



# CHEMISTRY

81<sup>st</sup> and 82<sup>nd</sup> Class, 03-01-2022

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## Last class



- ☐ Thermosets and Elastomers
  
- ☐ Addition and condensation polymerisation

Unified Time Table for B.Tech / M.Tech - Batch 1 WEF:-03-Jan-22

FROM	08:00	08:50	09:45	10:40	11:35	12:30	01:25	02:20	03:15	04:05
TO	08:50	09:40	10:35	11:30	12:25	01:20	02:15	03:10	04:05	04:55
Hour/Day Order	1	2	3	4	5	6	7	8	9	10
Day 1	A	A	F	F	G	P6	P7	P8	P9	P10
Day 2	P11	P12	P13	P14	P15	B	B	G	G	A
Day 3	C	C	A	D	B	P26	P27	P28	P29	P30
Day 4	P31	P32	P33	P34	P35	D	D	B	E	C
Day 5	E	E	C	F	D	P46	P47	P48	P49	P50

## Last class...

☐ Synthesis, properties and applications of

➤ Polypropylene

➤ Polystyrene

## In this class...

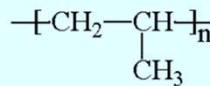


### ☐ Synthesis, properties and applications of

- PVC
- PET
- PTFE

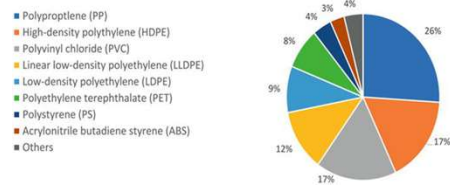
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## Polypropylene

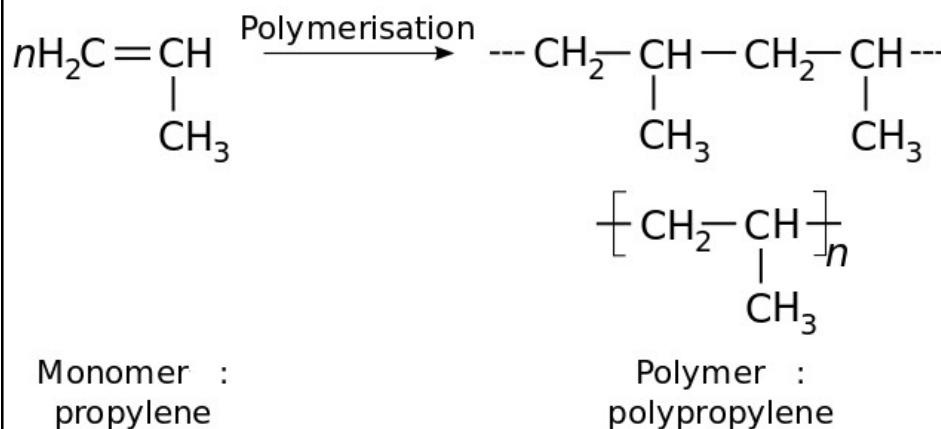


- ☐ Polypropylene is one of the versatile polymers.
- ☐ Most widely used commodity thermoplastic by volume.
- ☐ One of the cheapest plastics with great processability, chemical resistance and moisture barrier.
- ☐ PP with different tacticity found various downstream applications in textile, automotive, cosmetics, and consumer packaging.

Distribution of Polymer Demand worldwide



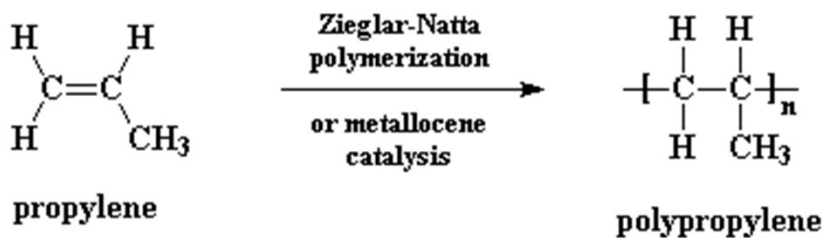
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## Polypropylene - Synthesis

- ❑ Structurally, it's a vinyl polymer, and is similar to polyethylene, only that on **every other carbon atom in the backbone chain has a methyl group attached to it.**
- ❑ Polypropylene can be made from the monomer propylene by **Ziegler-Natta polymerization** and by metallocene catalysis polymerization.



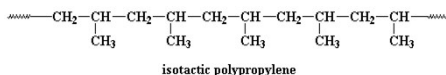
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- ❑ Ziegler - combination of titanium tetrachloride ( $\text{TiCl}_4$ ) and diethylaluminium chloride ( $\text{Al}(\text{C}_2\text{H}_5)_2\text{Cl}$ ) gave comparable activities for the production of polyethylene.
- ❑ Natta used crystalline  $\alpha\text{-TiCl}_3$  in combination with  $\text{Al}(\text{C}_2\text{H}_5)_3$  to produce first isotactic polypropylene.
- ❑ 1963 Nobel Prize in Chemistry - German Karl Ziegler, for his discovery of first titanium-based catalysts and Italian Giulio Natta for using them to prepare stereoregular polymers from propylene.

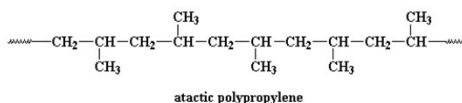
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## Polypropylene - Tacticity

- ❑ Most polypropylene in use is isotactic.



- ❑ Isotactic polypropylene has a high enough melting point comparing other tactic PP's.
- ❑ Atactic - the methyl groups are placed randomly on both sides of the chain, it has no commercial application because it's pretty much a messy blob.



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## Polypropylene – properties

- ☐ White & translucent in appearance.
- ☐ All-round thermoplastic with high durability and lightweight.
- ☐ It has a low density ( $1.04 - 1.06 \text{ g/cm}^3$ ), slippery surface & a low coefficient of friction.
- ☐ It also shows an excellent resistant to heat (MP -  $160 - 168^\circ\text{C}$ ), electricity, fatigue, chemicals and organic solvents.
- ☐ Stress-cracking is not an issue for PP as it also displays good levels of corrosion resistance.
- ☐ Polypropylene is by definition recyclable, as new products can be manufactured by melting and reforming PP into plastic pellets.

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## Polypropylene – properties

### Chemical Properties of Polypropylene:

- ☐ Acid does not affect polypropylene. It has excellent stability against acids.
- ☐ Base also does not affect PP
- ☐ Effect of bleaching: It has enough ability to prevent the harmful action of bleaching agent under  $65^\circ\text{C}$
- ☐ Organic solvent: Organic solvent does not cause harm to polypropylene

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## Polypropylene - Applications

- ☐ Economical material - automotive sector, textiles, medical sector, consumer goods, and industrial applications.
- ☐ Solvent containers.
- ☐ Electrical insulation.
- ☐ Hinges (shape retention and fatigue resistance)
- ☐ Flexible and rigid packaging, piping, food containers, clear plastic bags, ropes, carpets and concrete reinforcement.
- ☐ Polypropylene fibers are used in clothing.

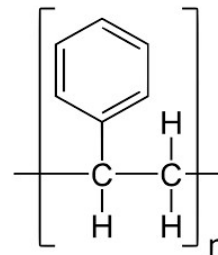


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## Polystyrene

- ☐ Polystyrene (PS), a synthetic aromatic polymer, is an inexpensive source of hard plastic.
- ☐ The production volume of polystyrene and styrene copolymers is several million tons per year. It is sold under various trade names, including Styrofoam™, Styropor®, and Styron™
- ☐ Dow Chemical Company invented the well-known polystyrene foam product “styrofoam” in 1941.

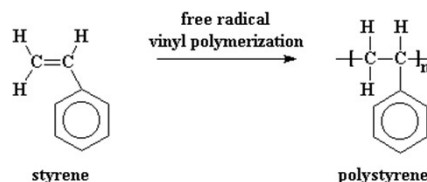
- ☐ Polystyrene is a vinyl polymer. Structurally, it is a long hydrocarbon chain, with a phenyl group attached to every other carbon atom.



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## Polystyrene – synthesis

- Polystyrene is produced by free radical vinyl polymerization, from the monomer styrene

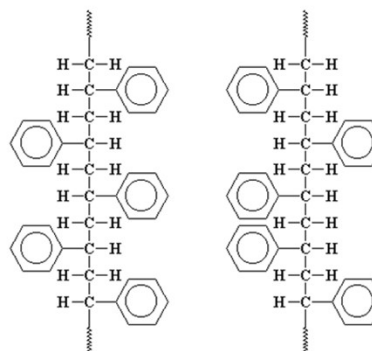


- Polystyrene is created via the polymerization of styrene - a petroleum based, liquid hydrocarbon monomer.
- In this three-step synthesis, styrene is formed via the radical bromination of ethylbenzene and the elimination reaction of (1-bromo-ethyl)benzene.
- The styrene created in this first step is then polymerized to synthesize the final product of polystyrene

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## Polystyrenes types

- Syndiotactic polystyrene. It's different because the phenyl groups on the polymer chain are attached to alternating sides of the polymer backbone chain.



- "Normal" or atactic polystyrene has no order with regard to the side of the chain (picture - right)

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## Commercial Polystyrenes

❑ The three most important grades of styrene are:

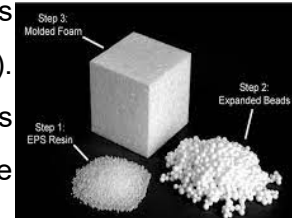
- GPPS - General purpose polystyrene
- EPS - Expandable polystyrene
- HIPS - High impact polystyrene

❑ **GPPS:** known as crystal-clear polystyrene, is a fully transparent, rigid & rather brittle, low cost thermoplastic.



❑ **EPS:** consists of micro-pellets or beads containing a blowing agent (usually pentane).

The expanded or foamed polystyrene is thermally insulating, has high impact resistance and good processability.

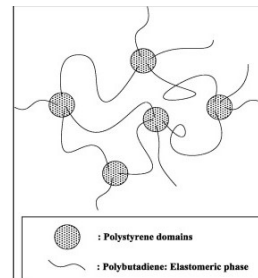
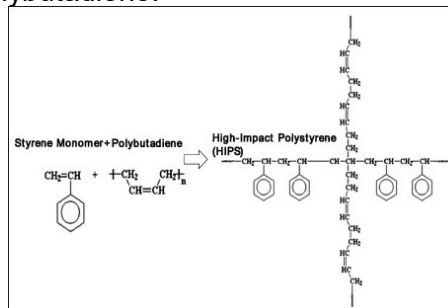


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## Commercial Polystyrenes

❑ **HIPS:** contains usually 5 to 10% rubber (butadiene) and is used for parts which require high(er) impact resistance.

❑ HIPS is a graft copolymer having polystyrene side arms. The grafting occurs when some of the radicals react with the double bonds of the polybutadiene.



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## Polystyrene – Properties



### PHYSICAL PROPERTIES

- ☐ Brittle, rigid, transparent
- ☐ Density 1.05 g/cm<sup>3</sup>. Low shrinkage & low cost
- ☐ Excellent X-ray resistance
- ☐ Free from odour and taste
- ☐ Easy to process
- ☐ Tensile Strength 2.30 - 3.60 N/mm<sup>2</sup>
- ☐ Max Cont. Use Temp 70 - 85°C

### CHEMICAL PROPERTIES

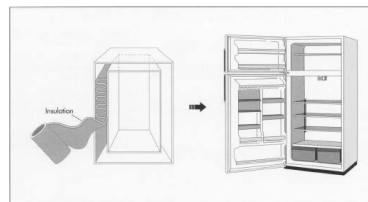
- ☐ Polystyrene is chemically inert & does not react with most substances.
- ☐ It is highly flammable
- ☐ It dissolves in some organic solvents. It is soluble in solvents that contain acetone

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## Polystyrene - Applications



- ☐ **Appliances** - Refrigerators, air conditioners, ovens, microwaves, vacuum cleaners, blenders – these and other appliances often are made with polystyrene (solid and foam) because it is inert (doesn't react with other materials), cost-effective and long-lasting.

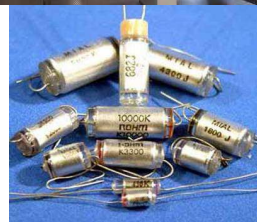


- ☐ **Insulation** - provides excellent thermal insulation - building walls and roofing, refrigerators and freezers, and industrial cold storage facilities. Polystyrene insulation is inert, durable and resistant to water damage.

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## Polystyrene - Applications

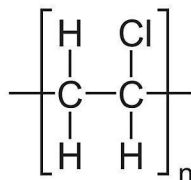
- ☐ Automotive - (solid and foam) is used to make many car parts, including knobs, instrument panels, trim, energy absorbing door panels and sound dampening foam.
- ☐ Electronics - used for the housing and other parts for televisions, computers and all types of IT equipment, where the combination of form, function and aesthetics are essential.
- ☐ Foodservice - packaging typically insulates better, keeps food fresher longer and costs less than alternatives.



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## Polyvinyl Chloride - PVC

- ☐ Poly(vinyl chloride) is the plastic known at the hardware store as PVC. This is the PVC from which pipes are made.
- ☐ PVC is a flexible or rigid material that is chemically non-reactive. Its chemical structure is



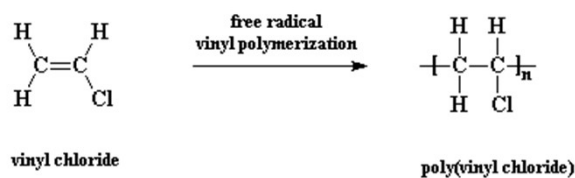
- ☐ PVC is the world's third-most widely produced synthetic plastic polymer (after polyethylene and polypropylene)
- ☐ About 40 million tons of PVC are produced each year.

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## Polyvinyl Chloride PVC - Synthesis



- ❑ Vinyl chloride monomer (VCM) is produced from the chlorination of ethylene and pyrolysis of the resulting ethylene dichloride (EDC) in a cracking unit.
- ❑ PVC is produced by polymerization of vinyl chloride monomer (VCM).



- ❑ The popular methods used to manufacture PVC commercially are Suspension PVC (S-PVC) , Bulk or Emulsion (E-PVC)

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## Basic Forms of PVC



- ❑ **Plasticized or Flexible PVC (PVC-P)** (Density: 1.1-1.35 g/cm<sup>3</sup>)
  - Formed by the addition of compatible plasticizers to PVC which lower the crystallinity.
- ❑ **Unplasticized or Rigid PVC (UPVC, PVC-U or uPVC)** (Density: 1.3-1.45 g/cm<sup>3</sup>)
  - Rigid PVC is a stiff and cost-effective plastic with high resistance to impact, water, weather, chemicals and corrosive environments.
- ❑ **Chlorinated Polyvinyl Chloride or perchlorovinyl (C-PVC)**
  - It is prepared by chlorination of PVC resin. High chlorine content imparts high durability, chemical stability and flame retardancy.

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## Basic Forms of PVC

### ☐ **Molecular Oriented PVC or PVC-O**

- It is formed by reorganizing the amorphous structure of PVC-U into a layered structured. Bi-axially oriented PVC has enhanced physical characteristics (stiffness, fatigue resistance, lightweight, etc.).

### ☐ **Modified PVC or PVC-M**

- It is an alloy of PVC formed by addition of modifying agents, resulting in enhanced toughness and impact properties.

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## Polyvinyl Chloride PVC - Properties

- ☐ Good resistant to weathering, chemical rotting, corrosion, shock & abrasion.
- ☐ Good flame retardancy because of high chlorine content, self-extinguishing.
- ☐ High dielectric strength – Good electrical insulation property
- ☐ Mechanical Properties: PVC is abrasion-resistant, lightweight and tough.
- ☐ Good chemical resistance - resistant to all inorganic chemicals, good resistance against diluted acids, diluted alkalis and aliphatic hydrocarbons.
- ☐ Great cost/Performance Ratio: PVC has good physical as well as mechanical properties and provides excellent cost-performance advantages. It has long life span and need low maintenance.

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## Polyvinyl Chloride PVC - applications



- ❑ **Building and Construction** - About three-quarters of all vinyl produced goes into building and construction applications
- ❑ Because it is strong and resistant to moisture and abrasion, vinyl is ideal for cladding, windows, roofing, fencing, decking, wallcoverings, and flooring.
- ❑ **Siding and Windows-** PVC products are extremely durable, affordable, and help conserve energy when heating and cooling homes. Vinyl windows have three times the heat insulation of aluminum windows.
- ❑ **Electrical wiring and Cables** - able to withstand tough conditions – such as exposure to changing temperatures and dampness.

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## Polyvinyl Chloride - applications



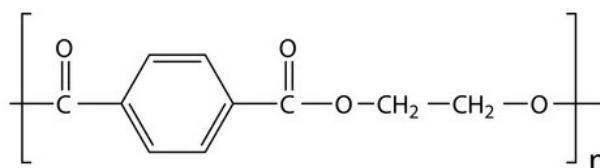
- ❑ **Water Pipes** - virtually leak-free pipes, corrosion free & resist environmental stress. PVC breakage rates are as low as one percent compared to cast metal systems.
- ❑ **Packaging** - durable, dependable, maintain the integrity of products and light weight. Clear vinyl in medications and shrink-wrap. Rigid vinyl in blister and clamshell packaging to protect medicines.
- ❑ **Healthcare** - IV bags and medical tubing. PVC blood-collection bag was a significant breakthrough because blood bags are flexible and unbreakable.
- ❑ **Household Products** - PVC's affordability, durability and water resistance make it ideal for rain coats, boots and shower curtains.

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## Polyethylene terephthalate (PET)



- ❑ Polyesters are engineering thermoplastics based on PBT (Polybutylene terephthalate) and PET (Polyethylene terephthalate).
- ❑ PET is a clear, strong, and lightweight plastic that is widely used for packaging foods and beverages.



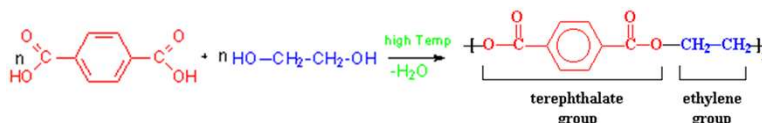
- ❑ The basic building blocks of PET are ethylene glycol and terephthalic acid, which are combined to form a polymer chain.
- ❑ PET is completely recyclable, and is the most recycled plastic in worldwide.

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## Polyethylene terephthalate - Synthesis



- ❑ Polyesters can be synthesized by direct reaction of a diacid with a diol.
- ❑ To produce PET, terephthalic acid is reacted with ethylene glycol as shown below.



- ❑ This reaction is a typical fisher type esterification in which an acid is reacted with an alcohol and follows the usual mechanism for that reaction.
- ❑ The fact that each molecule is bifunctional produces a polymer by the reaction.

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## Polyethylene terephthalate - properties



- ☐ Extreme low water absorption.
- ☐ Exceptional dimensional stability, due to the low water absorption.
- ☐ Excellent electrical properties.
- ☐ Excellent resistance to chemical attack and high environmental stress crack resistance, due to the semi-crystalline nature of polyesters.
- ☐ Very good heat and heat aging resistance.
- ☐ Very low creep, even at elevated temperatures.
- ☐ Very good colour stability.
- ☐ Excellent wear properties.

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## Polyethylene terephthalate - applications



- ☐ Because it is an excellent water and moisture barrier material - plastic bottles for mineral water and carbonated soft drinks
- ☐ Its high mechanical strength, makes PET films ideal for use in tape applications
- ☐ Non-oriented PET sheet - packaging trays and blisters
- ☐ Its chemical inertness, together with other physical properties, has made it particularly suitable for food packaging applications.



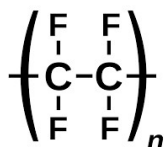
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## Polytetrafluoroethylene – PTFE(Teflon)



- Polytetrafluoroethylene, or PTFE, is made of a carbon backbone chain, and each carbon has two fluorine atoms attached to it.
- Polytetrafluoroethylene is better known by the trade name Teflon®.



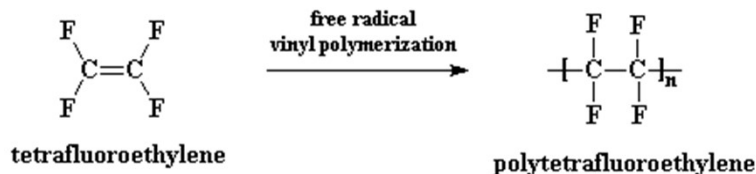
- Today, PTFE applications range from low-tech non-stick frying pan surfaces to high-tech exotic medical and hospital uses including implants, surgical instruments and test equipment, and dramatic uses in firefighting equipment etc.

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## PTFE (Teflon) - Synthesis



- Tetrafluoroethylene ( $\text{C}_2\text{F}_4$ ), a colourless, odourless gas, is made by heating chlorodifluoromethane ( $\text{CHClF}_2$ ) in the range of 600–700 °C



- Tetrafluoroethylene monomers (small, single-unit molecules) are suspended or emulsified in water and then polymerized (linked into giant, multiple-unit molecules) under high pressure in the presence of free-radical initiators.

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## Basic Forms of PTFE

- ☐ **Granular PTFE resin** - produced by suspension polymerization in an aqueous medium & mainly used for molding (compression and isostatic).
- ☐ **Fine PTFE powder** - prepared by controlled emulsion polymerization, and the products are white, small sized particles.
- ☐ **PTFE dispersions** - prepared by the aqueous polymerization using more dispersing agent with agitation. Dispersions are used for coatings and film casting.

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## PTFE Properties

- ☐ Good resistance to heat and low temperature – MP:327°C
- ☐ Hydrophobic: making it useful in cooking, wound dressings
- ☐ Chemically inert: Majority of solvents and chemicals will not damage PTFE.
- ☐ Low coefficient of friction: lowest of any solid in existence
- ☐ High flexural strength: ability to bend and flex, even at low temperatures
- ☐ Good electrical insulating power in hot and wet environments

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## PTFE Properties

- ☐ Good resistance to light, UV and weathering
- ☐ Low dielectric constant (2.0) / dissipation factor high insulation resistance
- ☐ Strong anti-adhesion properties
- ☐ Good fatigue resistance under low stress
- ☐ Availability of food, medical and high-purity grades
- ☐ Low water absorption

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## PTFE applications

- ☐ **Sheet and Film** - mainly in the packaging sector - chemical equipment, pharmaceuticals and cosmetic products, a chemically inert material is worth the extra cost in comparing materials.
- ☐ **Industrial Coating** - has a very low friction coefficient and high-temperature resistance,
- ☐ **PTFE lubricant** is used in the construction of igniters for rocket propellants, and to coat certain types of bullets to reduce wear on the inside of the barrel.
- ☐ Teflon coatings and non-stick wear are used on kitchenware to prevent food from sticking to pots and pans.

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## PTFE applications

- ❑ PTFE Powder - extruded into useful shapes such as tapes, wires and tubes for the insulation of wires and cables, tubing, pipe liners and films.

- ❑ Plain bearings

- ❑ Slide plates

- ❑ Seal rings

- ❑ Washers

- ❑ Gaskets

- ❑ Food industry



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# Thank you all for your attention

Information presented here were collected from various sources – textbooks, articles, manuscripts, internet and newsletters. All the researchers and authors of the above mentioned sources are greatly acknowledged.