Some Applications of Polymers

Bakelite radio 1930

1. Elastomers

- Rubbery materials, have a loose cross-linked structure. This type of chain structure causes elastomers to possess memory.
- Typically, about 1 in 100 molecules are cross-linked on average.
- When the average number of cross-links rises to about 1 in 30 the material becomes more rigid and brittle.
- Natural and synthetic rubbers are both common examples of elastomers.

2. Fibers

- ***i) Natural fibers:***

- ***1) Vegetable fibers*** e.g.cellulose, often with lignin: examples include cotton, hemp jute, flax, ramie, and sisal.
- Plant fibers serve in the manufacture of paper and cloth.
-

2) Wood fiber,

- distinguished from vegetable fiber, is from tree sources.
-

3)Animal fibers

e.g. silk, hair, wool

ii) Synthetic fibres

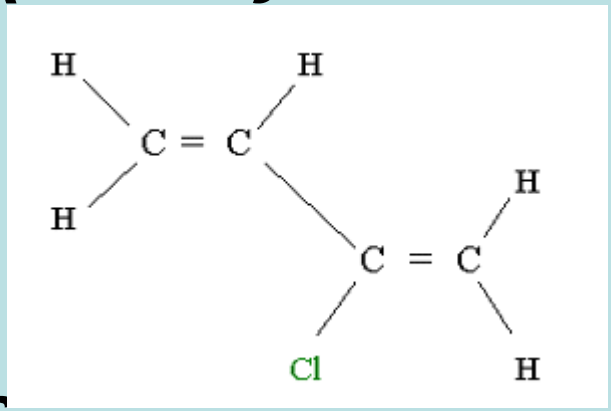
- ***Common synthetic fibres include:***
- Rayon (1910) (an artificial fibre, but not truly synthetic) Acetate (1924), Nylon (1939) , Modacrylic (1949) ,Olefin (1949) ,Acrylic (1950) ,Polyester (1953) ,PLA (2002)

Wallace H. Carothers (1896-1937)

- Inventor of nylon and neoprene rubber
- Graduated from University of Illinois
- Professor at Harvard University
- Leading scientist at du Pont

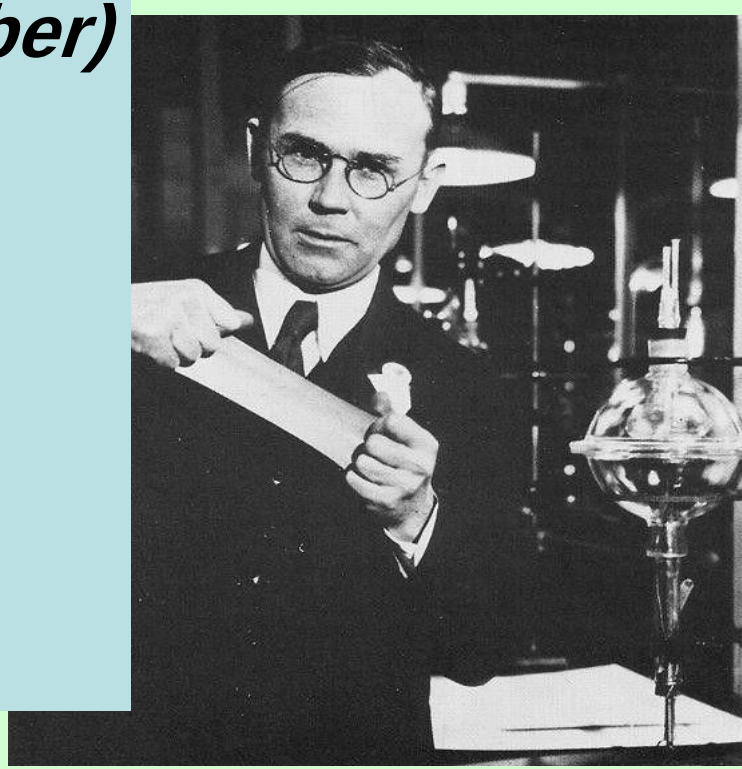
1929 Concepts of Addition and Condensation polymers, *Wallace Hume Carothers*

Neoprene (First Synthetic Rubber)



Polyesters

Nylons (Polyamides)



Wallace H. Carothers. *J. Am. Chem. Soc.*; 1929; *51(8);* 2548-2559.

***Chem. Rev.;* 1931; *8*(3); 353-426.**

Glass Fiber is used for:

- industrial, automotive, and home insulation (Fiberglass)
- reinforcement of composite and plastics
- specialty papers in battery separators and filtration

Metallic fiber (1946) is used for:

- adding metallic properties to clothing for the purpose of fashion (usually made with composite plastic and metal foils)
- elimination and prevention of static charge build-up
- conducting electricity to transmit information
- conduction of heat

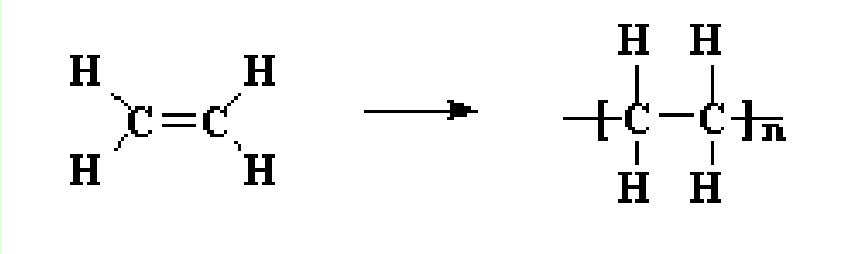
3. Polyethylene

- Polyethylene or polyethene is a thermoplastic commodity heavily used in consumer products (over 60M tons are produced worldwide every year).
- Its name originates from the monomer ethylene which used to create the polymer.

Polymers

Materials

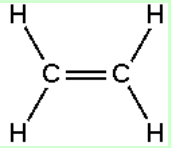
Polyethylene (PE)

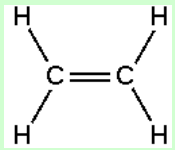


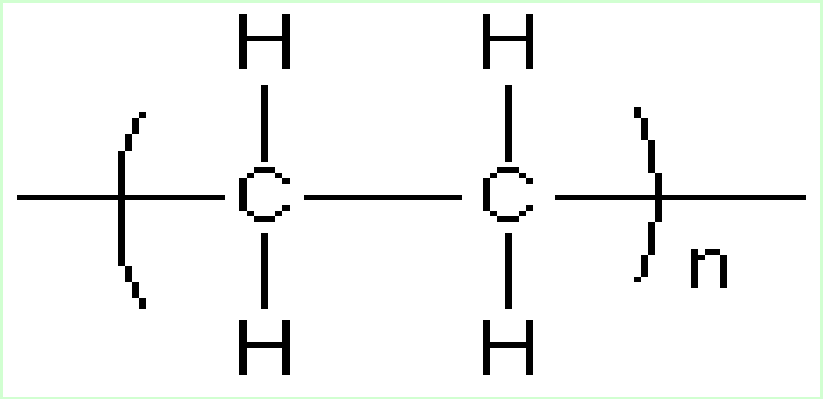
PE

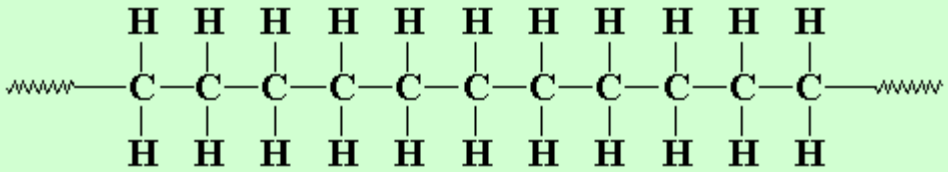
Formosa Plastics Corporation

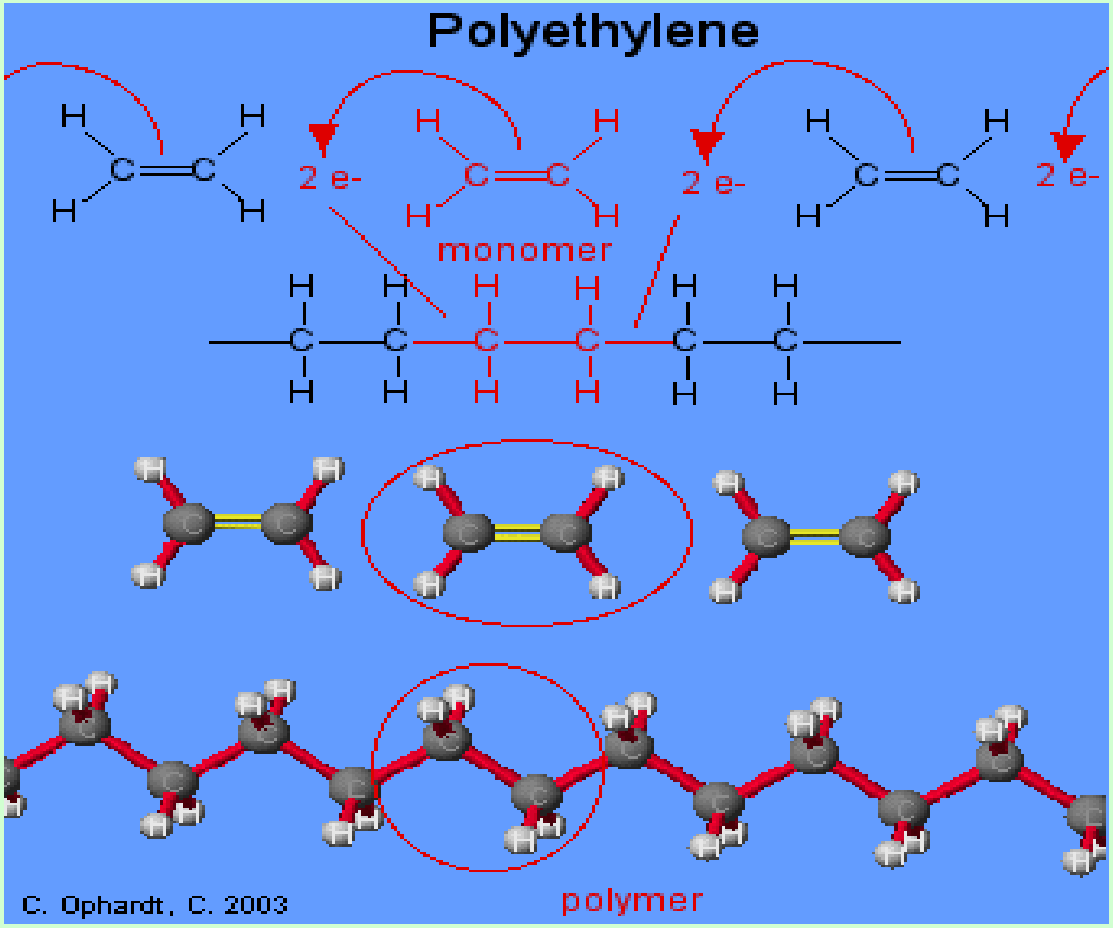
- The ethylene molecule (known almost universally by its non-IUPAC name ethylene), C2H4 is CH2 = CH2, Two CH2 connected by a double bond, thus:







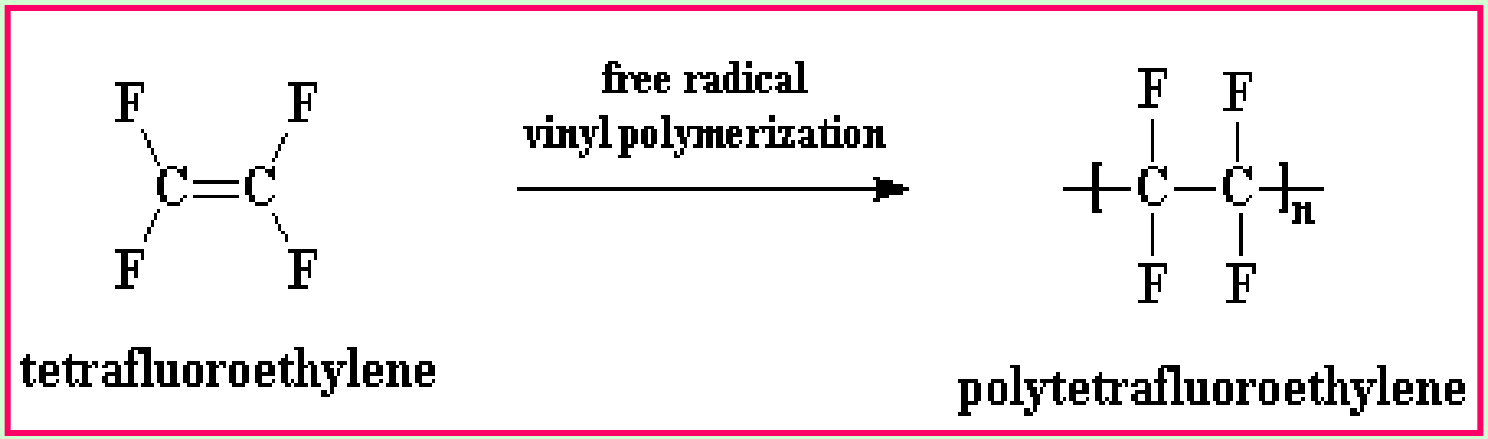


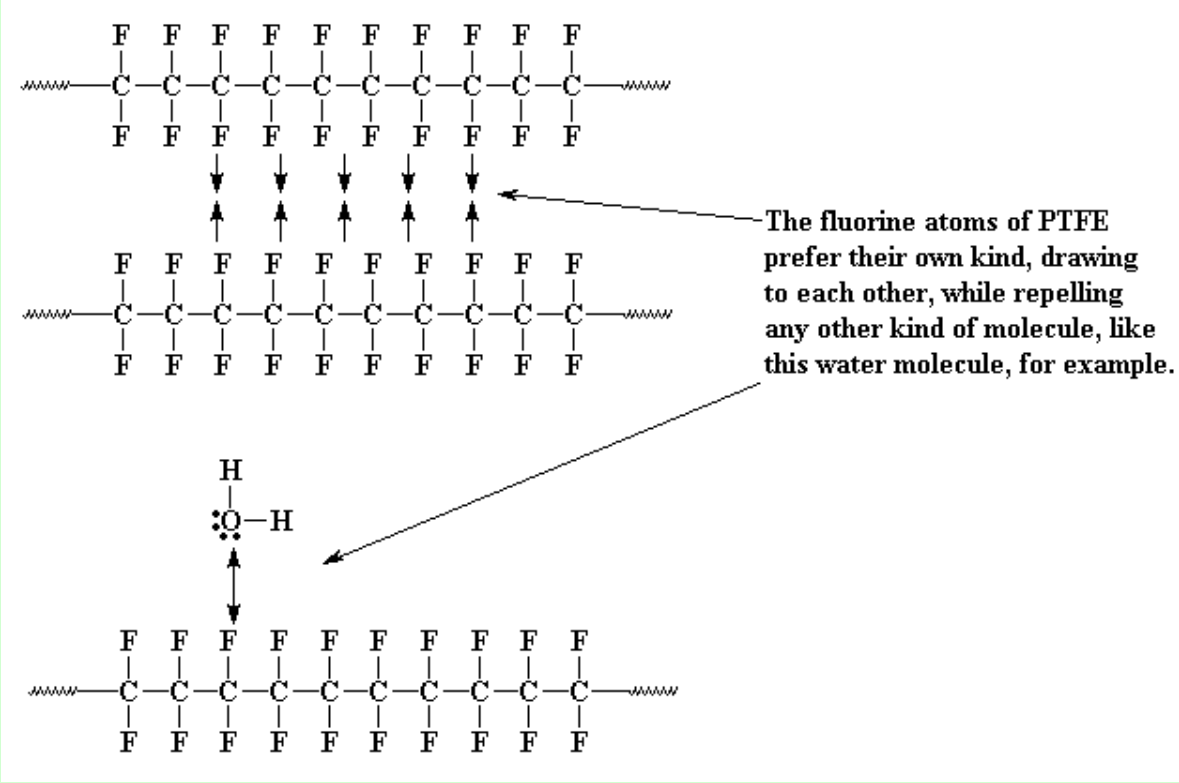

Polyethylene
2 e-
2 e-
2 e-
monomer
C. Ophardt, C. 2003
polymer

4. Polytetrafluoroethylene

- Polytetrafluoroethylene is better known by the trade name Teflon®. It is used to make non-stick cooking pans, and anything else that needs to be slippery or non-stick.
- PTFE is also used to treat carpets and fabrics to make them stain resistant.
-

- What's more, it's also very useful in medical applications. Because human bodies rarely reject it, it can be used for making artificial body parts.
- The monomer is tetrafluoroethylene - just like ethylene, but with fluorine atoms instead of hydrogen.


F
F
C=C
F
F
free radical
vinyl polymerization
F
F
C
C
n
F
F
tetrafluoroethylene
polytetrafluoroethylene


The fluorine atoms of PTFE prefer their own kind, drawing to each other, while repelling any other kind of molecule, like this water molecule, for example.

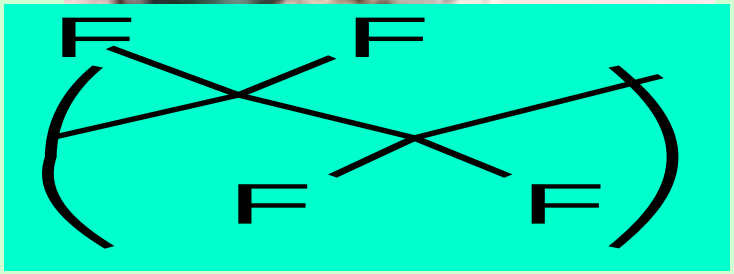

Teflon


Teflon® Industrial

المركبة الفضائية فونيكس

Teflon

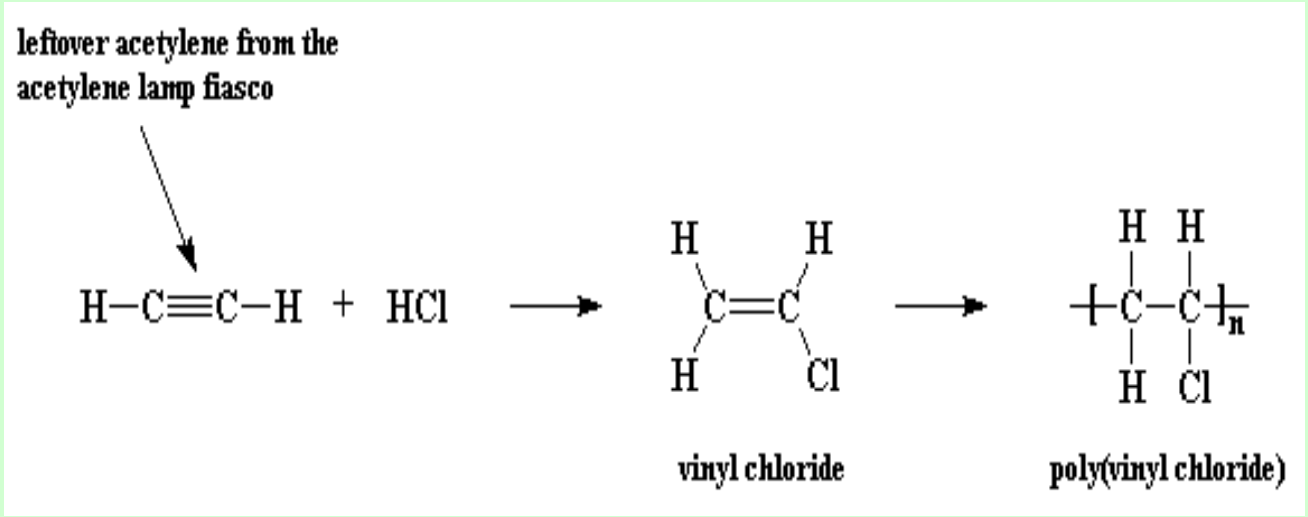
- **Teflon**
  - **Polytetrafluoroethylene (PTFE)**
  - **Dupont Chemical Department**
  - **First used for artillery shell covers**

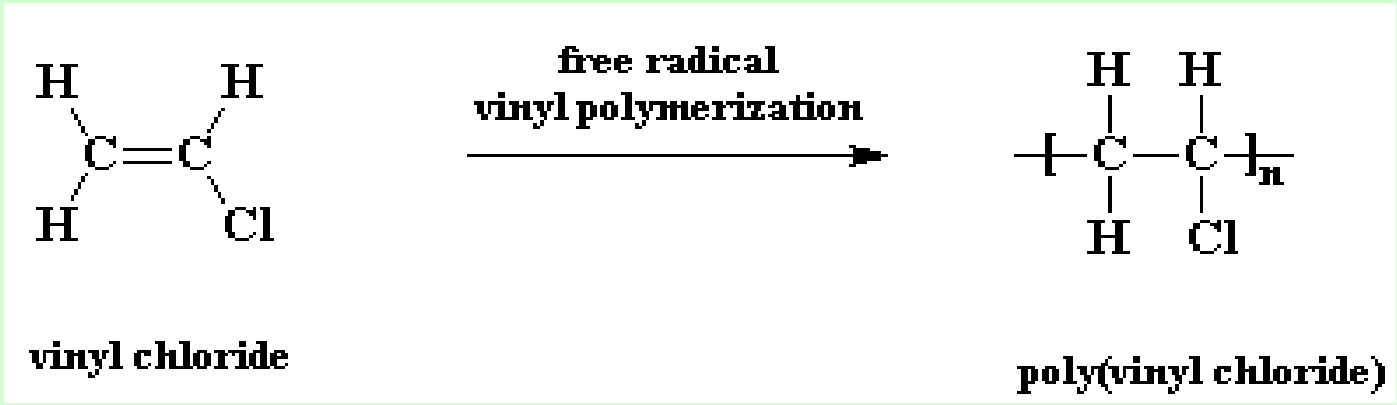


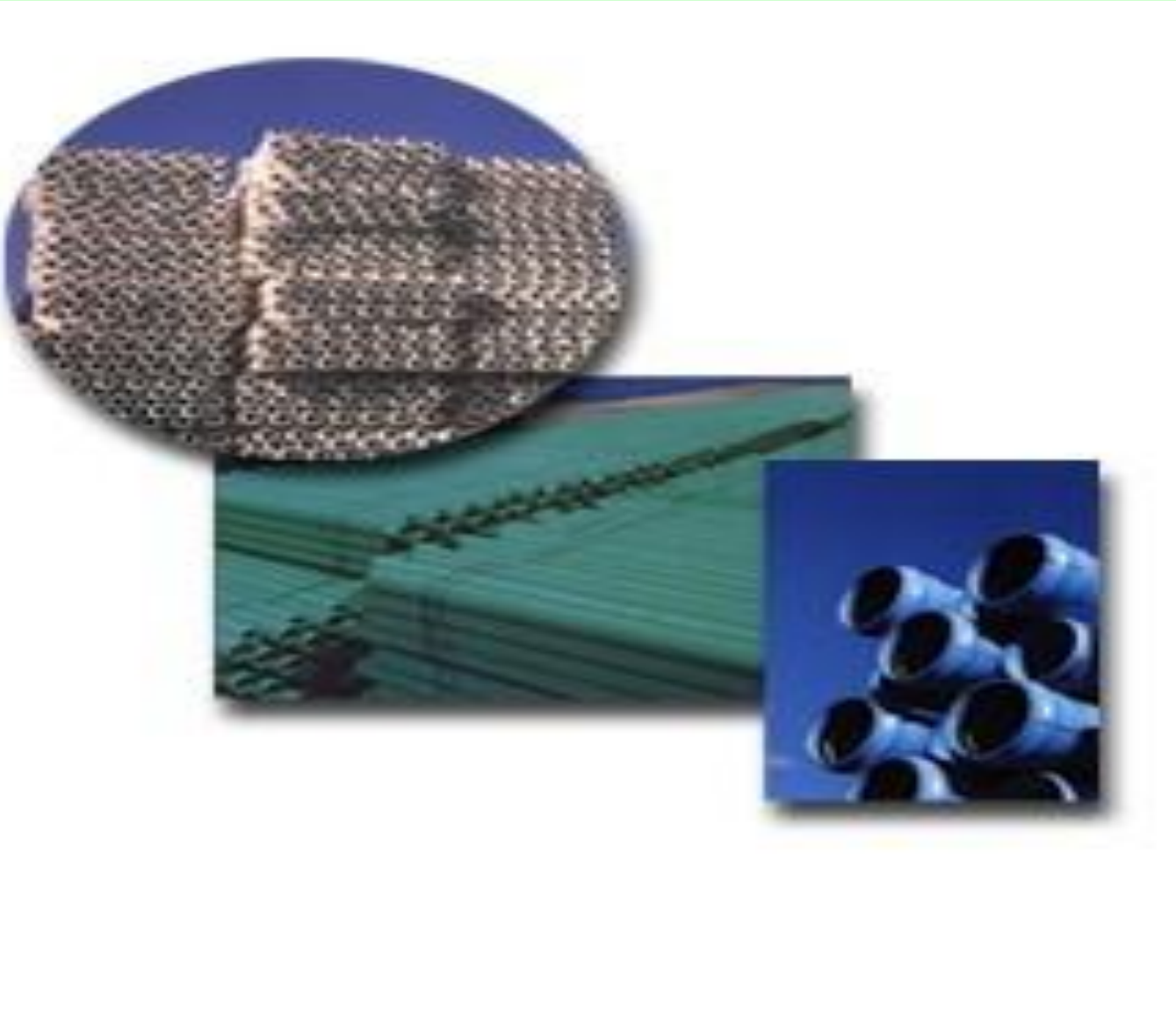
5. Poly(vinyl chloride) (PVC).

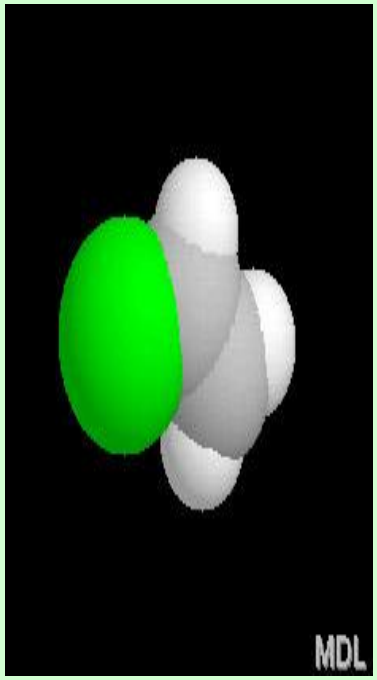
- Poly(vinyl chloride) is the plastic known at the hardware store as PVC.
- This is the PVC from which pipes are made, and PVC pipe is everywhere.
- The plumbing in your house is probably PVC pipe, unless it's an older house.

- PVC pipe is what rural high schools with small budgets use to make goal posts for their football fields. But there's more to PVC than just pipe.
- The "vinyl" siding used on houses is made of poly(vinyl chloride). Inside the house, PVC is used to make linoleum for the floor.
- In the seventies, PVC was often used to make vinyl car tops.

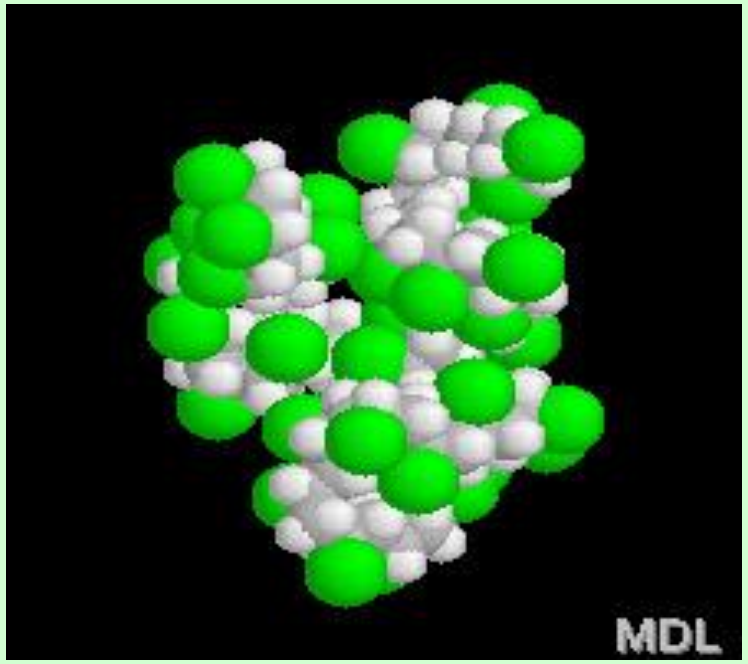

leftover acetylene from the
acetylene lamp fiasco
H–C≡C–H + HCl
H H
C=C
H Cl
vinyl chloride
H H
C C
H Cl
n
poly(vinyl chloride)


free radical
vinyl polymerization
vinyl chloride
poly(vinyl chloride)

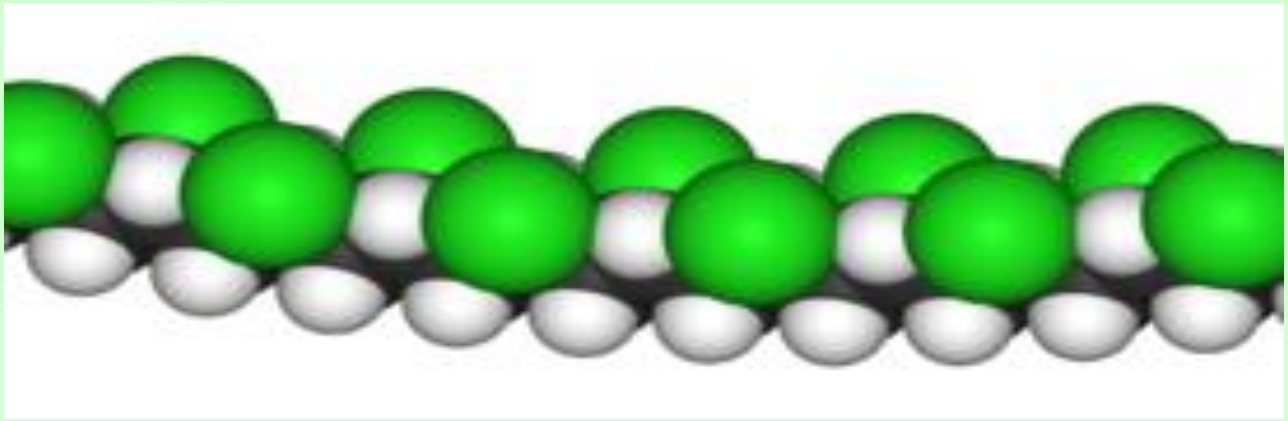




مونومير كلوريد الفينيل



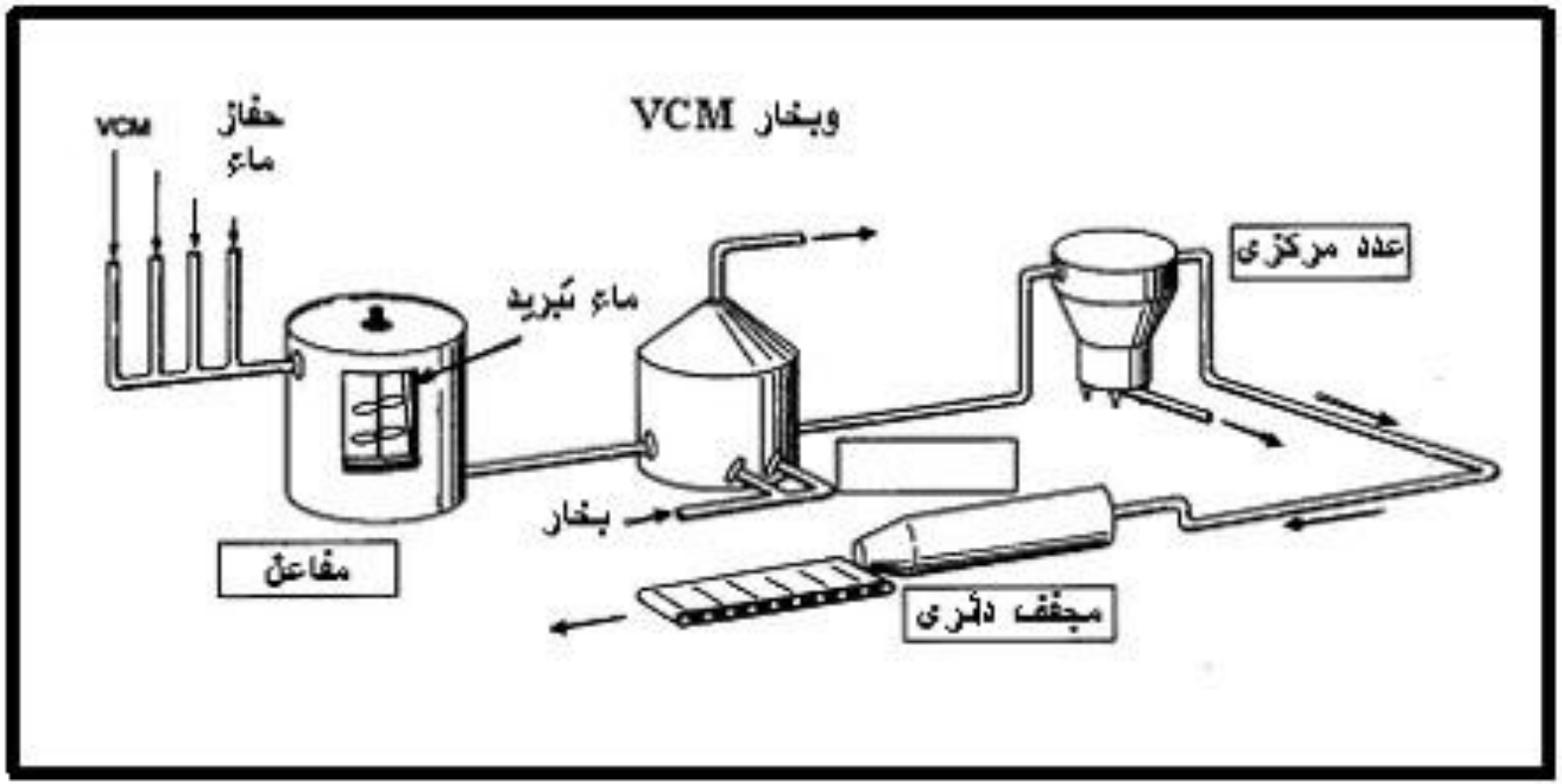
- بولى(كلوريد الفينيل)



جزئ الPVC

منزل حديث يستخدم البي في سي في بنائه

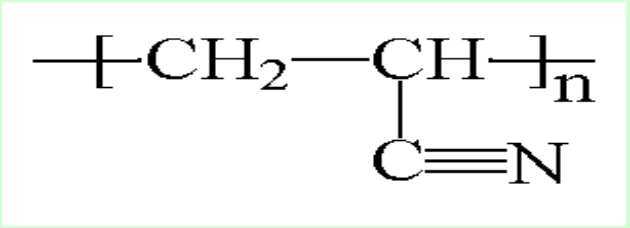
شكل



مصنع إنتاج PVC معلق

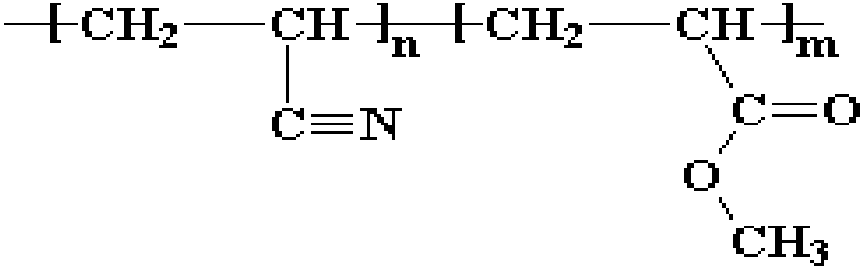
- **Where is PVC used? Click on any of the links below to view details on PVC in different applications.** **PVC in Medical Applications**
  PVC in Transport
  PVC in Building and Construction
  PVC in Toys
  PVC in Consumer Goods and Everyday Life
  PVC in Packaging
  PVC in Art and Design

6. Polyacrylonitrile



- Polyacrylonitrile is used for very few products an average consumer would be familiar with, except to make another polymer, carbon fiber.
- Homopolymers of polyacrylonitrile have been uses as fibers in hot gas filtration systems, outdoor awnings, sails for yachts, and even fiber reinforced concrete.
-

- But mostly copolymers containing polyacrylonitrile are used as fibers to make knitted clothing, like socks and sweaters, as well as outdoor products like tents and such.
- If the label of some piece of clothing says "acrylic", then it's made out of some copolymer of polyacrylonitrile.
- Usually they're copolymers of acrylonitrile and methyl acrylate, or acrylonitrile and methyl methacrylate:



poly(acrylonitrile-*co*-methyl acrylate)

Sweaters like this one can be made from wool, which is another form of collagen. So is your skin and hair, by the way. Sweaters are also made out of acrylics, like polyacrylonitrile or rayon .

Making Carbon Fiber

What is carbon fiber?

- Carbon fiber or carbon fiber is a thin long filament (strand) comprising of sheets of carbon atoms arranged in hexagonal pattern aligned along the axis of the filaments length.
- Carbon fiber is also sometimes called graphite fiber.

Why carbon fiber?

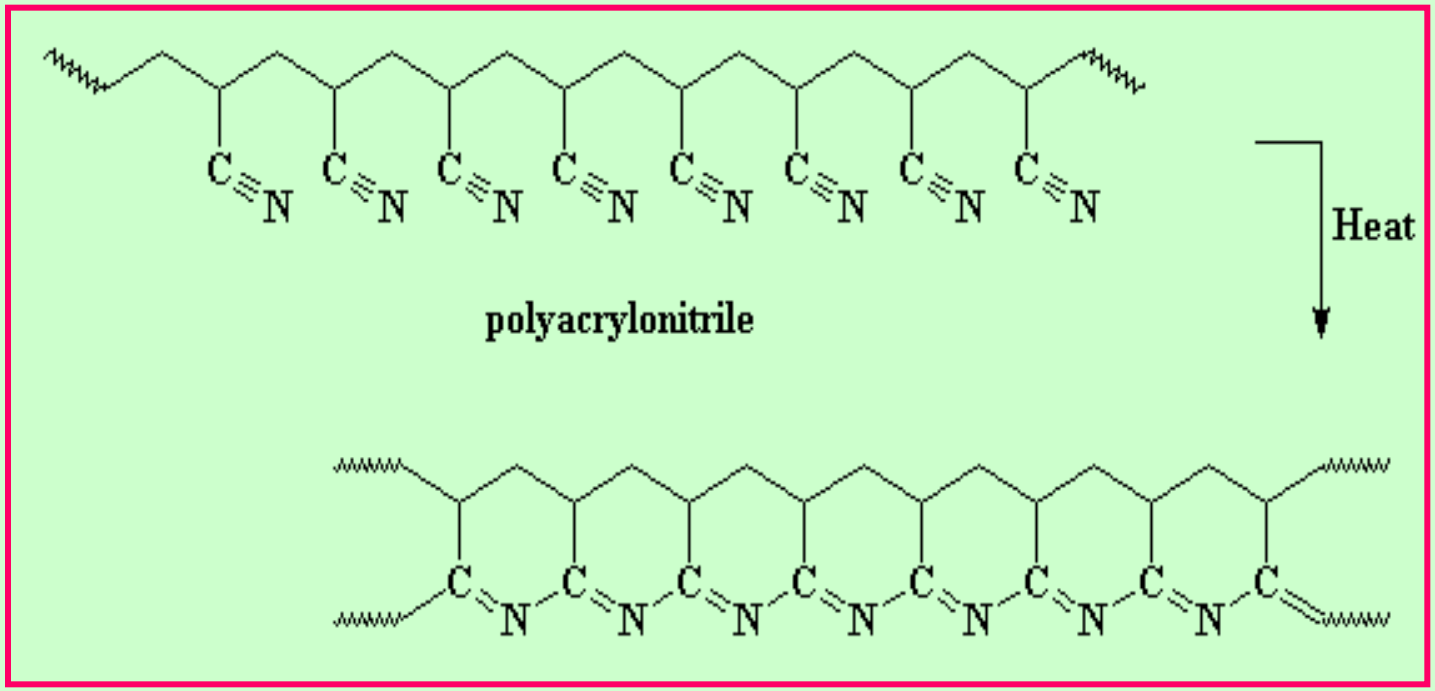
- Carbon fiber has a remarkably high strength and light weight compared to other traditional materials.
- It can be produced with very high modulus for applications such as space craft, arms etc.
- It is flexible in structural design

- It has chemical resistivity and non corrosiveness properties.
- It has good properties thermal and electric conductivity.

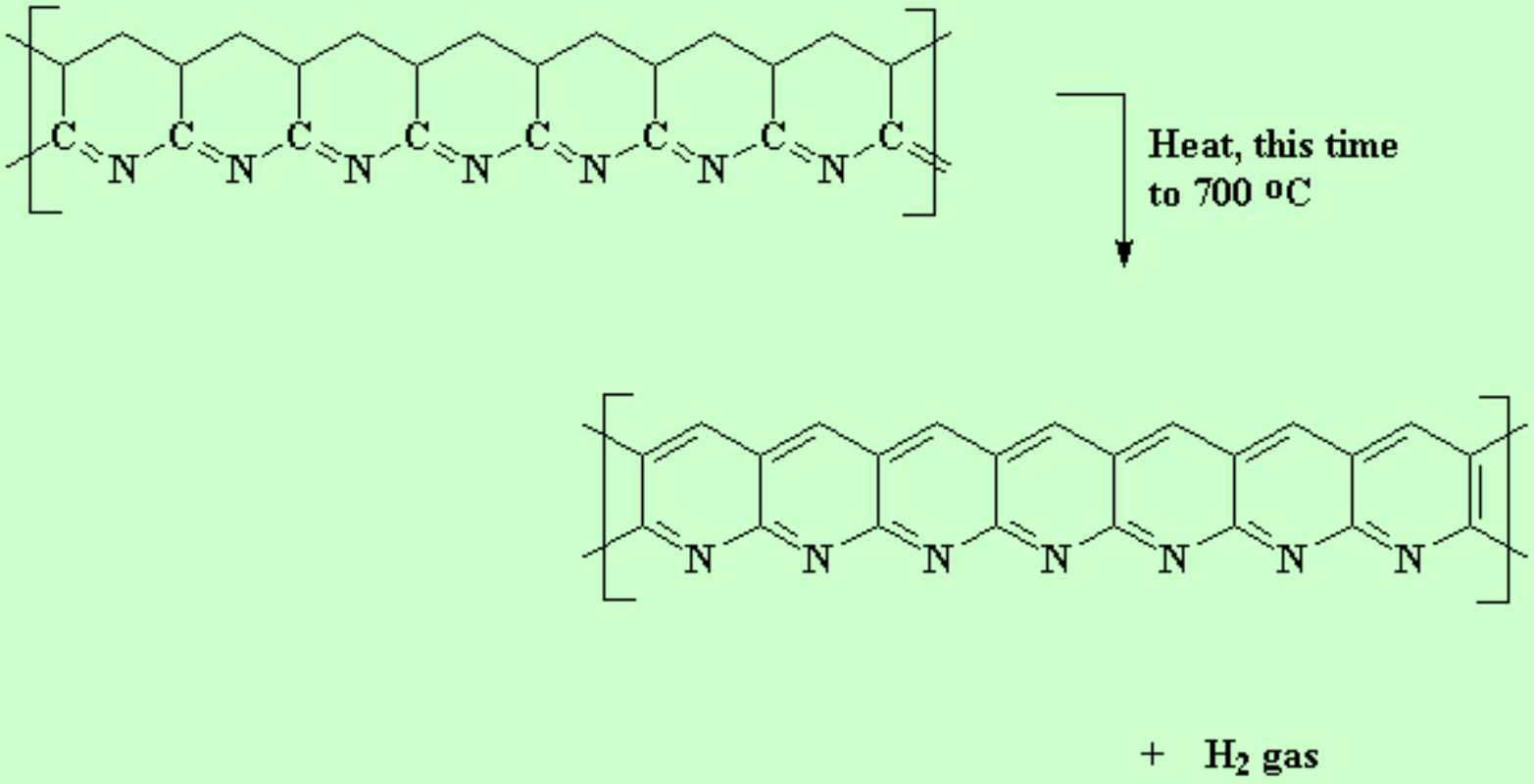
Manufacture of Carbon Fiber:

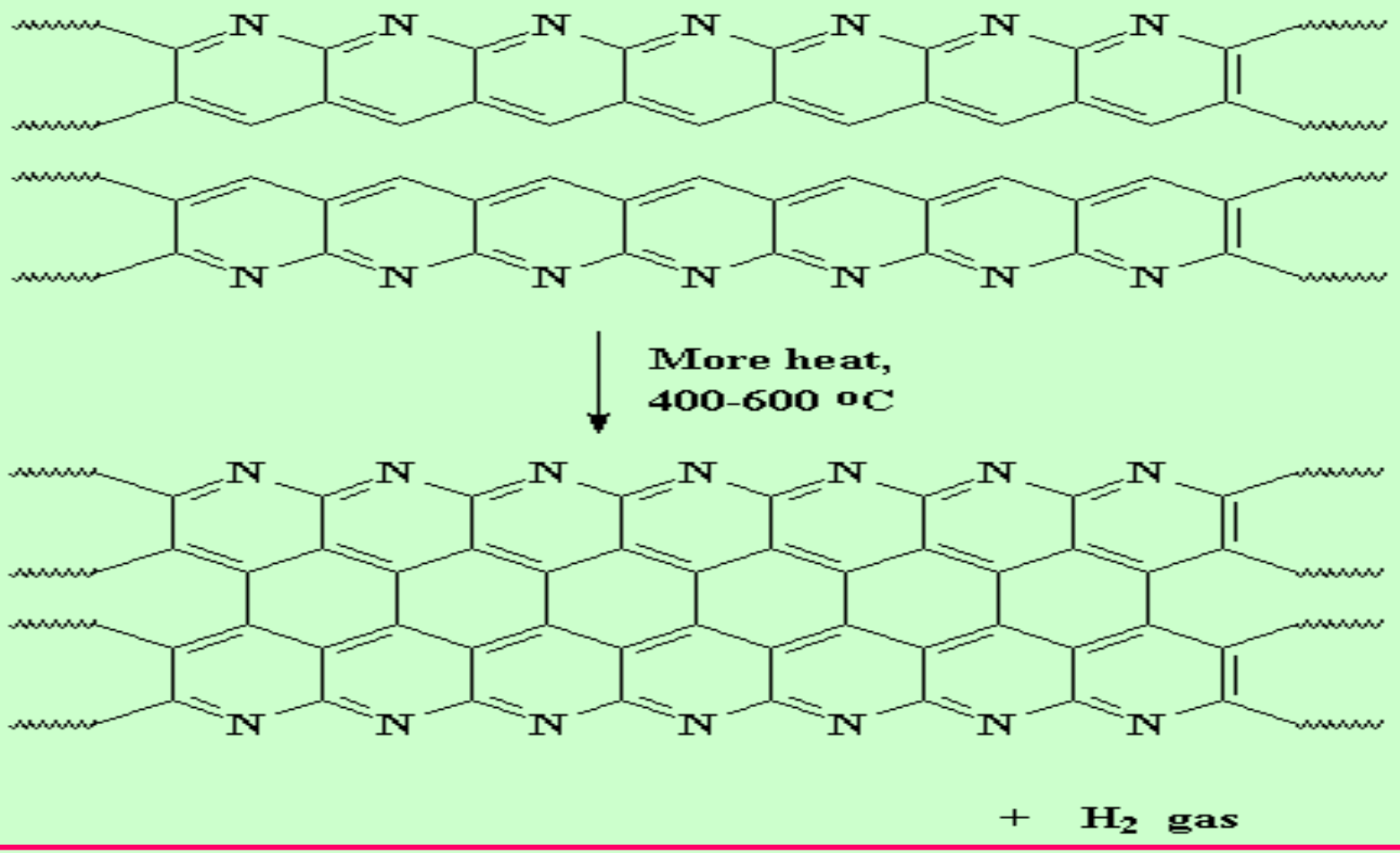
- Carbon fiber...the wonder polymer...stronger than steel and much lighter...but how does one make it? It's made something like this:

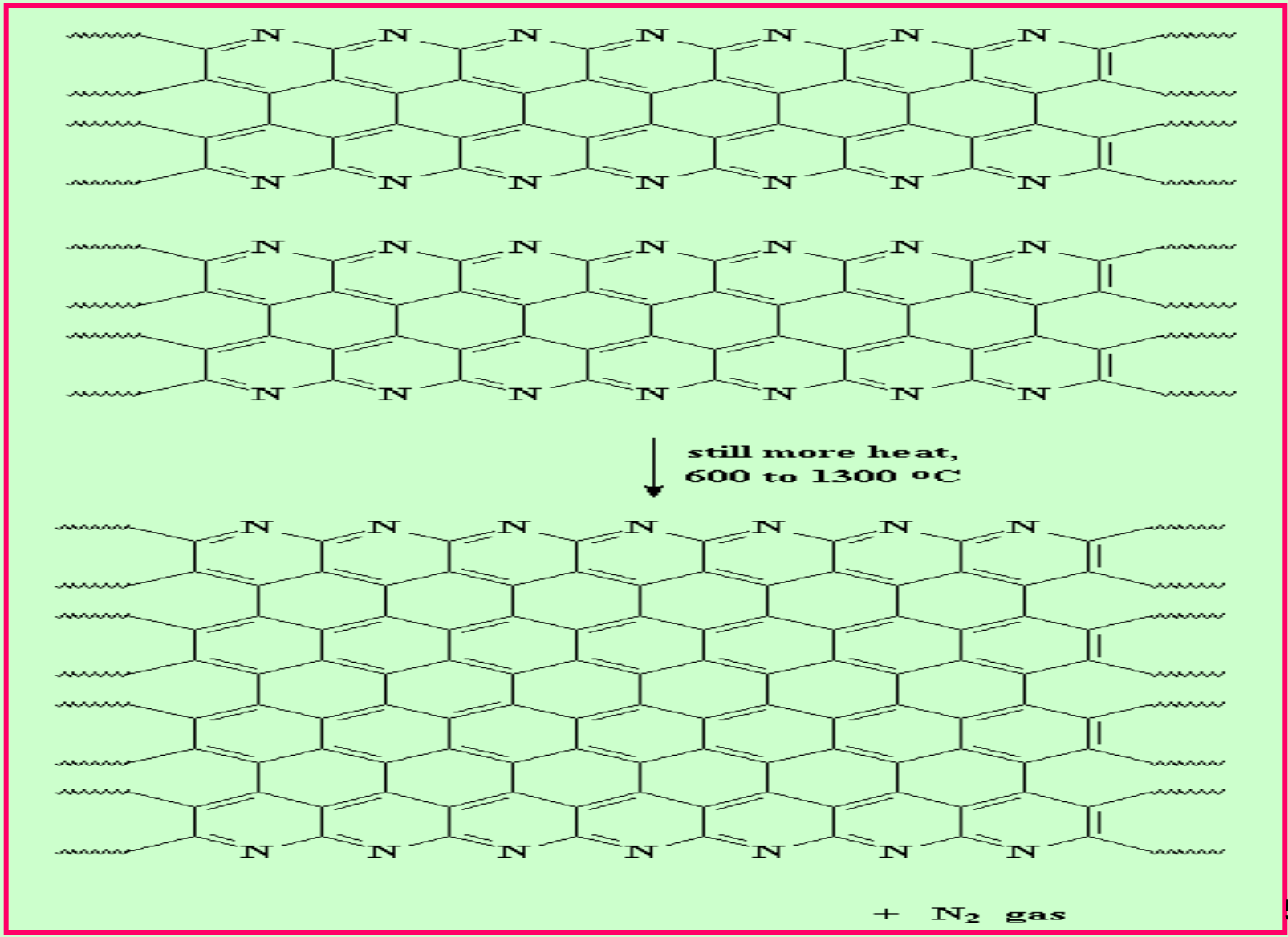
- We start off with another polymer, one called polyacrylonitrile. We take this polymer, and heat it up.


Heat
polyacrylonitrile

- Then you know what we do? We heat it again!
- This time we turn the heat up higher, and our carbon atoms kick off their hydrogen, and the rings become aromatic.
- This polymer is a series of fused pyridine rings.


Heat, this time
to 700 °C
+ H2 gas


More heat,
400-600 °C
+ H2 gas


still more heat,
600 to 1300 °C
+ N_2 gas

Acura RSX 02-04

Major applications of polymers

1. Plastics
2. Rubbers (or elastomers)
3. Fibers
4. Surface finishes and protective coatings
5. Adhesives
6. composites
7. Ion – exchanges resin

1. Plastic

6 Most Commonly-Used Recyclable Plastics

Symbols for Properties of Plastics


Gas Barrier


Moisture Barrier


Heat resistance


Clarity


Heat Insulation


Toughness


Gas Permeable


Chemical resist.

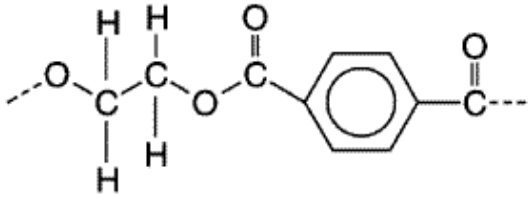

Grease&Oil resist.


Ease of forming


Hard


Flexible, Ductile

Polyethylene Terephthalate (PET or PETE)



-Strength/toughness, stiffness, resistance to heat

-Transparency: Containers for water,

-Grease&Oil resistance: vegetable oil

-Gas barrier property: Container for soda, carbonated drinks

Polyethylene Terephthalate (PET or PETE)

Uses: -- (major) soft drink bottles, mouthwash bottles,
food blow-molded containers

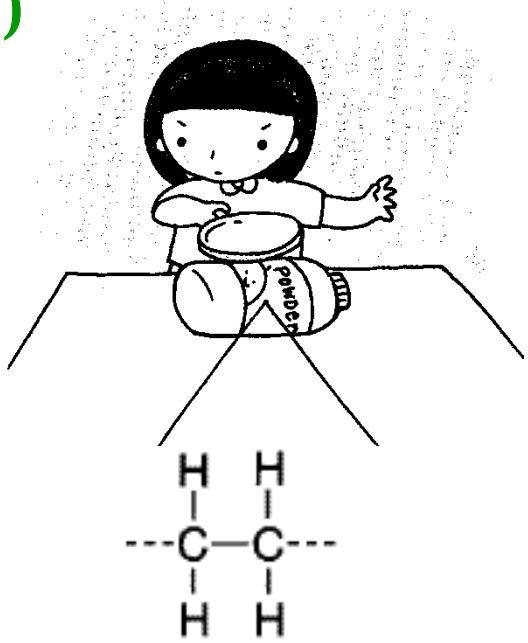
-- (minor) sheet applications

-- (minor) injection molded components ex. bicycle mud guards.

-- (minor) spinning fiber for carpet yarns, fiberfill, and geotextiles.

Recycled Products: Tote bags, dishwashing liquid containers, clamshells, laser toner cartridges, picnic tables, hiking boots, mailbox posts, fencing, furniture, sweatshirts.

High Density Polyethylene (HDPE)



-Relatively straight chain structure, higher density than LDPE

-Look milky white

-Stiffness, strength/toughness, low cost, ease of forming

-Resistance to chemicals

-Permeability to gas

-Ease of processing

High Density Polyethylene (HDPE)

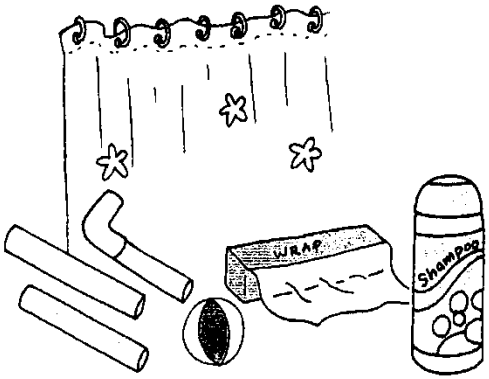
- *Uses:*

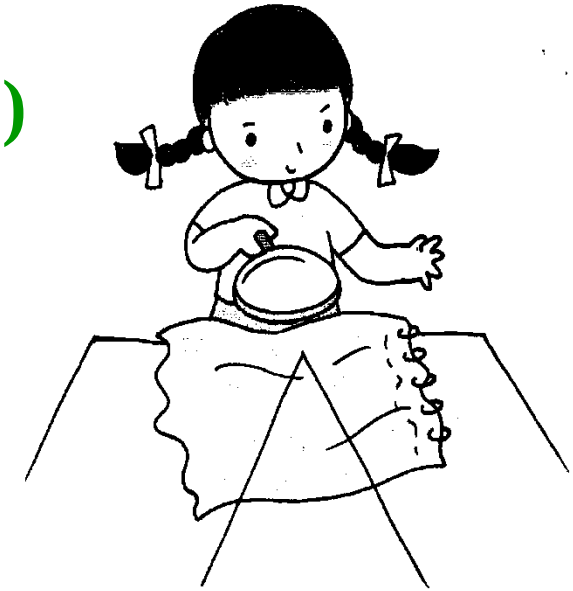
  wide application in blow molded bottles for milk, water and fruit juices, grocery bags, toys, liquid detergent bottles.(Copolymer HDPE, pigmented with a variety of colorants, is used for packaging toiletries, detergents and similar products.)

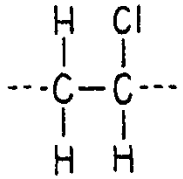
- *Recycled Products:*

  Recycling bins, benches, bird feeders, retractable pens, clipboards, fly swatters, dog houses, vitamin bottles, floor tile, liquid laundry detergent containers.

Polyvinyl Chloride or PVC)

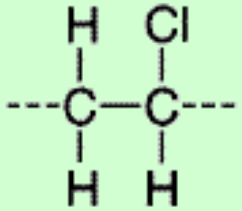






- Broadly divided into rigid and flexible materials.
-Versatility, ease of blending
-Strength/toughness
-Resistance to grease/oil and chemicals
-Clarity, Electrical Insulation
- Fire retardant

Polyvinyl Chloride or PVC)



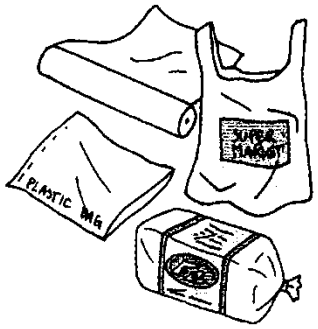
- *Uses*
  - Rigid PVC:60 percent of total PVC

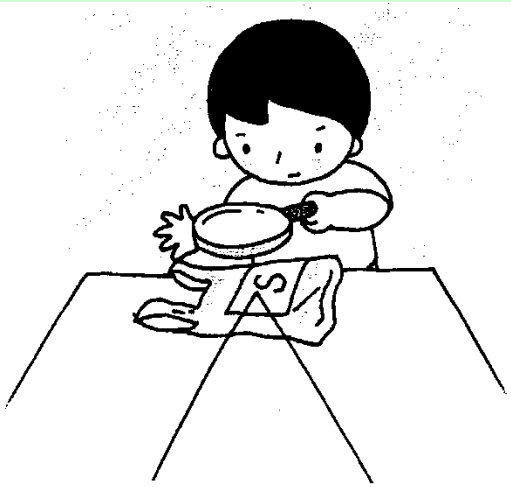
    (pipe and fittings, siding, carpet backing, windows, bottles and packaging sheet)
  - Flexible PVC:

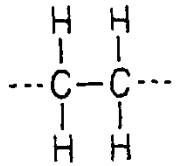
    (wire and cable insulation, film and sheet, floor coverings, synthetic-leather products, coatings, blood bags, medical tubing etc.)
- *Recycled Products:*

  Air bubble cushioning, flying discs, decking, film, paneling, recycling containers, roadway gutters, snowplow deflectors, playground equipment.

Low Density Polyethylene (LDPE)







-Ease of processing, ease of sealing, low cost

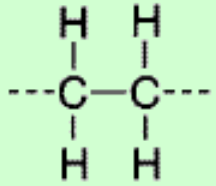
-Barrier to moisture,but air can pass through

-Good electrical insulation

- Strength/toughness, flexibility,

- Low T_g can be used with frozen food

Low Density Polyethylene (LDPE)



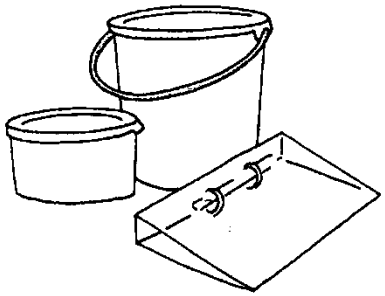
- *Uses:*

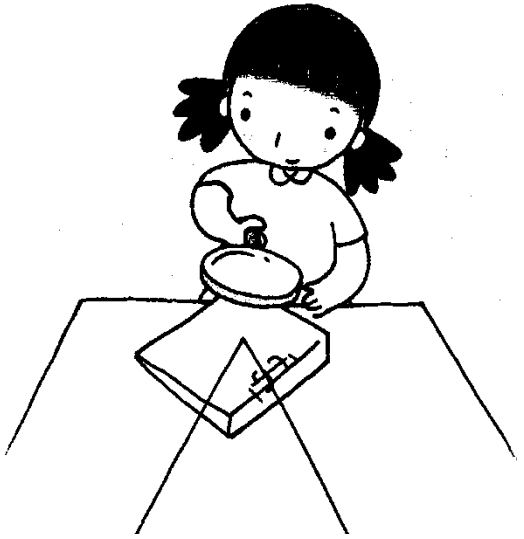
  film for plastic retail bags and grocery bags, some flexible lids, wire and cable applications Ex. Bread bags, frozen food bags, grocery bags.

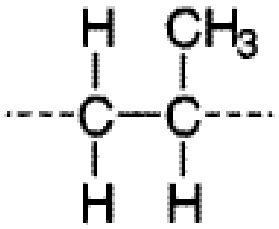
- *Recycled Products:*

  Shipping envelopes, garbage can liners, floor tile, furniture, film, compost bins, paneling, trash cans, landscape timber, mud flaps.

Polypropylene (PP)

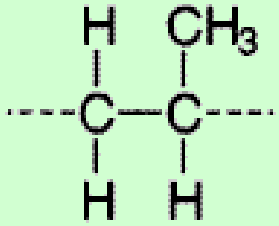






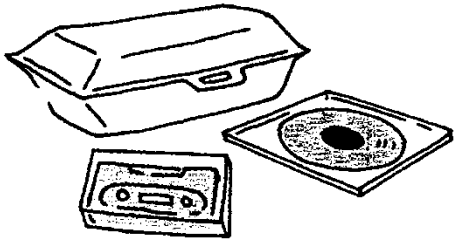
- Strength/toughness
- Excellent resistance to chemicals
- Resistance to heat, resistance to grease/oil, Barrier to moisture
- Low cost, versatility, ease of processing,
- Lowest density of the plastics used in packaging, high melting point

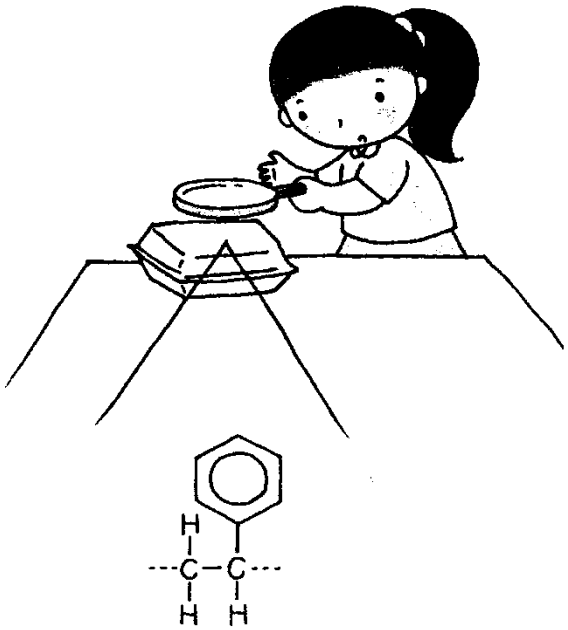
Polypropylene (PP)



- *Uses:* flexible and rigid packaging, fibers and large molded parts for automotive and consumer products ex. ketchup bottles, yogurt containers and margarine tubs, medicine bottles.
- *Recycled Products:* Signal lights, battery cables, brooms and brushes, ice scrapers, oil funnels, landscape borders, bicycle racks.

Polystyrene (PS)

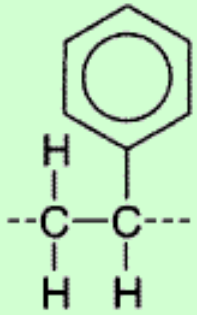




- very versatile, ease of processing, very cheap,
- clarity, hard and brittle
- poor barrier to oxygen and water vapor
- has relatively low melting point (not resistant to heat)

6
PS

Polystyrene (PS)



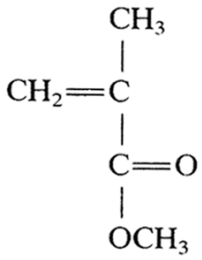
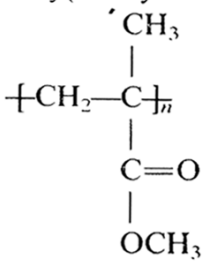
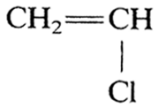
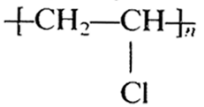
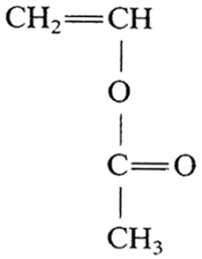
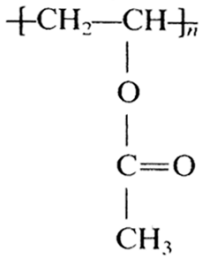
- *Uses:* can be rigid or foamed. Typical applications include protective packaging, containers, lids, bottles, trays ex. Video cassette cases, compact disc jackets, coffee cups, knives, spoons and forks, cafeteria trays, grocery store meat trays and fast-food sandwich containers.

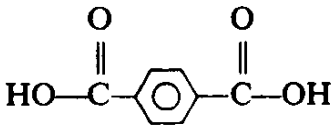
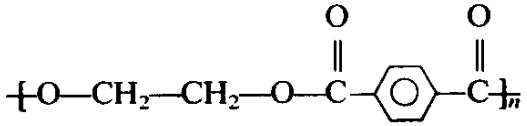
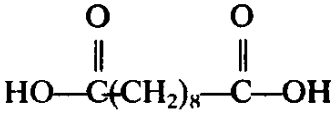
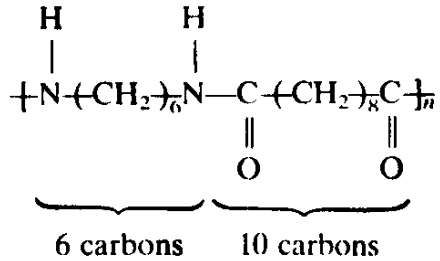
- *Recycled Products:* Thermometers, light switch plates, insulation, egg cartons, vents, desk trays, rulers, license plate frames, concrete.

Other recyclable plastics

Examples of 10 most popular polymers

Monomers	Polymer	Comments
(1) Ethylene $CH_2{=}CH_2$	Polyethylene (PE) $+CH_2{-}CH_2+_n$	Moulded objects, tubing, film, electrical insulation, e.g. 'Alkathene', 'Lupolen'.
(2) Propylene $CH_2{=}CH$ $\quad\quad\vert$ $\quad\quad CH_3$	Polypropylene (PP) $+CH_2{-}CH+_n$ $\quad\quad\vert$ $\quad\quad CH_3$	Similar uses to PE; lower density, stiffer, e.g. 'Propathene', 'Novolen'.
(3) Tetrafluoroethylene $CF_2{=}CF_2$	Polytetrafluoroethylene (PTFE) $+CF_2{-}CF_2+_n$	Mouldings, film, coatings; high temperature resistance, chemically inert, excellent electrical insulator, very low coefficient of friction; expensive, e.g. 'Teflon', 'Fluon'.
(4) Styrene $CH_2{=}CH$ $\quad\quad\vert$ $\quad\quad$ 	Polystyrene (PS) $+CH_2{-}CH+_n$ $\quad\quad\vert$ $\quad\quad$ 	Cheap moulded objects, e.g. 'Styron', 'Hostyren'. Modified with rubbers to improve toughness, e.g. high-impact polystyrene (HIPS) and acrylonitrile–butadiene–styrene copolymer (ABS). Expanded by volatilization of a blended blowing agent (e.g. pentane) to produce polystyrene foam.

(5) Methyl methacrylate 	Poly(methyl methacrylate) (PMMA) 	Transparent sheets and mouldings; used for aeroplane windows; more expensive than PS, e.g. 'Perspex', 'Diakon', 'Lucite', 'Oroglass', 'Plexiglas'.
(6) Vinyl chloride 	Poly(vinyl chloride) (PVC) 	Water pipes and gutters, bottles, gramophone records; plasticized to make PVC leathercloth, raincoats, flexible pipe and hose, toys, sheathing on electrical cables, e.g. 'Darvic', 'Welvic', 'Vinoflex', 'Hostalit'.
(7) Vinyl acetate 	Poly(vinyl acetate) (PVA) 	Surface coatings, adhesives, chewing gum.

(8) Ethylene glycol $HO—CH_2—CH_2—OH$	Poly(ethylene glycol) (PEG) $+CH_2—CH_2—O+_n$	Water-soluble packaging films, textile sizes, thickeners, e.g. 'Carbowax'.
(9) Ethylene glycol $HO—CH_2—CH_2—OH$ and terephthalic acid 	Poly(ethylene terephthalate) (PET)* 	Textile fibres, film, bottles, e.g. 'Terylene', 'Dacron', 'Melinex', 'Mylar'.
(10) Hexamethylene diamine $H_2N—(CH_2)_6—NH_2$ and sebacic acid 	Poly(hexamethylene sebacate) (nylon 6.10)*  6 carbons 10 carbons	Mouldings, fibres, e.g. 'Ultramid 6.10'.

* The polymer has two monomer units in the repeat unit.

(ref: Young and Lovell, Chapman & Hall [1991])

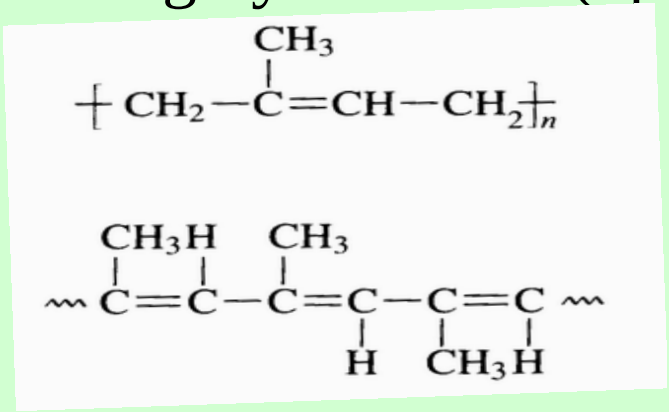
2. Rubbers (or elastomers)

2. Rubbers (or elastomers)

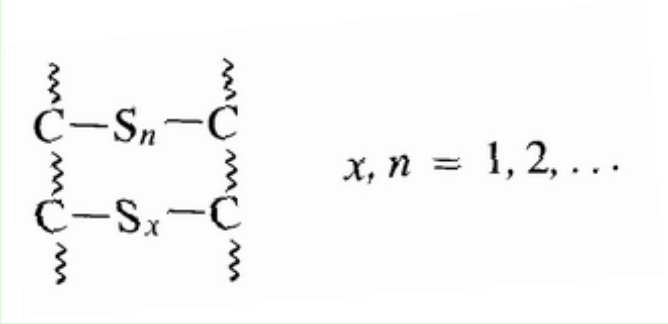
2.1 Natural rubbers

-polymers with T_g < application temp

-can be highly stretched (upto 700%)



reaction with sulfur ⟶ vulcanization



2.2 Polyurethane

Form by the reactions of urethane and polyol

urethane -CONH- (U)

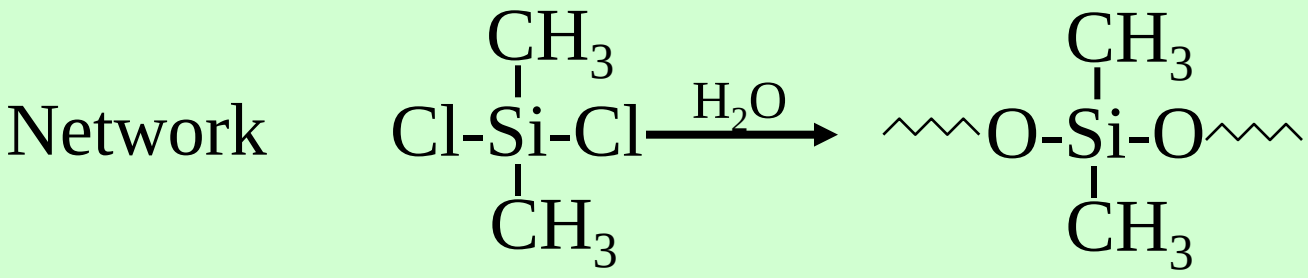
polyol OH----P-----OH (P)

-considerably higher tensile strength.

-higher tear and abrasion resistance

} Compare to natural rubber

2.3 Silicone rubbers



Pro:

- -low and high temp stability (-55 to 250 ^{o}C)
- -elastic even at low temp.
- -excellent electrical property
- -extremely inert

→

- กาว (nontacky self adhesive
- bouncing putty

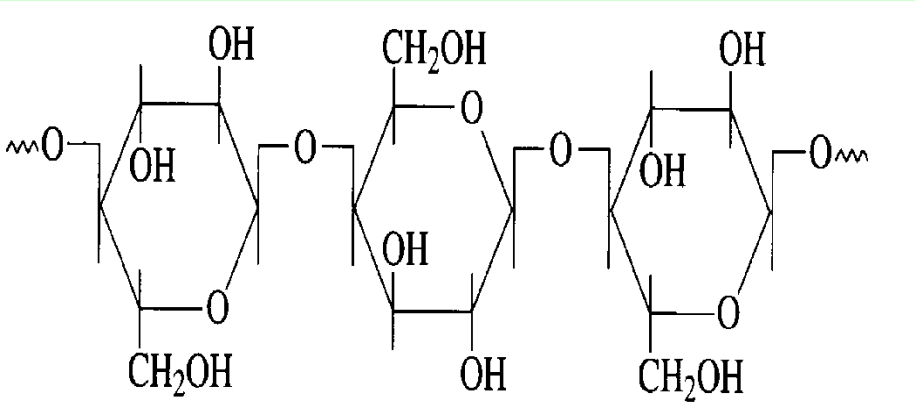
3. Fibers

3. Fibers

Cellulose plastics

- commonly found in plant's cell wall
- Cotton consists of 90% cellulose, 10% lignin and polysaccharides

Structure of cellulose:



Has 3 OH-groups in each ring

Celluloid –dissolvable in cloroform, acetone etc.

- inflammable, poor chemical resistance

Cellulose Acetate – substituted OH in cellulose with $O\text{-}\overset{\overset{O}{\|}}{C}\text{-}CH_3$

Pro: - water absorptivity

(decrease when OH is replaced by $\overset{\overset{O}{\|}}{O}\text{-}C\text{-}CH_3$

-หมู่ $\overset{\overset{O}{\|}}{O}\text{-}C\text{-}CH_3$ increase →stronger

-ใช้ทำฟิล์มถ่ายรูป(use in photographic film)

- Normally, “cellulose” cannot be dissolved in any solvent
- “Rayon” is regenerated cellulose (used to produce fibers)
- “Nylon” is synthetic polymer (used commonly as fibers)

4. Surface finishes and protective coatings

4. Surface finishes and protective coatings

Paints– need the following qualities:

-quick drying (แห้งเร็ว)

-cling well to surfaces (ยึดเกาะกับพื้นผิว)

-prevent erosion and corrosion (ป้องกันการสึกกร่อนและการกัดกร่อน)

Types of paints

- alkyd and polyester resin
- phenolic resin (reaction of phenol+formaldehyde)
- Acrylic resin
- Polyurethane

TABLE 2.4
Common terminology used in paints industry

Common names	Description	Remarks
Lacquer	Consists of a polymer solution with a suitable pigment. The solvent used is organic in nature, having high vapor pressure.	The chosen polymer should form a tough film on drying and should adhere to the surface. Acrylic polymers are preferred because of their chemical stability.
Oil paint	A suspension in drying oils, e.g., linseed oil. Cross-linking of oil occurs by a reaction involving oxygen.	Sometimes a catalyst such as cobalt naphthenate is used to accelerate curing.
Varnish	A solution of polymer—either natural or synthetic—in drying oil. When cured, it gives a tough polymer film.	Ordinary spirit varnish is actually a lacquer in which shellac is dissolved in alcohol.
Enamel	A pigmented oil varnish.	It is similar in nature to oil paint. Sometimes some soluble polymer is added to give a higher gloss to the dried film.
Latex paint	Obtained by emulsion polymerizing a suitable monomer in water. The final material is a stable emulsion of polymer particles in water. On drying, particles coalesce, giving a strong film with a gloss.	To give abrasion resistance to the film, sometimes inorganic fillers such as $CaCO_3$ are added. Because of their chemical stability, acrylic emulsions are preferred.

5. Adhesives

5. Adhesives

- Adhesive (กาว):is in liquid form when applying, then becomes solid and form joint between two surfaces afterwards.
- Crosslinking reaction (curing reaction)
  - To form network polymers (occurs in polymers with more than 2 functional groups)

Cured polymer = network high MW polymer

(not dissolve in any solvents)

Application: adhesive, paints, fiber-reinforced composite, ion-exchanged resin, polymeric reagents

Milky-white glue – PVAC (Polyvinyl Acetate)

Clear glue – PVOH (Polyvinyl Alcohol)

- 3 types of common adhesives are
  - Non-reactive
  - Pressure sensitive
  - Reactive

1. Non-reactive adhesive: quick-drying solvent containing polymer, tackifier and antioxidant

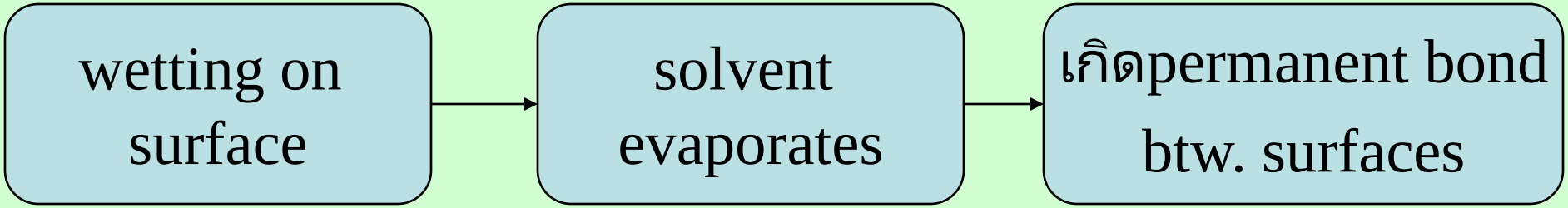
(tackifier = low MW liquid used to enhance surface adhesion of the glue)

ex. น้ำมันสน (pine oil), hydrocarbon derivatives)

Several polymers have natural permanent tack

→no need for tackifier ex. Nat. rubber, silicone rubber, polyvinyl ethyl isobutyl ethers

- กระบวนการ adhesion ของกาว nonreactive



2. Pressure-sensitive adhesive: กาวแบบ non-reacting (do not lose adhering property even when solvent is already evaporated. This is possible because the polymer used in this case is liquid polymers ex. Silicone rubber

(NOTE: silicone polymers→has permanent tack & high thermal stability (-75 to 250 C))

3. Reactive adhesive: ex. Epoxy adhesive –curing reaction occurs at room temp.

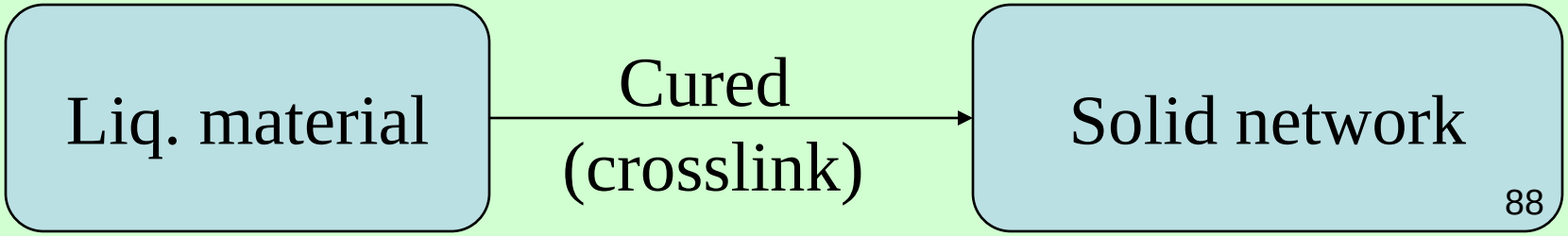


Table 2.3 Some common adhesive

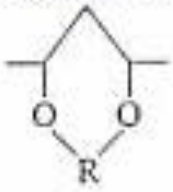
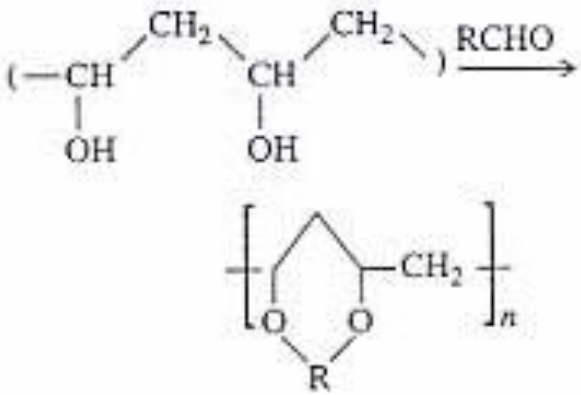
Type	Structure	Remarks
	Nonreactive adhesives	
Hot SBR	Styrene-butadiene copolymer	Its solution in hexane or toluene is used as tile cement and wallpaper adhesive. Its ability to stick on a surface is considerably improved if SBR is a terpolmer with a monomer having carboxylic acid (say, acrylic acid).
Nitrile rubber	Copolymer of butadiene and acrylonitrile (20–40%)	Used with any nonpolar solvent; provides good adhesion with surfaces.
Poly(vinyl acetate) and its copolymers	Copolymerized with acrylates and maleates to improve T_g, tack, and compatibility	Common household glue (white glues). It resists grease, oil, and hydrocarbon solvents; has poor resistance to weather and water. Copolymerization is done to improve this.
Polyvinyl acetals 		Polyvinyl formal (R═H) is used as a structural adhesive in the aircraft industry. Polyvinyl butyral (R═C_3H_7) is used as the interlayer in safety glasses in the automobile industry.

Table 2.3 Some common adhesive (con't)

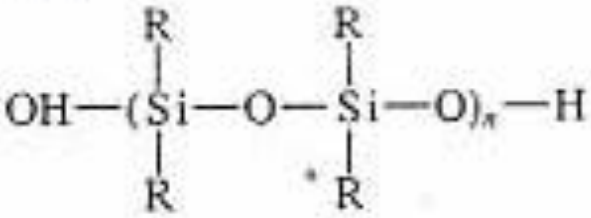
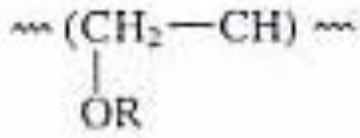
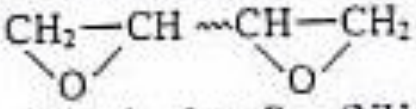
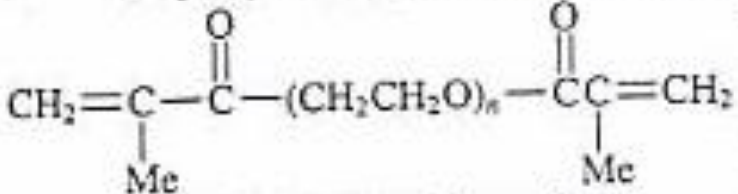
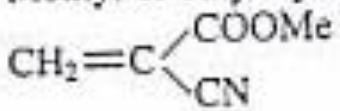
Pressure-sensitive adhesives		
Polyacrylates	Water emulsions of copolymer of 2-ethyl acrylate (352 parts), vinyl acetate (84 parts), and acrylic acid (4 parts)	Pressure-sensitive adhesive used for labels. They have permanent tack, and labels with this glue can be reused.
Silicone rubbers	 R: methyl or phenyl M = 500–600	The tack is considerably improved by the phenyl group. It can produce adhesion with any surface, including Teflon. Polymer-coated polyester films are used in plating operations and insulations.
Poly(vinyl ether)	 R: methyl, ethyl, or isobutyl	These polymers are frequently used in pressure-sensitive adhesive applications, as in cellophane tapes and skin bandages.

Table 2.3 Some common adhesive (con't)

TABLE 2.3
(*Continued*)

Type	Structure	Remarks
	Reactive adhesives	
Two-component polyurethane adhesives	Prepolymer NCO~~NCO with polyol OH~~OH hardener	Used as structural adhesive. Usually the curing is slow and the joint has low modulus.
Epoxy adhesives	Diglycidyl ether of bisphenol-A,  with triamines $R-(NH_2)_3$	Two-part epoxy resins are mixed before use. It exhibits excellent adhesion to metals, plastics, woods, glass, ceramics, etc. It is unaffected by water, and its major use is in aerospace, automotive, electrical, and electronics industries.
Anaerobic acrylic	Polyethylene glycol bismethacrylates  with a hydroperoxide catalyst	It cures at room temperature through free radical mechanism in contact with metal without air. Originally used as sealant but now also used as structural adhesive. Curing is sensitive to substrate.
Cyanoacrylates	Methyl or ethyl cyanoacrylates 	It polymerizes on a surface with a slight amount of moisture. It joins any surface except polyethylene, polypropylene, and Teflon.

6. Composites

6. Composites

- Contain at least 2 phases
- To increase mechanical properties ex. strength, toughness, high-temp application
- Polymer composite: the continuous phase is polymer. → 2 types of reinforcing materials
    (1) Particle reinforced composite
    (2) Fiber reinforced composite

Examples of reinforcing material: glass, carbon,ceramic, Kevlar (hard polymeric polyaramid)

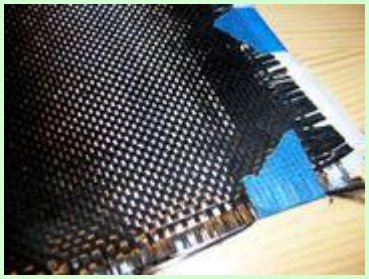
Glass Fiber

Glass Fiber Roll

Chopped Glass Fiber

Glass Fiber Mat

Carbon Fiber



Carbon Fiber Mat

Tail of an RC helicopter, made of Carbon fiber reinforced plastic

http://en.wikipedia.org/wiki/Carbon_fiber

Particles

Carbon black

Silica

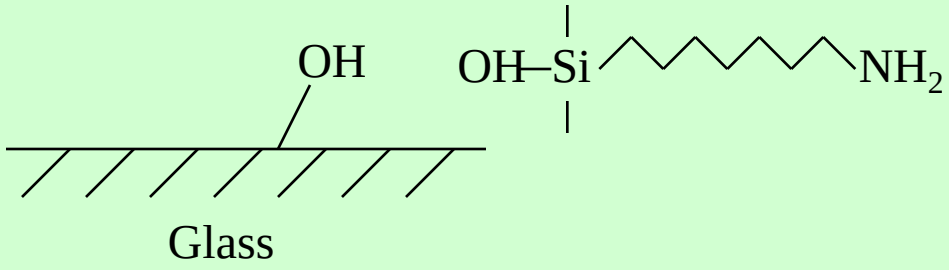
Talcum

- Polymer composites – commonly found are:

Thermoset : polyester, epoxy resin, polyimides, phenolic resin, rubber

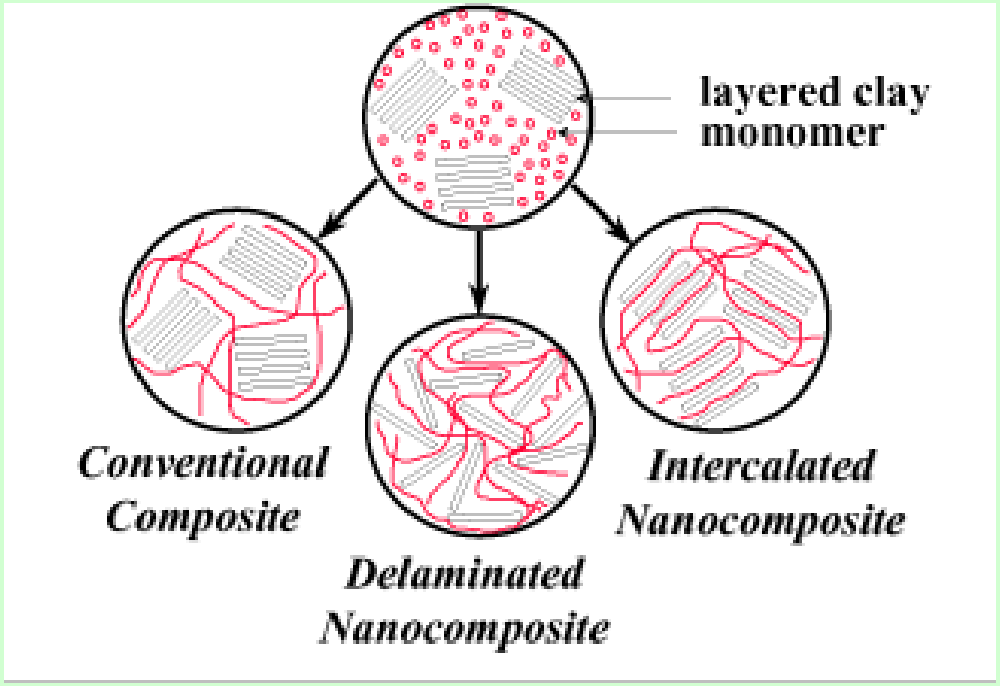
Thermoplastic composite: can be found in some application ex. PE, PP
Recycling is possible, strength is not as good as thermoset

Glass (SiO_2) : - used as filler
- compatibility w/ polymer is enhanced by treated w/ r-amino propyl ethoxy silane to form organic coating

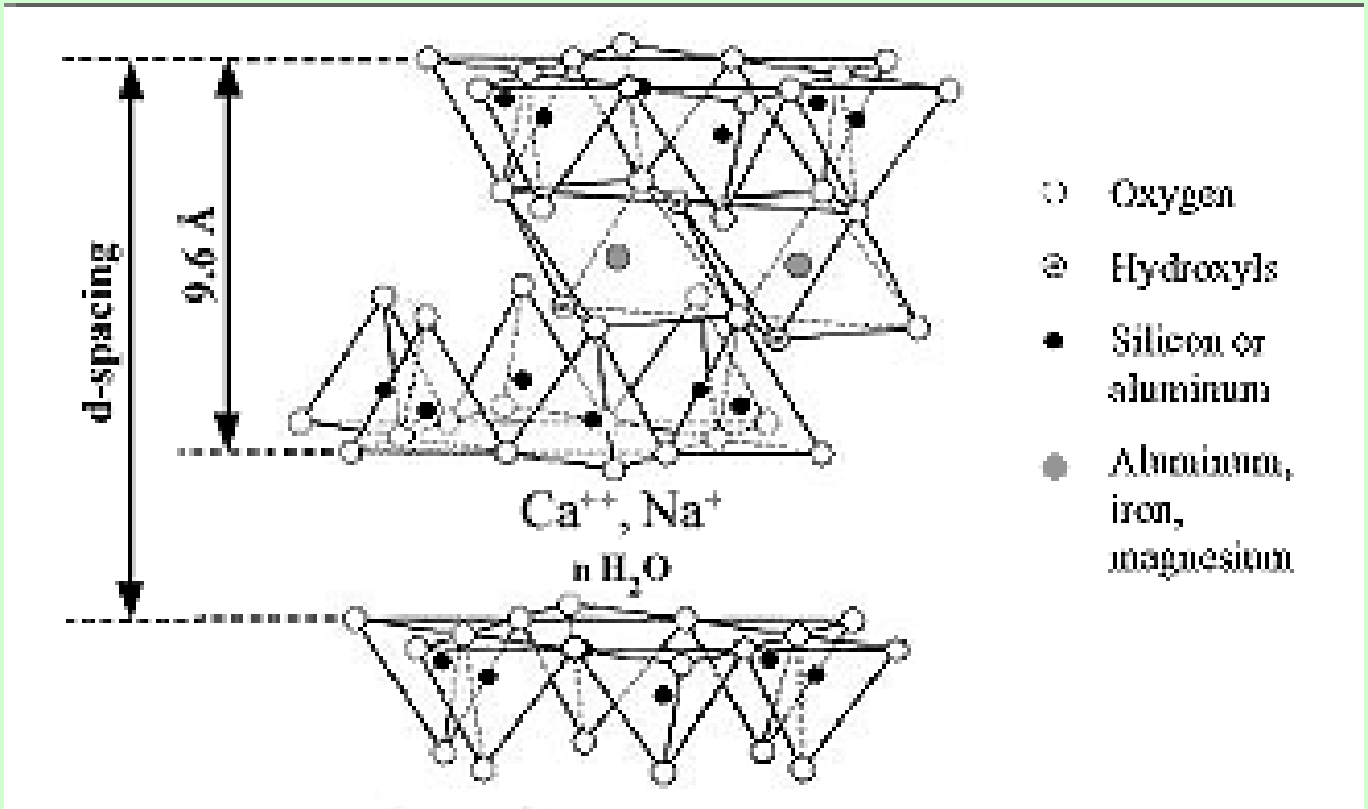


POLYMER COMPOSITE

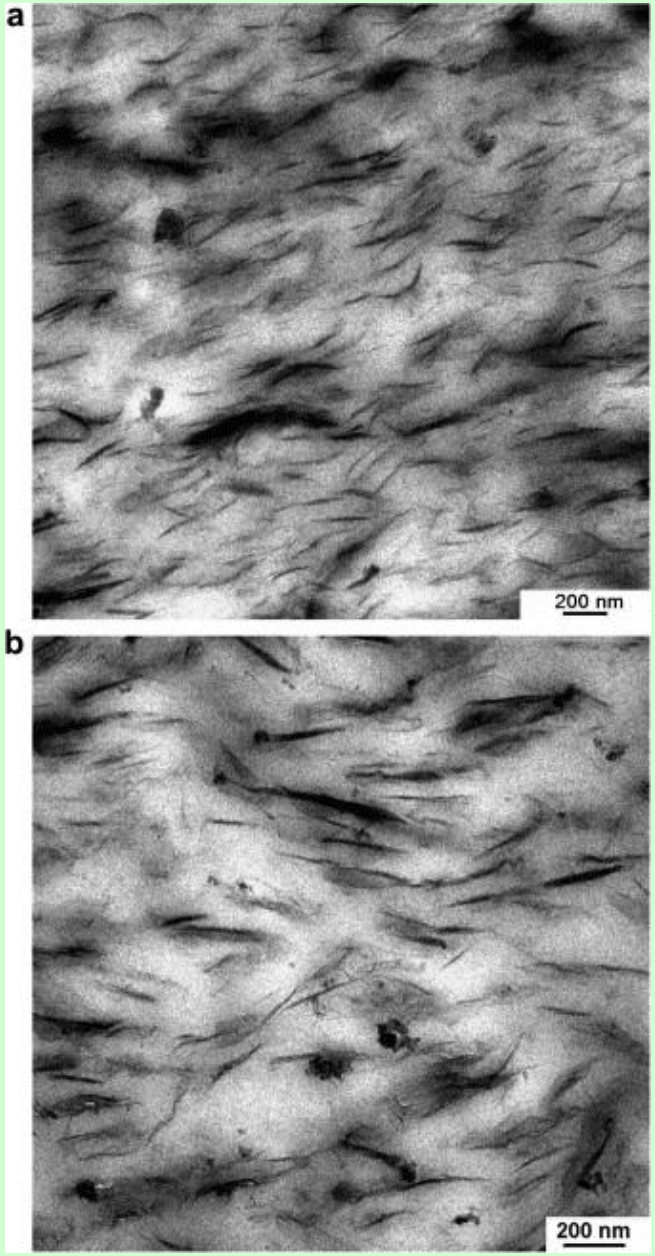
1. CONVENTIONAL COMPOSITE
2. NANOCOMPOSITE
   - Intercalated Nanocomposite
   - Exfoliated Nanocomposite



NANOFILLER : MONTMORILLONITE



MONTMORILLONITE IS HYDROPHILIC SILICATE

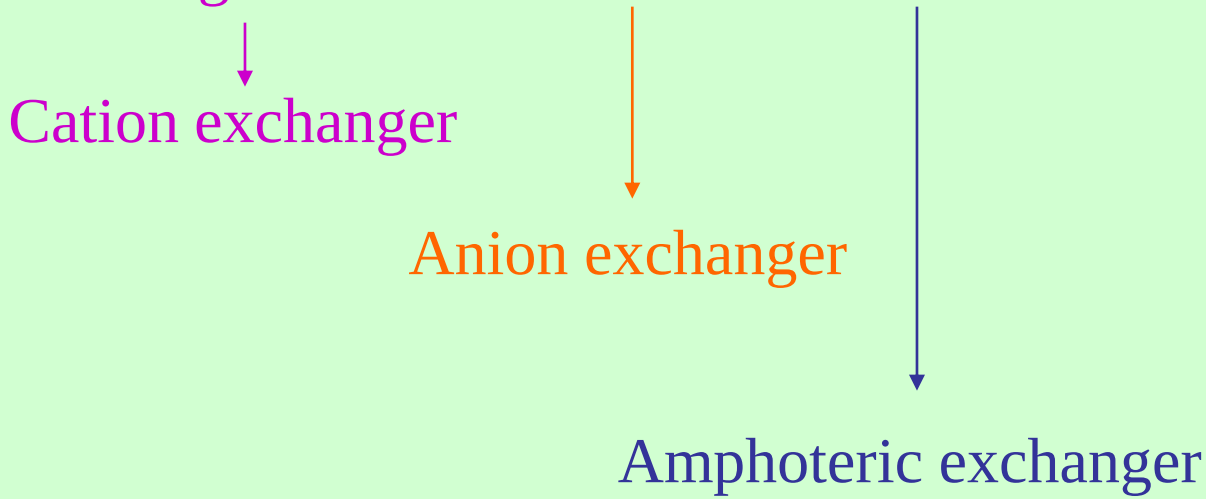


TEM images of
(a) HNBR/MMT–ODA and
(b) HNBR/FHT–ODA nanocomposites (10 phr filler amount).

7. Ion exchange resin

7. Ion exchange resin

- is solid object w/ exchangeable cations or anion or both



- Mostly porous solid object with functional group that can exchange ions
  ex. Zeolite, organic ion exchanger

Ion exchange resin: commonly found in water treatment by replacing Na^+ on the resin with Ca2+ from the hard water

• Zeolite – is a rather soft and porous compound of aluminosilicate
- synthetic zeolite is sometimes called molecular sieve

• Organic ion exchange
: is made of crosslinked polymer gels.
- The polymer matrix consists of ions that are cation or anion exchangers

Ex.

cation exchange เช่น SO_3^{-1}, CO^{-1}, PO_3^{-2}, AsO_3^{-2}

anion exchange เช่น $-NH_4^{+1}$, $-NH_2^{+}$, $-N^{+}-$, $-S^{+}$

Organic ion exchanger :

Most oftenly found are: coplymer gel of styrene and divinyl benzene (DVB), with ~ 8-12% DVB

Sulfonation was then carried out in conc. sulfuric acid

Two Possible form of ion exchange resins used for water treatment

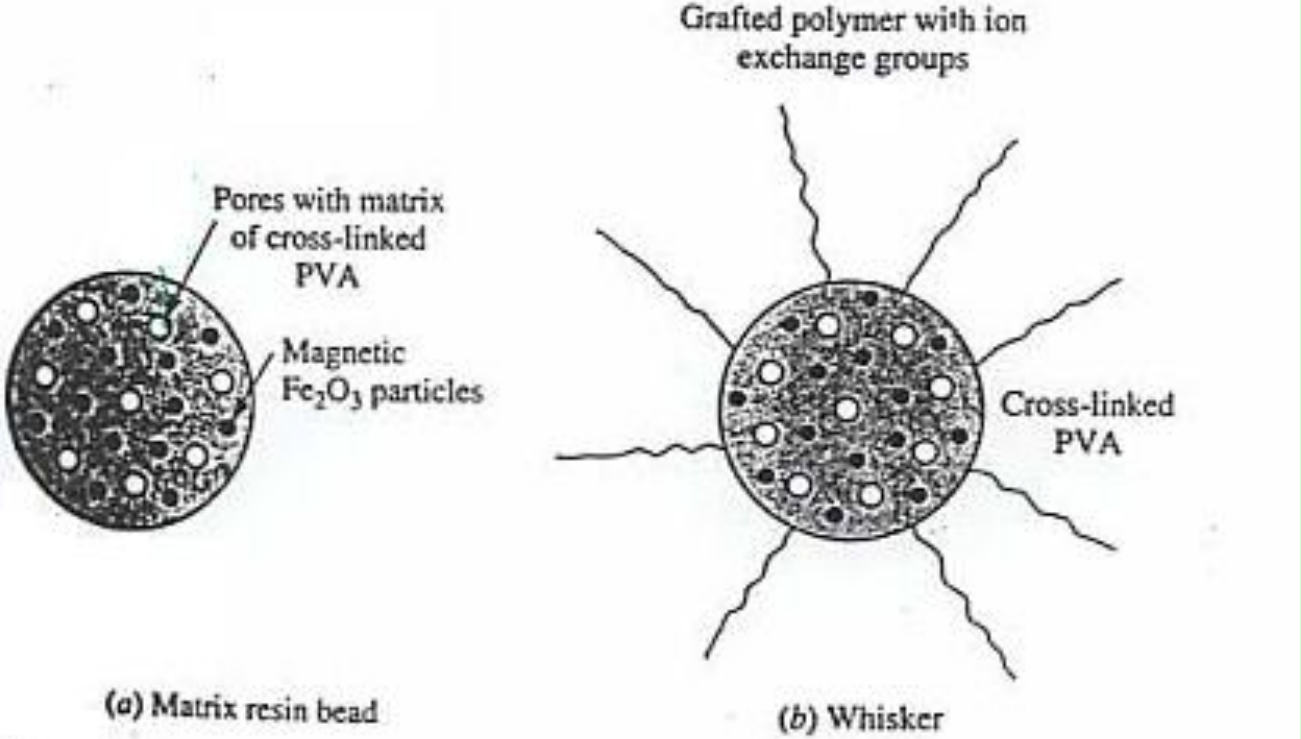


FIGURE 2.5
Two possible forms of ion exchange resins used for water treatment.

Approaches to Reduce Plastic Waste

Approaches to Reduce Plastic Waste

Synthetic and semi-synthetic polymers were developed for their durability and resistance to all forms of degradation including biodegradation.

BEFORE: Plastics → landfill → waste problems!

PRESENT: 2 approaches

- Recycling technology (management of plastic waste)
  - Labor intensive, downgrading performance from virgin plastics
- Environmentally degradable plastics (get rid of the non-degradable problem, but expensive!)
  - Ex. Biobased polymeric material, degradable polymers

History of Environmental Management

- ๑๙๖๐ 's: : Dilution is the solution to pollution
- Acceptable until the carrying capacity of the earth is exceeded exceeded

- ๑๙๗๐'s and 's and ๑๙๘๐'s: Treatment of wastes
  - Money down the drain?

- ๑๙๙๐'s onwards : Cleaner Production
  - Initially, focused on a particular process stream
  - Now, system-wide (holistic) or life-cycle approach

Waste Management Hierarchy

- Reduce
- Reuse
- Recycle
- Incinerate with energy recovery
- Incinerate without energy recovery
- Landfill

Recycling is not *Impact-free*

- Mechanical recycling
  - Thermosets : grinding, particulation for reuse
  - Thermoplastics : remelting and extrusion / pelletisation

- Chemical recycling
  - Materials recycling
    - Monomers for new plastics
    - Fuels
    - Energy

Plastic recycling

- Packaging industry→20-40% of plastic production → contributes greatly to the waste.
- Technologies based on recycling include:
  - Mechanical recycling
    - reprocessed to similar products, or new products of inferior quality—most widespread
  - Feedstock retrieval
    - By hydrolysis, pyrolysis →obtain basic chemicals
  - Energy recovery by incineration
    - By incineration →get high energy comparable to fuel
      →precaution: harzadous emission from chemical reactions with polymer additives

Environmentally Degradable Plastics

- Good for future sustainable development
- Difficult to produce, maybe more expensive