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# Micro/Nano Capsulation: Textile Functional Features and Application

**Abdallah N. El-Wekil [a], Amany G. Maraae [a], Lobna N. Allam [a], Lamiaa S. Abd-Elaal [a], and Ahmed G. Hassabo [b]***

[a] *Benha University, Faculty of Applied Arts, Textile Printing, Dyeing and Finishing Department, Benha, Egypt*

[b] *National Research Centre (Scopus affiliation ID 60014618), Textile Research and Technology Institute, Pre-treatment, and Finishing of Cellulose-based Textiles Department, 33 El-Behouth St. (former El-Tahrir str.), Dokki, P.O 12622, Giza, Egypt*

**Abstract**

The given text selection provides information on eco-friendly textile processing techniques, particularly focusing on microencapsulation. Microencapsulation involves creating tiny "packaging" structures known as microparticles or microcapsules that contain bioactive compounds or polymers. It is used to provide textiles with properties like thermoregulation, antimicrobial activity, fragrance, and mosquito repellency. Encapsulation has several purposes, including decreasing reactivity, preventing substance evaporation or loss, facilitating handling and storage, enabling regulated release, and masking taste, smell, and activity of enclosed components. The size of microcapsules can range from millimeters to nanometers. Various release mechanisms for microcapsules are external pressure, internal pressure, abrasion of walls, burning, radiation, temperature changes, chemical reactions, and enzymatic degradation. Microencapsulation of essential oils has shown potential in wound healing applications. Moreover, antimicrobial textiles are created by encapsulating non-toxic antimicrobial compounds to control the growth of bacteria on textiles. Mosquito-repellent textiles can also be developed using micro/nanocapsules containing repellent substances like essential oils.

**Keywords:** Microencapsulation, flame retardant, PCMS, UV protection, Aroma, Cosmeto-textiles.

## Introduction

Sciences has produced a number of eco-friendly textiles processing techniques, including as microencapsulation, natural product finishing, plasma technology, and enzymatic textile finishing.

Utilising cutting-edge technology, microencapsulation has been used to provide textiles useful properties like thermoregulation, antimicrobial activity, fragrance, and mosquito repellency. By microencapsulating the volatile and non-volatile components, a thin polymeric coating can delay the chemical's release and have a long-lasting functional effect.

Developing new biotechnological materials by microencapsulation has become challenging. The formation of tiny "packaging" known as microparticles, microspheres, or microcapsules—which are composed of structures containing one or more bioactive compounds or immobilised by one or more polymers—is referred to as microencapsulation. [1, 2]

The process of microencapsulating materials ensures that they are transported through an environment that won't damage them when they reach the action zone.

Encapsulation is commonly used for the following main purposes:

1. To decrease the reactivity of the item being encapsulated;
2. To stop the encased substance from evaporating or losing its contents into another medium;
3. Make it simpler to handle, apply, and store the enclosed substance.
4. Encourage regulated (delayed or prolonged) release.
5. Masking the taste, smell, and activity of the components that are enclosed. [2, 3]

* Corresponding author: Ahmed G. Hassabo, E-mail: aga.hassabo@hotmail.com, Tel. 00201102255513
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**Micro/Nano capsules**

Microcapsules vary in size from a few millimetres to a thousandth of a millimetre. Nanocapsules are microcapsules with a diameter in the nanometer range to emphasise their microscopic size. [4]

Several methods have been proposed for manufacturing microcapsules; the technique selected depends on the solubility, thickness, permeability of the shell, and physical characteristics. Physical, physicochemical, and chemical microencapsulation techniques are grouped into three groups. Physical , chemical and Physical - chemical methods. [1]

Through the use of various assemble blocks, LBL (Layer by Layer) microcapsules can be formed and combined with fabrics; functional textiles with varying degrees of stimulus-responsivity can be obtained by preparing the LBL microcapsules and coating them on fabrics; this work can potentially provide a technique to design stimulus-responsive textiles for applications in many areas. [5]

Encapsulating a substance at the micro or nano scale is important wherever it’s necessary to entrap a substance within a shell, permanently or temporally, in order to extend its life and stability and to control its release under specific environmental conditions. [4, 6-9]

**Release mechanisms**

Such effects in permeability and non-permeable microcapsules have been reported to be achieved by eight different release mechanisms.

1. External pressure: This procedure results in the mechanical breaking of the microcapsules.
2. Internal pressure: might perhaps lead to the microcapsule wall breaking, for instance, if the core shell contains substances that, when exposed to specific stimuli (such as radiation), change into gaseous products, as is the case when light synthetic leather is made.

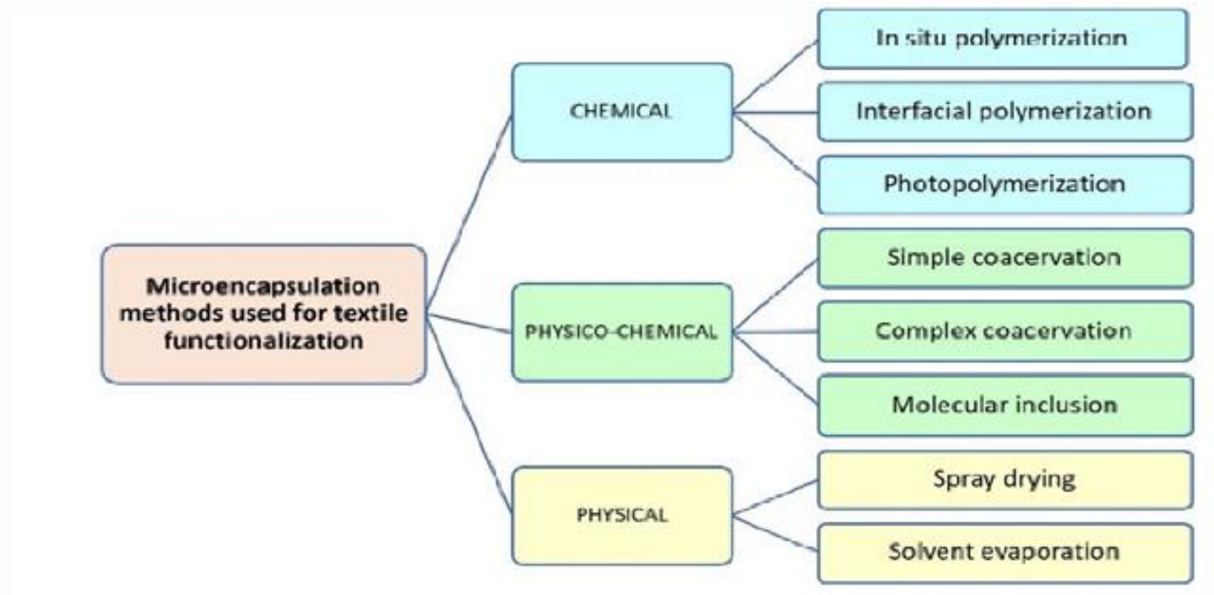



Fig. 1. Microencapsulation methods commonly used in textile. [10]

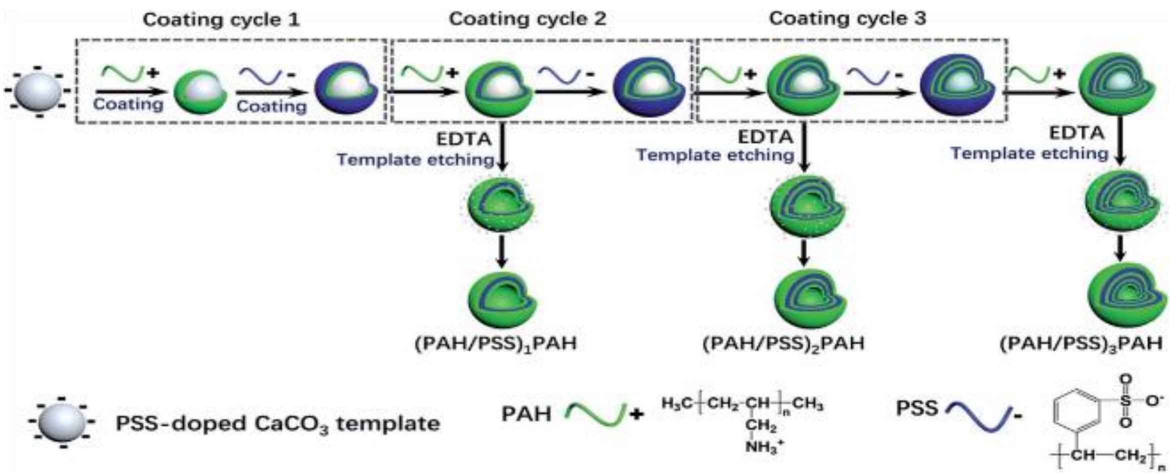



Fig2: microcapsules prepared via the layer-by-layer assembly [5]

3. Abrasion of microcapsule walls: This technique is frequently applied to fragrance release.
4. Burning: Fire retardants are released when a temperature reaches a particular point.
5. Radiation: This method can trigger photographic and light-sensitive processes, resulting in changes in the color of these fabrics due to the release of microencapsulated dyes.
6. Temperature Changes: Temperature variations can aid core material release. There are two separate processes for release:
    - Temperature-sensitive: When the crucial temperature is reached, the wall expands and falls.
    - Fusion-activated: The wall dissolves as the temperature rises.
7. Chemical reactions: This is the situation with microcapsules containing chemicals added to textile washing or cleaning formulations that are released throughout the wash cycle due to chemical composition or pH changes.
8. Enzymatic degradation: This is the case with microcapsules, which are destroyed by enzymes under strict circumstances. [1]

**Aroma Finishing using capsules**

In the textile industry, various finishes are applied to fabrics for a variety of purposes. The pleasant odour or scent that permeates food, spices, oils, and essential oils is known as the aroma or fragrance. We refer to them as "aroma compounds." When added to textile materials, fragrances in the form of essential oils and aromatic compounds provide the textile a pleasing scent that has the most positive impact on the wearer. Aroma Finish or Aromatic Finishes is the term for this procedure. [11-17]

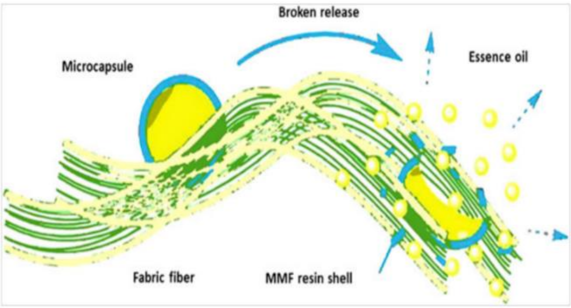
The study of the connection between psychology and scent technology, which elicits a range of certain sentiments and emotions including relaxation, enjoyment, and well-being, was given the name "aromachology" in 1982.

Most textile materials are exposed to bacteria that produce unpleasant odours, and as a result, they lose their freshness quickly. When sprayed to these materials, the fragrance finish enhances the usable goods' value. Aromatic fabrics provide a sense of freshness and wellbeing to the wearer. Additionally, the worlds of alternative and medical healing employ these fabrics. [2]

**Patterned Printing of Fragrant Microcapsules to Cotton Fabric**

Scent-infused microcapsules were utilised to create a scented fabric. A melamine-formaldehyde polymer served as the foundation for the microcapsule wall, while an essential oil made up the core.

Compared to the patterned cloth, the completely printed fabric has distinct mechanical characteristics. Compared to all the patterned samples, the completely printed sample was stiffer and had less air permeability. Given the increased covered surface, this was to be expected. Because the dot printed samples had the same proportion of printed area, there was little variation between them. Given that the fabric's comfort, softness, and breathability complement the patterned samples, it is appropriate for use in the production of home textiles or clothing**.** None of the tested samples exhibited antibacterial activity. All samples exhibited moderate bacterial growth and no inhibition zones were present. All printed samples showed an indication of biodegradability as none of them were resistant to decay. All samples showed a reduction of more than 80% in their breaking strength after burial, and major morphological changes occurred in all samples. As a result, we can say that throwing away the printed samples at a landfill won't endanger the environment. Compared to the patterned fabric, the completely printed cloth had over half as much free formaldehyde as measured. Both the amount and the variation between all samples really decreased after washing. The patterned fabric may be worn without coming into direct contact with the skin, and the completely printed fabric can be used for household textiles, in accordance with **OekoTex** Standard 100, which controls its quantity in the completed textile. In conclusion, all of the samples—fully printed and patterned—are appropriate for technical fabrics as well as scented apparel that isn't worn in close proximity to the skin.. Due to the better mechanical properties of the patterned samples and the lower amount of formaldehyde, printing in a pattern can be recommended. [18]




. Fig3: Release of aroma microcapsules under external force[19]

**Micro/nanoencapsulation of essential oils focus on wound healing**

Wound healing is one of the key functions of natural essential oils. A regulated release rate can be achieved by encasing natural essential oils with wound-healing properties in a natural polysaccharide like chitosan or alginate. For example, curcumin, a constituent of turmeric, is extensively utilised in Southeast Asian nations as a spice, colouring agent, and traditional medicine for the treatment of inflammatory illnesses. Curcumin was encapsulated by Gong et al. (2013) in a poly(ethylene glycol)-poly(e-caprolactone) copolymer via solid dispersion, and the poly(ethylene glycol)-poly(e-caprolactone)-poly(ethylene glycol) thermosensitive hydrogel composite was loaded. [20-23]

When the prepared hydrogel was used as a wound dressing, it showed good tissue adhesiveness and a prolonged curcumin release period.

Additionally, the incision model has a high tensile strength, thick epidermis, and improved wound closure. High collagen content, excellent granulation, and high wound maturity were present in the prepared wound dressing.

Furthermore, because Plectranthus plants contain antibacterial metabolites including polyphenols and diterpenoids, several varieties of the plant have been used to treat a variety of illnesses. [24]

P. barbatus, P. hadiensis var. tomentosus, P. madagascarensis, P. neochilus, and P. verticillatus water solutions were used to extract the bioactive components, and their toxicity and antibacterial properties were assessed.

The extrusion/external gelation process was used to encapsulate P. madagascariensis extract into alginate beads.. Better biological activities were brought about by the extended stability of the encapsulated extract; nevertheless, no experimentation about the application of the encapsulated extract in wound healing is offered.

included a variety of essential oils, including eucalyptus, lemongrass, cinnamon, lavender, tea tree, elicriso italic, chamomile blue, and lemon oils, in sodium alginate with glycerol acting as a plasticizer. They recommended using this film as a wound dressing, however the antimicrobial test revealed that the majority of the essential oils stop Candida albicans from growing. Additionally, oils of peppermint, cinnamon, and lemongrass had strong antibacterial action against E. coli. [25]

In most studies, encapsulated essential oils were used as the film or hydrogel with wound-healing properties. Suggested approach is the application of encapsulated essential oils on the textiles to produce a wound dressing. An intelligent bandage can be released natural essential oils during therapy of skin. Fig 5 shows the application of wound dressing finished with micro/nanocapsules containing essential oils for wound healing. [26]

**Antimicrobial textiles**

Underware and sportswear made of natural fibres offer the ideal warm, damp habitat for the development of microorganisms.

Antibacterial textiles are in greater demand as a means of lowering the risk of nosocomial infections.

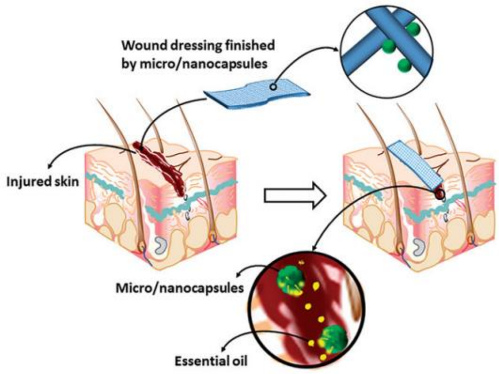



Fig 5: Application of wound dressing finished with micro/nanocapsules containing essential oils

A long-term controlled release for stopping or inhibiting the growth of hazardous bacteria is provided by the micro- and nanoencapsulation of non-toxic and environmentally acceptable antimicrobial compounds. By regulating the rate of release, encapsulation increases the textiles' capacity to be washed and ironed while extending the antibacterial effects of essential oils.

Most works employ the typical technique of pad-dry-cure. treated cotton cloth using acacia gum-encapsulated neem and Mexican daisy extracts as wall materials. The fabric showed higher antimicrobial activities against S. aureus than E. coli withstanding after 15 washes. [27-32]

Using a commercial binder at pH 5.5–6, microcapsules containing neem, tulsi, and turmeric were prepared using the simple diffusion technique and applied to cotton and silk textiles. They were then cured at 120 C for two minutes. The fixation of the microcapsules on the textiles was confirmed by SEM photographs of the treated fabrics. It was revealed that the antibacterial activity was particularly efficient against the chosen microorganisms. The silk fabric's air permeability was unaffected by finishing, whereas the treated cotton fabric's was less permeable than the control. applied geranium extract-containing microcapsules prepared using two coacervation-spray-drying and direct spray-drying processes to cotton fabric. Direct spray drying yields smaller capsules than coacervation-spray drying. The cotton fabric was treated with citric acid, dried at 80 degrees Celsius, and cured at 140 degrees Celsius for two minutes after the geranium microcapsules were adhered to it using the pad-dry-cure process. Gram-positive bacteria were more susceptible to the final materials than Gram-negative ones. The outer cell wall of the bacterium acts as a barrier to the antibiotics, which explains the geranium extract's poor efficiency against Gram-negative bacteria like E. coli. The cloth completed with direct spray-drying microcapsules demonstrated greater durability, but the durability rose to 15 washes with microencapsulation. [25]

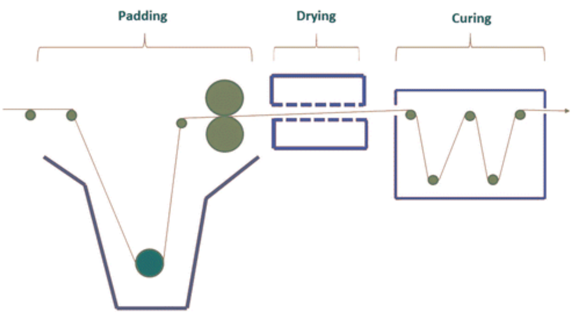


Fig6 : Pad-dry-cure technique

pad-dry-cure method wherein the fabric is first immersed in a solution containing the functional chemical, followed by drying and finally "curing" to fix the finish within the fabric [33]

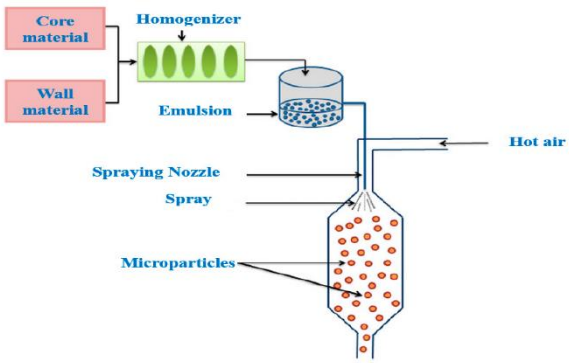


Fig 7: spray-drying technique

Using pH-responsive human serum albumin/silk fibroin nanocapsules immobilised onto cotton/polyethylene terephthalate (PET) blends loaded with eugenol, an antimicrobial phenylpropanoid, Quartinello, Tallian, Auer, and Schön produced novel antimicrobial wound dressings. Recent findings suggest that sweat glands play a role in wound reepithelialization. Therefore, eugenol release experiments were carried out using various pH-varying fake sweat formulations. At pH6.0, formulations with 10% silk fibroin and lower breakdown degrees showed the largest release, 41%. The functionalized cotton/PET blends were able to stop 33% of Escherichia coli and 81% of Staphylococcus aureus from growing after they were immobilised. The generated nanocapsules' high surface-area-to-volume ratio, homogeneous particle size, and concentration of silk fibroin were shown to be the main contributors to their potent antibacterial activity against both strains. Therefore, the production of antimicrobial textiles using nanocapsules loaded with an active natural compound that will not contribute to antibiotic resistance is seen as a potential future alternative to commercially available antiseptic wound dressings. [34]

**Mosquito-repellent textiles**

A chemical or finishing technique called mosquito repellent is applied to skin, clothing, or other surfaces to keep mosquitoes away.1. Out of the 3000 kinds of mosquitoes, only three are known to carry deadly illnesses. Only female mosquitoes possess the mouthpieces required to draw blood. Therefore, they are to blame for illnesses like Dengue, Chikungunia, malaria, and yellow fever, among others.2,3 There are mosquitoes that are discovered 200 kilometres from their original habitat. [6-9, 11, 35-39]

Chemical inhibitors served as poisons, growth regulators, repellents, and feeding deterrents against insects. However, repellents scented with essential oils derived from plants were favoured since they were thought to be a reliable and secure way to avoid mosquito bites. This prevented the user from being exposed to large amounts of dangerous chemicals while retaining the effects of pesticides for a predetermined amount of time. The pressure caused the fragrance-containing micro/nanocapsules on textiles to burst, releasing insects that were resistant to pesticides. These materials are frequently used in military gear, especially in tropical regions where mosquitoes are plentiful. Significantly, the fabrics treated with tea tree oil-containing microcapsules demonstrated their ability to repel mosquitoes. The materials that are encapsulated to repel insects are also appropriate for fabrics that have protein fibres, including such as wool as serving long-term protection against the larvae of moths.

Sodium alginate was used to encase lemon grass oil, which was then grafted onto polyester fabric using the pad-dry-cure method. The FTIR analysis showed that the peaks at 2000–3600 cm1 were associated with the functional groups of the microcapsules. For the completed fabric containing the lemon grass aqueous extracted from microcapsules and the methanolic lemon grass leaf microcapsules, respectively, a repellent activity of 92% and 80% was recorded. Additionally, after 15 washings, the cloth treated with the microencapsulated aqueous extract had 84% less repellent activity.

The herb Andrographis paniculata has a strong insect, snake, and mosquito repellent effect. produced sodium alginate microcapsules with andrographolide, which was removed from the plant in question, and applied them to the bamboo/cotton fabric until they were exhausted. 94% of the fabric treated with microcapsules and 96% of the fabric finished with direct application were effective in keeping mosquitoes away. After 30 washes, the encapsulated and direct finished textiles' respective efficiencies dropped to 52% and 40%. When microcapsules were applied to fabric, the repellent action remained longer than when it was applied directly. [25]

By using a complicated coacervation process, microcapsules containing citronella essential oil were created, and the resulting fabrics' repellant effectiveness was examined. The extractable content of citronella's primary components served as an indirect indicator of its release from treated textiles. Aedes aegypti mosquitoes were used to test the repellent efficacy of a human hand and arm coated in treated fabrics. Compared to textiles sprayed with an ethanol solution of the essential oil, fabrics treated with microencapsulated citronella offered a more robust and prolonged protection against insects, guaranteeing a repellent effect greater than 90% for three weeks. A straightforward, affordable, scalable, and repeatable process for generating encapsulated essential oils for textile application is complex coacervation.Repellent textiles were achieved by padding cotton fabrics with microcapsules slurries using a conventional pad-dry method. This methodology requires no additional investment for textile finishing industries, which is a desirable factor in developing countries. [40]

## UV- Protection textiles

Photoaging and sunburn are caused by excessive exposure to UV radiation from the sun, and skin cancer accounts for the great majority of cases in humans. Malignant melanoma is increasing every five years due to the ozone layer's 3% annual loss. The realization of the damaging effects of sunrays led to the necessity of using sunscreen preparations. The need for safer and more effective sunscreen products has grown due to their frequent and prolonged use. The most popular types of sunscreen formulations include emulsions, lotions, oils, gels, sprays, and sticks. Emulsions, a type of traditional sunscreen formulation, have a very low amount of UV protection power. They must stay on the skin for full protection, which means many applications are necessary. [11, 37, 41-49]

As a result of their high lipid solubility, some sunscreen agents might seep into the skin's deeper layers with repeated use. In addition to lowering the sun protection factor (SPF), this penetration causes the sun products' unintended negative effects. The goal of research has been to create novel delivery mechanisms with high SPFs and low concentrations of sunscreen agents. Considered the best UV filter, titanium dioxide (TiO2) is used in most high-protection formulas. It is a very stable, inorganic, and inert substance that is not broken down by UV radiation. On the skin, TiO2 does not cause allergic responses. It has been previously shown that there are several benefits to sunscreen compositions that combine organic filters with inorganic materials, such is lowering the amount of organic filter material to prevent the inherent irritation that many of these substances cause. The combination also lessens the whitening impact brought on by using a lot of inorganic sunscreen, such as TiO2, and allows for greater SPFs with simpler formulas. [50]

### TiO2-loaded nanocapsule preparation

The medium molecular weight chitosan from Sigma-Aldrich was utilised to make the nanocapsules with TiO2 inside of them. With vigorous stirring, chitosan was dissolved in a solution of acetic acid (0.1 weight percent in water). Using a microfeeder, the TS or P25 TiO2 that had been diluted in EtOH (10 ml) was added to the chitosan solution (KD Scientific, 781101). After preparation, the particles were dried and cleaned. The capsules that are filled with TS and P25 are referred to as C-TS and C-P25, respectively, from now on. [11, 30, 42, 47, 51-55]

The following protocol was used to produce the nanocapsules loaded with EPA and TiO2: After combining 0.1 ml of EPA with 10 ml of TS or a diluted P25 TiO2 solution with ethanol, a vigorous stir was performed. The EPA-containing TiO2 solution was added to the 10 ml of chitosan solution that had been made using the previously described technique. The nanocapsules were preserved for 24 hours at 190 8C in a freeze drier. A centrifuge running at 20,000 rpm was used to separate the encapsulated particles from the solvent. In the UV protection test, the nanocapsule sols that were acquired prior to conservation in the freeze dryer were utilised as a sunscreen ingredient. We designated C-E-TS and C-EP25 as the C-TS and C-P25 loaded with EPA, respectively.

To improve their capacity to guard against sun damage, titanium dioxide (TiO2) sol (TS) or TiO2 nanoparticles with a chitosan shell were enclosed. We assessed the ultraviolet (UV) absorbance and UV protection rate of nanocapsules containing TiO2. The impact of adding eicosapentaenoic acid (EPA) to the nanocapsules was investigated with respect to UV absorption. TiO2 crystallites in TS had a particle size of less than 30 nm, which was significantly smaller than the P25 TiO2 particles sold in stores. The loading efficiencies of TS in the encapsulation of TiO2 with chitosan were greater than those of P25 TiO2. The nanocapsules containing TiO2 particles varied in size, ranging from 30 to 80 nm. The addition of EPA to the irradiation wavelength increased the absorption range of nanocapsules. The TS-loaded nanocapsules exhibited a high

UV protection rate of up to 95% to both UV-A and UV-B. [56]

**Flame retardant textile**

Chemicals known as flame retardants are sprayed on objects to stop fires from starting or to limit their spread. Since the 1970s, they have been utilised in a wide range of commercial and industrial items to lessen the flammability of various materials.The following goods frequently have flame retardants added or applied to them.

Furnishings, including cloth blinds, carpets, mattresses, foam, and upholstery.

Electronics and electrical equipment, including wires and cables, as well as computers, laptops, phones, televisions, and home appliances.

Materials for construction and building, such as electrical cables and wires, as well as materials for insulation, such polystyrene and polyurethane foam insulation.

Transportation items, including bumpers, overhead compartments, seat coverings and fillings, and other components for cars, trains and aeroplanes. [57]

High flame retardance of polymer materials requires a large amount of flame retardant, but their physical properties are remarkably lowered. In the meantime, there is a strong need for a halogen-free flame retardant that prevents the production of toxic gases during combustion. However, the halogen-free flame retardant with a performance as high as the halogen flame retardant is not yet available. Here, we propose the halogen-free flame retardant's nanoencapsulation technology as one promising way to achieve a high flame retardant effect with a small amount of a conventional flame retardant. We were able to nanoencapsulate the halogen-free flame retardant in a layered compound by using a co-milling method as a nanoencapsulation technology. We discovered that the exfoliated and intercalated states of the nanocapsules are co-mixed with the resin. Despite the nanocapsule containing a modest quantity of flame retardant, the results indicate that the manufactured nanocapsule has a good flame retardant function. Additionally, by mixing the commercially available flame retardant with the nanocapsule, the synergy effect for the enhanced flame retardance has been examined. After that, the highly flammable cross-linked foam was used to verify the synergistic effect, and the material was rated as UL94 V-0.

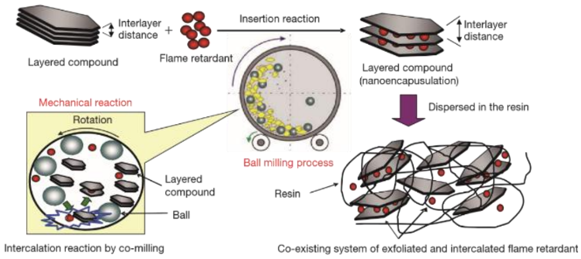


Figure 8: Nanoencapsulation of flame retardant prepared by the co-milling process.

It is possible to insert the flame retardant directly into the layered compound, as illustrated in Figure 8, without the need for ammonium salt expansion. The inserted flame retardant expands into the interlayer distance, replacing the quaternary ammonium salt, which lacks flame retardance. The nanocapsule is easily exfoliated in the resin by mixing and the flame retardant is nano-dispersed into the resin with the exfoliated layer, thereby significantly reducing the amount of the flame retardant through nanoencapsulation. [58]

A flame-retardant nonwoven substrate was created by using a microencapsulated flame retardant. Before being impregnated onto a core/sheet-type bicomponent PET/co-PET spunbond nonwoven substrate, melamine-formaldehyde polymer-shell microcapsules with Afflamit® PLF 280 (resorcinol bis(diphenyl phosphate)) as the core material were coated with an outer thermoplastic wall made of polystyrene (PS) or poly(methyl methacrylate). To attach onto the textile fibres, The temperature at which the thermoplastic shell softens was applied to the exterior wall of the microcapsules. Using thermogravimetric analysis, the microcapsules' thermal stability was investigated. Utilising a scanning electron microscope, the textile samples were examined, and the NF P92-504 standard was utilised to assess the flame retardancy performance. Given that the particles with a PS shell are more stable, the data indicate that the composition of the outer polymeric shell had an impact on the microcapsules' thermal stability. Additionally, the microcapsules were more concentrated on the nonwoven surface without changing the sample thickness. For every formulation that was evaluated, the flame spread rate was comparatively low, according to the findings of the NF P92-504 test. [59]

**Cosme to-textiles**

The phrase "wearing comfort" refers to a variety of factors, including rising consumer expectations that intimate apparel—like underwear or collant, for example—should be comfortable, that is, should not irritate the skin. Conversely, buyers anticipate that this type of apparel will improve skin tone by preventing roughness, delivering a revitalising scent, and aiding in the reduction of fatigue-related symptoms. Textiles have a significant role as an interface between people and their environment and may greatly enhance feelings of comfort and safety. [60]

A cosmeto-textile is defined as a textile piece that contains a material or preparation meant to be delivered onto the skin over an extended period of time by the Office of Normalisation of the Textile Industries and Clothing. It has to do with treating skin in a cosmetic manner. Cosmetic textiles serve as a foundation for the distribution of cosmetic chemicals when they come into contact with the skin. It is asserted that they can help one appear younger by preventing the signs of ageing on the skin or even by continuously delivering biological advantages. The idea is as simple as incorporating medicine and cosmetic chemicals into garment materials so that, as the body moves naturally, the skin gradually becomes more refreshed and vibrant. Scientific and technological advancements Vol. A variety of technologies can be used to incorporate active ingredients into textiles: (1) binding microcapsules, which encapsulate active ingredients and release them under controlled conditions during daily wear; (2) host-guest interaction of cyclodextrins, which are loadable cage molecules forming inclusion compounds; and (3) active softeners, which combine active ingredients with traditional softening agents to promote skin protection. [61]

### Available Cosmetic Textile Products

A novel technique known as Quiospheres® was created by Clariant and Lipotech. It is based on microcapsules that release and distribute their cosmetic contents when they react with natural skin enzymes. The capsules are applied uniformly and durably to knitted, woven, and non-woven fabrics. Cotton and nylon are two examples of textile materials that may be treated with Quiospheres® technology. Through the use of two-step affinity and progressive release technology, the cosmetic advantages are applied to the skin. Because of the unique architecture of Quiospheres, there is a strong affinity (attraction) between the microcapsules and the skin. Encased in a completely cosmetic and biocompatible shell, the cosmetic compounds gradually release (respond) with the body's skin enzymes to transfer the substances to the skin.

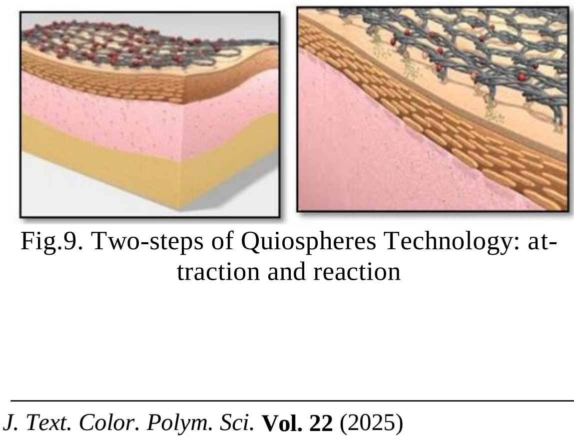


Fig.9. Two-steps of Quiospheres Technology: attraction and reaction

A brand named "Denim Spa Therapy for Legs" was introduced by Wrangler. Aloe vera, squalene, caffeine, and anticellulite ingredients are mixed with denim to provide the spa component. The jeans are even perfumed with jasmine.

Fig.10. Natural ingredients infused denims.

Tejin Co. Ltd. of Japan introduced Wow Amino Jeans, another product of this kind. Arginine, an amino acid beneficial for skin and maintaining skin young, was applied to the goods. These jeans have the same appearance as their more commonplace cousins and feel comfortable to wear. Similarly, Mizuno Corp. and Ajinomoto Co. collaborated to produce "Amino Veil," a garment material that improves the fabric's capacity to absorb moisture and helps maintain the pH balance of the skin by introducing amino acids into the fabric that dissolves during sweat. [62]

### **<u>Phase change materials Textiles</u>**

A vital component of human safety and thermal comfort is clothing's ability to defend against heat. The thermal comfort qualities of clothes may be influenced by a number of variables, including compression, air permeability, heat exchange with garments, moisture and vapour resistance, and dry thermal insulation. [63-69]

When heat fluctuates between the environment and a human body, phase-change materials (PCMs) can reverse phase shifts, such as solid to liquid and liquid to solid. This allows PCMs to control microclimate conditions.

The only materials used in textile and clothing manufacturing are linear-chain hydrocarbons, also referred to as paraffin waxes [i.e., alkanes (CnH2ná1)], because they have significant latent heat, excellent and uniform thermal properties, good chemical stability, low vapour pressures, and are nontoxic, recyclable, and environmentally friendly. [70, 71]

Since PCM-treated clothing is anticipated to actively regulate microclimate conditions by absorbing excess heat, releasing heat, and reducing perspiration, PCMs in clothing can contribute to thermal comfort by providing thermal regulation.Since microencapsulated phase-change materials (microPCMs) were applied to textiles because they can significantly improve the thermal properties of protective clothing, a lot of research studies on PCMs in textiles and their applications have actually used textiles or clothing treated with microPCMs.

These days, a variety of clothing styles make extensive use of PCMs' thermal qualities by coating or direct integration into fibres and foams. But up until now, there has been a poor thermal efficiency and a decline in fabric feel, which is directly tied to wear comfort. Selecting the appropriate PCMs based on an application, expanding the thermostatic range, and preserving the phase-change effect without breaking or removing PCMs from textiles are better ways to improve the corresponding performances in clothing. [72]

In general, PCMs may be separated into categories such as solid–liquid, liquid–gas, solid–solid, and solid–solid. It should be mentioned that PCMs can be made better by adding additives, changing PCM architectures, and improving storage methods because there isn't one perfect PCM that possesses all the necessary kinetic, thermal, economic, and physical qualities. As a useful method, PCMs can be effectively nanoencapsulated to improve their thermal conductivity, prevent leaks during melting, and perhaps interact with the surrounding matrix. Additionally, a variety of techniques such as chemical (emulsion polymerization, mini-emulsion polymerization, in situ polymerization, and interfacial polymerization), physicochemical (sol–gel entrapment), and physicomechanical methods can be used to create nanocapsules loaded with PCMs (electrohydrodynamic processes) [73]

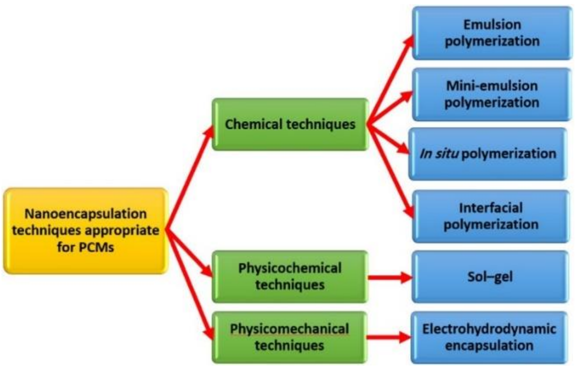


Fig. 11. Nanoencapsulation techniques appropriate for PCMs.

**PCMs integrated textile applications**

Textiles treated with phase change materials have enhanced heat regulation capabilities by altering their aggregation state within a certain temperature range. Due to their unique qualities, they are used extensively in a wide range of industries, including clothes, blankets, the medical industry, insulation, protective gear, and many more. Here are a few areas where PCM is used in the textile industry.

***Space***

To keep astronauts comfortable and shield them from the intense heat in space, phase change materials were created and used in gloves and space suits..

***Sports wear***

PCM-treated clothing is worn during physical activity to maintain a thermal equilibrium between the body's internal heat production and the external heat discharged. Thermal stress is typically increased during sports activities because the heat produced by the body is frequently not discharged into the environment in sufficient quantities. Clothes with thermoregulating qualities are often utilised to enhance the thermal performance of active wear. The amount of PCM used on the active wear clothing is determined on the intensity and length of the exercise. [74]

***Bedding and accessories***

Moreover, it may be applied to mattress coverings, pillows, and blankets to provide active temperature control in bed. The body cools down when its temperature rises because the extra heat energy is absorbed. The body releases its stored energy and stays warm as its temperature dips.

***Uses in medicine***

PCM-treated textiles may be used in bandages to control patient temperature in intensive care units, surgical garments, and patient bedding. In medical and hygiene applications, such as surgical gauze, diapers, and incontinence products, where both liquid conveyance and antibacterial qualities are needed, PCM-treated cloth may be helpful.

**1,6 Shoes and accessories**

Particularly, footwear with PCM incorporation is employed, such as race car drivers' boots, ski boots, and climbing boots. To avoid severe changes in the wearer's head, torso, hands, and feet, fabrics with heat-storage and thermoregulation properties can absorb, store, redistribute, and release heat. [75]

**Conclusions**

This review study has been focused on microencapsulation and application of nanocapsules on textiles , It has been found that the uses of nano capsules have many promising uses in all fields and in the field of fabrics in particular. We have discussed its use in aromatic fabrics and its importance in maintaining the body in a fresh state as well as wound healing and its use in protection from ultraviolet radiation , flame retardant , mosquitoes , microbes And also phase change and cosmetic fabrics, and in the end it revealed the importance of the nano capsule and that it is the future of textiles in the coming years

## Conflict of Interest

There is no conflict of interest in the publication of this article

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