



# ENGINEERING CHEMISTRY

---

Department of Science and Humanities



# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---



### *Class content:*

- *Conducting polymers*
  - *Introduction*
  - *Types of doping*
  - *Applications*

# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---

### Conducting polymers

- Polymers are **generally insulators** because the organic molecules of which they are composed have **no free electrons** to carry current
- An organic polymer with **highly delocalized pi-electron system**, having electrical conductance of the order of an electrical conductor is called a conducting polymer
- Also known as **synthetic metals**

# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---



### Development :

- **1977** - Heeger, Macdiarmid & Shirakawa demonstrated conductivity of polyacetylene can be increased 13 times by doping with electron acceptors and donors
- Norman et. al - achieved conductance of polyacetylene equal to copper
- Doping with less than 10% of chemical species results in dramatic changes in electrical, electronic, magnetic and optical properties of polymers – hence it is a new class of polymers
- **2000** - Heeger, Macdiarmid & Shirakawa won the Nobel prize for Chemistry

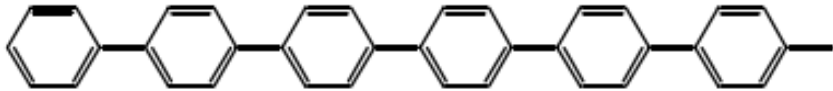
# ENGINEERING CHEMISTRY

## Functional materials-Polymers

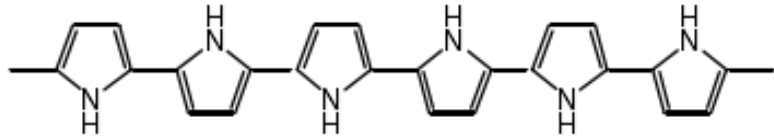
### Examples of polymers which conduct after doping



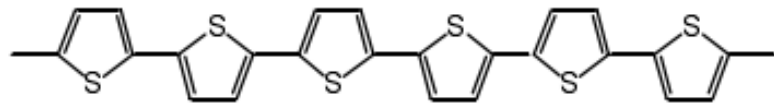
Polyacetylene



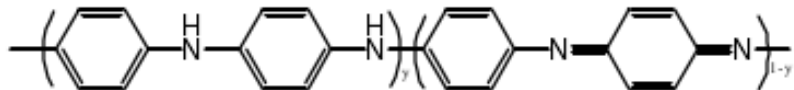
Polyphenylene



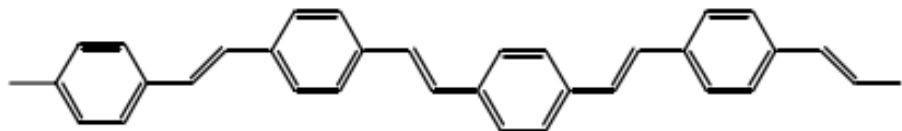
Polypyrrole



Polythiophene



Polyaniline



Poly(phenylene  
-vinylene)

Source: [https://www.researchgate.net/figure/3Molecular-structure-of-some-typical-conducting-polymers\\_fig2\\_304023062](https://www.researchgate.net/figure/3Molecular-structure-of-some-typical-conducting-polymers_fig2_304023062)

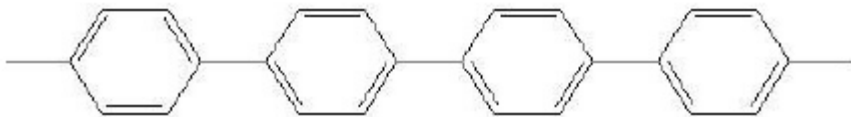
# ENGINEERING CHEMISTRY

## Functional materials-Polymers

- Conducting polymers conduct electricity due to **delocalization of  $\pi$  electrons**
- An organic polymer can be converted into conducting polymer if it has :
  - **linear structure**
  - **extensive conjugation in its polymeric back bone**



**POLYACETYLENE**



**POLYPHENYLENE**

Source: [https://www.researchgate.net/figure/Some-Examples-for-Conducting-Polymers\\_fig4\\_269993677](https://www.researchgate.net/figure/Some-Examples-for-Conducting-Polymers_fig4_269993677)

# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---

- These materials in **pure form** are not conductors but on **doping** (Introduction of charged chemical species) conduction increases

Types of Doping
Oxidative doping
Reductive doping
Proton doping

# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---

### Oxidative doping (p-doping)

- In this process, pi-backbone of a polymer is partially oxidized using a **suitable oxidizing agent**
- This creates **positively charged sites** on the polymer backbone which are the current carriers for conduction
- The oxidizing agents used are **Iodine in  $\text{CCl}_4$ ,  $\text{HBF}_4$**  etc.



# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---

### Reductive doping (n-doping) :

- In this process, pi-backbone of a polymer is partially reduced using a **suitable reducing agent**
- This creates **negatively charged sites** on the polymer backbone which are the current carriers for conduction
- The reducing agent used is **sodium naphthalide in THF**

# ENGINEERING CHEMISTRY

## Functional materials-Polymers

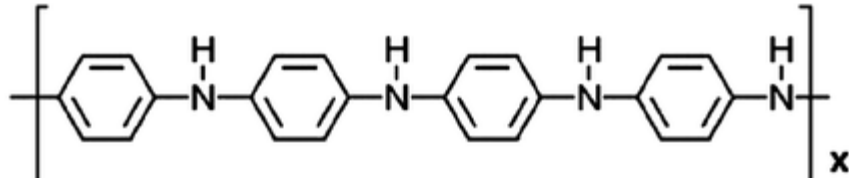
---

### Protonic acid doping :

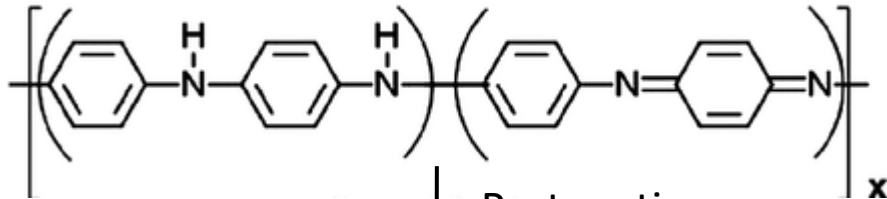
- In this technique, current carrying charged species (+ve and –ve) are created by using a **protonic acid** as dopant
- **Doping of polyaniline** is a typical example of this type of doping
- In polyaniline, current carrying charged species (+ve and –ve) are created by **protonation of imine nitrogen**

# ENGINEERING CHEMISTRY

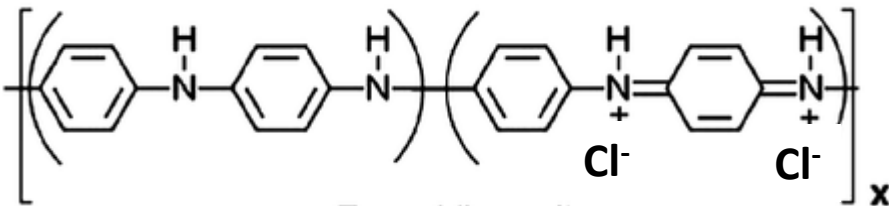
## Functional materials-Polymers



Partial oxidation  
 $\text{NH}_4\text{S}_2\text{O}_8$



Protonation  
 $\text{HCl (1M)}$



Source: <https://www.indiamart.com/prodetail/polyaniline-pani-semi-flexible-rod-polymer-leucoemeraldine-emeraldine-21303398497.html>

# ENGINEERING CHEMISTRY

## Functional materials-Polymers

---

### Applications :

- As electrode material for commercial rechargeable batteries, for higher power to weight ratio
- As conductive tracks on printed circuit boards
- As sensors-humidity sensor, gas sensor, radiation sensor, biosensor
- In electrochromic display windows
- In light emitting diodes



# THANK YOU

---

Department of Science and Humanities

