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Microencapsulation in textile industry

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Abstract
Due to competition, adding value, and expanding market opportunities, the significance of active coatings for smart textiles grew quickly. Since the past ten years, people look for functional as well as attractive qualities in products. Due to their unique characteristics, such as the protection of the active ingredient, controlled release, compatibility, and also the provision of a higher specific surface area to enhance the functionalities, microencapsulation and microcapsules have been playing a significant role in this context in order to achieve the desired properties. A broad variety of core materials, including aqueous solutions, water-immiscible liquids, and solid particles, may be encapsulated with this technology. Although several methods have been employed for a textile application, such as interfacial polymerization, *in-situ* polymerization, phase coacervation, or solvent evaporation, the formulation of microcapsules made of polymeric material and an encapsulating active principle is challenging. The most appealing commercial applications today focus on enhancing the capabilities of textiles, such as controlled release of active ingredients for cosmetic textiles, textiles that repel insects or provide medical benefits, thermal comfort with phase change materials, aesthetic effect with thermochromic solution, or wearer protection.

Keywords: Microcapsules, core material, release, technique

Introduction
Numerous new cleaner and greener methods have been developed as a result of growing environmental concerns and requests for environmentally friendly textile processing. Enzymatic finishing of textiles, plasma technology, finishing by natural ingredients, and microencapsulation are only a few of the technologies that science has developed for environmentally friendly textile processing.
Using tiny particles or droplets encased in a coating, the process of micro-encapsulation creates miniature capsules with a variety of beneficial features. The wall of the microcapsule is referred to as the shell, coating, or membrane, whilst the substance within is referred to as the core material. Microcapsules typically range in diameter from a few micrometres to a few millimetres. This method is now frequently used for finishing textiles as well. By microencapsulating the core substance, several unique and useful features may be added to the textiles. Any substance with a specific job to do for the fabric can serve as this core material.
Sportswear and medical fabrics are also increasingly using microencapsulation of anti-microbial chemicals. This method has a wide range of uses, including in the finishing of textiles, industrial chemicals, agrochemicals, food additives, flavours and essences, pesticides and herbicides, sealants, cosmetics, nutraceuticals, pharmaceuticals, and adhesives (Hammad *et al.*, 2011) [17].

Core components
It is the particular substance that has to be coated; it may be liquid or solid in foundation. Materials that are scattered or dissolved may be present in the liquid core. Active ingredients, stabilizers, diluents, excipients, release-rate retardants, or accelerators can all be a part of the solid core. Numerous core materials, such as living cells, adhesives, tastes, agrochemicals, enzymes and medications can be encapsulated (Rani and Goel, 2021) [13].

Coating materials
The choice of coating materials determines the physical and chemical characteristics of the final microcapsules/microspheres. They might be either hydrophilic or hydrophobic polymers, or a mix of the two. Alginates, gelatin, polyvinyl alcohol, ethyl cellulose, and cellulose acetate are a few coating materials that have been effectively employed. It needs to create a film that is consistent with the primary content (Mali *et al.*, 2013) [11].

Reasons for Encapsulation

Materials are microencapsulated to expand their field of action while preventing the environment they pass through from having a negative impact. The following are the main justifications for encapsulation:

- Separation of incompatible parts
- The transformation of fluids into freely moving solids
- Enhanced steadiness (protection of the encapsulated materials against oxidation or deactivation due to reaction in the environment)
- Masking of encapsulated compounds' odour, taste, and activity
- The nearby environment is safeguarded.
- Managed release of active ingredients (sustained or delayed release)
- The selective release of encapsulated substances (Chanana *et al.* 2013) [4].

Important new properties, such improved stability and the regulated release of active substances, may be added by the microcapsules to clothing and textiles. Its durability is increased by microencapsulation, a special process that enables a controlled release of these qualities as and when needed (Chinta and Wane, 2013) [5].

Herbal extracts are utilised as the "core material" and the "wall material" in the herbal finishing of textiles to produce a micro-encapsulated finish that is more durable than the other finishing processes. This wall material may be a chemical, such as sodium alginate, or it may be a substance derived from a plant, like gum acacia. When evaluated for anti-microbial activity and wash endurance up to 20 washes, the microencapsulated herbal extracts became increasingly effective.

The placement of fragrance-encapsulated capsules onto garments is another extremely well-liked usage for microencapsulation. Under typical circumstances, the capsules attached to the materials are resistant to breaking. When pressure is applied to the cloth, the capsules' smell is released, acting as a therapeutic component in aromatherapy (Sudha *et al.*, 2005) [16].

Techniques of Microencapsulation

Spray-Drying

For the most part, perfumes, oils, and tastes are microencapsulated using a low-cost commercial method called spray-drying. This process involves spraying core particles into a heated chamber while they are suspended in a polymer solution. As the solvent evaporates, the shell material hardens on top of the core particles, resulting in poly-nuclear or matrix-type microcapsules. When using a lot of core material, the enclosed particles are frequently aggregated, which might result in uncoated particles. However, larger core particle loadings of up to 50–60% have been seen. Due of the foul smells and environmental issues caused by a solvent-borne system, water-soluble polymers are mostly employed as shell materials (Ghosh *et al.* 2011) [7].

Coating with air suspension

Better control and flexibility are provided by this process. While floating in an air stream travelling upward, the particles get covered. A perforated plate with various hole designs inside and outside of a cylindrical insert supports them. To fluidize the settling particles, only enough air is allowed to ascend through the outer annular region. Particles ascend quickly because the majority of the rising air—which is often heated—flows within the cylinder. They settle back onto the outer bed near the top when the air stream slows and diverges, and they descend again to complete the cycle. In a few minutes, the particles go through the inner cylinder several times. Numerous coating materials are available as options for microencapsulation using the air suspension technique. In equipment with capacities ranging from one pound to 990 pounds, the procedure is capable of applying coatings in the form of solvent solutions, aqueous solutions, emulsions, dispersions, or hot melt. Air suspension methods may successfully enclose core components with micron or submicron sized particles, although this is often done by agglomerating the particles into a larger size (Bansode *et al.* 2010) [2].

Solvent Evaporation

This method involves using a liquid production vehicle to carry out the activities. A volatile solvent that is immiscible with the liquid production vehicle phase is used to dissolve the microcapsule coating. In the coating polymer solution, a core substance that will be microencapsulated is dissolved or disseminated. To create the proper size microcapsule, the core coating material combination is disseminated in the liquid production vehicle phase by agitation. The solvent for the polymer is then evaporated by heating the mixture, if necessary. A matrix-type microcapsule is created when the core material is dissolved in the covering polymer solution. When all of the polymer's solvent has evaporated, the liquid vehicle's temperature is lowered to room temperature while still being stirred. The microcapsules can now be employed as a solution, a coating on surfaces, or as isolated powders (Kumar and Rane, 2004) [9].

In-situ polymerization

A single monomer is directly polymerized on the particle surface in a few microencapsulation techniques. Cellulose fibres are encased in polyethylene in one procedure, for instance, while submerged in dry toluene. The average deposition rate is 0.5 m/min. The range of coating thickness is 0.2-75 m (0.0079-2.95 mils). Even across sharp projections, the coating remains consistent (Bansode *et al.* 2010) [2].

Use of Microencapsulation Textiles

Phase-change substances

Phase-change materials have the ability to convert an aggregation from a solid to a liquid within a specific temperature range. Extreme temperature changes are reduced using phase-change material microcapsules. This makes it easier for clothes to regulate its own temperature and maintain a steady temperature. Different fabrics, such as vests, parkas, snowsuits, blankets, mattresses, and duvets, are used with these sorts of microcapsules (Nelson, 2002) [12].

Fragrance finishes

Despite numerous instances of fragrance finishes being directly applied to fibres and fabrics, the aroma does not persist for more than two wash cycles. When applied to textiles, the process of microencapsulating perfumes prolongs the impact. This method is frequently employed in aromatherapy, where microcapsules may include flavours from essential oils like lavender, rosemary, pine, etc. In essence, this is done to relieve sleeplessness, headaches, and to stop unpleasant odour.

Fire retardant

To solve the issue of diminished softness brought on by the direct application of fire-retardant chemicals, microcapsules with a fire-retardant core were created. They are employed on materials for military purposes, such as tentage (Shrimali and Dedhia, 2015) [14].

Microcapsules that are thermochromic and polychromic (colour-changing technology)

The thermochromatic color-changing system changes colour in reaction to temperature, and the photo-chromatic color-changing system changes colour in response to UV radiation. Polychromic and thermochromic microcapsules are used in textiles for product labelling, security, and medicinal purposes. There are microencapsulated thermochromatic dyes that, in reaction to human touch, change colour at particular temperatures (Nelson, 2002) [12].

Antimicrobials

Bacteria frequently induce the microbiological degradation of textiles, which results in the loss of a variety of valuable qualities. Anti-microbial coatings, which may be applied with the aid of microencapsulation, can be used to prevent this issue. This finish is specifically for technical and medical fabrics (Bishop *et al*. 1998) [3].

Counterfeiting

Microencapsulation can be used to combat the imitation of high-end fabrics, branded items, and designer goods. A colour former or an activator is included in microcapsules affixed on labels. Microcapsules rupture under the influence of UV light or a solvent, releasing their contents and allowing for the development of colour, which allows for identification (Nelson, 2002) [12].

Release Mechanism of Microcapsules

Depending on the goal of microencapsulation, release mechanisms of materials are affected. The method of external pressure, which ruptures the microcapsule wall and allows the liquid to escape from the core, is frequently utilised. In antistatic and perfumes for textiles (abrasion in washers and dryers), or for grinding and cutting additives, abrasion releases the core substance of the microcapsule wall. In many applications, core materials are released by heat as well. Fire retardants used in wall papers, carpets, curtains, and flame-resistant clothing are microencapsulated and released when the capsule walls are burned (Venkatesan *et al.* 2009) [18].

The microencapsulated phase change components must stay enclosed within the impermeable and mechanically robust microcapsule wall in order to continue functioning for several phase transition cycles. These phase change materials are used in fabrics, shoes, and insulation for buildings since their primary purpose is the active collection and release of heat (Jyothi Sri *et al.*, 2012) [8].

Recent Application of Microencapsulation in Textile Industry

On cotton fabric, Wolela applied essential oils made from green, orange, and black (a blend of green and orange) lemon peel (Citrus limon). By measuring the zone of inhibition on cloth treated with fragrance, the antibacterial properties were assessed against the gram-positive Staphylococcus aureus and gram-negative Escherichia coli bacteria. In comparison to fabrics finished with orange and black lemon peel essential oils, the cotton fabric finished with green lemon peel essential oil showed strong antibacterial activity against Staphylococcus aureus (24-30 mm) and Escherichia coli (22-26 mm) germs. In comparison to the orange lemon peel, the black lemon peel essential oil (which is 50% green and 50% orange) demonstrated stronger antibacterial activity against Staphylococcus aureus (18-26 mm) and Escherichia coli (18-25 mm) germs. In comparison to the other two lemon peel essential oils, it was observed that the essential oil from the green lemon peel had a more powerful impact and long-lasting antibacterial ability (Wolela, 2020) [19].

Cross-linked polymeric microcapsules may be utilised to administer vetiver oil, according to Ali *et al.* Alginate-gellan gum mixes were used to create microcapsules utilising the ionotropic gelation process, which appropriately and repeatedly cross-linked the microcapsules. The prepared microcapsules that contained vetiver oil seemed to have a spherical shape. The encapsulated vetiver oil within the microcapsules made of alginate-gellan gum blends was found to be capable of providing a prolonged release of encapsulated oil in a sustained manner, indicating the potential for the sustained release sedative application (Ali *et al.* 2019) [1].

Geranium essential oil standard microencapsulation procedure by Kumari *et al.* The created microcapsules were medium in size, had good size and distribution regularity, and had sharp and thick walls. The ideal variables were geranium essential oil, gum, and gelatin with in ratio of 1:4:4 at temp 50° C with starting pH 4.5 and final pH 9.0. It was determined that the essential oil microcapsules could be prepared using these optimised factors and applied to fabrics to create fragrant textiles (Kumari *et al.* 2017) [10].

By using the pad-dry-cure method, Stan *et al.* incorporated melamine-based microcapsules featuring sage/rose essential oil content into cotton as well as cotton/polyester blended fabrics. The microcapsules were attached to the textile substrates using a commercial acrylate-based binder, and the stability of the scent against outside influences was evaluated. The physical and mechanical properties of the produced fabrics were examined. SEM was used to analyse the dispersion of microcapsules on the surface of the fabric both before and after 5 wash cycles and 1,000 abrasion cycles. The outcomes demonstrated that fragrance treatment had no impact on the mechanical and physical properties of woven materials. The results of air and water vapor permeability for all the treated fabric samples meet the minimal standards for skin-contact apparel items and home textiles, i.e., at least 30 L/m2/s on air permeability as well as at least 25% in water vapour permeability. A functionalized treatment including rose/sage microcapsules resisted five washing cycles and 1,000 abrasion cycles, according to the results of an examination of the endurance of the aroma (Stan *et al.* 2019).

Conclusion

The practise of microencapsulation is used in practically every sector in the modern world of evolving technology. It has developed into a notably effective procedure that improves the fabric's quality and ensures its longevity. Functional finish fabrics, textiles used in medicine and healthcare, textiles used in aromatherapy, textiles used in cosmetics, and many more industries make extensive use of this technology.

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