Analysis on the Development and Application of Biodegradable Polymers

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Abstract. Nowadays, synthetic high polymer materials have already been used in almost every facet of our life, but the use of them creates huge environmental problems to the world. The overuse of “white trash” or the explosive increase in landfill are all extremely urgent problems influencing the environment. Since more people begin to have global environment concerns, the biodegradable polymers have become an important topic. By degrading or decomposing with interactions from microorganisms, the process actually forms environmental-friendly products. In general, there are two basic kinds of biodegradable polymers, which are synthetic biodegradable polymers and natural biodegradable polymers [1]. Overall, natural biodegradable polymers seem to be superior than synthetic biodegradable polymers in some aspects. In order to further explain the developments and applications of biodegradable polymers, this paper also includes basic concepts of biodegradable reactions, characteristics of several individual biodegradable polymer, and fields of applications of biodegradable polymers. In addition, this paper also shows some influencing factors—not only from the internal characteristics of materials, but also external conditions from the environment—to reveal that different conditions or different materials may lead to different bio-degradation results. To conclude, biodegradable polymers are new technologies that people still research on it and it has a broad space for future development and exploitation.

1. Introduction
Entering the 21st century, the great technological breakthrough on synthetic high polymer materials authentically enhances people’s life quality and convenience. There are both advantages and disadvantages by using this synthetic high polymer materials. For the advantages, they all have light weight, high intensity and high chemical stability, which ensures that they can be safely used in lots of facets such as the specific production in factories for people’s daily life [2]. However, the extended use of synthetic high polymer materials also brings great environmental problems to the world. Many of them become wastes after being used. The whole process strongly influences living environment of people. What is more, because raw materials like petroleum are not inexhaustible, it is necessary to find other materials to replace the extended use of synthetic high polymers. Therefore, the importance of biodegradable polymers can be seen. According to the definition from American Society for Testing and Materials (ASTM), biodegradable polymers are polymers that degrade or decompose under chemical, physical and biological interactions with microorganisms from the environment, such as bacteria, fungus, and algae [3]. Under an ideal condition, the interaction of biodegradable polymers will only create carbon dioxide and water as products. That means the degradation or decomposition of biodegradable polymers actually have no environmental damage.
2. Analysis

2.1. The interaction principals of biodegradable polymers

Generally, reactions of biodegradable polymers are caused by microorganisms’ digestion and absorption, but they are not simple process. Bio-degradation is usually being regarded as a complex reaction mix, including but not limited to reactions of bio-physics, bio-chemistry, physical chemistry [4]. In order to better define the whole process of reactions of biodegradable polymers, researchers split it to three general sections. In the first section, microorganisms besieges the surface of the material and begins to destroy the surface structures. In the second section, microorganisms begins to secrete hydrolytic enzyme on the surface. Through hydrolysis and redox reaction, the reaction ruptured macromolecular chain of the biodegradable polymers, which let the polymers convert to low molecular weight compounds. This process of the second section is always repeating until the whole reaction of bio-degradation stops. In the third section, microorganisms start to absorb those small molecular weight compounds and operate digestion. After the circulation of physiological metabolism, the microorganisms actually convert the small molecular weight compounds into carbon dioxide and water, which are lately released into the natural environment again.

2.2. Influencing factors of biodegradable polymers

There are many influencing factors of biodegradable polymers, not only from the internal characteristics of materials, but also external conditions from the environment. From the internal perspective, the composition and structure of the material strongly influence its performance. On the contrary, temperature, humidity, PH value, radiation and soil composition also are important factors in the environment.

2.2.1. Influence from internal characteristics.

There are two basic assumptions found on bio-degradation polymers. One is degrading from the main molecular chain of the polymers with selection. The second one is degrading from the end of the molecular chain with intrusion [2]. That means the composition and structure are of importance to bio-degradation reactions. When there is hydrophilic bond found in the main chain structure, the polymer are easier to operate bio-degradation reactions. When the main train has high rigidity, the bio-degradation rate becomes slow and vice-versa.

2.2.2. Influence from external environment.

First of all, in general, the bio-degradation rate increases when temperature increases because most of the microorganisms living on earth are mesophiles and appropriate temperature can improve their metabolism process. However, there are exceptions, for which the bio-degradation rate increases when temperature decreases. Second, water is the fundamental element to support lives of microorganism so that it is indispensable. Third, for most microorganism, there is a corresponding and optimal pH value.
The average appropriate pH value is around 5-9 for living microorganisms. Fourth, some biodegradable materials can form free radicals after exposure to special radiation. It can also speed up the reaction rate. At last, because different soil types include different types of microorganisms, the soil composition can also influence the reaction process.

2.3. Specific examples of biodegradable polymers

2.3.1. Polylactic acid (PLA).
Polylactic acid (PLA) is one of the most important chemical synthesized biodegradable polymers. PLA has many advantages than other polymers. With high heat stability, compatibility, absorbability, and relatively dissolution resistant ability, it can be manufactured with a wide range of methods. PLA is also non-toxic, nonirritant and pollution-free. It can be completely converted to carbon dioxide and water during the biodegradation process. All the advantages make PLA become one of the most promising biodegradable polymers [5].

![Figure 2. Polymerization routes to polylactic acid][10]

2.3.2. Polyhydroxyalkanoate (PHA) and Polyhydroxybutyrate (PHB).
Polyhydroxyalkanoate (PHA) and polyhydroxybutyrate (PHB) are all practical microbiological synthesis biodegradable polymers [6]. They both use organisms as carbon sources and use the fermentation from microorganisms for creation. PHA has a comprehensive structure and has similar physical properties as plastics, which is an appropriate biodegradable polymer for making medical materials. PHB has a high solidity and high brittleness as well as similar physical property like polypropylene.

![Figure 3. The structure of polyhydroxybutyrate][11]

2.4. Applications of biodegradable polymers

2.4.1. Packaging.
Nowadays, materials like polystyrene (PS), polypropylene (PP) and polyethylene (PE) are usually being used for merchandise packaging, especially in food industries. However, the use of these materials resulted in huge degree of “white pollutions”. There is still no effective way to reduce their...
damage to the natural environment. However, the use of biodegradable polymers in packaging truly improves the situation. Biodegradable polymers are being added into the laminated membrane of packages which can let the package quality achieve standards. Both polyhydroxyvalerate (PHV) and polyhydroxybutyrate (PHB) are ideal applications for packing in that they have similar physical property as PE and PP [7].

2.4.2. Agriculture.
The all-season supplies of vegetables, fruits and other agricultural products can not only enhance human being life qualities, but also help farmers with economic supports. Unfortunately, in order to achieve supply level, farmers need to master special techniques by using different multiple plastic film to cover crops. The plastic films usually retain on the ground after the crops grown up. The films not only damage soil structures of the field, but also reduce the production efficiency of the crops. Now the biodegradable polymers are added into the films which make it to be biodegradable. After abandon those films, they can convert in to carbon dioxide and water by reacting with microorganisms. The degradation process also enhance the soil structure by adding air holes and supplying additional water.

2.4.3. Medicine and pharmacology.
The biodegradable polymers can also be used in the production of surgical sutures, artificial skin, and drug capsule release membranes [8]. By using traditional sutures like nylon, the patients need to come to the hospital again to take out the sutures, because the material cannot be absorbed into patients’ body. Suture made by biodegradable polymers can actually decompose harmlessly after wound healing. Patients do not need to go to see the doctor again, and can rehabilitate with no pain. Same for the artificial skin with biodegradable polymers, there are no rejection process from our body after transplanting the skin. Therefore, it becomes an effective method to treat fire burns.

3. Discussion
To some extent, the developments and applications of biodegradable polymers are especially important to the world. However, there are still lots of improving approaches for the whole progress. First, researchers need to find ways to improve physical properties for both existing and new biodegradable polymers. For most of the existing biodegradable polymers, there are still a lot of room for characteristic improvement. Some of the material still has problems, such as low waterproof ability and poor mechanical properties. They need to be modified by scientists in order to get better physical properties. For new biodegradable polymers, researchers need to develop new methods to synthesis them, making them more suitable for specific application products. Second, the producing cost of biodegradable polymers need to be reduced. Some existing biodegradable polymers are difficult to produce so that enterprises need to spend high producing cost to produce them. However, that is not the long term solution. In order to apply those biodegradable materials in a wide range of industries, the cost need to be reduced. Researchers can develop a different production process by using cheap raw materials, such as straw or round grass to produce biodegradable polymers. In this way the producing cost can be decreased and became rational for mass production. Third, new biodegradable polymers need to have time manipulation in order to better control time spend for degradation process. For example, when biodegradable materials are used for capsule shell in the field of medicine, it need to be calculated precisely for when do the capsule resolve in human’s body in order to effectively treat particular health problems or illness. Fourth, uniform regulation process are necessary as there are still no valid organizations or regulation systems take control on biodegradable polymers currently [6]. Once uniform regulation processes are formed, scientists from the whole world can communicate more effectively and work or do scientific research together. More and more biodegradable polymers can be produced and used for a wide range of applications which eventually benefits human beings’ lives. Fifth, researchers also need to find special microorganisms which can effectively decompose high molecular weight polymers. It is really important for researchers to know the fundamental
interactions between microorganisms and biodegradable polymers. It can help researchers screen appropriate microorganisms for future use.

4. Conclusion
Effective promotions for biodegradable polymers are especially important for next few years. The world needs environmental-friendly materials to achieve sustainable development. In order to better put biodegradable polymers into multiple applications, researchers not only need to improve their using functions, but also need to lower production cost, increase global market competency. The development rate of biodegradable polymers are already extraordinarily fast, especially when more and more people begin to pay attention on environmental problems and world protection. Although there are still weakness in the development of biodegradable polymers, their advantages in many facet still exceed every other high molecular weight polymers. That means the future development of biodegradable polymers are very promising. As a new measure to manage environmental problems and limited world resources, biodegradable polymers will eventually integrate into every perspective of life of human being and being used in a wide range of production fields [8]. In this research paper, the classification of biodegradable polymers are still not completely clear. That is because there are still lots of new biodegradable polymers not yet classified or need to be discovered in the future. The author will continue research on the classification process of exiting and new biodegradable polymers in the future.

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