

# Development of Cosmetic Textiles Using Microencapsulation Technology

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## ABSTRACT

In recent years, textile materials have been found in applications in the cosmetics field. A new sector of cosmetic textiles is introduced and several commercial cosmetic textile products are currently available in the market. On contact with human body and skin, cosmetic textiles are designed to transfer an active substance for cosmetic purposes. The principle is achieved by simply imparting the cosmetic and pharmaceutical ingredients into the fabric of clothing so that with the natural movement of the body, the skin is slowly freshened and revitalised.

Microencapsulation technology is an effective technique used to control the release properties of active ingredients that prolong the functionality of cosmetic textiles. This paper will address the historical background of microencapsulation technology, its significant advantages and the most commonly used microencapsulation methods. Some typical examples of commercially available microencapsulation based cosmetic textile products will also be examined. Recent applications, as well as potential development in cosmetic textiles production, will be discussed.

**Keywords:** Cosmetic Textiles, Microencapsulation, Body Care

## 1. Introduction

With the growing trend in enhancing beauty through healthy means, customers request for apparels and home textiles containing not only their original basic characteristics, such as warmth and comfort, but also ones that carry extra functions, including environmental protection, anti-pollution and most importantly, health and beauty care, in an attempt for a more natural and healthier life.

Owing to the rapid development of novel sciences and technologies, textile materials have also found applications in the cosmetics field in recent years. A new sector of cosmetic textiles is launched and the textile industry is very optimistic that these products will open up new target groups and sustainable markets.

On contact with human body and skin, cosmetic textiles are designed to transfer an active

substance for cosmetic purposes. One particular example is the transfer of skin moisturising substances. The principle is achieved by simply imparting the cosmetic and pharmaceutical ingredients into the fabric of the clothing so that with the natural movements of the body, the skin is slowly freshened and revitalised. To achieve these functional effects, microencapsulation technology appears as an alternative way to provide satisfactory performance with increased durability.

In view of the increasing demand in the relevant fields, researchers and textile manufacturers have invested extensively in cosmetic textiles for research and product development. Research and product development focus on:

1. the opportunities and limits for cosmetic and health related applications of textiles,
2. the possible ways of incorporating active substances in a functional manner, and

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- the practical methods of proving the effectiveness of products.

## 2. Microencapsulation Technology

### 2.1 Microencapsulation Technology and Its Advantages

Currently, microencapsulation technology is rapidly developing in the field of chemical finishing because of its versatility and flexibility. Figure 1 shows the scanning electron microscope (SEM) image of microcapsules. One major advantage of using microencapsulation technology is its ability to protect the active ingredients from hazardous environments, i.e. oxidation, heat, acidity, alkalinity, moisture or evaporation.

It also simultaneously, protects the ingredients from interacting with other compounds in the system, which may result in degradation or polymerisation. Another important advantage of this versatile technology is its controlled release properties that seem to be the best choice for increasing efficiency and minimising environmental damage (Anon, 2005; Holme, 2004; Milmo, 2006; Nelson, 2001).

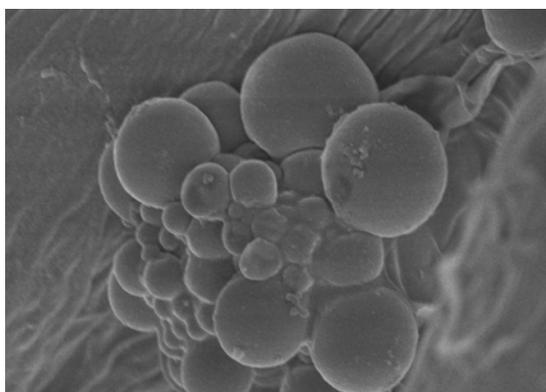


Fig. 1. SEM Image of Microcapsules

Microencapsulation is actually a micropackaging technique that involves the production of microcapsules which act as barrier walls of solids or liquids. The microcapsules are produced by depositing a thin polymer coating on small solid particles or liquid droplets, or on dispersions of solids in liquids. The core contents are released under controlled conditions to suit a specific purpose (Mei, 1995; Nelson, 2001; Simon, 2006).

Figure 2 shows the general structure of a microcapsule which generally consists of two major components:

- 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.

- Wall Shell

A polymer coating that surrounds the active ingredients which may also be called the wall, shell, external phase, membrane or matrix. It may be natural, semi-synthetic or synthetic polymer.

The release mechanisms of the core contents vary depending on the selection of wall materials and more importantly, its specific end uses. Table 1 demonstrates the relationship between the textiles end uses and their release mechanisms. 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 (Anon, 2005; Holme, 2003; Sudha, et al., 2005).

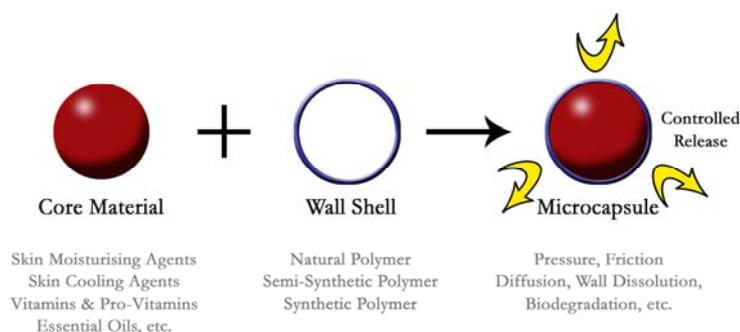


Fig. 2. Structure of a Microcapsule

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content may be released by friction, pressure, change of temperature, diffusion through the polymer wall, dissolution of the polymer wall coating, biodegradation etc (Anon, 2005; Holme, 2003; Sudha, et al., 2005).

Table 1. Textiles End Uses and their Release Mechanisms

End Uses	Release Mechanisms
Cosmetic Textiles (On contact with skin)	Friction, Pressure, Biodegradation (Achwal, 2003; Anon, 2005; Cognis, 2005)
Aromatherapy & Fragrance Textiles	Friction, Diffusion through Polymer Wall (Celessence International Limited, 2006; Devan Chemicals, 2007)
Phase Change Material (Thermoregulation)	Temperature (Shin et al., 2005)
Thermochromic & Photochromic (Colour Changing System)	Temperature, Ultra-violet Light (Sawada et al., 2005; Sekar, 1998; SolarActive® International, Inc., 2007)
Flame Retardant Textiles	Flame, High Temperature (Anon, 2005; Kover et al., 1997)

## 2.2 Microencapsulation: Historical Background

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 (Simon, 2006).

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 (Aggarwal, 1998; Simon, 2006).

Since then, the US-based Euraland America acquired the rights to subsequently develop and market microencapsulation technology for all new applications (Erkan et al., 2004).

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 (Erkan et al, 2004; Nelson, 2001).

The textile industry has reacted slowly to the possibilities of microencapsulation. It was not until the 1990s that a few commercial applications appeared at the research and development stages (Nelson, 2001).

In the 21<sup>st</sup> century, more commercial applications of microencapsulation in the textile industry can be found, particularly in Western Europe, Japan and North America. The technique is being used to develop textiles with new properties and added value, including climate-controlled materials, fragrance release fabrics, cosmetic, therapeutic and medical textiles.

Textiles and garment manufacturers are very optimistic that this novel technology will open up exciting market opportunities and a world of possibilities for consumers (Anon, 2005; Fisher, 2002; Swerev, 2001).

## 2.3 Microencapsulation Methods

Many different manufacturing approaches have been adopted for microencapsulation. This paper discusses the most commonly used

microencapsulation processes, including (1) Complex Coacervation, (2) Polymer-Polymer Incompatibility, (3) Interfacial Polymerisation and In Situ Polymerisation, (4) Spray Drying, (5) Centrifugal Extrusion, (6) Air Suspension Coating, (7) Pan Coating, and (8) Emulsion Hardening Process (Aggarwal et al, 1998; Simon, 2006; Holme, 2004; Microtek Laboratories, Inc., 2007)

### 1. Complex Coacervation

This method takes advantage of the abilities of cationic and anionic water-soluble polymers to interact with water, forming a liquid, polymer-rich phase called complex coacervation. When the complex coacervate

forms, it will be in equilibrium with a dilute solution called the supernatant. The supernatant acts as the continuous phase, whereas the complex coacervate acts as the dispersed phase. As the water-insoluble core materials are dispersed in the system, each droplet or particle of dispersed core material is spontaneously coated with a thin film of coacervate. The liquid film is then solidified to make the capsules harvestable. This method has been applied to encapsulate many water-immiscible liquids and is used in a variety of products. Figure 3 provides a schematic presentation of the formation of microcapsules of oil droplets in water by complex coacervation.

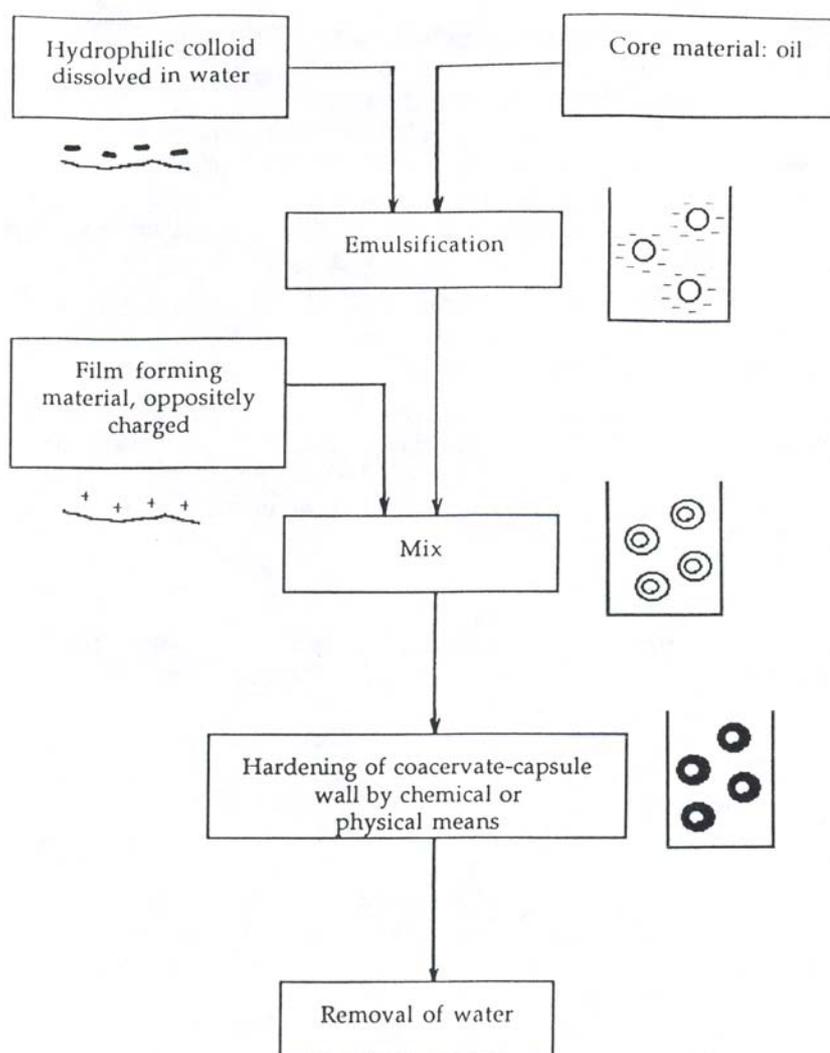


Fig. 3. Schematic presentation of formation of microcapsules of o/w by complex coacervation (Simon, 2006)

## 2. Polymer-Polymer Incompatibility

Two chemically different polymers dissolved in a common solvent are incompatible and do not mix in the solution. The essential chemicals repel each other and form two distinct liquid phases. One phase is rich in polymer and designed to act as the capsule shell while the other is rich in incompatible polymer. The incompatible polymer is presented in the system to cause the formation of two phases. It is not designed to be part of the final capsule shell, although a small amount may remain entrapped in the final capsule as an impurity. The process is normally carried out in organic solvents and used to encapsulate solids with a finite degree of water solubility.

## 3. Interfacial Polymerisation and in Situ Polymerisation

In interfacial polymerisation, the capsule shell is formed at or on the surface of a droplet or particle by polymerisation of reactive monomers. A multi-functional monomer is dissolved in the liquid core material. The resulting solution is dispersed to a desired drop size in an aqueous phase that contains a dispersing agent. The aqueous coreactant, usually a multi-functional amine, is then added to the aqueous phase. A rapid polymerisation reaction is then produced at the interface which finally generates the capsule shell. Both the liquid and solid can be encapsulated by interfacial polymerisation reactions, but the polymerisation chemistry is typically different.

For in-situ polymerisation, capsule shell formation occurs because of the polymerisation of monomers that is added to the encapsulation reactor, similar to interfacial polymerisation. However, no reactive agents are added to the core material. Polymerisation occurs exclusively in the continuous phase and on the continuous phase side of the interface formed by the dispersed core material and continuous phases. Polymerisation of reagents located there produces a relatively low molecular weight prepolymer. As this prepolymer grows in size, it deposits onto the surface of the

dispersed core material being encapsulated, where polymerisation with crosslinking continues to occur, thereby generating a solid capsule shell.

## 4. 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. Figure 4 illustrates a laboratory scale spray dryer.



Fig. 4. Laboratory Scale Spray Dryer (Keison International plc, 2005)

In the widely used spray drying process, the dried solid is formed by spraying an aqueous solution of the core material and the film-forming wall materials as fine droplets into hot air. The water then evaporates and the dried solid is usually separated by air-separation. This method has been used to encapsulate labile materials because of the brief contact time in the drier. However, one disadvantage of using the spray drying method is that some low-boiling point aromatics can be lost during the drying process. Another disadvantage is that the core material may also form on the surface of the capsule, which allows for oxidation and possible scent changes of the encapsulated product.

### 5. 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 place 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 400-2000 $\mu$ m in diameter. Since the drops are formed by the breaking up of a liquid jet, the process is only suitable for liquid or slurry. Figure 5 demonstrates a schematic diagram of a centrifugal two-fluid nozzle that was used to produce microcapsules.

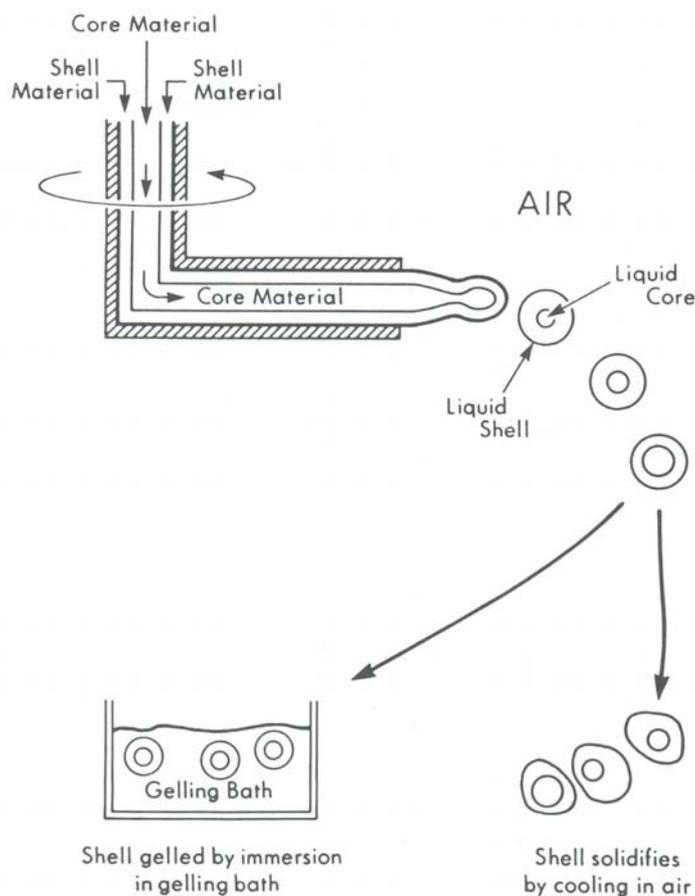


Fig. 5. Schematic diagram of centrifugal two-fluid nozzle that was used to produce microcapsules (Simon, 2006)

### 6. Air Suspension Coating

In air suspension coating, the particles are coated by dissolved or molten polymers while suspended in an upward-moving air stream. During the process, the solid particles to be encapsulated are first placed in a coating chamber where they are suspended in an air stream, which causes the cyclic flow of

particles passing through a nozzle at the chamber bottom.

The nozzle sprays a liquid coating phase onto the particle. The freshly coated particles are carried away from the nozzle by air stream and up into the coating chamber. The coating solidifies because of solvent evaporation or cooling of a melt. At the top of the spout, the particles settle back into the bottom of the

chamber to repeat the cycle. The cycle is repeated many times during the time frame of a few minutes until the coating has been applied to the desired level of thickness. Air-suspension coating of particles by solutions or melts generally gives better control and flexibility.

However, it is commonly used to encapsulate tablets, granules, crystals and powders. It is not used with liquid unless they are absorbed on a porous solid.

#### 7. Pan Coating

Widely used in the pharmaceutical industry, this method is a traditional industrial procedure for forming small, coated particles or tablets. During the pan coating process, the particles are tumbled in a rotating pan or other device while the coating material is applied slowly at a controlled temperature profile. Additional coatings of film-forming polymers may be added in successive stages.

#### 8. Emulsion Hardening Process

Emulsion hardening microencapsulation processes can be achieved when the core compound is highly soluble in the polymer solution (wall). The mixture is emulsified in an immiscible liquid and then the solvent is removed by evaporation, extraction etc. The core compound is solidified inside the polymer solution droplet and thus, forms the microcapsule. One typical example of this process is the production of poly(lactic) acid microcapsule for use in injectable particle systems.

### 2.4 Microencapsulation Applications in Cosmetic Textiles

In cosmetic textiles, the major interest in microencapsulation is currently in the application of vitamins, essential oils, skin moisturising agents, skin cooling agents, anti-aging agents etc. Focusing on the field of cosmetic textiles, the techniques of producing microcapsules containing essential oils and cosmetic substances have been studied extensively in the past.

Yamato et al. prepared microcapsules comprising

of active substances acting to improve the physiological conditions of human skin. The microcapsule would not break during production, but was gradually released when the textile structure was subjected to light pressure created by movement of the human body (US Patent, 1993).

The possibilities of using  $\beta$ -cyclodextrin as wall material have been investigated by a number of researchers (Hak et al. 2000; Wang et al, 2003).

Hak et al. investigated the flexibility of  $\beta$ -cyclodextrin as a protective wall.  $\beta$ -cyclodextrin was embedded onto cellulose fibres by using N-methylol-acrylamide. Benzoic acid and vanillin, which acted as an anti-bacterial agent and an aroma respectively, were encapsulated. It was claimed that the anti-bacterial activity was retained after 10 laundering cycles (Hak et al., 2000).

Wang and Chen developed aromatherapeutic textiles by using fragrance with  $\beta$ -cyclodextrin inclusion compounds and fixing them onto cotton fabrics with low temperature by using a conventional pad-thermofixed method. The fragrance release rates were greatly decreased and the results of sensorial evaluations showed that the performance of the fabric lasted for over 30 days (Wang et al., 2005).

Nelson et al. introduced the use of waste yeast cells in the microencapsulation process. After encapsulating the core material, the yeast cells were attached to both cotton and wool fibres by using crosslinking agents and binders. The processes of filling the yeast cells were very simple and the use of yeast cells as wall material generally provided several advantages, such as high loading, inthermoplastic, protection from light, oxygen and hazardous environments, and cost effectiveness (Bishop et al., 1998).

Copete Vidal et al. invented chitosan-based microcapsules containing various active components and investigated their durability with a mixture of microcapsules and a binding agent. With a finishing that used microcapsules and a binder, the active ingredients were released and found to wash out less quickly, and a high degree of hydration was also achieved (US Patent, 2005).

Korean researchers prepared melamine resin microcapsules containing Migrin oil by the in situ polymerisation method. The structure, mean particle size and size distribution, morphologies, thermal properties and released behaviours were characterised and discussed (Hong et al., 1999).

They also prepared poly(L-lactide) microcapsules for fragrant fibres by an interfacial precipitation method through solvent evaporation from water-in-oil-in-water emulsion. The microcapsules were then uniformly printed on cotton fabrics and the resulting fabric could withstand 15 cycles of washing (Hong et al., 2000).

Boh and Knez reported microencapsulation development in textile applications and prepared melamine-formaldehyde microcapsules containing essential oils and phase change materials. An in situ polymerisation method was used and the process was modified to achieve the desired characteristics of a microcapsule wall (Boh et al., 2006).

The special features of Questice provide a brainstorming development in a fully encapsulated system. Questice is a slow release coolant which is very mild and has little or no odour. On contact with skin, Questice is hydrolysed by the skin's natural enzymes to produce menthol, giving an extended cooling sensation.

Pyrrolidone carboxylic acid, a natural moisturising factor (NMF), is also released during this process. Equipped with the functional effects of Questice on fabric, a cooling effect is slowly released and is body responsive, providing cooling when it is needed (Kumar, 2004; In-Cosmetics, 2007).

At the same time, many researchers have also put forth much effort on improving the durability of microencapsulated functions. This is relatively the most difficult task in preparing cosmetic textiles.

Li et al. investigated the effects of UV curing for encapsulated aroma finishing on cotton. The aroma function was prolonged to 50 wash cycles whereas the traditional curing method could only withstand 25 wash cycles. If a cotton fabric was finished with the selected aroma capsule and UV resin, and cured under optimal conditions, the aroma function could withstand 50 wash cycles (Li et al., 2005).

Chang integrated the processing procedures of fabric treatment techniques with low temperature plasma, natural oil essence microencapsulation and fabric coating techniques to improve the adhesion property of microcapsules with fabrics. This invention increased not only the adhesion area of microcapsules on the fabric, but also enhanced the use for oil essences and promoted the additional value of the fabric (US Patent, 2005).

### 3. Commercially Available Cosmetic Textile Products

Microencapsulation technology offers many opportunities to improve the properties of textiles or enhance them with value-added functions. Many textile chemical companies have put forth much investigation in this area and offer various microencapsulation treatments that aim for skin care benefits.

#### Cognis – Skintex®

Cognis, a textile chemical company with headquarters in Germany, has developed a microencapsulation based cosmetic treatment for textiles, known as Skintex®, as shown in Figure 6.



Fig. 6. Cognis – Skintex® Microencapsulation Cosmetic Textile Product (Cognis, 2005)

The active ingredients are encapsulated by using chitosan, which is a substance made from the shells of shrimps. The microcapsules are embedded onto the fabric by exhaustion during wet processing and it is applicable to both natural and synthetic materials. A series of products are

marketed with moisturising, cooling, energising, relaxing, anti-heavy legs and mosquito repellent properties. The active ingredients are released by two separate mechanisms.

One of the methods is by the light friction created between the microcapsules and the skin. The other important method is that the chitosan membrane is biodegraded by the enzymes that are naturally present in skin. According to the washing instructions, these active agents will remain after several washes. Reloading of the active ingredients makes it possible for customers to recharge them for prolonging the functional effects.

### **Speciality Textile Product - BioCap**

Another chemical company based in the United Kingdom by the name of Speciality Textile Product also makes use of the microencapsulation technology to develop their biocapsule products called BioCap. The active ingredients are those that are widely used in the cosmetics industry, including Vitamin A, D, E and aloe vera, which provide various skin care benefits and promote a sense of well-being.

As the fabric is rubbed, the vitamins and aloe vera are released and absorbed by the human body. This cosmetic textile treatment can be applied to a wide range of fabrics for bedding, underwear, T-shirts, stockings and socks. The company is now continuing to explore the performance apparel market through the use of the microencapsulation technique. It markets anti-cellulite treatments which enable a body cooling effect and thermal-regulating treatment which has temperature balancing effects. The application of a depilatory agent to hosiery, which has already been patented, enables an automatic removal of unwanted hair during wear. The microcapsules are ruptured by the force created by the hair stubble as it grows.

### **Woolmark Development International Ltd (WDI) - Sensory Perception Technology**

Another new leading edge microencapsulation treatment for textiles is the so called Sensory Perception Technology (SPT), which is distributed by Woolmark Development International Ltd (WDI).

It is a microencapsulation delivery system for textiles with fragrance or active ingredients being encapsulated and then released when there is direct contact with skin. Figure 7 shows the scanning electron microscope (SEM) image of this commercial product.



Fig. 7. Sensory Perception Technology Microencapsulation Cosmetic Textile Product (Celessence International Limited, 2006)

The microcapsules contain various skin benefits, such as moisturising skin, repelling insects, anti-bacterial and anti-fungal abilities, and treating cellulite. The microcapsules release their contents in a controlled manner and will only break through normal wear and tear. The performance can be retained over a long period of time and through multiple domestic laundering. It is compatible with all types of fibres and has a wide range of application potentials, including apparel, hosiery, interior textiles etc.

Successful retail introductions include socks and leg wear in the U.S. and Europe, both of them incorporate aloe vera for moisturising benefits.

## **4. Potential Development and Conclusion**

The textiles industry is currently experiencing a revolution that aims at the unique needs of the modern consumer. Cosmetic textiles are increasingly popular and expanding considerably in the textile industry as its marketing message

becomes more widely appreciated. Many textile auxiliaries companies are now targeting this specific enhancement in apparel performance.

Owing to the increasing supply of commercial cosmetic textiles, systematic characterisation and representative measurements are thus concededly essential to prove and verify their performance and efficiency.

The integration of aromatherapy in textile application is a novel and user-friendly idea that enables an alternative means for essential substance delivery systems. At present, the application of aromatherapy in textiles is commonly concentrated on skin care benefits and stress management. More innovative ideas can be anything imaginable, such as hair care and treatment, body slimming and even medical applications etc.

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.

Several commercial cosmetic finishing products are currently available in the market. However, practical methods for proving the effectiveness of these products are doubtful. Hitherto, many research works have focused on the material characterisation methods and the release mechanism of cosmetic finishing products. Yet the fabric performance properties and their responses to human skin are often neglected. In other words, there is still a lack of empirical characterisation methods to assess the performance of cosmetic textiles. A systematic characterization system should be developed for evaluating the effectiveness of cosmetic textiles.

As a whole, it is anticipated that the development of cosmetic textiles will continue to grow and explore completely new possibilities for providing bioactive bodily care functions to wearers in the near future. It is a challenging and exciting time for the textile industry. The textile industry must continue to explore and develop functional textiles that fit capricious consumer behaviours.

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