - chlorotrifluoroethylene (CTFE) and $CH_2=CH_2$ - ethylene. The wear resistance, impact toughness and radiation resistance of ECTFE are similar to those of ETFE and better than PTFE. ECTFE has the lowest density.
  - **Perfluoroalkoxy (PFA)** is a fully fluorinated polymer made by a polymerization of two monomers: $CF_2=CF_2$ - tetrafluoroethylene (TFE) and R_t-O-CF=CF_2(R_t - perfluorinated alkyl group containing one or more carbon atoms) - perfluoroalkyl vinyl ether (PAVE). PFA has a high maximum service temperature 500ºF (260ºC). It aslo has excellent electrical properties and chemical inertness. PFA is often used as the melt processable alternative to PTFE.

Applying fluoropolymer coatings

- **Surface cleaning**. In order to provide good a strong adherence of the coating the substrate surface should be degreased - cleaned form mineral oils **(Rust protection oils, Cutting fluids (coolants), greases, etc.), miscellaneous organic soils** (paints, animal lubricants and vegetable lubricants, fingerprints). Degreasing may be performed by Solvent cleaning or Alkaline cleaning. Prebaking at a temperature above the final curing temperature will prevent blistering caused by an evaporation of the residual organic substances during the curing operation.
- **Abrading (roughening)** the surface substrate surfaces provides better bonding strength due to interlocking the fluoropolymer coating material in the surface micro-voids. Abrading also removes oxides, scale, smut, rust, paints and other solid contaminants from the surface. Techniques of sand blasting, steel wire brushing, Shot peening or sanding by glass paper are used for roughening operation.
- **Application**. The fluoropolymer coatings are commonly applied one of the following spray methods:
  - **Manual spray** by means of spray guns where a fluoropolymer in form of either water based or solvent based mixture is projected by pressurized air towards the substrate located at a distance of 4-12" (10-30 cm) from the gun.
  - **Automatic spray** utilizes the technique similar the manual spray. The parts to be coated are fed to the guns by a conveyor. The guns positions, directions and the motions are controlled much better than in the manual spray therefore automatic spray produce uniform coatings of high quality and good surface finish.
  - **Electrostatic spray** uses a high voltage (80,000 - 90,000 V) applied between the work part and the spray gun. The atomized liquid containing fluoropolymer particles is driven by the electrostatic force towards the substrate surface.
  - **Airless spray** employs pressurized liquid at high pressure for atomizing and accelerating of the atomized particles (droplets) towards the work piece surface.
  - **Powder coating** technique utilizes dry free-flowing powders of fluoropolymers particles of which are accelerated commonly by an electrostatic force.
- **Curing** is performed in order to achieve the required properties of the coating. The optimal values of the curing temperature and duration are different for different fluoropolymers. Excessive temperature or curing time may cause the coating material to degrade.

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