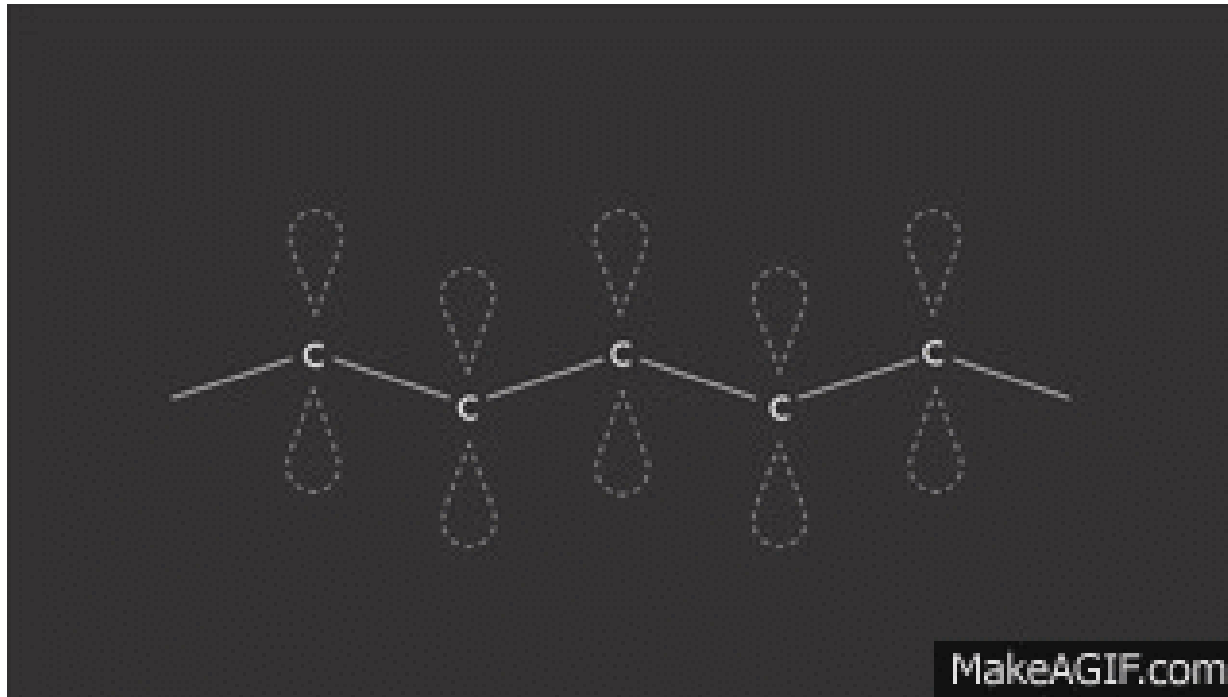


# Conducting Polymers

## Conducting Molecules



**Electrical conduction** is the movement of electrically charged particles through a transmission medium

# Electrical Conduction

- Electrical conduction of a material can be calculated by

$$\mathbf{J} = \sigma \mathbf{E} \rightarrow \mathbf{E} = \rho \mathbf{J}$$

$$R = \rho \frac{l}{a}; \sigma = \frac{1}{\rho}$$

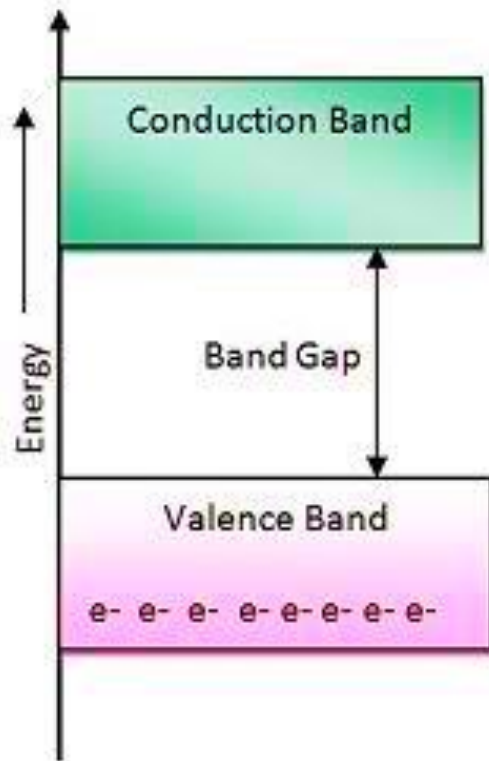
$$\sigma = ne\mu$$

$n$  – Charge carrier concentration

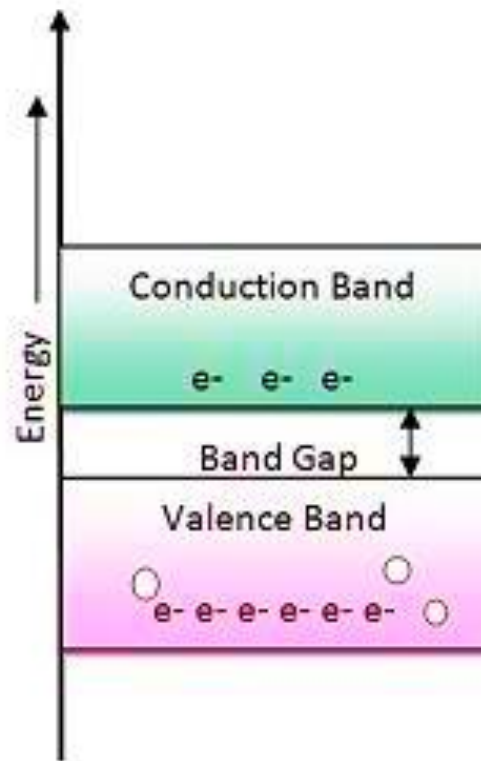
$\mu$  – charge carrier mobility

$e$  – charge of the carrier

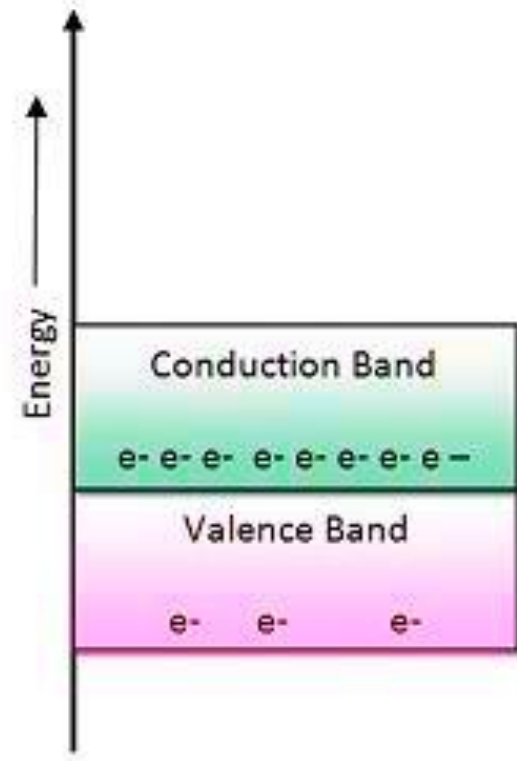
# Classification of materials based on conductivity



Insulators



Semiconductors



Conductors

Polymers??

Polymers

# Application of conducting polymers

- Organic polymers are normally insulators
- It can be presumed that conducting polymers must have an unusual structure
- Polymers with conjugated  $\pi$ -electron (i.e. system have C=C conjugated bonds) backbones display unusual electronic properties

## Application

Conducting polymers are highly useful in

- **Solar cell application**
- **Gas sensors**
- **Chemical sensors**
- **Organic Light Emitting Diodes (OLEDs)**

# Conducting Polymers

**Nobel Prize in Chemistry 2000**

**“For the Discovery and Development of Conductive Polymers”**



**Alan Heeger**  
University of California  
at Santa Barbara

**Hideki Shirakawa**  
University of Tsukuba

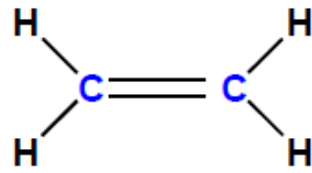


**Alan MacDiarmid**  
University of  
Pennsylvania

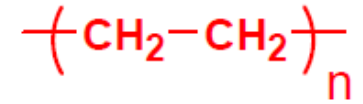
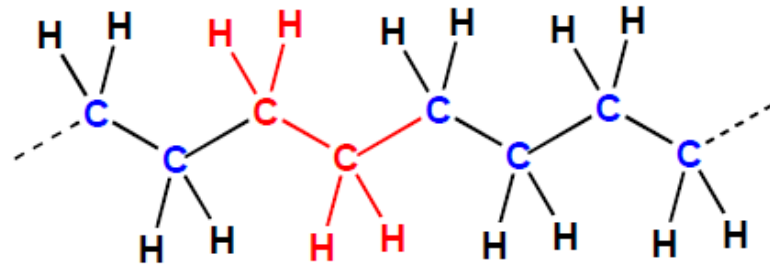
# Polymers

- Traditional plastic : Polyethylene

“Always insulator”



Ethylene



Combination of properties

Metals

High conductivity

Plastics

Lightness

Ease of processing (spin coating)

Low cost

Tailored synthesis

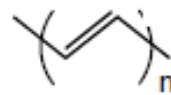
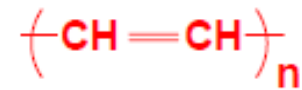
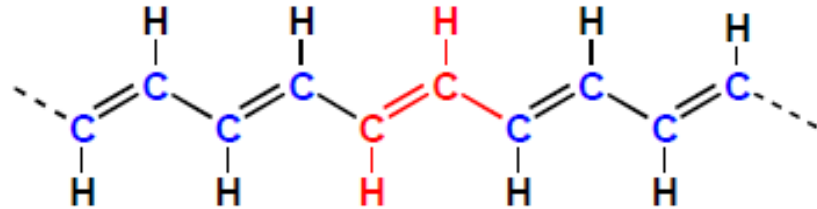
# Conducting Polymer

- The polymeric material which possess electrical conductivity are called conducting polymer
  - e.g. Polyacetylene, Polyaniline & Polypyrrole.
- **Intrinsically Conducting Polymer**
- **Doped Conducting Polymer**
- **Extrinsically Conducting Polymer**

# Conducting Polymer

- Conjugated polymer : Trans-polyacetylene

“insulator → conducting”  
HOW ?



Clue: alternate single-double bonds

c-PA :  $10^{-7} \text{ Sm}^{-1}$

t-PA :  $10^{-3} \text{ Sm}^{-1}$

Conduction → alternate single and double bond



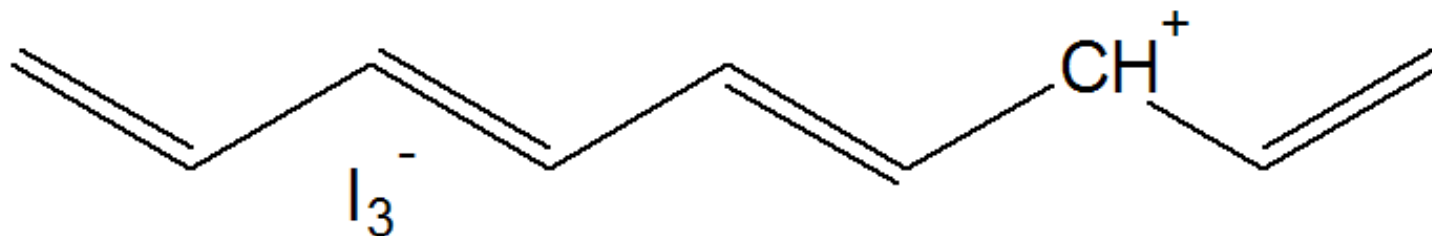
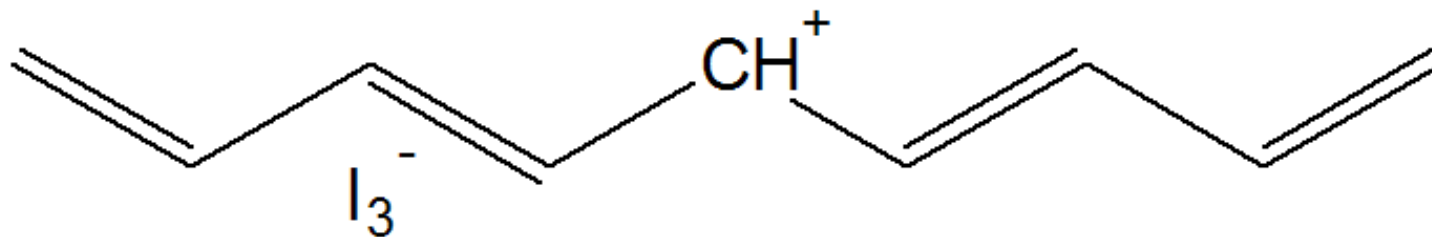
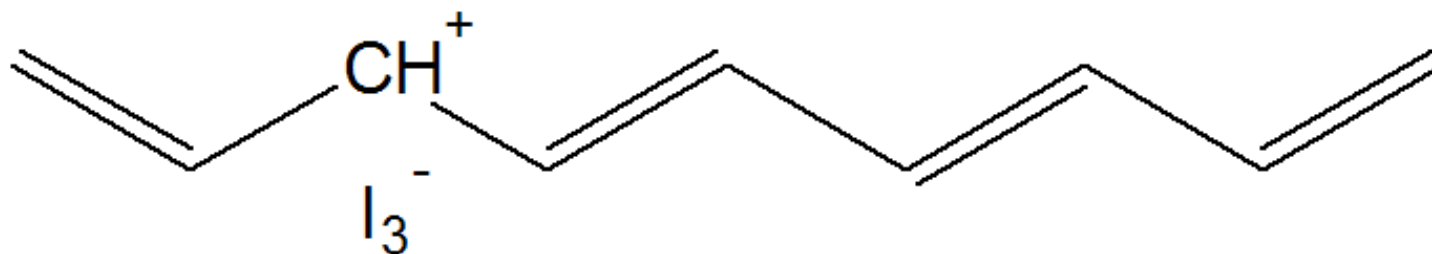
# Factors affecting the conductivity of the polymer

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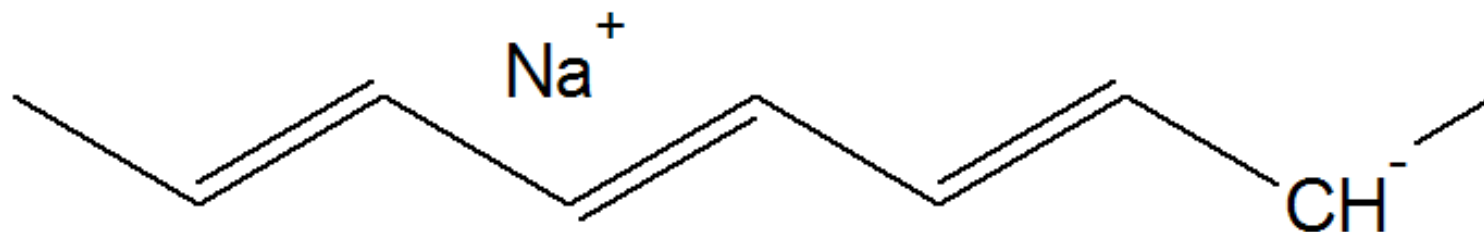
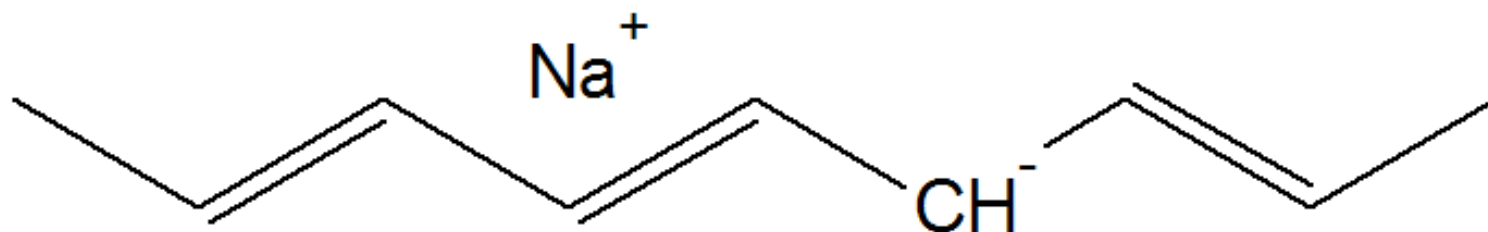
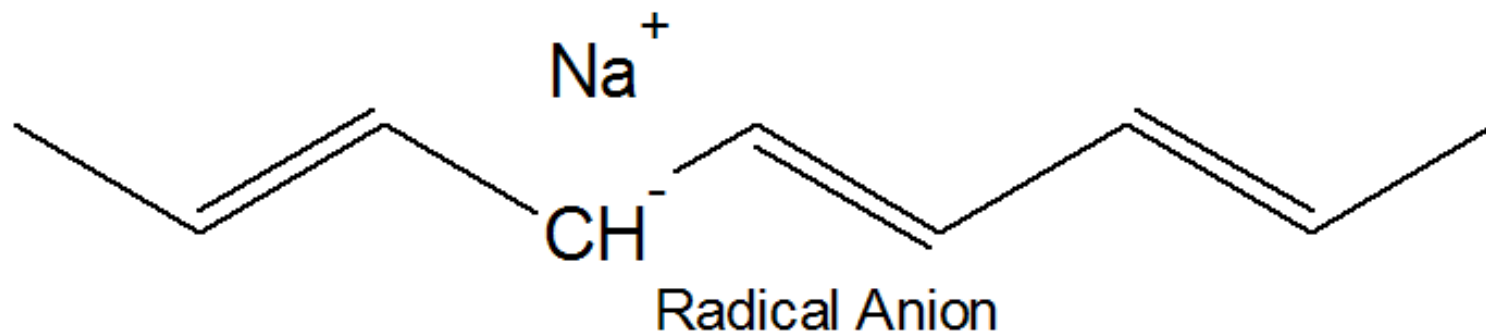
- 1) Density of charge carriers
- 2) Their mobility
- 3) The direction
- 4) Presence of doping materials  
(additives that facilitate the polymer conductivity)
- 5) Temperature

# Doping with Iodine

Radical Cation



# Doping with Na (*n* type)



# Doping in elemental semiconductor and conducting polymer

- Differences between doping in elemental semiconductor and conducting polymer
- Significant doping **levels** (until 10 mole %)
- There is a ***charge transfer*** between the incorporated dopant atom and the polymer chain  
→ the lattice is partially **oxidized or reduced**

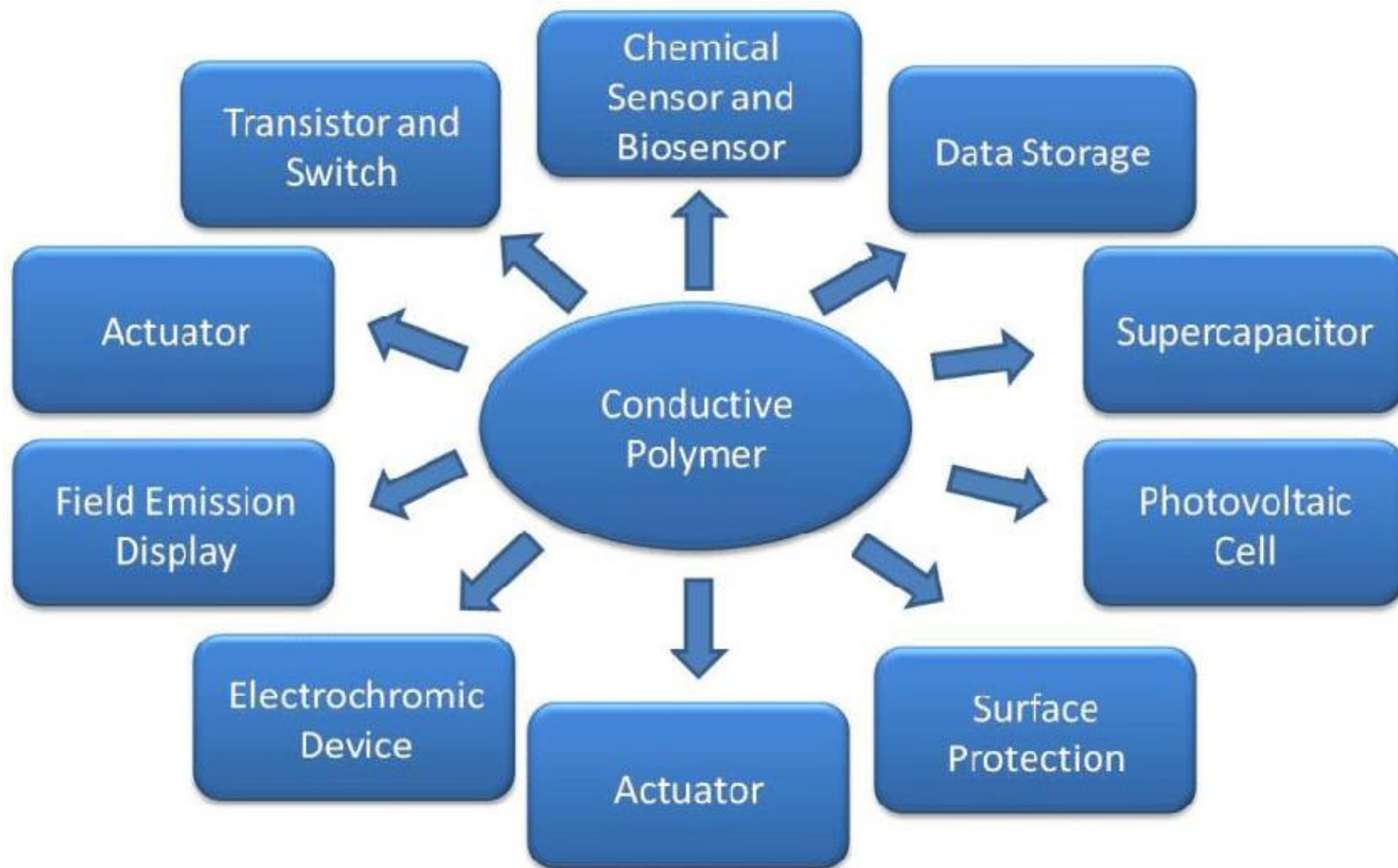
# Conducting Polymers

- Resin or polymer filled with conductive elements such as carbon black, metallic fibers, metal oxides
- Polymer acts as binder to hold the conducting elements together in the solid entity.
- These polymers possess reasonably good bulk conductivity

## Advantages:

1. Low cost
2. Light in weight, mechanically durable and strong
3. Easily processable in different forms, shapes and sizes

# Application of Conducting Polymers



# Gas Sensors based on conducting polymers

- This type of sensors can measure the change in the resistance of an electrically active sensitive material
- Compared with standard electrochemical sensors, polymer-based sensors do not require liquid electrolyte to work properly.

