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Classification and application of composite conductive polymer materials

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Abstract. In recent years, conductive polymer materials have become a hot topic in scientific research due to their wide applications. Conductive polymer materials are mainly divided into composite type and structural type. Due to the poor oxygen stability and mechanical properties in the air of the doped materials of the structural conductive polymer, its application is limited. However, the composite conductive polymer has become the most widely used conductive polymer material in the market because of its easy processing, wide application range, good corrosion resistance and the conductivity can change according to the electrochemical reversible reaction. In this paper, the composite conductive polymer materials with different doping types are reviewed, and their applications in the fields of stealth technology, battery materials, and sensors are studied. The research significance of this paper is to summarize the research progress of composite conductive polymer materials by scientists in various countries in recent years, and provide scientific and theoretical support for other researchers in this field.

Keywords: conductive polymer materials, composite, classification, application, conductivity.

1. Introduction

Conductive polymer material is a kind of polymer material with conductivity [1]. It can be a polymer material with conductive function or doped with other materials, or it can be filled with composite materials, blended with other polymer materials or doped with various conductive materials to obtain conductivity [2]. Conductive polymer materials are mainly divided into structural conductive polymer materials and composite conductive polymer materials. Structural polymer materials have not been used on a large scale due to their poor stability, processing formability and mechanical properties, and are still in the research and development stage [3]. Composite conductive polymer is the most widely used conductive polymer material in the market because of its easy preparation. Because the research on the properties and mechanism of structural conductive polymers has not reached the level of large-scale use, it is still of great practical significance to study the preparation process of composite conductive polymers to improve the conductivity [4]. After many years of development, people have conducted in-depth research on the conductive mechanism of composite conductive polymers and how to improve their conductivity, and explored their applications in many aspects.

In this paper, the development trend of metal doped composite conductive polymer materials, carbon doped composite conductive polymer materials and the application fields of composite conductive polymer materials are reviewed, and the important contributions made by scientists in

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various countries in this field are summarized. The research significance of this paper is to summarize the research progress of composite conductive polymer materials by scientists in various countries in recent years, and provide scientific and theoretical support for other researchers in this field.

2. Classification of composite conductive polymer materials

Composite conductive polymer material refers to a multi-phase composite system with conductive function obtained by adding conductive material to polymer matrix and dispersing, laminating, surface or gradient composite treatment [5]. This kind of material not only has the conductivity and electromagnetic shielding properties of conductive fillers, but also has the thermoplastic and molding properties of polymer matrix. Therefore, it has the advantages of good processability, simple process, corrosion resistance and low price. It has been widely used in electronic industry, information industry and other engineering applications. According to the different kinds of conductive materials added in the polymer matrix, it mainly include blend composite conductive polymer materials and filled composite conductive polymer materials [6].

This paper focuses on the categories of filled composite conductive polymer materials. The filling composite conductive polymer material is made by adding conductive filler to the matrix polymer. The matrix polymers mainly include polyethylene, polypropylene, polyvinyl chloride, polystyrene, ABS resin, epoxy resin, phenolic resin, acrylic resin, polyamide, polyurethane, silicone resin, etc. Conductive fillers include metal oxide based materials, metal based materials, carbon based materials, etc [7].

2.1. Metal filled conductive polymer materials

Metal filled conductive polymer is a kind of conductive material with excellent performance, which is made of electrically insulating polymer as the base material, metal powder, metal fiber, metal wire and other high conductive materials as the filling material, and after appropriate mixing and molding. Common metal filler materials include silver, gold, copper, aluminum, nickel, etc. for those metals that are easy to be oxidized, they should not be used in consideration of stability; among them, gold and silver have high conductivity and stable performance. They are widely used in electrical devices and electronic components with high reliability requirements. However, their biggest disadvantages are high price and high density; copper, aluminum and nickel all have good conductivity and low price, but their surface is easy to oxidize in the air, and their conductivity is not stable. At present, they are mainly used as conductive fillers in electromagnetic shielding materials and printed wiring lead materials [8].

2.2. Metal oxide filled conductive polymer materials

Many metal oxides have certain conductivity, high melting point, strong oxidation resistance and moderate price. They are also ideal conductive filling materials, such as tin oxide, zinc oxide, vanadium oxide and titanium oxide. The prominent feature of metal oxide is colorless or light color, but the relatively high resistivity is the main disadvantage of metal oxide additive materials.

He Xiaowei et al. [9] prepared polyvinyl alcohol/antimony doped tin dioxide (PVA/ATO) nanocomposites by solution blending. The nano ATO is well dispersed in the PVA matrix, and the composites with good electrical and mechanical properties can be obtained when the ATO content is low; When the mass fraction of ATO is 2.5~5%, the conductivity of PVA/ATO composite material suddenly jumps, and the conductivity can reach 10^{-4}s/cm.

Rajasudhag et al. [10] synthesized ZnO Nanoparticles by sol-gel method. Finally, polyindole ZnO nanocomposite polymer electrolyte was synthesized by in-situ polymerization and incorporation technology. In order to enhance the ionic conductivity of the composite, $LiClO_4$ was added to the system, and the conductivity of the electrolyte was at 50 ℃ measured by impedance spectroscopy 4.404×10^{-7}s/cm.

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2.3. Carbon filled conductive polymer materials

Carbon fillers can be mainly divided into: carbon black, graphite and carbon fiber. Carbon black is the most commonly used conductive filler in the preparation of conductive materials by dispersion composite method. It has low cost and low density, but it is black and affects the appearance color of products; graphite needs to be treated before use due to its many impurities; carbon fiber has the characteristics of high strength, high modulus, corrosion resistance and small addition [11].

The composite conductive polymer with carbon black as conductive filler is one of the most widely used conductive polymer materials with the largest amount at present [12]. Zaragoza Contreras et al. [13] used highly structured and highly concentrated conductive carbon black XC-72 as conductive filler and prepared carbon black/polystyrene conductive composite by suspension polymerization. The surface conductivity was 5×10^{-3}s/cm.

In recent years, composite conductive materials with new carbon materials as additives have also become a research hotspot. Yang Li et al. [14] used renewable bamboo as raw material, carbonized at 900 ℃ in the state of air isolation to obtain bamboo charcoal, and then used bamboo charcoal powder as conductive aggregate, carbon black as additive and phenolic resin as binder to prepare bamboo charcoal/phenolic resin composite conductive material by molding. With the increase of the content of phenolic resin, the flexural strength of the composites increased, and the electrical conductivity increased first and then decreased; Increasing the particle size of bamboo charcoal powder, increasing the amount of carbon black and increasing the curing temperature can improve the electrical conductivity of the composite, but will change the mechanical properties of the composite to varying degrees.

Graphene has attracted more and more researchers' attention because of its excellent electrical and thermal conductivity, large mechanical strength, large specific surface area and potential low manufacturing cost [15]. Yang Bo et al. [16] prepared a new composite conductive film by simple blending with graphene as conductive filler and aqueous styrene acrylic lotion as matrix. When the mass fraction of graphene is 5%, the surface resistivity of the composite conductive film can reach 0.29l Ω·cm; The conductivity of the composite conductive film can be improved by 2 orders of magnitude by adding a small amount of silver nanoparticles.

3. Application fields of composite conductive polymer materials

Conductive polymer materials not only have the processing properties of polymer materials, but also have the conductive properties of metal materials. They are widely used in many fields. The following will briefly introduce the application of conductive polymers in combination with the existing literature.

3.1. Application in stealth technology

The electromagnetic wave will form an induced current in the conductor and generate heat, thereby consuming the energy of the electromagnetic wave. However, too high conductivity will increase the emission of electromagnetic waves on the surface of the material, which is not conducive to the absorption of electromagnetic waves. Because conductive polymer materials have adjustable conductivity, reasonable adjustment of the conductivity of conductive polymer materials can play a perfect stealth effect on electromagnetic waves.

3.2. Application in battery materials

The doped structural conductive polymer has good electrical conductivity and reversible electrochemical redox characteristics. This kind of battery has the advantages of flexibility, high energy and easy processing. After the durability and stability of conductive polymer are solved, it will be the perfect material for making new batteries.

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3.3. Applications in sensors

The conductivity of conductive polymer changes obviously with the change of temperature, air environment, concentration and other factors. Common sensors such as electrochemical sensors, ion concentration sensors and temperature sensors made of conductive polymers have been used in various fields. In addition, because polymer materials have certain affinity with human body, conductive polymers as biomedical sensors are being studied in depth.

4. Conclusion

Composite conductive polymer materials have the characteristics of light weight, durability, stable conductive performance, low cost, easy processing and suitable for large-scale and mass production. They have broad application and development prospects in optoelectronic devices, energy, information industry, sensors, electromagnetic shielding, metal corrosion prevention and stealth technology, The demand for this new type of material will also be increasing, so the research, development and application of composite conductive polymer materials have a good development prospect.

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