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Micro-encapsulation: A Novel Technique

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Abstract: Micro-encapsulation is a process in which tiny particles or droplets are surrounded by a coating to give small capsules of many useful properties. In a relatively simple form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred to as the core, internal phase, or fill, whereas the wall is sometimes called a shell, coating, or membrane. Most microcapsules have diameters between a few micrometers and a few millimeters. The reasons for microencapsulation are countless. Microencapsulation system offers potential advantages over conventional drug delivery systems and also established as unique carrier systems for many pharmaceuticals. Although significant advances have been made in the field of microencapsulation, still many challenges need to be rectified during the appropriate selection of core materials, coating materials and process techniques.

Key words: Microcapsules, Microencapsulation, Microspheres, Gelatin, Coating material

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1. Introduction

Micro-encapsulation is a process in which tiny particles or droplets are surrounded by a coating to give small capsules of many useful properties. In a relatively simple form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred to as the core, internal phase, or fill, whereas the wall is sometimes called a shell, coating, or membrane. Most microcapsules have diameters between a few micrometers and a few millimeters.

IUPAC definition: Hollow microparticle composed of a solid shell surrounding a core-forming space available to permanently or temporarily entrapped substances.The substances can be drugs, pesticides, dyes, etc.[2]

Reasons for encapsulation

The reasons for microencapsulation are countless. In some cases, the core must be isolated from its surroundings, as in isolating vitamins from the deteriorating effects of oxygen, retarding evaporation of a volatile core, improving the handling properties of a sticky material, or isolating a reactive core from chemical attack. In other cases, the

objective is not to isolate the core completely but to control the rate at which it leaves the microcapsule, as in the controlled release of drugs or pesticides. The problem may be as simple as masking the taste or odor of the core, or as complex as increasing the selectivity of an adsorption or extraction process. In environmental science, a pesticide may be microencapsulated to minimize leaching or volatilization risks.[3]

Techniques to manufacture microcapsules

Physical methods

Pan coating

The pan coating process, widely used in the pharmaceutical industry, is among the oldest industrial procedures for forming small, coated particles or tablets. The particles are tumbled in a pan or other device while the coating material is applied slowly.

Air-suspension coating

Air-suspension coating, first described by Professor Dale Eavin. Wurster at the University of Wisconsin in 1959, gives improved control and flexibility compared to pan coating. In this process the particulate core material, which is solid, is dispersed into the supporting air stream and these suspended particles are coated with polymers in a volatile solvent leaving a very thin layer of polymer on them. This process is repeated several hundred times until the required parameters such as coating thickness, etc., are achieved. The air stream which supports the particles also helps to dry them, and the rate of drying is directly proportional to the temperature of the air stream which can be modified to further affect the properties of the coating.

The re-circulation of the particles in the coating zone portion is effected by the design of the chamber and its operating parameters. The coating chamber is arranged such that the particles pass upwards through the coating zone, then disperse into slower moving air and sink back to the base of the coating chamber, making repeated passes through the coating zone until the desired thickness of coating is achieved.

Centrifugal extrusion

Liquids are encapsulated using a rotating extrusion head containing concentric nozzles. In this process, a jet of core liquid is surrounded by a sheath of wall solution or melt. As the jet moves through the air it breaks, owing to Rayleigh instability, into droplets of core, each coated with the wall solution. While the droplets are in flight, a molten wall may be hardened or a solvent may be evaporated from the wall solution. Since most of the droplets are within ± 10% of the mean diameter, they land in a narrow ring around the spray nozzle. Hence, if needed, the capsules can be hardened after formation by catching them in a ring-shaped hardening bath. This process is excellent for forming particles 400-2,000 µm . Since the drops are formed by the breakup of a liquid jet, the process is only suitable for liquid or slurry. A high production rate can be achieved, i.e., up to 22.5 kg (50 lb) of microcapsules can be produced per nozzle per hour per head. Heads containing 16 nozzles are available.

Vibrational Nozzle

Core-Shell encapsulation or Microgranulation (matrix-encapsulation) can be done using a laminar flow through a nozzle and an additional vibration of the nozzle or the liquid. The vibration has to be done in resonance of the Rayleigh instability and leads to very uniform droplets. The liquid can consists of any liquids with limited viscosities (0-10,000) mPa have been shown to work), e.g. solutions, emulsions, suspensions, melts etc. The soldification can be done according to the used gelation system with an internal gelation (e.g. sol-gel processing, melt) or an external (additional binder system, e.g. in a slurry). The process works very well for generating droplets between 20-10,000 µm applications for smaller and larger droplets are known. The units are deployed in industries and research mostly with capacities of 1-20,000 kg per hour (2-44,000 lb/h) at working temperatures of 20-1500 °C (68-2732 °F) (room temperature up to molten silicon). Nozzles heads are available from one up to several hundred thousand are available.

Spray drying

Spray drying serves as a microencapsulation technique when an active material is dissolved or suspended in a melt or polymer solution and becomes trapped in the dried particle. The main advantages are the ability to handle labile materials because of the short contact time in the dryer, in addition, the operation is economical. In modern spray dryers the viscosity of the solutions to be sprayed can be as high as 300 mPa·s. Applying This technique along with the use of supercritical Carbon Dioxide, also sensitive materials like proteins can be encapsulated.

Physico-chemical methods

Ionotropic gelation

Coacervation-phase separation

Process consist of three steps carried out under continuous agitation.

1. Formation of 3 immiscible chemical phases: liquid manufacturing vehicle phase, core material phase and coating material phase .
2. Deposition of coating: core material is dispersed in the coating polymer solution. Coating polymer material coated around core. Deposition of liquid polymer coating around core by polymer adsorbed at the interface formed between core material and vehicle phase.

3. Rigidization of coating: coating material is immisible in vehicle phase and it gets rigid form. It done by thermal, cross-linking, or dissolvation techniques.

Chemical methods

Interfacial polycondensation

In Interfacial polycondensation, the two reactants in a polycon densation meet at an interface and react rapidly. The basis of this method is the classical Schotten-Baumann reaction between an acid chloride and a compound containing an active hydrogen atom, such as an amine or alcohol, polyesters, polyurea, polyurethane. Under the right conditions, thin flexible walls form rapidly at the interface. A solution of the pesticide and a diacid chloride are emulsified in water and an aqueous solution containing an amine and a polyfunctionalisocyanate is added. Base is present to neutralize the acid formed during the reaction. Condensed polymer walls form instantaneously at the interface of the emulsion droplets.

Interfacial cross-linking

Interfacial cross-linking is derived from interfacial polycondensation, and was developed to avoid the use of toxic diamines, for pharmaceutical or cosmetic applications. In this method, the small bifunctional monomer containing active hydrogen atoms is replaced by a biosourced polymer, like a protein. When the reaction is performed at the interface of an emulsion, the acid chloride reacts with the various functional groups of the protein, leading to the formation of a membrane. The method is very versatile, and the properties of the microcapsules (size, porosity, degradability, mechanical resistance).[4] Flow of artificial microcapsules in microfluidic channels:

In-situ polymerization

In a few microencapsulation processes, the direct polymerization of a single monomer is carried out on the particle surface. In one process, e.g. Cellulose fibers are encapsulated in polyethylene while immersed in dry toluene. Usual deposition rates are about 0.5Î¼m/min. Coating thickness ranges 0.2-75 µm (0.0079-2.95 mils). The coating is uniform, even over sharp projections. Protein microcapsules are biocompatible and biodegradable, and the presence of the protein backbone renders the membrane more resistant and elastic than those obtained by interfacial polycondensation.

Matrix polymerization

In a number of processes, a core material is imbedded in a polymeric matrix during formation of the particles. A simple method of this type is spray-drying, in which the particle is formed by evaporation of the solvent from the matrix material. However, the solidification of the matrix also can be caused by a chemical change.

Release methods and patterns

Even when the aim of a microencapsulation application is the isolation of the core from its surrounding, the wall must be ruptured at the time of use. Many walls are ruptured easily by pressure or shear stress, as in the case of breaking dye particles during writing to form a copy. Capsule contents may be released by melting the wall, or dissolving it under particular conditions, as in the case of an enteric drug coating.[5] In other systems, the wall is broken by solvent action, enzyme attack, chemical reaction, hydrolysis, or slow disintegration.

Microencapsulation can be used to slow the release of a drug into the body. This may permit one controlled release dose to substitute for several doses of non-encapsulated drug and also may decrease toxic side effects for some drugs by preventing high initial concentrations in the blood. There is usually a certain desired release pattern. In some cases, it is zero-order, i.e. the release rate is constant. In this case, the microcapsules deliver a fixed amount of drug per minute or hour during the period of their effectiveness. This can occur as long as a solid reservoir or dissolving drug is maintained in the microcapsule.

A more typical release pattern is first-order in which the rate decreases exponentially with time until the drug source is exhausted. In this situation, a fixed amount of drug is in solution inside the microcapsule. The concentration difference between the inside and the outside of the capsule decreases continually as the drug diffuses.

Applications of microencapsulation

The applications of micro-encapsulation are numerous. The ones mentioned below are some of the most common ones.

- Adhesives
- Carbonless copy paper
- E-paper or e-ink
- Essential oils, Flavors and other volatile bioactives for food or in Feed additives
- Pesticides and herbicides
- Phase change materials
- Powder perfume
- Scratch-n-sniff
- Self-healing material such as novel plastics that can automatically repair damage:
- Textiles
- Temperature release (controlled release) in baking

- Thermochromic dyes
- Time release technology for pharmaceuticals
- Visual indicators

Conclusion

Microencapsulation system offers potential advantages over conventional drug delivery systems and also established as unique carrier systems for many pharmaceuticals (targeted drug delivery systems).

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