ISSN 2319 – 7757 EISSN 2319 – 7765

Indian Journal of Engineering

# Use of microencapsulation in textiles

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Received 04 March; accepted 21 April; published online 01 May; printed 16 May 2013

## ABSTRACT

Microencapsulation is a process in which tiny particles or a coating to give small capsules with many useful properties surrounds droplets. Microencapsulated finished fabrics are among the latest generation of intelligent textiles. The application of microencapsulation technique offers the possibility of producing novel products with many advantages compared to traditional textile products. The micro encapsulates can introduce important new qualities of garments and fabrics, such as enhanced stability and the controlled release of active compounds. Micro encapsulation process act as a means of imparting finishes and properties of textiles which were not possible or cost effective using other technology. This paper highlights the major reasons behind microencapsulation, important techniques of microencapsulation and application of microencapsulated products in different areas of science and technology (Tiwari S, et al. 2010, Marinkovic S,et al.,2006,Yoshizawa H, 2004).

**Keywords:** Textile finish, microencapsulation, intelligent textiles, garments.

## 1. INTRODUCTION

The needs of consumer and their demands and expectations of a healthier and more comfortable life are greater every day even when it comes to clothing. Today textiles can be treated so that they protect one from all kinds of adverse conditions yet at the same time are comfortable. The properties of textiles and their offer are increasingly diverse. Clothes can be water resistant, anti-microbial, nonflammable etc. This kind of properties can be achieved with special chemical compounds that are bound to the surface of the fibre by different techniques like padding, coating, immersion, etc. One of the processes as a mean of applying different finishes and properties on textiles is microencapsulation. Microencapsulation technologies offer many opportunities to improve the properties of textiles, or to give them new functions. Microencapsulation is the packaging of micronized liquid or solid material in the form of microcapsules, which range in the size from less than 1 µm to more than 100 µm depending upon method of encapsulation. Microcapsules are spherical granules with core/shell structure comprising of polymeric skin or wall (shell) enclosing a core. A core material commonly acts as the main functional component in a core/ shell structure and the shell material provide insulation from the environment and means to protect the core from the environment. For this reason the widespread interest has developed in microencapsulation technology (Boh et al. 2007).

## 2. WHAT IS MICROENCAPSULATION?

Microencapsulation is a technique to prepare tiny packaged materials called microcapsules that have many interesting features. This technique has been employed in a diverse range of fields of chemicals and pharmaceuticals to cosmetics and printing. Microencapsulation is a process in which tiny particles or a coating to give small capsules with many useful properties surrounds droplets. Fig.1 shows the general structure of a microcapsule which generally consists of two major components.

*1. Active ingredient*

An active ingredient is the substance that may be in a liquid or solid form. It also refers to the core contents, internal phases, encapsulations, payloads or fillers.

*2. Wall Shell*

A polymer coating that surrounds the active ingredients which may also be called the wall, shell, external phase, membrane or matrix. Gelatin is a common wall-forming material but synthetic polymers like polyvinyl alcohol, ethyl cellulose, polyvinyl chloride and other materials also may be used. The

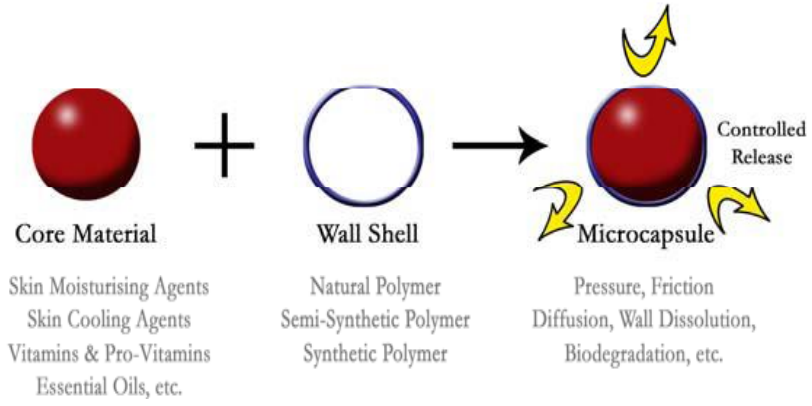


**Figure 1**
Structure of a Microcapsule

release mechanisms of the core contents vary depending on the selection of wall materials and more importantly, its specific end uses. The core content may be released by friction, pressure, change of temperature, diffusion through the polymer wall, dissolution of the polymer wall coating, biodegradation etc. (Cheng et al. 2008).

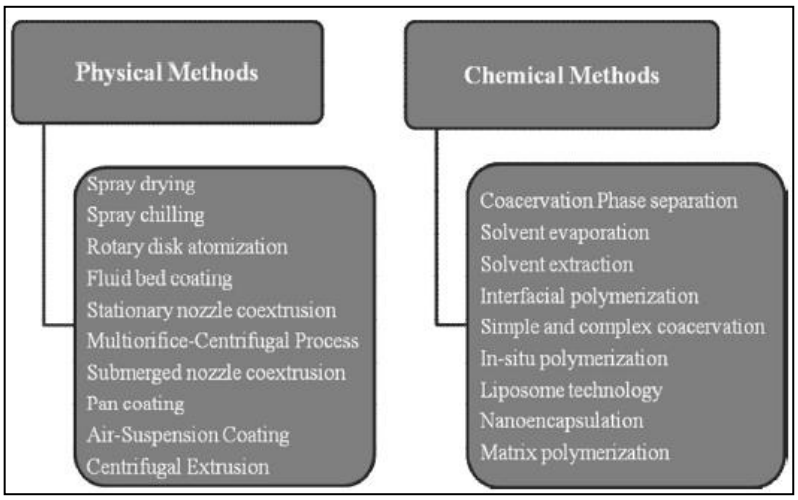


**Figure 2**
Techniques for Manufacturing of Microcapsules

## 3. HISTORICAL BACKGROUND BEHIND MICROENCAPSULATION

The earliest conception of microencapsulation, which carries or holds a core material trapped within a shell material, possibly dates back to the 1930s by using the spray-drying technique. Until the 1950s, the first significant application of encapsulation technology was developed by Barrett Green of National Cash Register Company to provide carbonless copy paper by using a complex coacervation technique. This was employed in a novel printing system which incorporated a colourless dye within the oil phases and coated a second paper sheet with acidic clay. Since then, the US-based Eurand America acquired the rights to subsequently develop and market microencapsulation technology for all new applications. Microencapsulation techniques developed by a number of companies were noted henceforth. This versatile micropackaging technique has been applied in a wide range of fields, including the pharmaceutical, bulk chemical, agricultural, food processing, cosmetic and toiletry industries (Cheng et al. 2008).

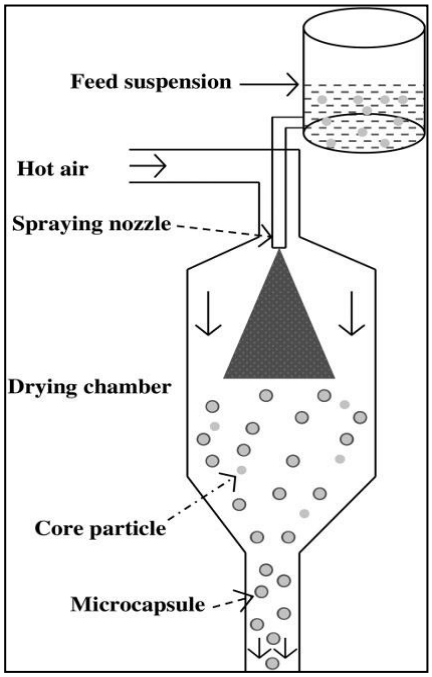


**Figure 3**
Schematic illustrating the process of micro-encapsulation by spray-drying

## 4. 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. Microencapsulation of materials is resorted to ensure that the encapsulated material reaches the area of action without getting adversely affected by the environment through which it passes.
The principal reasons for encapsulation are as follows.

1. Separation of incompatible components
2. Conversion of liquids to free flowing solids
3. Increased stability (protection of the encapsulated materials against oxidation or deactivation due to reaction in the environment)
4. Masking of odour, taste and activity of encapsulated materials
5. Protection of the immediate environment
6. Controlled release of active compounds (sustained or delayed release)
7. Targeted release of encapsulated materials (Dubey et al. 2009).

## 5. TECHNIQUES FOR MANUFACTURING OF MICROCAPSULES

Many different manufacturing approaches have been adopted for microencapsulation (Fig.2). The most commonly used techniques are as follows-

### 5.1. Physical methods

#### 5.1.1. Spray-Drying

Microencapsulation by spray-drying is a low-cost commercial process which is mostly used for the encapsulation of fragrances, oils and flavors. Core particles are dispersed in a polymer solution and sprayed into a hot chamber (Fig.3). The shell material solidifies onto the core particles as the solvent evaporates such that the microcapsules obtained are of polynuclear or matrix type. Very often the encapsulated particles are aggregated and the use of large amounts of core material can lead to uncoated particles. However, higher loadings of core particles of up to 50–60% have been reported. Water-soluble polymers are mainly used as shell materials because a solvent-borne system produces unpleasant odors and environmental problems (Ghosh et al. 2011).

#### 5.1.2. Air-suspension coating

Air-suspension coating of particles by solutions or melts gives better control and flexibility. The particles are coated while suspended in an upward-moving air stream. They are supported by a perforated plate having different patterns of holes inside and outside a cylindrical insert. Just sufficient air is permitted to rise through the outer annular space to fluidize the settling particles. Most of the rising air (usually heated) flows inside the cylinder, causing the particles to rise rapidly. At the top, as the air stream diverges and slows, they settle back onto the outer bed and move downward to repeat the cycle. The particles pass through the inner cylinder many times in a few minutes methods. The air suspension process offers a wide variety of coating materials candidates for microencapsulation. The process has the capability of applying coatings in the form of solvent solutions, aqueous solution, emulsions, dispersions or hot melt in equipment ranging in capacities from one pound to 990 pounds. Core materials comprised of micron or submicron particles can be effectively encapsulated by air suspension techniques, but agglomeration of the particles to some larger size is normally achieved (Bansode et al. 2010).

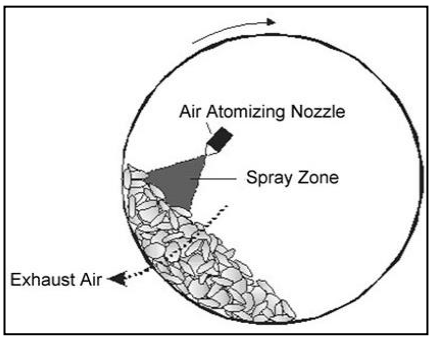


**Figure 4**
Representation of a typical pan coating

#### 5.1.3. 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 (Fig.4). The particles are tumbled in a pan or other device while the coating material is applied slowly. The pan coating process, widely used in the



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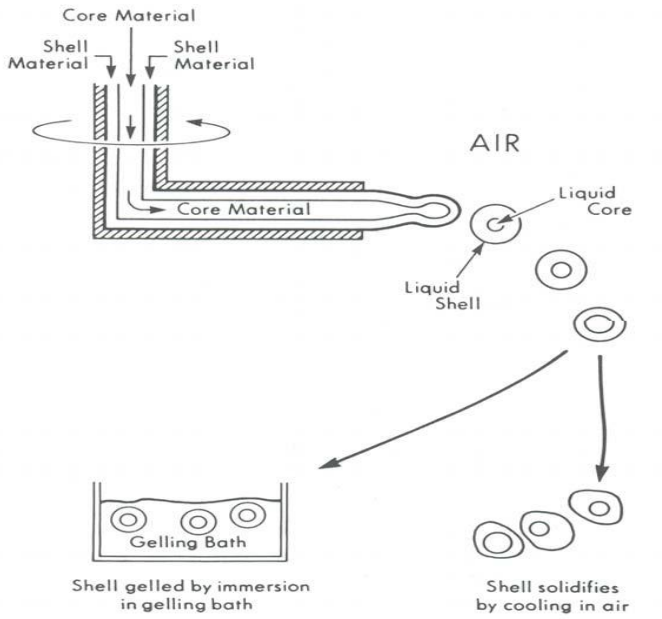


**Figure 5**

Schematic diagram of centrifugal two-fluid nozzle that was used to produce microcapsules

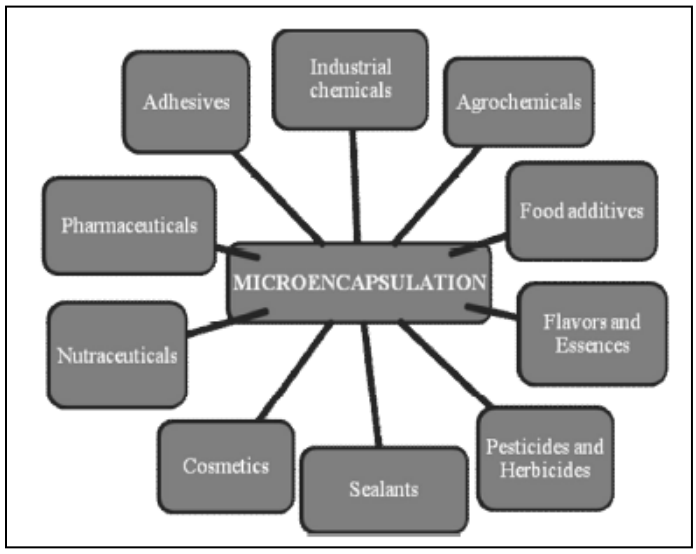


**Figure 6**

Schematic Representation of Microencapsulation Application

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 with respect to microencapsulation, solid particles greater than 600 microns in size are generally considered essential for effective coating, and the process has been extensively employed for the preparation of controlled - release beads. Medicaments are usually coated onto various spherical substrates such as nonpareil sugar seeds, and then coated with protective layers of various polymers (Bansode et al. 2010).

### 5.1.4. Centrifugal Extrusion

In centrifugal extrusion processes, liquids are encapsulated by using a rotating extrusion head with concentric nozzles. The fluid core material is pumped through a central tube while the liquefied wall material is pumped through a surrounding annular space. A membrane of wall material is formed across a circular orifice at the end of the nozzle and the core material flows into the membrane, causing the extrusion of a rod of material. Droplets break away from the rod and hardening takes places on a passage through a heat exchanger. Solid capsules are removed by filtration or mechanical means and the immiscible carried fluid is reheated and recycled after passing through the files. This process is excellent for forming particles of 400-2000µm in diameter. Since the drops are formed by the breaking up of a liquid jet, the process is only suitable for liquid or slurry. Fig.5 demonstrates a schematic diagram of a centrifugal two-fluid nozzle that was used to produce microcapsules (Cheng et al. 2008).

## 5.2. Chemical process

### 5.2.1. Solvent Evaporation

This technique has been used to produce the microcapsules. The processes are carried out in a liquid manufacturing vehicle. The microcapsule coating is dissolved in a volatile solvent, which is immiscible with the liquid manufacturing vehicle phase. A core material to be microencapsulated is dissolved or dispersed in the coating polymer solution. With agitation, the core coating material mixture is dispersed in the liquid manufacturing vehicle phase to obtain the appropriate size microcapsule. The mixture is then heated (if necessary) to evaporate the solvent for the polymer. In the case in which the core material is dissolved in the coating polymer solution, a matrix-type microcapsule is formed. Once all the solvent for the polymer is evaporated, the liquid vehicle temperature is reduced to ambient temperature with continued agitation. At this stage the microcapsules can be used in suspension form, coated on to substrates or isolated as powders (Dubey et al. 2009).

### 5.2.2. Coacervation-Phase separation

Microencapsulation by coacervation-phase separation process consists of three steps carried out under continuous agitation;
1) Formation of three immiscible chemical phases
2) Deposition of coating
3) Rigidization of coating

**Step 1** of the process is the formation of three immiscible chemical phases; a liquid manufacturing vehicle phase, a core material phase and a coating material phase. To form the three phases, the core material is dispersed in a solution of the coating polymer, the solvent for the polymer being the liquid manufacturing vehicle phase.
**Step 2** of the process consists of depositing the liquid polymer coating upon the core material. This is accomplished by controlling, physical mixing of the coating material and the core material in the manufacturing vehicle. Deposition of the liquid polymer coating around the core material occurs if the polymer is absorbed at the interface formed between the core material and the liquid vehicle phase, and this adsorption phenomenon is a prerequisite to the effective coating.
**Step 3** of the process involves rigidizing the coating, usually by thermal, cross linking, or desolvation techniques to form a self sustaining microcapsule (Kumar et al. 2011).

## 5.3. Polymerization

### 5.3.1. Interfacial polymer

In Interfacial polymerization, the two reactants in a polycondensation 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 polyfunctional isocyanate 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 (Bansode et al. 2010).

### 5.3.2. 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 0.5µm/min. Coating thickness ranges 0.2–75 µm (0.0079–2.95 mils). The coating is uniform, even over sharp projections (Bansode et al. 2010).

### 5.3.3. Matrix polymer

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. Using this phenomenon, Chang prepares microcapsules containing protein solutions by incorporating the protein in the aqueous diamine phase. Chang has demonstrated the permselectivity, by their ability to convert blood urea to ammonia, the enzyme remaining within the microcapsules when incorporated within an extracorporeal shunt system. Numerous groups are utilizing polymerization techniques to accomplish microencapsulation. Examples are the National Lead Corporation, Eurand America (Bansode et al. 2010).

## 6. APPLICATIONS OF MICROENCAPSULATION

The applications of micro-encapsulation are numerous. Some of the most common applications are as follows (Fig.6).

- Cell immobilization: In plant cell cultures, Human tissue is turned into bio-artificial organs, in continuous fermentation processes.
- Protection of molecules from other compounds:
- Drug delivery: Controlled release delivery systems.
- Quality and safety in food, agricultural & environmental sectors.
- In textiles**:** means of imparting finishes.
- Protection of liquid crystals.
- Carbon less papers
- Scratch-n-sniff
- Flavors and essences
- Pharmaceuticals
- Adhesives
- Visual indicators
- Thermochromic dyes
- Phase change materials
- Temperature release (controlled release) (Nelson G, 2002; Bansode et al. 2010).

## 7. CONCLUSION

Microencapsulation is both an art and a science. There is not a single way to do it, and each new application provides a fresh challenge. Research and development activities are required in this area to make the micro-encapsulation technology techno-economically viable, so that products like hygienically finished, fragrant smelling, and other smart garments can be made available to the masses. Microencapsulation technology is an effective technique to achieve satisfactory performance; even it is still relatively new to the textile and apparel industry. The wide range of benefits for aromatherapy and controlled release of essential oils is expected to be appreciated by consumers. Today there is almost no field where microcapsules would not be presented. Encapsulation became a very powerful tool, because it is invisible and comes to life at the slightest touch (Bansode et al. 2010; Ocepek et al. 2008).

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