Coductive Polymers

Conductive polymers or, more precisely, intrinsically conducting polymers (ICPs) are organic polymers that conduct electricity or can be semiconductors. The biggest advantages of conductive polymers is their processability, mainly by dispersion. Conductive polymers are generally not thermoplastics, i.e., they are not thermoformable. But, like insulating polymers, they are organic materials. They can offer high electrical conductivity but do not show similar mechanical properties to other commercially available polymers. The electrical properties can be fine-tuned using the methods of organic synthesis and by advanced dispersion techniques.

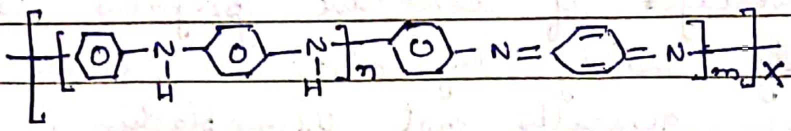
Synthesis : Conductive polymers are prepared by many methods. Most conductive polymers are prepared by oxidative coupling of monocyclic precursors. Such reactions entail dehydrogenation :

$$n H-[X]-H \longrightarrow H-[X]_n-H + 2(n-1)H^+ + 2(n-1)e^-$$

There are two main methods used to synthesize conductive polymers, chemical synthesis electro (co) polymerisation.
The chemical synthesis means connecting C-C bond of monomers by placing the simple monomers under various conditions, such as heating, pressing, light exposure and catalyst. The advantage is high yield
The electro (co) polymerisation means inserting three electrodes (reference electrode, counter electrode and working electrode) into solution including reactors or monomers.

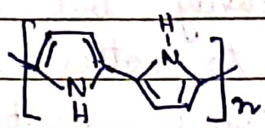
Examples of conducting polymers

--- $CH = CH - CH = CH - CH = CH$ ... ~ Polyacetylene

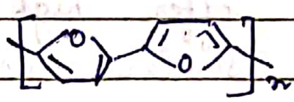


Polyaniline (PANI)

Polythiophene



polypyrrole



polyfuran

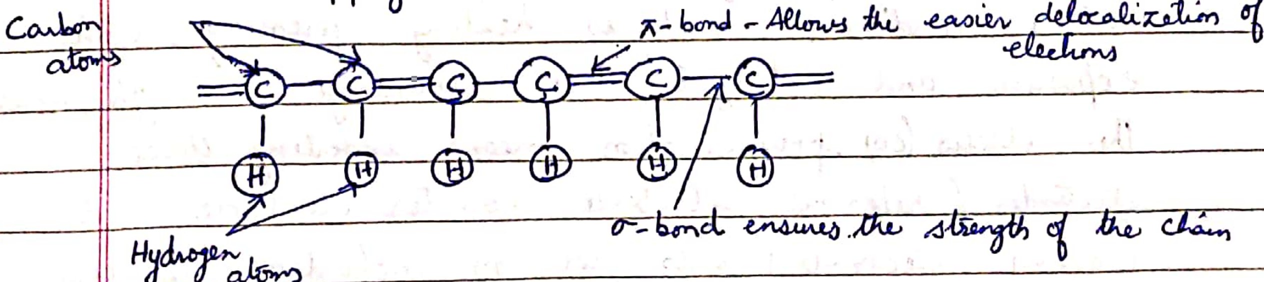
Classification of conducting polymers

1. Intrinsically conducting polymers
   a. conducting polymers having conjugated π-electrons in the backbone
   b. doped conducting polymers

2. Extrinsically coducting polymers
   a. conductive element filled polymers
   b. blended conducting polymers

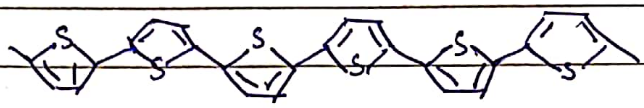
Intrinsically Conducting polymers:

a. Conducting polymer having conjugated π-electrons in the backbone are conducting in nature because the π-electrons are overlapping over the entire backbone.



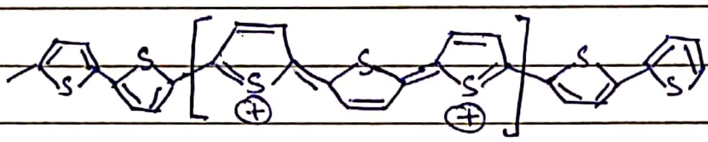
b) Doped conducting polymers : It is of two types

i) p- doping (oxidative doping) : It is done by oxidation process (i.e. removal of electrons from the polymer pi-backbone). This formation is known as polaron



Polythiophene

⇅ Doping



Polymer + Lewis acid → p- Doped polymer (oxidative coupling)

ii) N- doping : It is done by reduction process (i.e addition of an e^- to polymer)

It forms polaron and bipolaron in two steps : This is followed by recombination of radicals yields two negative charge carriers on each chain of polyacetylene. The doping with Lewis base causes N-type doping

Polymer + Lewis Base → n- Doped polymer (reductive coupling)

Extrinsically Conducting Polymers

a) Conductive element filled polymers : In this, the polymers act as a binder to hold the conducting element (such as carbon black, metallic fibres, metallic oxides etc.) together in the solid entity.

Carbon black is very used as filler which has very high surface area ($1000\ m^2/gm$) more porosity and more of filamentous properties. It bears good conductive properties and low in cost, light in weight, as well as durable

b) Blended conducting polymers: It is obtained by blending a conventional polymer with a conducting polymer. They have better physical, chemical, electrical and mechanical properties. e.g. polypyrrole with a carbon-black filled compound are used in electromagnetic shielding.

Electrical conductivity of some important polymers is as

Polymer	Electrical conductivity ($ohm^{-1} m^{-1}$)
Nylon 6,6	$10^{-12} - 10^{-13}$
Polyethylene	$10^{-15} - 10^{-17}$
Polystyrene	$< 10^{-14}$
Phenol formaldehyde	$10^{-9} - 10^{-10}$

Applications of Conducting polymers

Baytron PEDOT/PSS (Baytron P) 3,4-polyethylenedioxythiophene-polystyrenesulphonate: Polythiophene is marketed under the trade name Baytron. It is used in electrodes, high performances tantalum capacitors, computers and automobile products.