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BRIEF DISCUSSION ON THE PROPERTIES AND APPLICATIONS OF POLYPYRROLE AND POLYTHIOPHENE CONDUCTING POLYMER

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ABSTRACT

Conducting polymers are polymeric materials with metallic and semiconductor characteristics. In addition to this these polymeric materials are light in weight, flexible, and can be easily processed. This makes them suitable candidates for micro and nano scale molecular electronic devices. One of the important characteristic of conducting polymers is the presence of conjugated double bonds along the polymer chain. In2000 the Noble prize in chemistry was awarded to three prominent scientists Alan G.Mac Diarmid, Alan J. Heeger and Hideki Shirakawa for the discovery and development of conducting polymers. Among various conducting polymers polypyrrole (PPY) and polythiophene (PTP) are the most promising materials for multifunctionalized applications. Further they are easy to synthesise and with lower cost. These polymers have wide range of applications ranging from containers to clothing. Various applications of conducting polymers include rechargeable batteries, electronic displays, solar cells, molecular electronics, field-effect-transistors, chemical sensors, drug release systems, catalysts , biosensors, and so on. Although conducting polymers have several interesting applications however, there are some of the factors which hinder some of their applications. This issue can be overcome by the formation of composites and nanocomposites with specific dopants. The composites attain either new or improved chemical properties that can be exploited for various applications.

Keywords: Conducting polymers, Polypyrrole, Polythiophene, Chemical synthesis, electrochemical synthesis, composites.

I. INTRODUCTION

Polymers have attracted the scientific and technical interest owing to their unique properties. Promising new materials with interesting electrical, optical and magnetic properties can be synthesised from polymers. A special class of organic polymers known as conducting polymers have ability to conduct electricity owing to conjugation [1]. Conducting polymers contain contagious sp^2 hybridized carbon atoms. Each sp^2 hybridized carbon atom contains one valance electron in an un-hybridized P_z orbital. The electrons residing in the un-hybridized P_z orbitals delocalise over the entire polymer backbone chain via conjugation and thus lead to a one-dimensional electronic band with energy gap greater than 2 eV. This is higher than thermal conduction to happen; as a result conjugated conducting polymers are usually insulators or semiconductors having conductivity in the range of 10^{-10}-10^{-5} Scm^{-1}. However, the conductivity in these polymers can be improved

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upon doping due to some structural changes in the polymer backbone chains. Doping leads to higher mobility of charge carriers and is usually accomplished through oxidation and reduction methods (Redox doping).

The discovery of conducting polymers dates back to 1970s, when three scientists namely, Shirakawa, Alan J Heeger and MacDiarmid witnessed significant increase in conductivity of polyacetylene, on treatment with robust oxidizing agents like I_2 vapours [2]. The disclosure alongside broad research in the field of conducting polymers prompted the honour of Noble prize to the three prominent researchers (Shirakawa, Heeger and MacDiarmid) in the year 2000. The revelation prompted a spurt in the field of research in conducting polymers like polyaniline (PANI), polypyrole (PPY), polythiophene (PTP) etc. and their derivatives [3]. Now a day a vast research is being carried out in the field of conducting polymers. Conducting polymers are viewed as potential materials for various scientific applications such as photovoltaic cells, organic light emitting diodes, electrochromic displays, electromagnetic shielding materials, gas sensors, biosensors, charge storage devices and so one [4-6].

Among various conjugated conducting polymers polypyrrole (PPY) and polythiophene (PTP) are the most interesting conducting polymers due to their excellent chemical and electrochemical stability [7 - 10]. The monomer unit of PPY and PTP are pyrrole and thiophene respectively. Both Pyrrole and thiophene are five membered heterocyclic aromatic organic compounds with the formula C_4H_4NH and C_4H_4S respectively. The structure of the monomer units of PPY and PTP is shown in Figure 1. PPY and PTP can be prepared chemically or electrochemically via oxidative polymerization of pyrrole and thiophene monomers. The schematic representation of synthesis of PPY and PTP is shown in Figure 2. The properties of these polymers depend upon fabrication conditions and preparation techniques used. PPY and PTP have unique electrical properties, significant thermal stability, and oxidation resistance [11] which makes them most promising members for wide range of applications such as optoelectronics, biosensors, electrochromic displays, chemical sensors, field-effect transistors, electroluminescent devices, solar cells, photochemical resists, non-linear optical devices, batteries, diodes, microwave absorbing materials, new type of memory devices, nano switches, optical modulators, DNA detection, transistors etc. [12].

II. COMPOSITES AND NANOCOMPOSITES OF CONDUCTING POLYMERS (PPY AND PTP):

The properties of conducting polymers can be improved through the formation of suitable composites with specific dopants. Composite materials usually consist of two or more components with different properties and the components are separated by distinct boundaries. The composites produced by combining several components achieve new properties which even the individual components cannot attain. The organic/inorganic composites of nanoscale dimensions are called as nanocomposites and are generally defined as composites in which the components have at least one dimension (i.e., length, width or thickness) in the size range of 1-100 nm. Nanocomposites are of increasing importance due to their multifunctionality, and potential applications such as conductivity amplification. Nanocomposites offer interesting properties in comparison to composites due to complex interaction of the nanostructured heterogeneous phases. The composite materials have increased much enthusiasm among researchers because of the amazing change in properties, for example mechanical,

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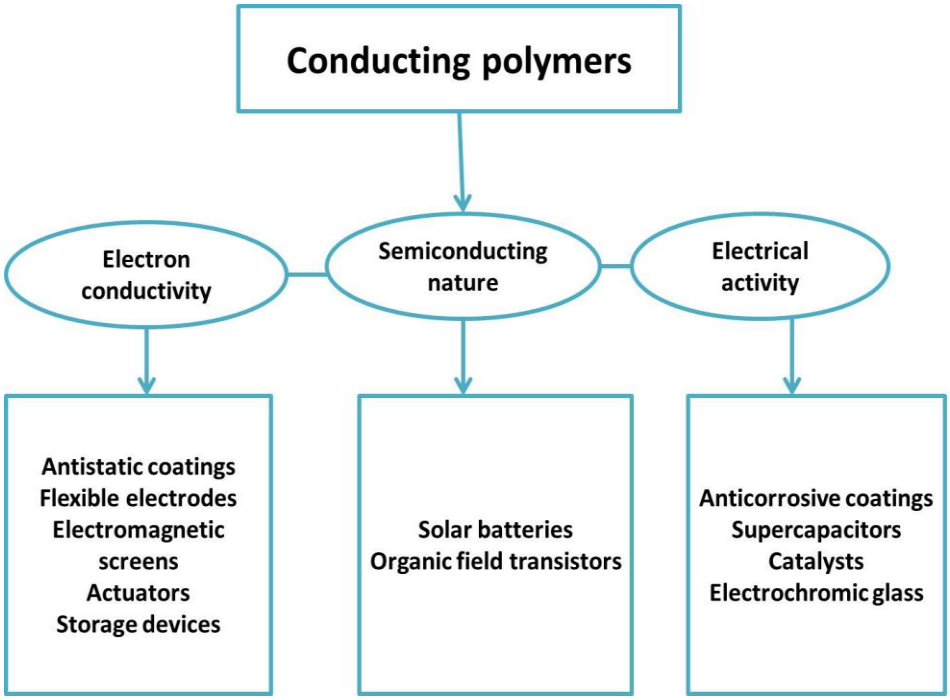
thermal, electrical and magnetic compared to pure organic polymers [13]. From literature survey it is evident that PPY and PTP have been doped with wide range of organic/inorganic dopants such as CNT's, metallic oxides, metals, inorganic moieties, and the composites have attained fascinating properties.

III. APPLICATIONS OF CONDUCTING POLYMERS:

Owing to the various advantages like low density, low cost, flexibility of design, ease of fabrication, low energy and labour requirements for fabrication and processing etc. Conducting polymers have been exploited for various applications in different fields like polymer battery electrodes, rechargeable batteries, EMI Shielding and solar cells etc.

The applications of conducting polymers can be summarised in three main groups which are based on the three main properties i.e. conductivity, electroactivity and semiconducting nature of conducting polymers. This is depicted in scheme 1.



Scheme I: Schematic representation of applications of conducting polymer

IV. CONCLUSION

In this chapter the various synthesis procedures, properties and the applications of conducting polymers in various fields has been discussed. Further the composites and nanocomposites of conducting polymers (PPY and PTP) are described.

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