

# CONDUCTING POLYMERS AND THE EVOLVING ELECTRONICS TECHNOLOGY

Bashir A. Syed, Sr. Engineer, SAIC/SR&QA at NASA/JSC, Houston, TX

**INTRODUCTION.** Polymers are generally known as insulators. In 1981, the U.S. produced more than 24 million metric tons of polymers, more than the volume of steel. Polymers are simply very large molecules (macromolecules) that are made up of smaller molecules (monomers) that can be linked together in various ways, resulting in a range of what we call microstructures (e.g. linear chains, branched chains, densely interconnected networks etc.). Plastics that conduct electricity have been around since 1970's, but their electronic properties, and widespread use, have been limited by structural disorder. Polymers are a shiny material derived from acetylene, whose electrical conductivity surpassed those of conductors. The oxidation of Polyacetylene with Iodine, using Ziegler-Natta-catalyst yielded this material. H. Shirakawa, A.G. MacDiarmid, and A. J. Heeger shared the 2000 Nobel Prize for Chemistry, for the discovery of Conducting Polymers. This new technology is being used in anti-static and anti-corrosive materials, electronic integrated circuits, photonics, displays, lasers, sensors, photovoltaics, actuators, and electromagnetic shielding. Compared to silicon technology, polymers are not only flexible, but cost less to manufacture.

The most promising materials are conjugated organic polymers, which are molecules with a "back bone" of alternating double and single bonds, along which electrons can flow. The simplest of these polymers is polyacetylene. The mechanical flexibility and tunable optical properties of some conducting polymers make them attractive materials for new optical and electronic devices, such as light emitting displays and biomolecular sensors. The properties of polymers used in emerging technology are: conductance, hydrophilic/hydrophobic state of the surface, color, volume, and permeability for gases/ions. Altering the specific chemical structure of intrinsically conducting polymers, (i.e. doping through oxidation or reduction processes) can vary conductivity.

Conducting polymers or synthetic metal oxidation introduces positive (+) charge carriers in the material and negative (-) ions in between these chains. Reduction produces the opposite effect. Intrinsically, conducting polymers were first discovered in 1977, as reported by C. K. Chiang et al. in *Phys. Rev. Lett.* **39**, p. 1098 (1977). Since that time many more were discovered, but they could not be processed, nor were they air-stable. Now, we know of several conducting polymers that are air-stable and can be processed.

There are four types of semi-conducting polymers: (1) filled polymers with carbon black, graphite and metal particles, (2) ionically conducting polymers, (3) charge transfer polymers, and (4) conjugated conducting polymers.

- I. Filled polymers are polymers loaded with conductive fillers such as carbon black, graphite fiber, metal particles or metal oxide particles.
- II. Ionically conducting polymers are also called ionomers or polymer electrolytes. They have a wide range of commercial electronic applications, including rechargeable batteries, fuel cells and polymer light-emitting devices.
- III. Charge transfer polymers have become the most established semi-conducting organic systems because of their commercial use in xerographic photocopiers. Most charge transfer polymers, including trinitrofluorenone doped poly(vinyl carbazole or PVK), triarylamine doped polycarbonate, and polysilanes are p-type materials. Although n-type materials have been reported, the electron mobility in such polymers is about three orders of magnitude lower than p-type materials.
- IV. Conducting conjugated and charge transport polymers are the two important classes in semi-conducting organics. In conjugated polymers, polyaniline and modified polyaniline are being used as conductive fillers to give conducting filled polymers. Conducting polymers have bright light, they are cheap, flexible, easy to manufacture, and are sometimes better conductors.

The process of doping and de-doping is reversible. Due to this process, the intrinsically conducting polymers can easily be switched. They can go from the conducting to insulating state, from a permeable to non-permeable state, and range from red to blue in color [e.g. polyaniline (PAn) and poly (3-n-hexylthiophene)]. Polyaniline exists in a variety of oxidation and protonation forms. The various reaction conditions can lead to products with widely varying chemical, macromolecular and supramolecular structures.

### **APPLICATIONS:**

The new devices made of conducting polymers are going to be used in every phase of life on earth, as well as in space. Compared to other existing technologies, conducting polymers are lightweight, take up less space, and are less expensive to manufacture. They are also flexible, and in many cases unbreakable. These characteristics make them excellent for use in space vehicles, for human or robotic exploration and satellites. For example, the flexible and lightweight nature of these devices would be suitable to introduce built-in computers in space suits, with associated sensors to monitor the health of astronauts while they perform extra-vehicular activities. These devices could also be beneficial for tele-medicine in space due to their flexible nature that can follow the contours of the body. Conducting Polymer actuators are also being explored to be used in micro-robots, for un-manned space missions utilizing micro-satellites. To further qualify these devices for use in the harsh environment of space, more testing is needed to determine reliability, with regard to ionizing radiation, Solar UV, and extreme temperatures.

Currently, the benefits of these new devices are being used in a variety of parts in Commercial-Off-the-Shelf (COTS) equipment. Below is a list of some of the applications.

- Photonics (organic light emitting diodes, lap-top and TV displays, photo-diodes, and image sensors).
- Energy related equipment (fuel cells, flexible solar cells, improved energy density storage batteries, and super capacitors, etc.).
- Sensors (flow injection, electric field, pressure, voltage, light, stress, temperature, humidity, gas, odor and hazardous chemicals).
- Materials (gels, thermoplastics, composites).
- Electronic devices and integrated circuits (silicon hybrid thin film transistor, FETs, nano-FETs, electro-chromic devices, high current switches, and flexible printed circuit boards).
- Computing and information technology (storage, neural networks, optical signal processing, etc.).
- Medical Field (flexible vital sign and toxin sensors).
- Flexible light sources, as well as display devices.
- Lasers and electro-optics (electrically driven lasers and laser arrays, etc.).