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Research Progress of Microcapsule Technology

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Abstract

Microcapsule technology has become one of the key technologies in the world because of its superior structure and performance. In this paper, the composition of microcapsules, the selection of wall materials, different preparation methods and their advantages and disadvantages are discussed, and their application fields and existing research disadvantages are prospected in order to provide theoretical guidance for the development of microcapsules.

Keywords

Microcapsule; Wall Material; Preparation Methods.

1. Introduction

Microcapsule technology is a technology in which solid or liquid materials are coated with film-forming materials to form tiny particles with the help of polymer polymerization technology. The tiny particles obtained are called microcapsules, and the general particle diameter is 2-1000 microns [1-2]. Microcapsules can change the appearance and properties of substances, prolong and control the release of substances in the membrane, so that the wrapped substances have stronger environmental stability, in order to give full play to their effects in application. Microencapsulated particles have a series of advantages, such as small size, large specific surface area, good stability and good biocompatibility. In the 1950s, with the invention of carbon-free carbon paper, microcapsule technology began to enter the practical stage. After the 1980s, nanocapsules [3] were put forward and gradually developed, which makes the research of microcapsule technology become the focus of attention. Nowadays, microcapsule technology has been widely used in coatings, medicine, food, pesticides, chemical fertilizers and other fields. At present, this technology has been listed as a key high and new technology for research and development in the 21st century, and has been widely used in various fields.

2. Composition of Microcapsules

Microcapsules are usually composed of wall materials and core materials. The substances wrapped in microcapsules are called core materials, and their physical states can be solid, liquid or even gaseous. The film-forming material coated in the outer layer is called wall material, which can be natural or synthetic polymer compounds, or small molecular inorganic compounds [4]. Microcapsules are coated to form tiny particles called microcapsules. The material inside the microcapsule is called core material, and the core of the capsule can be solid, liquid or gas. Microcapsules can change the appearance and properties of substances, prolong and control the release of substances in the membrane, improve storage stability, and isolate immiscible components. In addition, considering the mutual selectivity of wall materials and core materials, generally speaking, oil-soluble core materials need water-soluble wall materials, and water-soluble core materials need to choose oil-soluble wall materials.

2.1. Core Material

The material wrapped inside the microcapsule wall material is usually called the core material, which can be liquid or solid. The core material is composed of a single substance or a mixture of several substances, which is wrapped in the interior of the microcapsule. In most cases, the function of the core material must be released from the wall material before it can be realized. The release of core material can be divided into instantaneous release and slow release. Instantaneous release refers to the rupture of the wall material under the action of friction, deformation, mechanical crushing and other external forces, or melting after heating. Slow release refers to the release of core material through the dissolution or degradation of wall material or the diffusion of capsule wall. The release of core materials from microcapsules generally follows the zero-order or first-order reaction rate equation.

2.2. Wall Material

The microcapsule wall material affects the permeability, solubility and sustained release effect of microcapsule particles to a certain extent. The selection and design of microcapsule wall material should not only consider the stability, degradability, mass transfer performance, source and price of the wall material, but also focus on evaluating the protection and release effect of the wall material on the core material. Generally speaking, the sources of wall materials can be divided into three categories: natural polymer materials, semi-synthetic polymer materials and synthetic polymer materials.

Natural polymer materials are mainly divided into three categories: carbohydrates, proteins and lipids. Specifically, carbohydrates mainly include sodium alginate, chitosan, pectin and so on. These wall materials have good solubility and low viscosity, and have a wide range of sources and varieties. Low price, but low entrapment rate and load. Proteins can promote the formation of emulsion and easy to form film, but there are safety problems, such as Zein, whey protein, soy protein isolate and so on, while lecithin and fatty acids are common in lipids, which have good antioxidation, but the preparation efficiency is low.

Cellulose derivatives are most commonly used in semi-synthetic polymer materials, such as hydroxypropyl cellulose, carboxymethyl cellulose and nanocellulose, which are widely used because of their easy surface modification, good mechanical properties and biocompatibility. In addition, there are Maillard reaction products, which have good emulsifying ability, thermal stability, foaming property, solubility, antioxidation and antibacterial activity. Modified starches, such as chemically modified starch and enzyme modified porous starch, have the characteristics of safety, high efficiency, biodegradability and strong adsorption, but their biocompatibility is poor.

Synthetic polymer materials such as polyethylene glycol, polyamide and polyethylene are the most widely used. Although these compounds have high preparation cost and may cause environmental pollution, they have good film-forming properties, stable chemical properties, high mechanical strength and convenient storage and transportation. it is still the first choice for microcapsule wall materials.

In addition to the necessary core and wall materials, the preparation of some microcapsules need to add an appropriate amount of emulsifier to improve the entrapment rate of the core material. Emulsifiers, including hydrophilic and lipophilic parts, are amphiphilic molecules with surface activity. During emulsification, the emulsifier prevents the accumulation of oil droplets by forming an oil-water interface. Emulsifier and grease, wall material solution

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together to form emulsion to prepare microcapsules. Emulsifiers can be divided into four types: Nonionic, anionic, cationic and bisexual. It has been reported that Nonionic additives can reduce the critical micelle concentration of emulsifiers and may contribute to the emulsification of emulsifiers. Anionic emulsifiers such as sodium dodecyl benzene sulfonate (SDBS) can stabilize the emulsion. Nonionic surfactants and anionic emulsifiers are usually mixed [5].

3. Preparation Method of Microcapsules

Up to now, there have been many microencapsulation methods, which can be divided into physical method, chemical method and physicochemical method according to the material properties, the mechanism of capsule wall formation and the conditions of microencapsulation [6].

3.1. Physical Method

The physical method has the advantages of simple operation and low cost, which is beneficial to large-scale production. At present, air suspension spraying and spraying are widely used.

3.1.1. Spray Drying Method

The principle of spray drying is that the core material is dispersed in the emulsion of the wall material, and then the emulsion is sprayed into the dry high temperature medium by using the spray device, so that the solvent evaporates quickly and the wall material precipitates to form microcapsules, which is suitable for hydrophobic and thermosensitive substances. This method has a short drying process and can avoid being heated for a long time and loss of biological activity; good dispersion, high purity, high solubility, low cost, easy transportation and storage. The process is easy to operate and conducive to continuous production, so it is widely used, but it will cause uneven particle size and some sunken fracture; the core material adsorbed on the surface is easy to oxidize and deteriorate.

3.1.2. Air Suspension Method

The principle of the air suspension spraying method is that the core particles are suspended in the air by using the strong air flow of the fluidized bed, and then the wall material solution which has been adjusted to appropriate viscosity is sprayed on the surface of the core particles by nozzles. finally, the solvent in the wall material is volatilized by increasing the temperature of the strong air flow, and the above steps are repeated to form microcapsules[7]. This method is suitable for porous particles adsorbed liquids or solids. Although the surface of the microcapsule prepared by this method is easy to be damaged and the yield is relatively low, the wall material is moderate and uniform, and the operation is simple and can achieve large-scale production.

3.1.3. Extrusion Method

The extrusion method usually refers to the pore membrane extrusion method, that is, under the condition of low temperature, the emulsion formed by the core material and the wall material is extruded through the pore membrane, and once the wall material is in contact with the dehydrating agent, it will be dehydrated and hardened into microcapsules. this method is suitable for heat-sensitive materials, the preparation temperature is not high, and the porosity of the microcapsules is small, which can block the volatilization of effective components and the entry of O_2, but the yield of this method is general. Large-scale production will result in a certain waste of cost. Molecular embedding method.

The molecular embedding method is mostly used in the food industry, which can microencapsulate oils, pigments, flavors and vitamins. Its principle is to use the hollow and hydrophobic β-cyclodextrin carrier to encapsulate the hydrophobic core material. The microcapsule products made by this technology are not easy to absorb water and accumulate, and the preparation can be completed without special equipment, but the coated core material is more demanding. The droplets of the core material are of the same size.

3.2. Chemical Method

Chemical methods can be divided into interfacial polymerization, in-situ polymerization and sharp hole-coagulation[8].

3.2.1. Sharp Hole-coagulation Method

The sharp hole-solidification method is through the sharp hole device, the suspension of the core material and the wall material is rapidly dropped into the curing agent, usually $CaCl_2$ or aldehyde solution, so that the wall material is cross-linked to form microcapsules. Usually, the curing of the polymer is completed instantly, so the polymer solution containing the core material is pre-molded with the help of microporous devices such as syringes before adding the polymer solution containing the core material to the curing agent. The method is suitable for fat-soluble substances and UV-sensitive bioactive substances, and the operation is simple and environmentally friendly, but the microcapsules prepared by this method have large particle size and low entrapment rate.

3.2.2. Interfacial Polymerization

The interfacial polymerization method is to add two kinds of monomers with different solubility to the continuous phase of the wall material and the dispersed phase of the core material, and then add the emulsifier respectively to form an emulsion. After mixing, when one kind of solution is dispersed in another solution, the two monomers move to the interface of the emulsion droplet to produce monomer Polycondensation, that is, the process of forming a microcapsule shell on the surface of the core material. This method is not only simple to operate, but also has high entrapment efficiency, good compactness and fast reaction rate, and is mostly suitable for liquid core materials such as pesticides, glycerin, medicinal lubricants and so on, but it is worth noting that some monomers will remain without Polycondensation in this method.

3.2.3. In Situ Polymerization

In the in-situ polymerization method, the core material and catalyst insoluble in water are added to the continuous phase of the wall material, and the monomer is uniformly dispersed after intense stirring. in this process, the prepolymer is first produced by the monomer, and the prepolymer is polymerized and deposited on the surface of the core material gradually. to form microcapsules. The scope of application of this method is similar to that of interfacial polymerization [9], which has the advantages of wider range of monomers, low cost and high embedding rate. The key of in-situ polymerization is to control the monomer to form polymer on the surface of the core material. The premise is that the polymer monomer forming the wall material is soluble in water, while the resulting polymer is insoluble in water.

3.3. Physical and Chemical Method

The physicochemical method means that by changing the external conditions, the dissolved film-forming material is precipitated in the solution and coated on the surface of the core material to form a microcapsule. At present, there are two kinds of physical and chemical methods: water phase separation method and oil phase separation method. According to the capsule wall materials, the water phase separation method can be divided into complex condensation method and single condensation method.

3.3.1. Phase Separation Method

The phase separation method is to uniformly disperse the core material in the wall material, add appropriate precipitant, make the wall material and the core material precipitate from the solution together, and solidify it on the surface of the core material by heating and cross-linking, or reduce the solubility of the polymer by changing the temperature or pH, and condense out from the solution, so as to realize the entrapment of the core material and complete the preparation of microcapsules. According to the difference of the solubility of dispersion medium and core material in water, the phase separation method can be divided into water phase separation method and oil phase separation method. The phase separation method for microencapsulation of water-insoluble (or poorly water-soluble) solids or liquids is called aqueous phase separation. The phase separation method for microencapsulation of water-soluble solids or liquids is called oil phase separation. This method is suitable for water-soluble core materials, and the equipment is simple, but the process is complex and time-consuming, and the entrapment effect is easily affected by external conditions.

4. Summary

Today, with the rapid development of high and new technology, the application of microcapsule technology has brought a lot of valuable products, which not only brings people a lot of convenience, but also greatly improves the technical content of industry products.

Because of its superior structure and performance, microcapsule technology has become one of the key technologies in the world, and great progress has been made in the research and development of microcapsules. many problems have been solved by the application of microcapsule technology, such as in the application of functional coatings, in the field of stealthy coatings, the main factors that affect the target infrared radiation function in the middle and far infrared band are surface temperature and infrared emissivity. It is a simple and feasible method to change the surface temperature and infrared emissivity of the target by using phase change material microcapsule or multi-function microcapsule coating. In the field of food, microencapsulation technology is used to encapsulate additives to prolong the usage period and reduce the dosage. Microencapsulation of oils can improve the antioxidant properties, shield bad odors and control the release of oils and fats. The wide application of microcapsules promotes the rapid development of the whole food industry. In the field of biomedicine, the sustained release function of microcapsules is mainly used, that is, drugs and microcapsules are combined into the organism, and the active components are released at an appropriate concentration and rate, so as to give full play to the efficacy of drugs.

However, there are still many problems that need to be further studied, such as the accurate control and measurement of microcapsule wall thickness, the service life of self-repairing microcapsule materials and the environmental friendliness of microcapsule wall materials. the development of microcapsules with excellent performance and moderate cost will also be the focus of numerous scholars. It is expected that microcapsule technology can make a greater breakthrough in the future, be more widely used in various fields, and bring greater social and economic benefits for people.

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