New Technologies in Polymer Synthesis and Applications of Polymers

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Abstract. Polymers as a kind of significant materials are widely used in human life including eat, wear, live and work. Because products made from polymers are increasingly appearing in people's lives, the technology and applications associated with polymers are also advancing. This article will review the new polymer synthesis technologies of recent years and summarize the applications of polymers in biology, medicine and electricity.

Keywords: Polymer Synthesis, Polymerization, Emulsification Equipment, Medicine.

1. Introduction

Polymers as natural substances have occupied an indispensable place in people's lives, but in recent years, after the discovery that polymers can be synthesized by means of chemical reactions, etc., various synthetic polymers have also entered people's daily lives. Due to their structural characteristics, polymers have the following basic properties: low specific gravity, high specific strength, elasticity, malleability, wear resistance, insulation, corrosion resistance, radiation resistance, inability to vaporize, frequent insolubility and high viscosity. With the increasing maturity of polymer-related technologies, people's daily lives and industrial production have gradually been taken over by polymer products. The fields of health care and agricultural production are also being expanded as a result of advances in polymer technology.

In recent years, researchers have made great progress in polymer synthesis and polymer applications. In the direction of polymer synthesis, continuous polymerization techniques have been widely used [1]. And organ catalysts have also been applied to polymerization [2]. As the demand for polymers becomes increasingly sophisticated, polymer synthesis is no longer satisfied by the original chemical reaction synthesis. The length, structure and functional groups of polymers have a huge impact on their properties. This implies that the development of more sophisticated polymer synthesis techniques has been an urgent topic for polymer science.

Furthermore, polymers already have broad applications in several areas, for instance biology, medicine and power applications. In biology, polymers can be used as fluorescently labelled probes, offering the opportunity to track the path of substances in living organisms. Polymers are also gaining widespread and effective use in the medical field. Polymers can be used to make targeted drugs to treat injured tissues in the body and, when combined with metal nanoparticles, can be used to treat cancer. In power applications, polymers can be used to make batteries, to create bulkheads that can withstand high voltages, and to generate electricity from seawater.

In this paper, some novel strategies for polymer synthesis will be presented including atom transfer radical polymerization, microfluidic-assisted synthesis of polymer particles and living polymerization. Moreover, the applications of polymer in medicine, biology and electricity will also be carefully summarized. This work could provide some new methods for different polymer synthesis and give some references for polymer practical application in the different fields.

2. The novel methods of Polymerization

Natural polymers such as rubber, wood and silk have been around for a long time in human history. People have used these natural polymers to make tools, clothes and so on. In the late 19th century, researchers developed artificial polymers, such as phenolic resins and polyformaldehyde. When the technology of synthetic polymers first emerged, researchers were basically using chemical reactions to synthesize polymers. In the 1940s, nylon was synthesized by combining chain and step polymerization, and in the 1950s, catalytic polymerization was investigated with the introduction of the Ziegler-Natta catalyst. The synthesis of polymers has long been of interest because of their wide range of applications.

2.1. Atom Transfer Radical Polymerization

Transition metal complexes, such as Cu, Fe, Ru, Ni and Os, are often used as catalysts for atom transfer radical polymerisation (ATRP), using alkyl halides as initiators (R-X). The principle of ATRP is that the process involves the activation of dormant substances by the transition metal complexes and the production of radicals by the substances through an electron transfer process. At the same time, the transition metal is oxidised to a higher oxidation state. An equilibrium is rapidly established in this reversible process and the free radicals are thus transferred mainly to the side where the concentration of free radicals is very low. In this process, the number of polymer chains is determined by the amount of initiator. During the propagation of the growing chains and monomers together, the probability of active or dormant polymer chains forming is the same. As a result, polymers with similar molecular weights and narrow molecular weight distributions can be prepared by this method. ATRP reactions also have the advantage of being very stable, as they can tolerate many functional groups in the monomer or initiator, such as allyl, amino, epoxide, hydroxyl and vinyl groups [3]. The following diagrams show the chemical equations for some of the basic ATRP reactions (Fig. 1a, Fig. 1b).

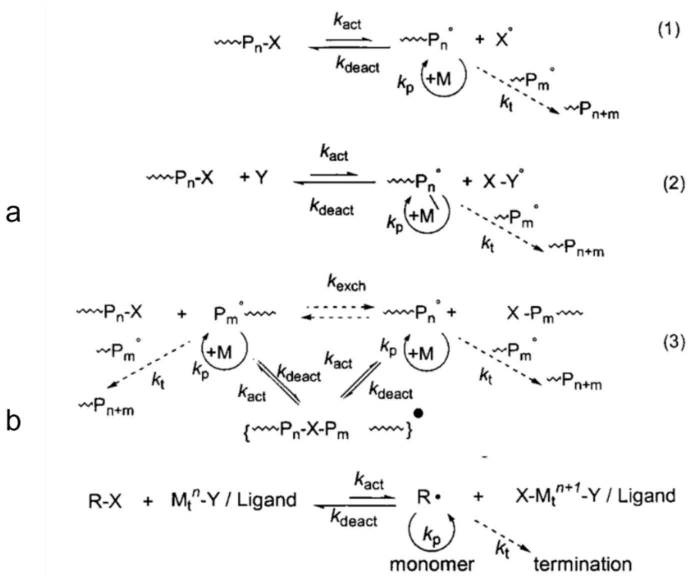

Figure 1. Basic equation of ARTP [3]

2.2. Microfluidic-Assisted Synthesis of Polymer Particles

In general, heterogeneous polymerisation processes have been used to synthesise polymer particles of a few micrometres to a few hundred micrometres, and polymer particles can also be synthesized by precipitation in inorganic substances. However, both methods have a significant impact on particle diameter distribution. In contrast to conventional processes, particle size, shape and composition can be precisely controlled in a microfluidic assisted process. The principle of the microfluidic assisted process is the emulsification of two incompatible liquids using small sized capillaries. This results in polymer particles that are 2-10% smaller than the initial droplet. There are currently two types of devices utilizing microfluidics: (1) Direct polymerization of two incompatible liquids into monomer droplets after emulsification. (2) Direct polymerization by continuous flow projection lithography [4].

2.2.1 Emulsification

There are two different methods of emulsification of polymerizable liquids. The principles applied in both methods are the same, the first method has the continuous and the dispersion flowing in the same tube, while the second method separates the two, with the continuous phase flowing in the tube and the dispersion flowing in a small sized capillary. The diagram below shows two different devices used for microfluidic control.

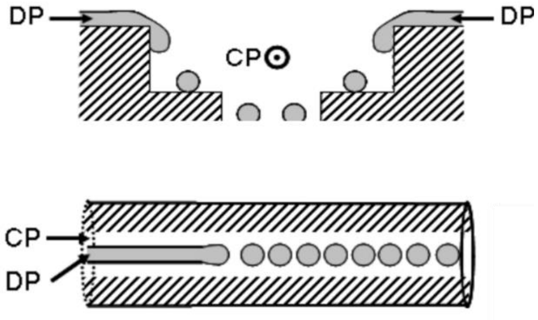

Figure 2. Two types of emulsification equipment [4]

2.2.2 Continuous flow projection lithography

This technique uses ultraviolet light to irradiate the substance and the light is directed through the objective lens of an optical microscope onto a polymer solution flowing in a microchannel. The desired particle shape can be polymerized and 'printed' into the flowing monomer solution by means of a mask placed on the field cut-off plane of the microscope [4].

2.3. Living Polymerization

In vivo polymerization is a polymerization method in which the polymer remains active at the tail end during the polymerization process. There are two live polymerization methods that are currently in use: anionic live polymerization and cationic live polymerization [5]. Monomers such as styrene, butadiene, methacrylate, acrylate, ethylene oxide and lactone are used in the anionic living polymerization technique.

3. Polymer application in biology

3.1. Fluorescent labeling

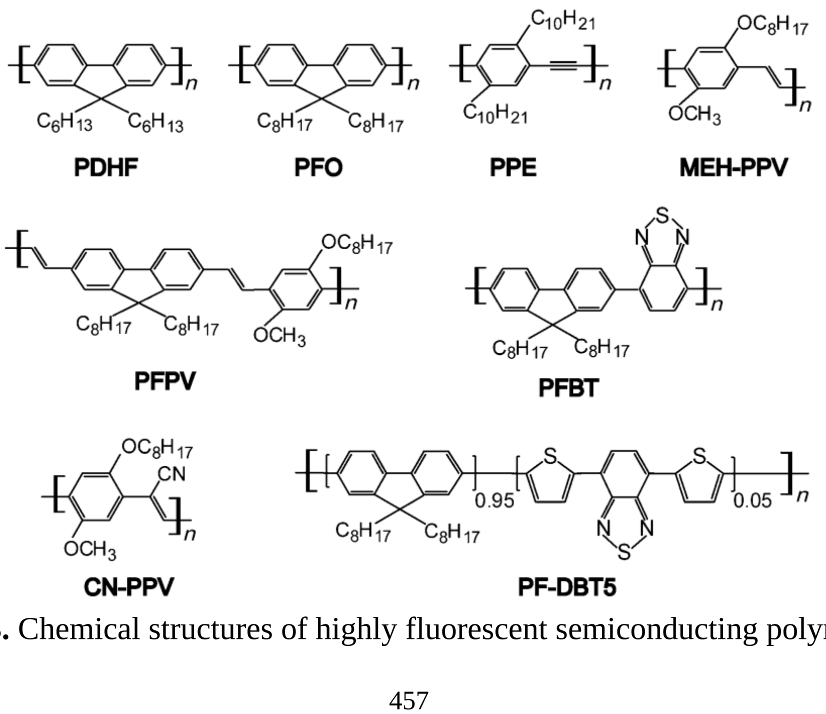

Figure 3. Chemical structures of highly fluorescent semiconducting polymers [6]

3.1.1 Cellular Labelling through Endocytosis

Pdots have the advantages of high brightness, being very stable under light, fast and consistent emissivity and non-toxicity. They can therefore be applied to living organisms without causing any harm. It has been found that cells can take up bare Pdots, even at very low concentrations, to label organisms because of their high brightness and photostability [6].

3.1.2 Immunofluorescent Labeling

Cell labelling by phagocytosis is successful in labelling cells but is unable to specifically label a fraction. Therefore, further specific labelling techniques have been developed. This technique uses the principle of antigen-antibody interactions. Based on the research of Wu et al, they have developed biolabeling methods for Pdot-IgG and Pdot-streptavidin probes (hydrodynamic diameter of about 10-20 nm). With this method, they have successfully labelled a substance used to detect tumour cells on the surface of epithelial cells. At the same time, the brightness of labelling with pdots is tens of times brighter than other probes [6].

4. Polymer application in medicine

The use of nanomaterials in medicine has given rise to a new discipline known as nanomedicine. It includes the diagnosis, treatment, cure, prevention of disease and the management of trauma [7].

4.1. Antibacterial medicine

Polymeric nanomaterials, using both natural and synthetic polymers as raw materials, have shown powerful antibacterial properties against specific bacteria in tests. Thus, polymeric nanomaterials can be used to manufacture antimicrobial drugs and produce more antimicrobial drugs through the combined action of synthetic and natural polymers. For example, biopolymer nanocomposites made from CS-enhanced nano-TiO2 exhibited excellent antibacterial activity of 100% within 24 hours when treated with Escherichia coli (E. coli) [7].

4.2. Tissue engineering

Polymeric nanocomposites have many applications in the field of regenerative medicine. They can be used to produce a three-dimensional framework on which cells can proliferate and differentiate and form functional tissues. The structure of the polymer scaffold required will also vary depending on the tissue. For example, osteoblasts need large voids in the polymer scaffold because they need to provide space for their proliferation to be deposited. The use of polymeric nanocomposites for tissue engineering has led to more diverse structures for biological scaffolds, providing transplantable spaces for cells and signalling molecules to regenerate functional tissues [7].

4.3. Cancer treatment

The use of mineral (magnetic) nano, gold nanoparticles and polymers to form nanocomposites is the underlying principle of cancer nanomedicine. The substances are used as non-toxic, folic acid-targeting, pH-responsive drug carriers for the early detection and treatment of cancer cells with high folic acid secretion properties. Gold nanoparticles can accomplish the conversion of light to heat for high-temperature cancer therapy and photothermal drug delivery. Thus, combining nanometals with polymers offers further possibilities for cancer therapy [7].

4.4. Drug delivery

For the development of targeted drug delivery systems, polymers have been chosen as the backbone of the structure because of their biocompatible characteristics [8]. For example, alginate-CS-hyaluronic acid nano polymer particles are a new carrier for the delivery of intra-articular NSAID (osteoarthritis) meloxicam. At a pH of 7.4, this polymeric nanocomposite achieved a cumulative drug release of 85% in 96 hours [7].

5. Polymer application in electricity

5.1. Battery

Solid polymer electrolytes can be used to make solid-state rechargeable lithium batteries, particularly polymer electrolytes that (a) do not contain low molecular weight plasticisers (b) have sufficiently high ionic conductivity. Alternatively, the polymer matrix can be used as a carrier for the gel electrolyte, a combination with ionic conductivity that can also be used in the fabrication of lithium batteries [9].

5.2. Polymer Nanogenerators

Polymer-based nanogenerators (PNGs) can convert mechanical energy into electrical energy and have many other advantages, such as being low cost, flexible, producing renewable energy and being very adaptable to any shape of surface [10]. The use of this type of generator is a good way to reduce costs and save space. Its flexibility also offers more possibilities for the location of use. It can convert renewable energy sources like solar, thermal, electrostatic and kinetic energy into electrical energy and, thanks to its biocompatibility, can also be used to make wearable electronic systems [10].

6. Conclusion

In summary, this paper describes three new methods of polymer synthesis and the application of polymers in medicine, biology and electricity. Three methods of polymerization are described: atom transfer radical polymerization, polymer particles for microfluidic assisted polymerization and in vivo polymerization. In terms of applications of polymers, three aspects of their use in biology, medicine and electricity are described. In biology, polymers are mainly used to make polymer probes. In medicine, polymers are used in pharmaceuticals, cancer treatment and tissue repair. In electricity, polymers are used to make batteries and generators. Due to their chemical stability and the many ways in which they can be synthesized, and the increasing number of synthetic polymers that have been discovered in recent years, polymers will increasingly occupy people's everyday lives in the future, and their potential is worth the time and effort of researchers.

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