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Exploring Recent Applications Of Conducting Polymers

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ABSTRACT

Conductive polymers have been defined by scientists as materials with unusually mixed properties of plastics and metal. Researchers have explored them for a wide variety of uses due to their multifunctional properties, such as easy synthesis, good environmental stability, and useful optical, electrical, and mechanical properties. Since its discovery in 1977, conducting polymers (CPs) have garnered a growing amount of attention as an interesting new class of electronic materials. In comparison to non-conducting polymers, they provide a number of benefits, especially in the areas of electronics and optics. They have also found application in electronic device manufacturing, solar energy conversion, rechargeable battery technology, and sensor technology. In this survey, we will look at the various uses for conducting polymers.

Keywords: Conducting polymers, Applications, Sensors, Electronic, Polyacetylene.

I. INTRODUCTION

Researchers have been hard at work developing new uses for conducting polymers ever since they were discovered in the late 1970s. Some of these uses include thin film transistors, polymer light emitting diodes (LEDs), corrosion resistance, electromagnetic shielding, sensor technology, molecular electronics, supercapacitors, and electrochromic devices. Multifunctional molecular structures that can be used for practically any purpose may be constructed by carefully selecting the component combinations.

Electric current may be conducted through conductive polymers, which are organic polymers. They may or may not be metallically conductive, and they may or may not also be semiconductors. Their capacity to be processed, especially by dispersion, is their main advantage. The inherent qualities of conductive polymers have led to their widespread use in modern technology. These polymers are created using redox and chemical or electrochemical oxidation processes, and include polythiophene, polyindole, polyacetylene, polypyrrole, polyphenylvinylene, polyaniline, etc. Most conductive polymers cannot be formed by heating and cooling like regular thermoplastics. However, these substances are organic and include insulating polymers. While conductive polymers have excellent electrical conductivity, they lack the mechanical properties of more common polymers. Through the use of cutting-edge dispersion and organic synthesis methods, the electrical properties may be altered.

Not only do conductive polymers carry electricity, but they are also elastic, optically active, and simple to create. Because of these characteristics, conductive polymers have a wide range of potential uses in the biomedical and industrial sectors. According to previous studies on conductive polymers, the conductivity of polymers like polyacetylene may be improved by a factor of millions by oxidation by doping with iodine vapour. Numerous studies have found that polymers' conductivity may be improved by doping. Therefore, the molecular arrangement of conductive polymers allows electrical charges to flow across them. Conductive polymers are able to transport charges because their molecular architectures include both double and single chemical bonds.

There are two distinct meanings associated with the word "conductive polymer." Polymers including conductive elements like carbon black, metal flakes or threads, etc. fall within the first and most well-known category (I). The polymer matrix's primary useful role is as the "glue" that keeps the conducting components together as one solid object. The polymer component is appealing because it is inexpensive, lightweight, mechanically durable, and easily process able, and the material as a whole has reasonable bulk conductivity. The second definition is applicable to polymers whose backbones generate and carry charges (Category II). Potential benefits include tunable conductivity by manipulation of oxidation/reduction levels, control over the composition of the predominant carrier population, and the ability to switch between conducting and insulating states with ease. In this essay, we shall discuss the Category II conductive polymers in depth. These conductive polymers have the potential to provide desirable benefits over Category I materials; nevertheless, significant challenges, including poor process ability, poor mechanical characteristics, and (most troublesome of all) environmental instability, must be overcome before they can be used widely.

II. ELECTROCHEMICAL FEATURES OF THE CONDUCTING POLYMERS

A high electrical conductivity was first seen in the organic polymer polyacetylene when it was doped with iodine in 1977. Since then, scientists curious about conducting polymers have studied their unique electrical properties. These materials have advantages over conventional organic polymers, such as increased electron affinity, electrical conductivity, and redox activities. The p-electron backbone in these materials regulates unusual electronic properties including strong electron affinity, low ionisation potential, and low optical transition energy. In addition, the extended pconjugated system of the conducting polymer has single and double bonds that alternate throughout the polymer chain.

Because of their wide conductivity range—approximately 15 orders of magnitude—and the fact that many of them have different conduction processes in different regimes, polymers of this kind are notoriously difficult to understand. The electrical conductivity of conducting polymers has been proven to be improved by several orders of magnitude. Electrochemical doping of CPs is also possible, with oxidation leading to a p-doped state and reduction producing an n-doped one. The conductivity of CPs may be regulated by redox processes. Features, shape, thickness, and conductivity of the polymer might be addressed by electrochemical preparation methods. The electrical phenomena in these systems have been variously referred to as soliton, polaron, and bipolar by researchers. Several factors, including conjugation length, polaron length, overall chain length, and charge transfer to nearby molecules, influence the conductivity of conducting polymers. Several ideas based on hopping between different types of solitons, hopping between localised states helped by lattice vibrations, hopping within the chain of bi-polarons at three different ranges, and hopping across conducting domains all provide plausible explanations for these situations.

Functionalizing CPs and monomers with unique materials allows for the customization of their properties. Therefore, the performance and physicochemical qualities of the main polymer chain, such as the enhanced mechanical and electrical characteristics, are improved by the addition of the substituents. Preparing the CPs composite from the highly conductive nanomaterials, in addition to the catalysts, can help improve the CPs' characteristics.

III. SYNTHESIS OF CONDUCTING POLYMERS

The simplest models are polyacetylene and polyphenylene, which may be thought of as a series of vinylene or phenylene units, respectively. It is the responsibility of those involved in the synthesis of conjugated organic polymers to provide as many well-characterized materials as possible so that their electrical properties can be thoroughly investigated. However, even these very simple systems can be put together in quite a variety of ways to create a number of structurally different materials. Some of the most common protocols for synthesising conducting polymers are discussed here.

Figure 1 depicts the two basic paths that can be taken while attempting a synthesis. The first is the direct method, while the second is known as the indirect approach. In the direct way, a suitable monomer is directly transformed into a conjugated polymer by an addition or condensation process, resembling the conventional approach to polymer synthesis.

Some of the structurally simplest conjugated polymers, such as polyacetylene and poly-para-phenylene, are basically insoluble and intractable materials, and this discovery introduces various practical issues, which is one of the downsides of the direct method. The indirect approach allows for more creative control over the synthesis process. Thus, addition or condensation polymerization processes can be used to create the precursor polymers, while a wide range of reactions can be used to complete the second step.

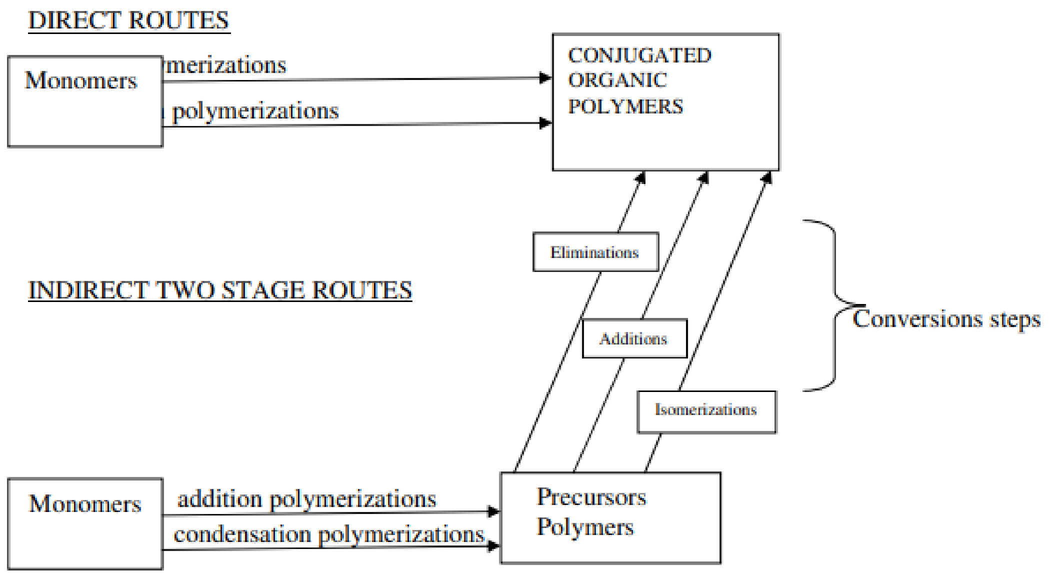

Figure 1: Outline of possible routes to conjugated organic polymers

IV. APPLICATIONS OF CONDUCTIVE POLYMERS

All facets of terrestrial and extraterrestrial life will benefit from the new technologies built using conducting polymers. Conducting polymers are less expensive to produce, more portable, and take up less room than competing technologies. They may bend and stretch and are often rather tough to crack. Thanks to these qualities, they are ideal for use in satellites and spacecraft designed for human or robotic exploration of the cosmos. Because of their portability and durability, these gadgets might be integrated inside astronauts' spacesuits, complete with sensors to track their vitals during spacewalks. The adaptability of these gadgets means they might be useful for tele-medical applications in outer space, such as scanning the body's contours. Micro-robots powered by conducting polymer actuators are being researched for application in unmanned space missions by means of micro-satellites. More testing is required to ensure dependability, especially with regards to ionising radiation, solar UV, and severe temperatures, before these devices may be qualified for use in the harsh environment of space. It is anticipated that conducting polymers will find applications in molecular electronics, as well as in lightweight and rechargeable batteries, solid state batteries, and light emitting diodes.

Electron beam lithography uses conductive polymers as discharge layers and conducting resists; printed circuit board technology uses them to plate through-holes; they protect electronic equipment from electrostatic discharge; they protect metals from corrosion; and they may even be used to shield against electromagnetic interference. Lightweight, which is of paramount relevance in aircraft applications, corrosion resistance, simplicity of processing, and variable conductivities make intrinsically conducting polymers like PANI and PPY the most promising alternative choices for EMI shielding.

Conducting polymers have chemical features that make them excellent sensor materials. The high degree of design freedom offered by conducting polymers (CPs) has led to their widespread application in gas sensors. When the analyte gas interacts with the conducting matrix, a main change in a physical parameter in the transduction mechanism is generated, and the resulting selected layers may be extracted.

In theory, conductive polymers might be used as antistatic components. Industrially made batteries and other electrical gadgets now include them. Numerous studies have shown that conductive polymers can be used as an alternative to the commonly used translucent conductor indium tin oxide and as a material for light-emitting diodes, supercapacitors, solar cells, biosensors, chemical sensors and actuators, electromagnetic shielding, and flexible translucent displays.

They are currently also quickly garnering interest because of the increased processability of material with enhanced physical and electrical qualities and decreased prices. Scientific studies have shown that the capacitance of nanostructured conductive polymers in the form of nanofibres is significantly higher than that of regular, nonnanostructured conductive polymers. Optoelectronics, the medical field, and even energy storage devices have all found uses for conductive polymers in the form of flexible conductors.

Because polyaniline and poly(3,4- ethylenedioxythiophene) are so easy to make and maintain, they have found use in a variety of different fields. When making a printed circuit board, polyaniline is commonly employed because its final result prevents copper corrosion. In contrast, poly(3,4-ethylenedioxythiophene) is typically used as an antistatic material and as a transparent conducting layer. Polyindole's superior reduction-oxidation activities, thermal stability, and degradation properties make it a promising alternative to polypyrrole and polyaniline in a variety of contexts.

Table 1: Characteristics and Applications of Some Conjugated Conductive Polymer Composites

S. No.	Conductive polymer composite	Potential application
1	Polypyrrole/chitosan	Foodstuff packaging and biomedical applications
2	Polypyrrole/poly(D,L-lactic acid)	Artificial nerve conduits
3	Polypyrrole nanoparticles/polyurethane	Tissue engineering

4	Polythiophene derivative/ polyurethane	Tissue engineering
5	Polypyrrole/hyaluronic acid	Wound-curing purposes and tissue engineering
6	Polyanilinenanofibres/collagen	Biomedical applications: scaffold material
7	Poly(3,4ethylenedioxythiophene):polystyrene sulfonic acid/ polyurethane/ ionic liquid	Actuating devices
8	Polyanilinenanofibre/bacterial cellulose	Tissue engineering, biosensors

V. CONCLUSION

Recent decades have seen a rise in interest in conducting polymer nanostructures from both the realms of basic science and their many potential practical applications. Due to their novel characteristics at the nanoscale and their ability to significantly boost device performance, research into conducting polymer nanostructures has flourished during the past decade. Scientists have been looking at various chemical modification techniques since conductive polymers have drawbacks including low mechanical properties or flexibility, limited process-ability, and poor biocompatibility. Light-emitting diodes, supercapacitors, solar cells, biosensors, chemical sensors and actuators, electromagnetic shielding in tissue engineering, flexible transparent displays, and a replacement for indium tin oxide are just some of the possible applications for conductive polymers.

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