



Latexes and their Applications in Textile Industry

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Abstract

In several areas of the textile industry, latexes and their hybrids have gained significant attention. They have demonstrated their effectiveness in the printing, dyeing, and finishing of various types of textiles. They are often created via the emulsion process, which requires the creation of both an oil phase and a water phase before combining them to create the colloidal solution known as latex. Some latex particles varieties also feature what is known as a core-shell structure. Without using binders, latexes are employed to attach the printing paste to the cloth. They aid in the dyeing procedure as well, preventing the agglomeration problem. Last but not least, they have several uses in the textile finishing industry in terms of UV protection, antibacterial performance, and hydrophobic and oleophobic properties.

Keywords: Hybrid Latex – Printing – Dyeing – Hydrophobicity – UV protection- Antimicrobial

Introduction

Recently, polymer composites have been receiving considerable attention for a broad spectrum of uses [1]. Which led to the emerging of ground-breaking polymeric composite called latex. Contemporary water-based latex coatings contain intricate blends of monomers, linkers, surfactants, buffers, coalescing agents, anti - oxidants, UV stabilizers, antimicrobials, defoamers, and other additives. These films are strong and resistant to degradation, several chemicals, water, heat, and bacterial and fungus invasion after drying. As a consequence, latexes are widely employed as insulation materials for textiles in both indoor and outdoor applications [2]. By stating the above, it has become clear that latexes may be created and supplied with specific specifications [3] with which it is possible to fulfill the demands in the textile sector, such as in textile printing, finishing, and dyeing.

There are four phases to the complicated procedure of latex sheet creation (Scheme 1). The polymer nanoparticles used for

applications are first dispersed in a diluted aqueous solution in phase 1. Phase 2 begins with a thin covering of those same dispersions, and as water evaporates, latex particles encircle one another and produce an immediately sticky film. In phase 3, when the remaining water is gone, the coating thins and the interfacial tension between the polymer and the water and the air create permeability that compress the delicate latex particles. The latex particles are bent into polyhedral geometries by this force, resulting in a densely compacted film with interstitial spaces that are far smaller than the wavelength of light. When the latex nanoparticles combine in phase 4, the polymer chains begin the interdiffusion across the interlayer boundaries while the latex particles are still flexible and movable, ultimately producing a solid film. As the operation goes on, the polymer chains, and consequently the film, grow stiffer [2].

The latex particles might also provide the opportunity to combine various polymer characteristics. This type of structure, known as a "core-shell," is created through a multi-stage

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emulsion polymerization process in which a monomer composition is polymerized to generate the core and a different monomer compound is post-polymerized over the core-seed to create the shell. It is feasible to get final polymer qualities by choosing distinct monomer compositions for the core and shell phases that are challenging to accomplish by mixing two polymers or with randomized copolymerization. By altering the structure of the core and shell phases, their percentages, or the layer count, the morphologies may be changed. Even opposite qualities like inorganic-organic, soft-hard, water repellent-hydrophilic, and low-high refractive indices can be mixed to boost the functioning of the resulting polymer [4].

All types of textile fibers may be printed with pigment since it binds to them without reacting with or depositing between the threads. Nevertheless, given the adhesive in the pigment paste, pigment printing has drawbacks such as less vibrant color, a harder texture, and inadequate color fastness. Latexes are offered as a form of glue to address these problems. For example, the printing paste can be added with the core-shell adhesive of polyacrylate adjusted with silicon and polyurethane to create a three-dimensional network structure between both the crosslinking and fiber molecule offering soft-handling, enhanced color fastness, and higher wet and dry rubbing durability [5].

Moreover, as people's living standards and quality of life quickly advance, so do the demands placed on textiles, particularly those that have been chemically altered to serve as UV-blockers, antimicrobials, and hydrophobic fabrics. Latexes are used in the finishing of textiles. For illustration, to create a waterproof cotton fabric, a fluorinated polyacrylate colloid was created using amphiphilic Janus particles and the monomers BA (Butyl Acrylate), MMA (Methyl Methacrylate), and G02 (Hexafluorobutyl Methacrylate) [6]. The self-assembly of a poly(styrene-methyl methacrylate-acrylic acid)-avobenzene core-shell latex spherical, which included the frequently used UV absorber avobenzene, was employed to create a type of functional structural color dye with outstanding UV rays' protection capability. Avobenzene was encapsulated in a latex sphere to guarantee the structure color's great UV protection function on cotton garments. At the same time, the structure color dye was ready and had excellent color perception [7]. As a fabric finishing agent, Ag/ fluorine-containing polyacrylate latex was also utilized. Rough surface,

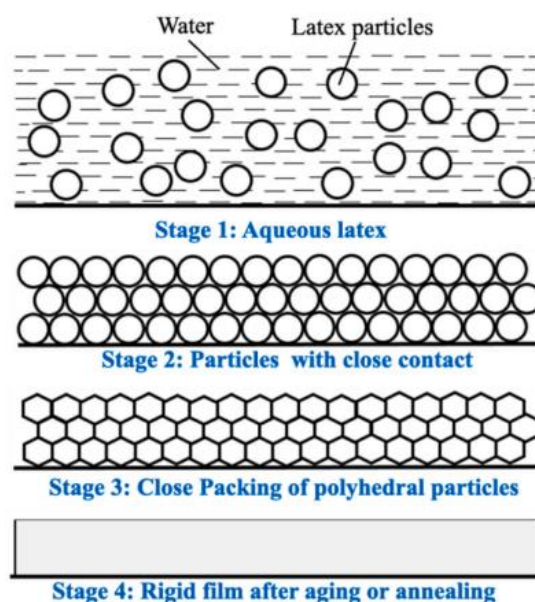
great oil and water resistance, and remarkable antimicrobial potential were all demonstrated for the finished cotton fabric [8].

Additionally, latexes play a significant part in the coloring of clothes. As such an example, knitted cotton fabric may be changed by CHPTAC to have positive charges imparted to it before being dyed with fluorescent pigment latex that has negative charges by exhaust dyeing procedure [9]. Additionally, papaya latex-coated super paramagnetic iron oxide nanoparticles have demonstrated their effectiveness in eliminating the dye Methylene Blue (MB) from wastewater [10].

Applications of Latexes in the textile industry

Applications of latex in textile dyeing

The physical properties of the fibers, the structure of the material being dyed, the chemical structure of the goods utilized to color the fabrics, the category of dyes, the procedure, as well as the equipment utilized for coloring the materials are only a few of the many linked elements that affect the constantly changing procedure of textile dyeing [11-27]. Through dyeing processes, colored latex pigments may be utilized to color cloth substrates while displaying typically acceptable color uniformity and durability qualities.



Scheme 1: An explanation of the latex film's development phase [2]

Dyeing characteristics fluorescent pigment latex

Some of the most commonly widespread anionic dyes for cotton fabric dyeing include reactive dyes and

direct dyes. Nevertheless, huge amounts of electrolytes are necessary to improve dye absorption, which causes major ecological challenges once the coloring waste is disposed away. One solution is to cationize fabrics made of cotton by chemical treatment to improve the attraction of anionic dyes for cloth. Pigments may also be used to cotton fabrics due to their straightforwardness of utilization, reasonable cleanliness, ecologically harmless form, and wide hue range. The fluorescent pigments are a particular kind of such pigments. Nonetheless, non-soluble in water pigments frequently agglomerate, resulting in weak dispersion in the liquid phase, limiting the use of luminescent pigment. To prevent the aforementioned issue, a technique was developed that resulted in increased pigment distribution consistency and improved the attraction between pigment with cotton fibers [9].

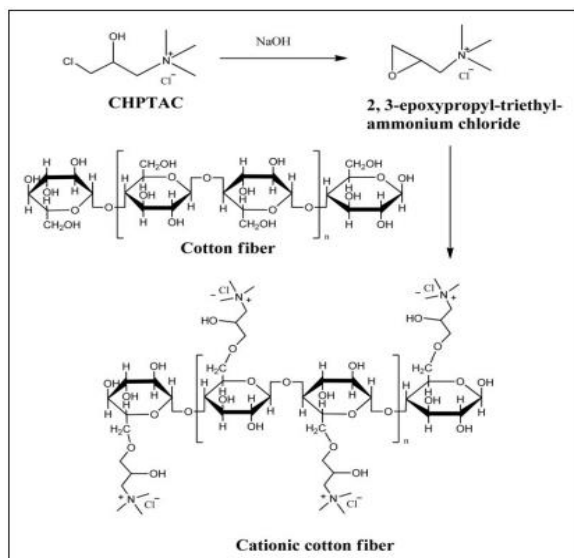
Li et al. carried out a technique in which they injected positive electrical charges into the material's exterior while performing a certain kind of cationic pretreatment on cotton textiles, after which these cationic fibers absorbed the pigment's charges that were negative. To insert polymers onto the pigment's surface, an emulsion-based polymeric reaction was used to generate a fluorescent pigment latex. They first created the oil stage of the oil/water emulsion through the addition of 10 grams of methyl methacrylate (MMA), 10 grams of butyl acrylate (BA), and 3 grams of hexadecane (HD, co-stabilizer) while mechanically mixing at 600 revolutions per minute for 30 minutes. A reactive emulsifying agent called DNS-86 (1 g Allyloxy nonyl alcohol polyoxyethylene (10) ether sulfate) was subsequently submerged in 25 mL of water to create the phase that is water-based. For 30 minutes, the water plus organic phases were gently combined. The combination then underwent to an additional treatment of ultrasonic vibrations with a frequency of 28 kHz and a power of 360 W for 10 min in an ice-water bath. The oil/water emulsion was eventually produced [9].

Moving the solution of emulsion into a four-neck beaker containing a stirrer, thermometer, and condensation device allowed the researchers to start polymerizing the mixture. The temperature was raised to 75 degrees Celsius and kept there for 30 minutes. 0.45 g of ammonium persulfate (initiator) was submerged in 5.0 mL water followed by injection into the beaker within 30min and was kept that way for 3 h. Later, after allowing the solution to cool withing room

temperature, it was centrifuged for a whole hour at 10,000 rpm. To eliminate the agents that didn't react, the sludge was subsequent rinsed three times using methanol and then three more times with freshwater. Lastly, the sludge was vacuum-dried at 60 degrees Celsius to produce the pigment powdered material [9].

Li et al. performed an initial treatment procedure upon the cotton cloth prior to coloring it. By soaking the fabric made of cotton in a mixture of 40 g/L (3-chloro-2-hydroxypropyl) trimethylammonium chloride CHPTAC (cationic chemical) and 10 g/L sodium hydroxide at a liquid proportion of 1:30, the chemicals were able to cationize the material. The researchers raised the temperature till it reached 70 C then kept it there for 40 minutes. They subsequently took the cationized cloth out of the tub and gave it a wash with water. In (**Scheme 2**), the cationization procedure of fabric made from cotton is described. Following that, the cloth was colored using the exhaustion process in a laboratory dyeing equipment using a 1:30 liquor proportion. The dyeing solution was made by distributing the fluorescent pigment latex in purified water that was left at 80 degrees Celsius for 50 minutes, with a pH of 7, plus a temperature rise of 2 degrees Celsius every minute [9].

When the structure of the fluorescent pigment latex underwent study, it was discovered that its particles in dispersion possessed a diameter of 160 nm. The latex with fluorescent pigment was also rather seamless. And by examining the K/S parameters, it was discovered that they rise as CHPTAC concentrations rise to approximately 40 g/L, proving that cationizing effectively provided more cationic locations on cotton fiber. Additionally, the K/S measures rose when the NaOH levels within 10 g/L rose. Results was related to the cotton fiber surface's strongest opposite polarity, which could take in the most CHPTAC. Time is an additional variable that boosted the color intensity; when cationization period rose, the material's adsorption equilibrium was attained after 40 minutes. The ideal cationization conditions for cotton were CHPTAC 40 g/L and NaOH 10 g/L at 70 degrees Celsius for 40 minutes. The cationized fabric made of cotton and negatively charged pigment formed bonds of ion charge that allowed the colored material to adapt well in terms of washing durability (4 rating) as well as moist rubbing durability (4-5 rating). Additionally, the colored textiles showed exceptional color brightness and levelness [9].



Scheme 2: The chemical process of 3-chloro-2-hydroxypropyl trimethylammonium chloride (CHPTAC)'s interaction with textiles made of cotton [9]

Colored polyurethane latex

Polyurethane (PU) colored latexes have recently been employed extensively in the dyeing of fabrics due to their benefits of having an extensive color spectrum, strong color durability, and adjustable intensity of color [28]. Combining organic dyes into PU latex is a typical technique for coloring it. Yet, the resultant latex typically displayed fundamental flaws such inconsistent polymeric coloring and poor dye light/solvent durability; additionally, dye agglomeration and latex diminishing might be seen whenever kept. These outcomes might be attributed to the polymer's and pigment/dye's generally incompatibility. Despite mini-emulsion polymerization enabled the incorporation of dyes with various polymeric substances, dye dispersion remained unavoidable during prolonged storage [29].

The latter issue was addressed using a simple method by B. Li et al., who produced a positively colored PU latex from commercial reactive dyes using a simple chemical-based process. This method was chosen to address the drawbacks of creating equivalent colored latex, including high production costs and a restricted selection of color types, and this limited the number of uses and massive manufacturing. Given that the amination reaction of traditional reactive dye can be done in moderate conditions and the fact that the dye monomer had a significant efficiency in polymerization, the researchers' technique is regarded as being facile, eco-friendly, and adaptable [29].

A blue reactive dye (Ramazol Brilliant Blue R) with an anthraquinone chromophore (AQ) was first altered by B. Li et al. using a single-step reaction, and the method for producing it is illustrated in (Scheme 7). Following the alteration, a number of water-soluble colors with several amino groupings were created. These dyes were subsequently utilized as monomers in a chain-extension reaction during the self-emulsion process to create the covalently colored PU latex. EKNR, HKNR, and DEKNR are the names for those dyes, accordingly. PU latex following the instructions in (Table 1) by initially charging isophorone diisocyanate (IPDI) and polyether diol (N210) into a three-necked container that included a condenser that produces reflux as well as a powered electrical stirrer, followed by adding a tiny amount of dibutyltin dilaurate as a catalyst. 1,4-Butanediol (BD) was added the contents of the container, which had been kept at 80°C in an oil bath over 1 hour while being stirred. The process then proceeded for another hour. Dimethylolbutanoic acid (DMBA) dispersed in 2 mL acetone was thereafter incorporated for a further 2 h of reaction after the system had been lowered to 65 °C[29].

Following that, the reaction solution was brought down to 50 °C then 2 mL of acetone was incorporated to lessen the PU prepolymer's rigidity. Triethylamine (TEA) was used to neutralize the carboxylic groups for 20 minutes after which the dye monomer water-based solution was added and a 40-minute fast-speed distribution was carried out, in opposition to investigations in which the dye monomer solution had been added at various distribution certain points. After the acetone had been eliminated by centrifugal evaporation, the covalently colored PU latex was finally produced. By pouring the PU latex onto a glass then letting it cure for two days at ambient temperature, the matching PU latex films having thicknesses of 150±10 µm were created [29].

The findings from the analysis showed that the zeta potential of colored PU latex slightly decreased when compared to uncolored PU latex. Because these dye monomers were anionic hydrophilic molecules, the addition of dye monomer supplemented the negative charges within the PU nanoparticles, causing a reduced potential and this might experience enhancement in colloidal stability. The chemically colored PU nanoparticles have been demonstrated to be mainly spherical, consistently dispersed, and have a dry particle size around 60 and 70 nm. The covalently colored PUs' UV-vis absorption spectrum matched those of the dye monomers, with

highest absorption wavelengths at 581 nm and 621 nm, showing that the dye chromophore remained chemically unaffected during polymer formation. The conversion rate of dye monomers proved to be a value greater than 92% whenever the dye concentration of the polymer seemed 1.0 wt%, although this conversion was significantly impacted by the timing and quantity of the dye monomer additions during the dispersion operation. In comparison to the non-covalent colored specimen, the finished covalently colored PU film displayed higher light durability. This showed that additional reactive dyes may also be used to create polymer latexes with different hues [29].

Table 1: Formulas for making PU latex that has been chemically colored [29]

Ingredients	Amount (g)
IPDI	3.9
N210	4.0
DMBA	0.5073
BD	0.45
Dye monomer	Variable*
TEA	0.34
H ₂ O	37

Applications of latexes in textile printing

Textile pigment printing has advanced quickly in the past few decades due to its many benefits, including energy, water, and pollution reduction, which is considered an eco-friendly method for greener fabric coloring [30]. The effects of affinity between the pigment particles lead the pigment nanoparticles to agglomerate, which makes it challenging and takes time to prepare an even and homogeneous pigment dispersion. Additionally, because pigments and textiles are not compatible, binder in the pigment printing paste might glue the pigments onto the surface of the fabric during printing. Yet it may additionally lead printed cloth to have a poor color durability and an unpleasant hand feel [3]. Here comes the role of latexes to solve the latter problems, due to their small particle size, high specific surface area, and adhesion properties, latexes are capable of combining pigment molecules with one another and with the fabric as a whole without leaving a harsh handle feeling or significantly reducing the color intensity.

Fluorosilicone modified polyacrylate/pigment hybrid latex

Since fluorosilicone combines an adaptable perfluoro ether side-chain along with an elastic siloxane spine, it has been demonstrated to be a low-glass-transition substance. Additionally, it was created lately using ring-opening polymerization and utilized to alter polymer compounds [30]. In order to develop a hybrid latex that can create a binder-free pigment printing experience, this fluorosilicone substance was added to the polyacrylate printing adhesive.

According to (Scheme 3), Lu et al. created the fluorosilicone altered polyacrylate/pigment (FSi-PAcr/PB) hybrid latex in a single procedure using an in situ mini-emulsion. Researchers initially produced the water-like phase (that is, continuous phase) by combining 0.3 g of dodecylbenzene sulfonic acid (DBSA), which serves as both an emulsifier as well as a catalyst for the fluorosilicone component's positively charged circle-opening polymer, with 0.3 g of DNS-86 in 108 g of water. They subsequently created the oil stage, that contained the following: 4.8 g of 1,3,5-tris (3,3,3-trifluoropropyl)-1,3,5-trimethylcyclotrisiloxane (D₃F), 1.2 g of octamethyl cyclotetrasiloxane (D₄), 0.03 g of 3-(trimethoxysilyl) propyl methacrylate (MPS), 3 g of butyl acrylate (BA), 3 g of methyl methacrylate (MMA), 0.6 g of α , α' -azoisobutyronitrile (AIBN), 0.36 g of hexadecane (HD), and 0.6 g of Ltd. C.I. Pigment Blue 15:3 (PB), components were blended and put to the aqueous phase in a beaker, in addition the resulting unrefined emulsion was pre-emulsified for 20 minutes under string [30].

Following pre-emulsification, the resultant emulsion was blended by ultrasound using a Scientz Jy92-IIsonifier for 15 min while being cooled with ice (70% amplitude, 650 W). The created mini-emulsion was then put in a 250 mL three-necked round-bottom flask with a condensing pipe and a mechanical stirrer. After that, the setup was purified by flowing N₂ for 15 minutes. To formulate the FSi-PAcr/PB hybrid latex, the emulsion was lastly synthesized by polymerization at 80°C in a tub of water for 6 hours. Finally, the names of the FSi-PAcr/PB hybrid latexes have been given based on the mass to weight proportions of D₄ and D₃F: PAcr/PB, FSi-PAcr/PB-1/0, FSi-PAcr/PB-4/1, FSi-PAcr/PB-1/1, and FSi-PAcr/PB-0/1. And the chemical structure of the resultant polymer is shown in (Scheme 4) [30].

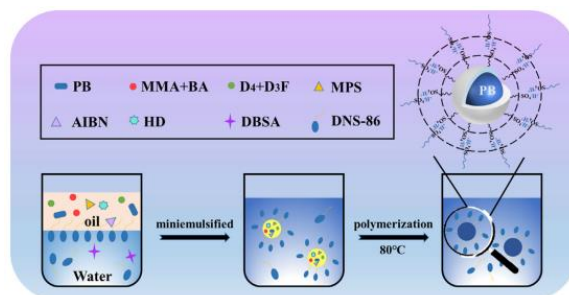
The hybrid pigment emulsion was subsequently applied to a polytetrafluoroethylene plate, dehydrated for 5 minutes at 40°C with a moisture content of 60% for 24 hours, and then heated for 5 minutes at 120°C. Lastly, to produce a homogenized printing paste with a specific density, 0.2 g of thickener was added to 9 g of the hybrid pigment latex, and the two were then blended by stirring until the desired material was produced. A 100-mesh flat-screen device was used for warping scrape the printing paste onto the polyester cloth. The colored textiles were subsequently baked at 150°C for 3 minutes after being previously baked at 90°C for 5 minutes [30].

The analysis revealed that the FSi-PACr/PB hybrid latex particles were mono-dispersed and ranged in diameter from 178.7 to 207.9 nm. Furthermore, the hybrid latex demonstrated improved water resistance and simpler migration. Additionally, the hybrid latex of FSi-PACr/PB-0/1 produced a water contact angle (WCA) on printed PET fabric of 103.7°. Furthermore, FSi-PACr/PB coated polyester fabric's color yield was somewhat lower than that of PACr/PB coated fabric, yet it had substantially enhanced moist and dry fastness, hand sensation, and air flow through the pores of the fabric. For example, the firmness value for a fabric coated with PACr/PB was 55.28, whereas the firmness value for a comparable fabric coated with FSi-PACr/PB - 4/1 hybrid latex was 40.63, meaning that it decreased by 26.5%. Also, the fabric coated with FSi-PACr/PB - 4/1 latex had a breathable porosity of 164.44 L/m², whereas the fabric coated with PACr/PB turned out to be 54.13 L/m². Moreover, the fluorosilicone's decreased surface energy and superior elasticity allow the hybrid latex film to spread effortlessly and coat fabric surfaces inconsistently, which improved the properties of the FSi-PACr/PB hybrid latex printed fabric. Finally, this straightforward and ecologically beneficial one-step in situ process may be employed to create binder-free pigment colorant in real production circumstances [30].

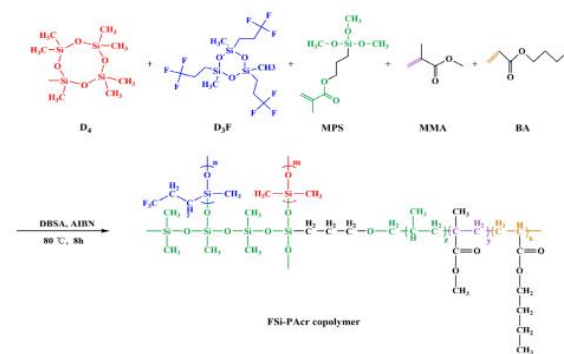
Silicone modified styrene-acrylate latexes (PSBMA)-colored polymer latex

A chromophore is by chemical means integrated within the polymer's primary or side chains in colored polymer latex. Among those colorful polymers is monodispersed colored polymer latex (PSBMA), which possesses chemically crosslinking properties along with the ability to create a film. The resulting polymer was subsequently utilized in the production of printed textiles. Anthraquinone

chromophore-based polymerizable dye was initially created in order to create the colored polymer in question. After that, the colorful polymer (PSBMA) came into existence utilizing styrene (St), n-butyl acrylate (BA), polymerizable AHAQ, and vinyltrimethoxysilane (VTMS) as the monomers during semi-emulsion procedure [3].



Scheme 3: The conceptual framework for the in situ Mini-emulsion polymerization of FSi-PACr/PB hybrid latex in a single process

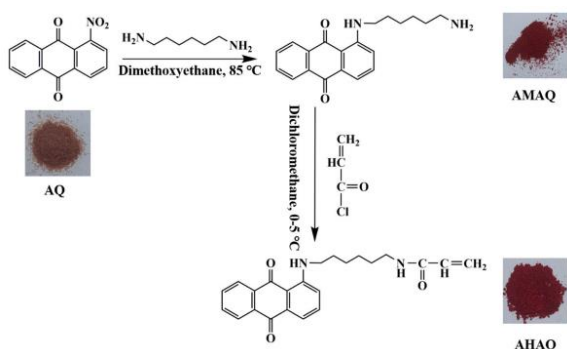


Scheme 4: methodology of FSi-PACr copolymer's formation

In order to create 1-(6-acrylamidoethylamino) anthraquinone (AHAQ), Y. Yang et al. initially had to create 1-(6-aminoethylamino) anthraquinone (AMAQ). Dimethoxyethane (50 mL), 1-nitroanthraquinone (2.53 g, 10 mmol), Na₂CO₃ (1.06 g, 10 mmol), and 1,6-diaminohexane (4.64 g, 40 mmol) were added to a solution then condensed for two hours at 85 degrees Celsius while being agitated. After allowing the combination to cool to ambient temperature, they added it to a conventional aqueous solution of sodium hydroxide (0.2 weight percent). Three times of purified water were used to purify and rinse the solid residue. The resulting substance has been purified via recrystallization using ethyl acetate after water had been evaporated at low pressure in order to generate the deep crimson solid. A three-necked beaker was subsequently set within a tub of ice while the researchers mixed AMAQ (2.58 g, 8 mmol) and

triethylamine (1.2 g, 12 mmol) in dichloromethane (40 mL). 0.905 g of acryloyl chloride (10 mmol) had been dispersed into dichloromethane (10 mL) and poured gently through a period of 15 minutes to the aforementioned mixture. Thin-layer chromatography (TLC) had been employed to track the reaction's completion point, with a dichloromethane/ethyl acetate (3:1 v/v) combination serving as the mobile phase during the process. The AHQA was created when the remaining emerging solvents were eliminated, and (Scheme 5) shows the process for synthesizing the dye [3].

The researchers subsequently created (PSBMA) as well as its films via dispersing AHQA into a suspension of Styrene (St), n-butyl acrylate (BA), methacrylic acid (MAA), and vinyltrimethoxysilane (VTMS). The combined solution, Polyoxyethylene octylphenol ether-10 (OP-10), sodium lauryl sulfate (SDS), as well as 25 mL deionized water were subsequently incorporated in a glass beaker and agitated using ultrasonic vibrations to create the undergo-emulsion. Ammonium persulfate APS (0.15 g) was dispersed in 5 mL of water that had been deionized then parted into two equal portions. A third portion of the undergo-emulsion was transferred to a 250 mL four-neck round bottom glassware beaker containing N₂ and an electric mixer. subsequent to raising the temperature to eighty degrees Celsius, 40% of the APS mixture was introduced in order to begin polymerization, in addition the remaining pre-emulsion and 60% APS solution were inserted by drops into the flask and left there for 1 hour. It then proceeded to react throughout additional 1 hour [3].



Scheme 5: The AHQA's pathway during synthesizing

Lastly, the silicone-modified styrene-acrylate latexes (PSBMA-0, PSBMA-1, PSBMA-2, PSBMA-3, PSBMA-4, and PSBMA-5) containing varying amounts of VTMS had been created. The formula is

shown in (Table 1). The method is shown in (Scheme 6) after the produced PSBMA was poured into a spotless PTFE template (10 cm 10 cm 2 mm) then dried at 60 °C for Twelve hours. After Y. Yang et al. diluted the ammonium poly-acrylate thickener (DM-5221) a total of five times with water that had been deionized, they produced prints on cotton. After applying the print paste using a screen-printing method and using the formula in (Table 2), they eventually achieved the printed cotton material via drying it at 80 degrees Celsius and curing it at 130°C for a period of six minutes [3].

Table 2: PSBMA preparation formula [3].

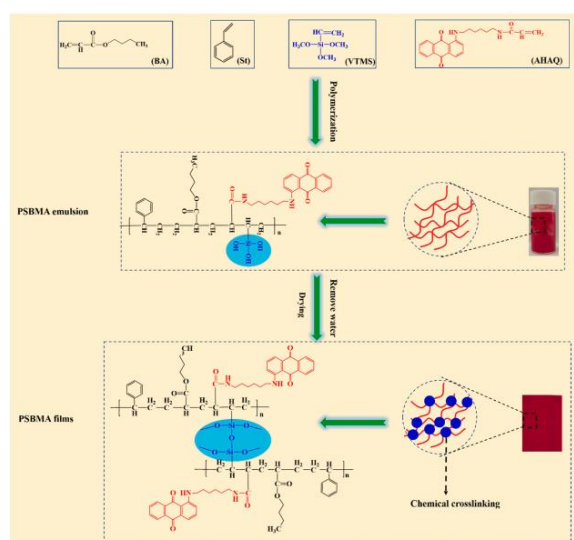
Ingredients	Amount (g)
St	7.5
BA	7.5
AHQA	Variable amount ^a
VTMS	Variable amount ^b
MAA	0.15
SDS	0.3
OP-10	0.15
APS	0.15
H ₂ O	30

^a 0–1.5 wt% based on total monomers.

^b 0–5 wt% based on total monomers.

Table 3: paste formula to obtain printed fabrics [3].

Components	PSBMA-0 printing	PSBMA-4 printing	Pigment printing
PSBMA-0 (g/kg)	20	0	0
PSBMA-4 (g/kg)	0	20	0
Binders (g/kg)	0	0	300
Pigment dispersion (g/kg)	0	20	0
DM-5221 (g/kg)	400	400	400



Scheme 6: the steps used to prepare the PSBMA including its film

The analysis revealed that VTMS had been selected as the linking chemical for connecting the chains of polymers. During the process of radical-free latex polymerization, the Si (OCH₃)₃ groups were hydrolyzed to create Si-OH. Following this, during a drying environment, the condensation of Si-OH might produce the Si-O-Si compounds. The polymer chains are able to be linked by these groups (Si-O-Si) to increase the durability of printed fabrics. As the VTMS levels grew, so did the cross-linked density as well. Additionally, it was discovered that the substance PSBMA displayed mono dispersity with a particle diameter of 78 nm along with possessing superior dispersion durability through the use of (Dynamic Light Scattering) DLS, TEM, and durability examinations [3].

The PSBMA films additionally possessed an UPF measurement of 471, indicating that they performed exceptionally well in terms of UV shielding. Furthermore, it turned out that the hue of the PSBMA colored films had slightly altered after being exposed to light for 10 days, indicating the outstanding ageing durability property these films possess. Since the latex film had been chemically crosslinked, the PSBMA could be utilized on cotton fabrics minus the use any kind of binding agents. The K/S values of the printed textiles made of cotton were 5.05 and 5.09, demonstrating outstanding color effectiveness. In contrast to printing that uses binders, they also showed strong color durability and a nice and smooth sense of touch [3]. This demonstrates the benefits of using PSBMA films as a substitute of traditional pigment paste as well as their capabilities.

Polysiloxane-modified polyacrylate/pigment hybrid latex

A number of heterogeneous polymerization techniques for encapsulating coloring agents have been investigated and generated across the past few years in order to deal with the issue of accumulation, and also to enhance the binding forces that occur between the pigments and textiles, as well as to strengthen the degree of color and durability along with the hand feel. These methods include emulsion polymerization, mini-emulsion polymerization, and microemulsion. A unique technique for making polyacrylate hybrid pigment latex incorporating silicone was investigated with the aim to enhance the efficiency of pigment

printing. This technique involved the a single-step mini-emulsion copolymerization of silicone and acrylic monomers [31].

In the beginning, mini-emulsion polymerization had been employed by Wang et al. to create polyacrylate pigment PAcr/PB hybrid latex. In a standard experiment, the dodecylbenzene sulfonic acid (DBSA), sodium dodecyl sulfate (SDS), triton (X-100), and 0.6 g of the initiating agent ammonium persulfate (APS) were dissolved in 108 g of aqueous solution to create the water stage (that is, continuous stage). Using the assistance of ultrasound (ultrasonic cleaner SK7200H, 350 W, 5 minutes), the oily stage was created by combining 5.3 g of styrene (St), 6.7 g of butyl acrylate (BA), 0.6 g of methacrylic acid (MAA), 0.36 g of hexadecane (HD), and 0.4 g of phthalocyanine blue (PB; CI Pigment Blue). The water-based stage and the oil stage were then combined, and the mixture was subsequently pre-emulsified around 20 minutes using a stirrer with magnets (85-1 type, 200 r/min). Pre-emulsification was followed by a fifteen-minute period of additional homogeneity using a JY92-II ultrasonic cell crusher (power 70%, 650 W) in a bath of ice. The microemulsion was put into a 250 ml three-necked beaker where it was heated to 80 degrees Celsius and stirred with nitrogen for 5 hours. Following the process, a buffering agent consisting of sodium bicarbonate was employed to bring the pH of the colloid down to 7 [31].

The silicone-altered PAcr/PB hybrid latex is subsequently produced by the researchers using a one-step mini-emulsion polymerization process, as shown in (Scheme 6). Similar to the usual experiment, 108 g of liquid was utilized to dissolve 0.6 g of APS, 0.3 g of X-100, 0.3 g of SDS, and 0.3 g of DBSA into the water-based phase (continuous phase). Among them, DBSA served as a surfactant and an initiator for the D4 ring-opening of cyclic siloxanes (octamethylcyclotetra-siloxane). Using the aid of ultrasound (ultrasonic cleaning device SK7200H, 350 W, for five minutes), the oily stage was produced by combining 12 g of D4, 5.3 g of St, 6.7 g of BA, 0.6 g of MAA, 0.06 g of vinyltriethoxysilane (VTES), 0.36 g of HD, and 0.4 g of PB. The water-based stage and the oily stage were then combined, and over the following twenty minutes, a pre-emulsion was created using a magnetic stirrer of the 85-1 types and 200 revolutions per minute. The homogenization procedure and the polymerization reaction parameters are identical as when the PAcr/PB hybrid latex is prepared. Following the process, a buffering agent

containing sodium bicarbonate was used to bring the emulsion's pH to 7 [31].

They also made the hybrid latex sheet by spraying the Si-PACr/PB hybrid latex emulsion into a 6-cm-diameter round polytetrafluoroethylene mold, which followed by drying for a full 24 hours at 35°C with 65% rh in a sealed container. The Si-PACr/PB hybrid latex films were subsequently baked for 10 minutes at 120 degrees Celsius. Lastly, room temperature cooling was allowed for the hybrid latex films. Following the creation of the latex film, the following common composition for the pigment printing paste was created: Si-PACr/PB hybrid latex weighing 10 g and thickening agent weighing 0.5 g (PTF, acrylic polymer). The colored cloth had been dried for three minutes at 150°C after 15 minutes of drying at 80 degrees Celsius [31].

Transmission electron microscopy (TEM) was used to examine the hybrid latex's structure. The median diameter of the particles of PACr/PB was found to be 127.4 nanometers, whereas the dynamic light scattering DLS analysis revealed that the polydispersity index (PDI) of unaltered latex was 0.127. However, once the silicone altered latex's structure was examined, it turned out that its particle size ranged from 110 to 170 nanometers. Those earlier findings suggested that the dimension of the latex was not significantly affected by the in-situ polymerization that opens rings of cyclic siloxanes or the mechanism of coupling involving alkoxysilane grafting on the PACr rings. Si-PACr/PB-30/1 hybrid latex particles' zeta potential was 66.7 mV, indicating that the probability of particles aggregating during preservation was anticipated in being much decreased and that the hybrid latex remained electronically durable [31].

The hue's durability against both wet and dry friction, as well as the K/S value, have been evaluated. It became clear that printed textiles coated with Si-PACr/PB hybrid latex had no effect on K/S when compared to materials coated with PACr/PB hybrid latex. The lowest K/S of printed fabric in the Si-PACr/PB setup, for instance, was 14.17, suggesting that the screen-printed textiles had excellent hue intensity. The dry friction durability of Si-PACr/PB hybrid latex pigment coated fabric, on the other hand, was 4-5. The amount of damp friction durability achieved 3-4 or 4. The Si-PACr/PB technology improved the color durability of the coated cloth, according to the forementioned analysis. The coated polyester textiles with Si-PACr/PB also have a silky

texture. Furthermore, the printed materials demonstrated waterproof activity with minimal penetration of water and improved flexibility, in addition, as the silicone concentration grew, so did the hydrophobic characteristic [31].

Fluorescent pigment latex

Because of the quick manufacturing time, facile operating, and lack of material choosing, pigment accounts for approximately 50% of printed fabrics. The fluorescent pigment represents a particular kind of pigment. due to its high reflectance and vibrant hue, fluorescent pigment had been used to cloths for various uses including police garments, sports apparel, sanitary workers' garments, and so on. Pigments, on the other hand, do not chemically adhere to textiles. As a result, prior treatments were implemented to increase the affinities between the cloth with the pigment. Due to the high granularity of the binder and pigments utilized, as well as the combined binder's introduction of stiffness via inter-fiber bonding, the fabric's texture sensation remained troublesome even though the attraction between the fibers and pigment was reinforced. Fluorescent pigment latex (FPL) was created via mini-emulsion polymerization to address the latter issue. lacking the necessity of a binder, this fluorescent pigment coating allowed the pigment particles to become flexible and strongly bonded to the cloth substrate [32].

Li, M., et al. created an oil-in-water emulsion to create the fluorescent pigment latex (FPL). By combining 10 grams of the monomer methyl methacrylate (MMA), 10 grams of the monomer butyl acrylate (BA), and 3 grams of the co-stabilizer hexadecane (HD) while being mechanically stirred at 600 revolutions per minute for 30 minutes. They then were able to create the oil phase. The reactive emulsifier allyloxy nonyl alcohol polyoxyethylene (10) ether sulfate (DNS-86) was subsequently submerged in 35 mL of water to create the stage of water. The oil phase was then gradually put within the water stage, where they were emulsified for 30 minutes. The combination was then subjected to 10 minutes of treatment using ultrasonic vibrations at an intensity of 28 kHz and a voltage of 360 W in a tub of ice-cold water. The reactive emulsifier was added together with MMA and BA, which co-polymerized on the outermost part of the FPL to give it negative electrical charges [32].

Li, M., et al. polymerized the emulsion first, then printed the cotton cloth using latex. In a four-neck flask using a stirrer, the oil/water emulsion was placed. They increased the temperature to 75 °C and kept it there for approximately 30 minutes. In 30 minutes, a diluted initiator in water was introduced into the flask and kept there for a further three hours. The mixture was subsequently brought down to ambient temperature and spun for one hour at 10,000 rpm. To get rid of the unreacted chemicals, the sludge was rinsed repeatedly with methanol, then 3 times using freshwater. Lastly, the sludge was vacuum-dried at 60°C to produce the powdered pigment. Then, 50 g of filtered water was added to 0.6 g of this colored powdered. The fluorescent pigment latex emulsion (FPLD) was created by subjecting the combination to ultrasonic vibrations for five minutes. The following ingredients made up the printing paste: FPLD (56 g), DM-5268 (3 g), and filtered water (43 g). The cotton cloth was lastly printed using a screen-printing process, followed by being baked for three minutes at 150 degrees Celsius [32].

SEM analysis of the pigment-coated cotton fabric revealed that the FPL distributing produced a dense and homogeneous film on the surface as opposed to the traditional pigment printing approach, which results in rougher films on textiles. This outcome might be explained by the encapsulating polymer, that caused the particles of pigment to disperse evenly over the material and demonstrated film formation on each particle. Additionally, FPL printing without a binder demonstrated less bending stiffness and persistence than traditional printing techniques. This showed that the earlier type had less bending stiffness and decreased energy during tensile loading compared to the latter, which ultimately improved hand sensation. Once the printed fabric's hue durability, laundering, and abrasion resistance were examined. The findings showed that compared to traditional printing techniques, the FPL printing had a little improved rubbing durability and comparable rinsing durability. The flexible and strongly bonded pigment particles to the fabric substrate were made possible by the dense and uniform layer, which is responsible for that. Additionally, the polymer coated on the fiber had no effect on the color tone or depth of color [32].

Self-adhesive polymer (PSBM-SP) latex particles

Uses for stimuli-responsive fabrics have escalated dramatically during the last few decades. These "intelligent fabrics adjust their physical and chemical

features in accordance with stimulation brought on by changes in ambient factors including temperature [33], pH [34], light [35], and others. Photochromic fabrics, a particular kind of intelligent fabric, have captured curiosity of researchers in the past few years because of its quick and easy responsiveness and ability to reverse [36]. Photochromic particles are often attached upon the outermost layer of fabrics by a film-like creation of binders with the goal to make photochromic fabrics [37]. Nevertheless, the printing of photochromic substances for textiles has experienced several issues, including poor ability to be washed and an unpleasant touch sensation because of the additional binders used. This problem was addressed, and a novel method for producing photochromic fabrics with great durability by easy screen printing in a binder-free environment was investigated [38].

Y. Yang et al. created a spiropyran-based polymerizable and photochromic dye (SPMA). The photochromic color was subsequently submerged within the combined monomers of styrene (St), n-butyl acrylate (BA), and vinyltrimethoxysilane (VTMS), plus the necessary quantities of polyoxyethylene octyl phenol ether-10 (OP-10), sodium lauryl sulfate (SDS), and NaHCO₃ were added to a solution in water that was deionized (45mL). The pre-emulsion was created through the combination of the monomers and surfactant mixture with supersonic agitation. In 5 mL of water that had been deionized, 0.15 g of ammonium persulfate APS was dispersed. In a 250 mL four-neck glass beaker containing N₂ and a stirring device, one-third quantity of the pre-emulsion and two-fifths amount of the APS mixture had been combined. Upon heating the container to 80 degrees Celsius, the remaining pre-emulsion and APS mixture had been incorporated by drops for 1 hour. The procedure was then extended for a further two hours and cooled to ambient temp to produce PSBM and PSBM-SP latex particles. Lastly, the produced PSBM and PSBM-SP latex particles were poured upon an uncontaminated PTFE (10 cm 10 cm 2 mm) mold and baked at 60 degrees Celsius for 12 hours to produce PSBM as well as PSBM-SP film [38].

The photochromic cotton textiles were created by first creating the printing pigment mix as described in (Table 3), and then printing them using a traditional screen-printing process. Finally, the coated textiles had been baked at 80 degrees Celsius and fixed at 130 degrees Celsius for 4 minutes. According to the results of the investigation, the

inclusion of the photochromic dye (SPMA) engaged in copolymerization with the monomers contained in the semi-emulsion polymerization that formed the PSBM-SP latex particles. The inclusion of the photochromic dye led to photochromic characteristics being integrated into the PSBM-SP latex particles. Furthermore, the presence of VTMS crosslinking monomer in the free radical-induced latex polymerization method allowed Si (OCH₃)₃ groups to be degraded to Si-OH groups. Following treatment, condensing of Si-OH might form the Si-O-Si groups, enhancing the color durability of coated textiles [38].

SEM was utilized to analyze the modifications to the surface structure of the photochromic pigmented cotton fabric. The coating of latex film on the fabric made of cotton was discovered to be linked to it due to the subsequent film development of PSBM -SP latex nanoparticles. Furthermore, within 30 seconds of exposure to sunlight, the photochromic textiles demonstrated a rapid change from colorless to violet. Furthermore, the photochromic functionality of the produced materials may be maintained following 30 cycles of ordinary laundering. Hand sensation and color stability research revealed that photochromic textiles have smoother touch sensation and greater color durability than typical printed materials [38]. This resulted in the conclusion that the technique of manufacturing photochromic printed textiles with great durability qualities and acceptable hand feeling with no use of binders was a success.

Table 4: The formula of the paste used for printing [38].

Components	PSBM-SP printings	Conventional printings
PSBM-SP (g)	10	0
Pigment red 112 dispersion (g)	0	10
DM-5128 (g)	0	15
DM-5221 (g)	20	20
Water (g)	20	5
Totally (g)	50	50

Applications of latexes in textile finishing

The demand for multipurpose textiles that enhance living quality will keep on increasing as textile consumers seek out improved lifestyles, providing these textile goods with a chance to succeed in the textile sector [39]. Chemical finishing procedures have been utilized extensively over the years in order to enhance the unique characteristics as well as imparting certain functionality on both organic and synthetic fibers and textiles. The textiles might be improved by having water/oil resistance, antibacterial

properties, and resistance to the damaging UV radiation, among other properties [40]. The usage of latexes, a type of chemical finishing, can improve the capabilities of textiles by including various aspects, as was previously mentioned.

Latexes for hydrophobic and/or oleophobic textile finishing

Surfaces that are hydrophobic are commonly defined as materials that reject water while having a water contact angle of at least 90 degrees. Surfaces that are extremely hydrophobic include those having water contact angles (WCA) exceeding 150 ° as well as water slide angles (SA) below 10 °. Fabrics that might be subjected to a variety of finishing procedures and supplies that affect the outermost layer of the textile belong to such hydrophobic fabrics [41]. Latexes, which are made up of polymers, are among these substances utilized to treat textiles. Latexes are employed to roughen the outer layer of the fabric and reduce its surface energy, both of which are required to generate extremely hydrophobic fabrics.

Nanocrystalline Cellulose/Fluorinated Polyacrylate Latex

Long-chain-fluorinated polyacrylate polymer compounds have undergone extensive research and are being utilized in numerous industries, including fabrics' finishing, because of their outstanding hydrophobic and oleophobic characteristics, that are caused by their robust fluorine-carbon chains as well as their big van der Waals diameter. These polymers are typically more effective to their polyacrylate equivalent in regards to their outermost activity and hydrophobicity. Fluorinated polyacrylate may enhance the distribution of core-shell kind nanoparticles as well as the number of fluorocarbon networks within the shell, thus being beneficial to the migration of fluorocarbon networks and increases the hydrophobicity of the film. Core-shell sort of nanomaterials altered fluorinated polyacrylate with shorter fluorocarbon linkages that have been generated using certain types of nanomaterials, including nano-SiO₃ and Polyhedral Oligomeric Silsesquioxanes (POSS) [42].

Unluckily, almost all nanoparticles were artificial particles, that were bad for the ecosystem and human well-being since they could easily last for an extended

period in the environment without being degraded. In addition to address this issue, rod-like crystallized nanoparticles known as nanocrystalline cellulose (NCC) were typically produced by chemically treating cellulosic fibers with sulfuric acid. Because of its widespread distribution, degradability, and sustainability, NCC has recently emerged as a fascinating possibility for the development of new functioning environmentally friendly substances in nanotechnology. Additionally, NCC were altered by attaching Poly (Acrylic Acid) to NCC surfaces using the Z-group technique of RAFT polymerization, and they were then employed as a macro-RAFT reagent for the production of core-shell materials. NCC-modified fluorinated polyacrylate surfactant-free emulsion was employed for the hydrophobic finishing of the fabric [42].

In an experiment, Yao, H., et al. first manufactured the PAA grafted NCC by carrying out a two-step process to produce the NCC-g-PAA yellow powder, with an extraction rate of around 66.7%. The researchers utilized RAFT to facilitate surfactant-free emulsion polymerization to create the nanocrystalline cellulose/fluorinated polyacrylate latex. The polymerization was carried out in purified water without ionization in accordance with a standard reaction technique. The pH of the mixture was initially set to 9.38 utilizing 1 M NaOH after NCC-g-PAA (0.05 g) was introduced to 10 g of filtered water and ultrasonically processed for 5 minutes. After that, the NCC-g-PAA dispersed solution was combined with 0.5 g of hexafluorobutyl acrylate, and it was ultrasonically treated for 10 minutes. The resultant mixture was put into a 100 mL round-bottom container, followed by a third portion of the activator liquid solution (ACPA, or 4,4-azobis (4-cyanopentanoic acid), 0.06 g in 2 g of water that had been deionized), was put into the cylindrical container. The resulting solution was subsequently heated in a water bath to 80 degrees Celsius while being agitated with argon gas. In the meantime, the reactor received the addition of the second half of the activator's liquid solution (ACPA, 0.06 g in 2 g of deionized water) in less than 90 minutes. After that, the combination spent 6 hours at 80 degrees Celsius. Placing the beaker in a cold bath eventually caused the process to cease. Following that, NCC-g-(PAA-b-PHFBA), with a conversion rate of up to 94.8%, had been reached [42].

In the subsequent step, the researchers included 6.5 g NCC-g-(PAA-b-PHFBA) liquid solution, 0.573

g of methyl methacrylate MMA, 0.1288 g of hexafluorobutyl acrylate HFBA, 0.573 g of butyl acrylate BA, 0.013 g of ammonium persulfate APS, and 10.6 mL distilled water to a 100-milliliter round-bottom beaker supplied with a device for stirring function. The combination was dehydrated using argon gas for 30 minutes before being held at 80 degrees Celsius. Following that, a monomer combination (HFBA, 0.257 g (MMA), 1.146 g, (BA), 1.146 g) and the APS fluid solution (0.026 g in 2 mL deionized water) were transferred into the beaker throughout 90 minutes. The resulting product was subsequently set in an oven at 80 degrees Celsius for 3 hours. The reaction eventually halted by immersing the beaker inside an ice bath. Finally, the latex film was formed in an own-made 6 cm 6 cm glassware container. Following 24 hours of vaporization, the films were then placed in a vacuum oven at ambient temperature in order to eliminate moisture till a stable weight was reached. Yao, H., et al. were then successful in treating the cotton material via the produced latex by padding it by applying two dips and nips (70-80% wet pick up) in a 70 g/L NCC/fluorinated polyacrylate latex. Following the procedure, the cotton materials were left to dry at 80 degrees Celsius for 3 minutes and fixed at 160 degrees Celsius for 3 minutes [42].

The water and oil repellent characteristics were subsequently evaluated using contact angle measurements, since the more the water/oil repellency, the larger the contact degree. As the concentration of NCC-g-(PAA-b-PHFBA) grew, so did the film's water contact angle (WCA) and oil contact angle (OCA). This indicates that when monomer conversion increases, fluorinated groups increase, resulting in a drop in surface energy and a decline in water-oil property. Furthermore, when the surface structure of the finished fabric was examined in relation to that of the unaltered material, it was discovered that the untreated substrate had numerous deep cavities on its outermost layer, as opposed to the one finished with latex, because the hybrid latex film tucked the finished fabric's pores. Because of the application of NCC, there additionally existed several granular convex formations on the outermost layer. Droplets of liquid were also easily soaked up whenever applied to untreated materials, yet the water's interaction angle of the finished fabric reached up to 156.1 because of the reduced surface energy and rough surface finish. The NCC/fluorinated polyacrylate latex effectively

bonded to the fiber exterior, leading to good water repellency when applied to the cotton fabric [42].

Polystyrene Latex Particles and Polydimethylsiloxane

Cotton textiles are a type of substance that is frequently utilized in the field of textiles, owing to their exceptional permeability and ease. Nevertheless, because of their large surface regions and moisture adsorption capabilities, they can be easily impacted by perspiration or oil discharge from the outermost layer of the skin [43]. A protective coating approach is utilized to increase the water-repellent characteristics of fabric made from cotton by producing polystyrene (PS) latex particles using mist polymerization technique. After atomizing latex particles onto a single side of the cloth to enhance its roughness, the polydimethylsiloxane (PDMS) liquid was subsequently atomized onto the exact same surface of the substance that was treated. The PDMS layer may stop PS latex particles from migrating off the outermost layer of fabric and can help to reduce the material's surface energy [44].

The mist polymerization treatment process was utilized by Xu, Q., et al. to manufacture extremely water-resistant cotton textiles. They began by dissolving 2 ml of PS latex particles liquid in 98 ml of filtered water, following that, stirring the combination for 30 minutes to create the PS dispersed solution. The mixture was then atomized with an air compression-type atomizer, supplied (0.360 ml/min) onto the outer layer of the clean cotton material for 5 minutes, then heated at 100 degrees Celsius for a period of one hour. PSF specimen was the term given to the cloth that had been obtained. The finished sample was obtained by atomizing a solution of PDMS diluted in chloroform (4 wt%) upon the aforementioned fabric specimens' surface for 5 minutes, heating at 100 degrees Celsius for 1 hour, and performing this operation 5 times [44].

The finished fabric was examined and found to have good water-resistant characteristics with a water contact angle WCA of 158.1. despite 1400 abrasion cycles or 50 laundering processes, the WCA values of treated cloth were above 154.0 °, demonstrating exceptional structural endurance. Furthermore, the resulting fabric demonstrated exceptional chemical fastness. The treated fabric's extremely hydrophobic exterior demonstrated remarkable oil-water

separation capabilities. Furthermore, using mist polymerization technique, a single-sided extremely hydrophobic cotton material was effectively developed, while the desirable qualities of the finished material were not greatly affected. As a consequence, the resulting material with long-lasting extremely hydrophobic qualities has an excellent prospect for use in oil-water separation applications [44].

Latexes for antimicrobial textile finishing

Our surrounding atmosphere is overflowing with microbes. Therefore, the growth of such microbes on fabrics may result in discoloration or stains, degradation of fiber substances, diminished endurance, as well as of obviously, a hazard to the consumer's health. Many textiles and polymers tend to not be resistant to microorganisms. [45]. Thus, a latex-based textile finishing method was used to impart microbial activity to the materials.

Ag/fluorine polyacrylate latex

It became necessary for the textile industry to create textile substrates that address the market's requirement for enhanced textiles. Additionally, finishing techniques that produce textiles with antimicrobial properties have to be introduced due to the dangers that bacteria pose to human health and the environment. In order to overcome this, a sort of polyacrylate hybrid latex containing fluorine and Ag nanoparticles was created via Pickering emulsion polymerization [8]. Ag has been shown to possess antibacterial effects on several different types of microorganisms [46]. Fluorine-containing acrylic polymers are given special antibacterial properties in addition to improved water-oil durability and thermal endurance by the addition of silver nanoparticles (Ag NPs). Fluorine is also renowned for having hydrophobic properties [8].

To obtain the polyacrylate latex that was impregnated with Ag and fluorine, Zhou, J., et al. undertook a procedure. To create the catalyst solution, they first mixed 300 mL of deionized tap water with 2,2'-Azobis(2-methylpropionamide) dihydrochloride AIBA. The Ag/P(DMAEMA-co-HFBA) mixed tiny particles liquid (10 mg/mL, 42.03 g) was then incorporated to the combined monomers, methyl methacrylate MMA (6.08 g), butyl acrylate BA (6.08 g), and hexafluorobutyl acrylate HFBA (1.35 g). The combination was then mixed together

for three minutes in order to create a stable Pickering colloid. The finished Pickering emulsion was put into a 100 mL dynamically agitation reactor that included a condensing pipe and an exhaust intake. The system's temp was raised to 75 °C once the entire system had been decontaminated by bubbled nitrogen for 30 minutes. In 1 hour at steady velocity, an AIBA initiator liquid was introduced by drops to the system. After the incorporation was complete, the system was kept in reaction mode for an hour and a half at 75 degrees Celsius [8].

The polyacrylate latex incorporating Ag and fluorine was subsequently poured onto a transparent matrix, where it hardened in the open air to create the latex film. The film was subsequently dried for three hours at 80 degrees in a hot-air dryer. it was produced after 30 minutes of heating at 120 degrees Celsius. The cotton fabric then underwent treatment by being infused with an aqueous solution comprising Ag/fluorine-containing polyacrylate latex at a dosage of 70 g/L through two dips and two nips. The cotton fabric was eventually squished to a 70-80% wet pick-up, dried for 3 minutes in a hot-air dryer at 80°C, and finally fixed for 3 minutes at 160°C. After further examination, it was discovered that the cloth has antibacterial properties [8].

This potent antibacterial activity is believed to be result from the interaction between Ag nanoparticles and cationic compounds containing quaternary ammonium. N^+ ions, that can render bacteria inactive by aggregating upon the cell walls via their electrostatic attraction, are carried by the cationic quaternary ammonium side chains. When the bacterial cell membrane is destroyed, the water-repellent chains carried by the integrated Ag/fluorine-latex may disrupt the membrane's ability to breathe, causing protein degradation as well as inhibiting microbial development. On the contrary, recombination of DNA can be stopped by nanoparticles of silver because they release silver ions which bond with DNA's phosphorus groups. The fabric's exterior has also been shown to be somewhat rough, which gives it water-resistant qualities. Although the whiteness of final cotton cloth marginally lowered, the fabric's durability was definitely raised. In conclusion, in addition to its positive effects on the environment, this Ag/fluorine-containing polyacrylate latex has great potential be used in textile finishing [8].

Nano-TiO₂/Fluorinated Polyacrylate Core-Shell Latex

Given its numerous qualities, including film forming, binding, and physical capabilities, polyacrylate is frequently utilized in the textile sector. Nevertheless, it has a number of drawbacks that significantly restrict its practical applicability, including low solvent obstruction, poor resistance to stains, and poor weather durability. Fluorinated polymer had been employed to get over these drawbacks. Additionally, nano-TiO₂ nanoparticles may be added to polyacrylate, giving it the chance to acquire outstanding durability, thermal endurance, and antibacterial qualities. The heavy reliance on fluorinated polymers is nonetheless constrained by the high cost of fluorinated monomers. Keeping its great surface characteristics while reducing the number of fluorinated monomers is the difficult part. Making core-shell fluorinated polymer latex using a shell that is fluorine-rich is a highly efficient solution to tackle this conundrum [47].

Through the use of alkyl vinyl sulfonate to be an emulsifier as well as dodecafluoroheptyl methacrylate (DFMA) to be a monomer that's fluorinated, Zhou, J., et al. created a nano-TiO₂/fluorinated polyacrylate latex that has a core-shell arrangement. Also given in (Table 5) are the formulas for creating the incorporated hybrid latex. The latex film was created by pouring the soap-free latex into a Pyrex plate of glass once the hybrid polymer had been created. Around ambient temperature, the latex transformed into a thin film. To get rid of the liquid that was within the film, it was subsequently dried at 80°C during 3 hours. The film was finally toughened at 120°C for 30 minutes. The cotton fabric afterwards underwent treatment by applying two dips and nips (70–80% wet pick up) in a mixture comprising 70 g/L of fluorinated polyacrylate soap-free latex enhanced using nano-TiO₂. The cotton textiles were treated, dried afterwards at 80°C for 3 min. and fixed at 170°C lasting 3 min [47].

Next, the morphology of the artificial hybrid latex was examined. It was discovered to be that hybrid latex molecules have a limited range of sizes and are well-shaped in the form of spheres having a radius of around 120 nm. Additionally, it became apparent that the hybrid latex particles have typical core-shell spherical parts with a deep colored nano-TiO₂/polyacrylate core and a translucent fluorinated polyacrylate exterior. Tensile strength and UV-visible spectral data further demonstrated that the hybrid films had superior physical capabilities than the fluorinated polyacrylate film. Following that, the

chemically treated textiles' antimicrobial properties were investigated [47].

Table 5: Latex formulations using fluorinated polyacrylate and nano-TiO₂ [47].

Samples	TFPA ₀	TFPA ₁	TFPA ₂	TFPA ₃	TFPA ₄	TFPA ₅
Modified nano-TiO ₂ /g	–	0.05	0.12	0.16	0.24	0.32
MMA/g	24.30	24.30	24.30	24.30	24.30	24.30
BA/g	16.20	16.20	16.20	16.20	16.20	16.20
AVS/g	1.58	1.58	1.58	1.58	1.58	1.58
DFMA/g	2.05	2.05	2.05	2.05	2.05	2.05
APS/g	0.57	0.57	0.57	0.57	0.57	0.57
DI water/g	100.00	100.00	100.00	100.00	100.00	100.00

It was determined that the fabric specimens subjected to nano-TiO₂/fluorinated polyacrylate soap-free hybrid latex shown more antibacterial properties when contrasted to the fabric specimen coated with fluorinated polyacrylate soap-free latex. This outcome may be linked to the reactivity of oxygen species' breakdown of the wall of the bacterial cell and membrane, that is caused by the photocatalytic action of nano-titanium dioxide particles. Additionally, once the amount of altered nano-TiO₂ in the coated cloth specimens grows, so does their antibacterial effectiveness. The textiles' ability to develop a rough texture that allows them to acquire water-resistant characteristics was also demonstrated. As a result, cotton fabrics subjected to nano-TiO₂/fluorinated polyacrylate hybrid latex shown outstanding antibacterial properties as well as exceptional repellent properties to water [47].

Latexes for textiles UV protection properties

Sunlight's harmful ultraviolet (UV) rays are a fundamental threat to the well-being of humans and may result in major medical issues. Human skin that is subjected to ultraviolet (UV) light without protection can suffer from major health issues. UV-blocking or shielding substances are put on humans' skin to shield it from harmful UV rays. These goods include textiles that have been treated to have UV blocking characteristics [48]. Latexes, which have characteristics of blocking UV rays, are one form of treatment used to textiles to create UV-protectant textiles.

Nano-TiO₂/Fluorinated Polyacrylate Core-Shell Latex

Polyacrylate is commonly used in the textile industry due to its many pros, involving film developing, binding, as well as durability. However,

it comes with a variety of shortcomings which considerably inhibit its general use, such as poor solvent obstruction, inadequate stain removal, and inadequate environmental endurance. To overcome these limitations, fluorinated polymer was developed and used. Polyacrylate can also be given a boost in its resilience, heat stamina, and antibacterial properties via the inclusion of nano-TiO₂ nanoparticles. The high price of fluorinated monomers regardless places a limit upon our extensive dependence on fluorinated polymers. The challenging aspect is preserving its excellent surface features with lowering the quantity of fluorinated monomers. Developing core-shell fluorinated polymer latex with a fluorine-rich shell is an exceptionally efficient method to deal with the issue at hand [47].

Zhou, J., et al. conducted an experiment where alkyl vinyl sulfonate was employed to serve as an emulsifier and dodecafluoroheptyl methacrylate (DFMA) as a fluorinated monomer in order to create a nano-TiO₂/fluorinated polyacrylate latex that has a core-shell structure. The soap-free latex was dumped into a Pyrex glass platter, baked at 80°C over three hours, finally reinforced at 120°C for thirty minutes in order to generate the latex film. Two dips and nips in a solution of fluorinated polyacrylate soap-free latex supplemented with nano-TiO₂ were used for treating cotton fabric, which was dried off at 80°C for 3 minutes and set at 170°C for 3 minutes. Once the morphology of the synthetic hybrid latex was studied, it turned out that the particles were well-formed cylindrical ones with a radius of around 120 nm. The hybrid latex particles feature a core-shell structure composed of a fluorinated polyacrylate shell and a deep-colored nano-TiO₂/polyacrylate core. In comparison to the fluorinated polyacrylate film, the hybrid films performed better in terms of tensile strength and UV-visible spectrum data [47].

As UV permeability of the hybrid nano-TiO₂/fluorinated polyacrylate film is less compared with that of the fluorinated polyacrylate film along with a visible decrease of the transmission quality alongside increased amounts of the modified nano-TiO₂ concentration, the analysis also demonstrated that the hybrid film had highly evident UV-shielding capability. Previous research revealed that the hybrid films outperformed the fluorinated polyacrylate film in terms of mechanical characteristics and UV protection, making them ideal for use on protective outdoor fabrics [47].

Conclusion

In summary, latexes have demonstrated their superiority in applications for the textile sector. It was discovered that latexes might be employed in place of conventional binders, eliminating their drawbacks. They might also be used to dye fabrics, causing the color to distribute more effectively and preventing dye aggregation. Last but not least, their performance in terms of textile finishing was superb since they could hold and apply any desired fishing material to the fabrics. Integration with fluorine, for instance, has demonstrated its efficacy in making cotton textiles hydrophobic. They were also ideal for antibacterial textile finishing due to their impregnation with Ag nanoparticles. Last yet not least, their TiO₂ nanoparticle impregnation made them superb UV shields. In conclusion, latexes show significant promise for enhancing nearly all of the operational elements of the textile business.

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Author Declarations

The authors declare that the data supporting the findings of this study are available in the article

The authors declare that there is no conflict of interest.

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