Application of Self-Healing Intelligent Polymer Materials in Anti-aging Research

Lianyi Huo1, Alan Allman1,∗and Siming Chen2

1Queen Mary University of London Engineering School, Northwestern Polytechnical University, Xi’an, Shaanxi, P.R. China
2School of Water & Environment, Chang’an University, Xi’an, Shaanxi, P.R. China
Email: huolianyi@mail.nwpu.edu.cn

Abstract. The self-healing materials come from the bionic research of the self-healing phenomenon of the organism. Self-healing materials can self-repair and restore some mechanical properties when damaged. With the development of material science in recent years, more and more attention has been paid to intellectual materials. Self-healing polymer materials play an important role in the field of intellectual materials because of their unique properties. It is significant for polymer materials in the engineering field to repair micro-cracks in time. This article summarizes the related characteristics of self-healing polymer intellectual materials and the causes and coping modes leading to the aging of polymer materials, as well as the application of self-repairing polymer intelligent materials at home and abroad in anti-aging research, and expounds its broad prospects for development.

1. Introduction
The conception of intelligent materials originated from bionics; that is, scientists want to develop materials that are similar to organisms. The materials have the ability to perceive and distinguish external conditions and control their own properties according to the changes in conditions. Therefore, intelligent polymer materials can respond to the stimulation of environmental factors just like organisms, such as changing their shape [1]. It has great development potential both in the current world and in the future. Generally speaking, intelligent materials have seven functions: sensing function, feedback function, information recognition and accumulation function, response function, self-diagnosis, self-healing and adaptive ability[2]. The basic types of self-healing intelligent polymer materials are foreign aid-based self-healing polymer materials and intrinsic self-healing polymer materials[3].

The foreign aid-based self-healing polymer materials mean that timely repair can be achieved by embedding the required materials in it in advance. There are two kinds of self-healing material systems: micro-capsule self-healing system and liquid core fiber self-healing system [4]. The intrinsic self-healing polymer materials refer to the damage caused by the chemical reaction between the reversible covalent bond and non-covalent bond, which can be healed with the help of its own structural properties without the help of repair agents.

The researchers of polymer materials get inspiration from the healing function in the field of natural biology and take certain ways to make polymer materials have this self-healing ability. As long as the polymer material has this ability, it belongs to self-healing polymer materials [5].

The development and application of new materials is an important symbol of human civilization and social development. Therefore, developing intelligent materials can meet the strategic needs of the current era. Facing changing external conditions, intelligent polymer materials can judge the needs of
current conditions by themselves and make structural changes to adapt to the demand. Self-healing intelligent polymer composites will become an important development direction of polymer materials in the future. These materials will be widely used in the future construction industry, aerospace, biomedicine and daily life. Moreover, it is expected to realize large-scale preparation of polymer materials with designated structure and expected performance in the future.

The materials aging has been troubling scientists and engineers for a long time. After aging, the materials are faced with the failure of functions and even lead to failures and more serious accidents. For example, as the polymer structure changes, the physical properties also change, such as changes in environmental stress or plasticizing of the material. These factors will lead to the aging of polymer materials, reducing the material properties and value. It has become an important issue; that of how to delay the aging of materials. This article summarizes the factors that affect aging and the measures to prevent aging.

2. Aging Phenomenon and Self-healing
Polymer materials will undergo structural changes in the process of manufacturing, storage, and using. Whether it is a synthetic or natural polymer, its physical and chemical properties will gradually deteriorate to the point that it loses its initial use-value. This is the aging phenomenon of polymer materials.

Under different environmental conditions, the aging trend of polymer materials is different. For example, after drying agricultural plastic film turns yellow, brittle, opaque, the transparency of aero Plexiglas decreases after using it for a long time. After long-term use, the elasticity of rubber products will decrease, harden, crack or soften, viscous; after long-term using paint will lose luster, powder, bubbles, peeling.

Materials will age and damage during the process of manufacture and use. The self-healing polymer materials of micro-capsules are divided into two types according to their functions and characteristics: the preparation technology based on a single capsule remediation agent and the preparation technology based on a double capsule remediation agent. Microencapsulated self-healing materials have attracted researchers' attention since the 1990s. For the first time, the white team embedded dicyclopentadiene as a repair agent in the micro-capsules and dispersed the treated micro-capsules repair agent and Grubbs catalyst in the epoxy resin matrix[6].

Self-healing types can repair aging (or damage) by itself. Materials with this character can repair micro-cracks and so on to a great extent. For example, after being damaged by mechanical force, homogenous or heterogenous cracking of polymer materials produces micro-capsules that are difficult to detect. Self-healing polymer materials can quickly repair micro-capsules to avoid material failure [3].

3. Factors Affecting Material Aging
The properties of polymers are closely related to their chemical structures. A polymer is a long chain structure connected by covalent bonds. When external conditions destroy the molecular forces, the physical properties of the material will change, affecting the use of the material. The factors affecting the aging of polymer materials can be divided into two categories: internal factors and external factors.

3.1. Internal Factors
The effect of polymer structure is crucial to the properties of intelligent polymer materials. Because there are many weak bonds in intermolecular forces, the impact of the external environment easily causes the weak bonds to break, and the break of the chain segment will produce free radicals. At this time, the aging of the polymer material is caused by the substances generated by this free radical reaction. To prevent aging it is necessary to prevent the chemical reactions in the material due to external condition changes [7].

The difficulty of material aging is determined by the number of end groups in the molecular chain, and the molecular weight distribution will affect the number of end groups. In conclusion, the
molecular weight and distribution of the material mentioned above will affect the anti-aging ability of the material[8].

In the manufacturing process of polymer materials, contact with the external environment or chemical agents in the residual processing process is unavoidable, which may cause the aging of materials in the future use of materials[8].

The molecular bonds of polymers are divided into ordered and disordered. The ordered molecular bonds are called crystalline regions, and the ordered molecular bonds are called amorphous regions. Generally, the aging of materials originates from the amorphous zone and spreads to the crystalline zone. Therefore, it can be seen that the tacticity of polymer materials has a certain influence on the aging of materials [7].

3.2. External Factors

The rate of movement of molecules is related to temperature. In a certain range, the higher the temperature is, the higher the absorbed energy will be. When the absorbed energy is greater than or equal to the dissociation energy of the molecular bond, the rupture will occur, leading to the degradation of the polymer material and the aging of the material.

Water molecules in the air permeate into the material, making the material swell or even dissolve, damaging the aggregation structure of the polymer material, making intermolecular forces change, and the original properties also change, resulting in aging.

The chemical medium in which the material is located penetrates the material and contacts with its covalent bond, thus triggering a chemical reaction. For the secondary valence bond of the polymer, the reaction with the chemical medium will not change the chemical structure of the polymer but also has a significant impact on the polymer structure of the material. The physical properties of the material will change due to the change in the polymer structure. These factors will cause the aging of materials and reduce the service life of materials [7].

Reproduction of microorganisms and moulds is the main cause of material biological aging. Microbial metabolites contain enzymes and other chemical substances, which can affect the service life and physical and chemical properties of materials.

4. Anti-aging Measures of Intelligent Polymer Materials

4.1. Traditional Ways of Anti-aging Preventive Measures

In view of the above possible causes of material aging, the following traditional measures can be used to prevent it:

Adding plasticizer is one of the main means to prevent thermal aging. Plasticizers can improve the plasticity of polymer materials, reduce the glass transition temperature, and enhance the cold resistance of materials, to avoid thermal degradation of materials and other reactions affecting the properties of materials [9].

Polyester, polyacetal, polysaccharide polymer, and other high polymers will hydrolyze under the condition of acid or alkali. In areas prone to acid rain and serious pollution, it is mainly used to cover the surface of the polymer material with waterproof film to avoid its contact with water molecules to avoid wet aging.

The usual way to prevent biological aging is to add an anti-mildew agent in the material, to inhibit the growth of mould and other microorganisms. Another costly method is to coat the material surface with anti-microbial factors [7].

4.2. Anti-aging Measures of Self-healing Intelligent Polymer

With the development of intelligent polymer materials, in the face of material aging, based on prevention, the ability of self-repair can be applied to reduce the damage caused by aging damage to materials and accidents caused by component material failure.

S. Bode et al. [10] developed a sol-gel system whose morphology changes with pH, and its principle is shown in figure 1. The system self-repairs through pH changes. The material reacts with tri [4-formacypheinoxyl] -methyl] ethane after modification of dibenzoyl hydrazide at both ends of
Polyethylene glycol to generate self-healing polymer material through condensation reaction mechanisms. Its properties can be applied to repair aging caused by pH changes due to acid rain or pollution.

![Figure 1](image)

**Figure 1** Self-healing mechanism of the hydrazone bond[11]

The self-healing material based on DA reactions can repair itself according to the temperature-dependent, and its temperature-dependent self-healing mechanism can be used to repair the damage caused to the material by thermal aging. Oehlenschlaeger and Barner-Kowalik et al.[12] produced self-healing materials rapidly at 120°C by DA reactions without catalyst.

5. Application of Self-healing Intelligent Polymer Materials in Anti-aging Research

Self-healing polymer material plays an important role in industrial production. In the process of material manufacture and use, it is inevitable that there will be aging damage, which will affect the performance and service life of the material, and even lead to the occurrence of accidents. Some micro-cracks are difficult to find, and even if found, difficult to repair in time, which leads to potential hidden trouble. The self-healing polymer material can repair itself after material damage, which greatly extends the service life of the material and improves the safety of the equipment. Specifically, it has the following applications:

5.1. Self-healing Intelligent Polymer Materials Application in Repairing Micro-cracks Caused by Physical Reasons

An epoxy resin/mercaptan remediation system is a common type of self-healing polymer material. Epoxy resin is widely used in industrial production due to its corrosion resistance and strong stability. The epoxy resin with good adhesive effect is used as the repair agent, and the curing agent is packed with micro-capsules and embedded into the matrix of the material. When the material is subjected to physical factors (such as impact and fatigue) aging, and the phenomenon of micro-cracks occurs, self-healing polymer materials can repair the micro-cracks generated. The capsule around the micro-crack will crack so that the curing agent and repair agent in the capsule will enter the micro-crack together in first, and then the chemical reaction will occur to complete the repair of micro-crack[5], as shown in figure 2.
5.2. Self-healing Intelligent Polymer Materials Application in Repairing Oxidative Aging
The causes of material aging are various, especially the oxidation caused by exposure to oxygen in the air. At present, the main way to combat oxidative aging is to improve the properties of materials to make it more difficult to react with oxygen in the air. However, self-healing intelligent polymer materials focus on reducing the change of material properties by the reverse reaction after oxidation.

5.3. Self-healing Intelligent Polymer Materials Application in Repairing Stress Cracking
When the polymer material is under continuous stress, it may lead to fatigue aging, crack, or fracture. Self-healing intelligent polymer can be used at the beginning of the release of repair agents and curing agents to repair the small cracks, to prevent the further expansion of the cracks, so that can achieve the role of preventing stress cracking.

5.4. Self-healing Intelligent Polymer Materials Application in Repairing Photo Aging
In addition to using traditional methods to deal with photoaging, smart polymer materials can repair photoaging in a way similar to biology. Self-healing intelligent polymer absorbs light and uses it to repair the damage caused by light aging, which not only solves the problem of energy required for repair but also repairs the material aging caused by light.

5.5. Self-healing Intelligent Polymer Materials Application in Biomedicine
The bionic self-healing matrix is mainly used in biomedicine. The biomimetic self-healing matrix is similar to the self-healing system of micro-capsules, which can prevent the damage and aging of the material by burying the required repair agent or curing agent in the material and curing it after the outflow of liquid is used for repair. Currently in biomimetic self-healing aspects of human blood vessels have made relevant advances, such as Sun T L [14] use dicyclopentadiene resin as a liquid and buried the resin in the bionic vascular, then insert the vascular system of epoxy resin in the polymer matrix, and at the same time is helpful to epoxy resin curing catalyst in polymer, made self-healing coatings.

6. Prospect
Self-healing polymer material has a good prospect in the field of anti-aging and has a very broad application in repairing damage caused by aging problems. At present, the main direction of self-healing materials is to develop their properties and functions. It is an important concern for the development of self-healing materials to give consideration to excellent mechanical properties and self-healing functions, so as to achieve the goal of maintaining the required properties of self-healing materials in the repair process. Functional development should be close to the direction of practical applications. Such as wear-resistant, transparent and antifogging coating. How to apply self-healing materials to reality and realize commercialization is the future research direction for researchers.
The complex and diverse structure of polymer materials is not only an advantage of its variety of properties but also a disadvantage of increasing the difficulty of research and development. In the future, it is expected that self-healing polymer intelligent materials can be widely used in anti-aging.

7. References

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