Conducting Polymers







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Conducting polymers

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OUTLINE

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Introduction

Polymers (or plastics as they are also called) are known to have good insulating properties.



Polymers are one of the most used materials in the modern world. Their uses and application range from containers to clothing.
 They are used to coat metal wires to prevent electric shocks.



Yet Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa have changed this view with their discovery that a polymer, polyacetylene, can be made conductive almost like a metal.



Alan G. MacDiarmid Professor at the University of Pennsylvania, Philadelphia. USA. Hideki Shirakawa Professor Emeritus, University of Tsukuba, Japan.

Alan J. Heeger Professor at the University of California at Santa Barbara. USA.

What is conductivity?

Conductivity can be defined simply by Ohms Law. V= IR

Where R is the <u>resistance</u>, I the current and V the <u>voltage</u> present in the material. The conductivity depends on the number of charge carriers (number of electrons) in the material and their mobility. In a metal it is assumed that all the outer electrons are free to carry charge and the impedance to flow of charge is mainly due to the electrons "bumping" in to each other.



An external influence repels a nearby electron

The electron's neighbors find it repulsive. If it moves toward them, they move away, creating a chain of interactions which propagates through the material at the speed of light.

Insulators however have tightly bound electrons so that nearly no electron flow occurs so they offer high resistance to charge flow. So for conductance free electrons are needed.

What makes the material conductive?

Three simple carbon compounds are diamond, graphite and polyacetylene. They may be regarded as three- two- and one-dimensional forms of carbon materials .



670 pm



Diamond lattice

Diamond, which contains only σ bonds, is an insulator and its high symmetry gives it isotropic properties. Graphite and acetylene both have mobile π electrons and are, when doped, highly anisotropic metallic conductors.

How can plastic become conductive?

Plastics are *polymers*, molecules that form long chains, repeating themselves. In becoming electrically conductive, a polymer has to imitate a metal, that is, its electrons need to be free to move and not bound to the atoms. *Polyacetylene* is the simplest possible conjugated polymer. It is obtained by polymerisation of acetylene, shown in the figure.





Two conditions to become conductive:

1-The first condition for this is that the polymer consists of alternating single and double bonds, called conjugated double bonds.

In conjugation, the bonds between the carbon atoms are alternately single and double. Every bond contains a localised "sigma" (σ) bond which forms a strong chemical bond. In addition, every double bond also contains a less strongly localised "pi" (π) bond which is weaker.





2-The second condition is that the plastic has to be disturbed either by removing electrons from (oxidation), or inserting them into (reduction), the material. The process is known as **Doping.**

There are two types of doping:

1-oxidation with halogen (or *p*-doping).

$$(CH_n) + \frac{3x}{2}I \rightarrow (CH_n)^+ + I_3^-$$

2- Reduction with alkali metal (called *n*-doping).

$$(CH_n) + xNa \rightarrow (CH_n)^{x-} + xNa^+$$





The game offers a simple model of a doped polymer. The pieces cannot move unless there is at least one empty "hole". In the polymer each piece is an electron that jumps to a hole vacated by another one. This creates a movement along the molecule - an electric current.



Doping process

The halogen doping transforms polyacetylene to a good conductor.



Oxidation with iodine causes the electrons to be jerked out of the polymer, leaving "holes" in the form of positive charges that can move along the chain.



The iodine molecule attracts an electron from the polyacetylene chain and becomes I₃. The polyacetylene molecule, now positively charged, is termed a radical cation, or *polaron*.

- The lonely electron of the double bond, from which an electron was removed, can move easily. As a consequence, the double bond successively moves along the molecule.
- The positive charge, on the other hand, is fixed by electrostatic attraction to the iodide ion, which does not move so readily.

DOPING - FOR BETTER MOLECULE PERFORMANCE

Doped polyacetylene is, e.g., comparable to good conductors such as copper and silver, whereas in its original form it is a semiconductor.



Conductivity of conductive polymers compared to those of other materials, from quartz (insulator) to copper (conductor). Polymers may also have conductivities corresponding to those of semiconductors.



Factors that affect the conductivity

- 1-Denesity of charge carriers.
- 2- Thier mobility.
- 3-The direction.
- 4-presence of doping materials
 (additives that facilitate the polymer
 conductivity)
- 5-Temperature.





The conductivity of conductive polymers decreases with falling temperature in contrast to the conductivities of typical metals, e.g. silver, which increase with falling temperature.



Applications

- Conducting polymers have many uses. The most documented are as follows:
- anti-static substances for photographic film
- Corrosion Inhibitors
- Compact Capacitors
- Anti Static Coating
- Electromagnetic shielding for computers "Smart Windows"
- A second generation of conducting polymers have been developed these have industrial uses like:
- Transistors
- Light Emitting Diodes (LEDs)
- Lasers used in flat televisions
- Solar cells
- Displays in mobile telephones and mini-format television screens











Solar cell

Photographic Film

against electromagnetic

"smart" windows

radiation





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smart" windows

Conclusion

- For conductance free electrons are needed.
- Conjugated polymers are semiconductor materials while doped polymers are conductors.
- The conductivity of conductive polymers decreases with falling temperature in contrast to the conductivities of typical metals, e.g. silver, which increase with falling temperature.
- Today conductive plastics are being developed for many uses.





