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Polyurethane (PU) in Textile Finishing Process

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Abstract

When it comes to the area of textile finishing applications, polyurethanes are practically a wonder material. They blend the suppleness of rubbers with the hardness and stiffness of metals and plastics. Polyurethane has become the standard material for many applications due to this combination of material properties and qualities. It has been used in a variety of industries, including the bio-medical sector, marine industry, elastomers, foams, textiles, coatings, adhesives, sealants, and adhesives. A variety of polyols and isocyanates can be used to create polyurethanes, To create high-performance products, water-borne urethanes have replaced solvent-based urethanes in a variety of finishing applications for textiles. As a result, PU has significantly advanced the field of functional textiles due to its low cost, capacity for mass production, and intriguing physicochemical characteristics. The PU-coated fabrics are extremely electrically and adhesively strong, more resistant to abrasion and weather, and highly resistant to chemicals and water.

Keywords: Polyurethane (PU), PU application, finishing process.

Introduction

In comparison to more modern polymers, polyurethane is highly different and versatile in many ways. Polyurethane is one of the most sought-after polymers due to its ease of manufacture and outstanding characteristics. In 1937, the polyurethane industry was created as a result of the reaction between diisocyanate and polyester diol [1, 2]. Initially created as a replacement for the elastic rubber used in World War II, it gradually supplanted other materials like woven fibers and metals due to its versatility. For instance, PU coatings were specifically used to deliver apparel that was resistant to mustard gas and rust and to impregnate paper [3]. They were also used as polished finishes for airplanes and as synthetically secure coverings for metal, wood, and stone, additionally the production of flexible foams and other automotive and upholstery.[4]

The longevity, toughness, and superior chemical resistance of polyurethane have been its key benefits. The polymer has the strength of metal and the flexibility of rubber [5, 6]. Because it combined elongation, hardness, strength, and modulus, PU has been employed in a wide range of industries, including biomedicine, automotive, construction, and textiles [7, 8]. A diol and an isocyanate react chemically to produce a urethane group. Therefore, a diol and an isocyanate, which react to produce urethane linkage, are the primary raw materials in the manufacturing of polyurethane. [3, 9, 10]

PU has significantly advanced the field of finishing functional textiles because of its low cost, capacity for mass production, and intriguing physicochemical characteristics[11, 12]. Numerous materials, including textile, leather goods, plastics, furniture, and flooring are regularly coated with chemically modified PU in addition to being utilized as base coats for automobiles, topcoats for vinyl upholstery, footwear adhesives, and printing inks [13, 14].

Polyurethane has a variety of methods for finishing textile processes, such as the synthesis of polymers from vegetable oil and the production of vegetable oil-based polyurethane, which is used in a variety of industries including those involving transportation, clothing, paint and coatings, packaging, and medicine. By adjusting the polyol concentrations relative to 1,4 -butanediol, water-borne polyurethane dispersions were created using

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the renewable resource cottonseed oil-based polyol.[15]

Curcumin, a naturally occurring biomolecule, is also employed as an antibacterial agent. It has been effectively inserted into the backbone of water-dispersible polyurethane to create biobased antibacterial textile treatments. This curcumin-based water-dispersible polyurethane (CUR-WDPU) dispersions were made by combining curcumin (CUR) in varying molar amounts with isophorone diisocyanate (IPDI), polyethylene glycol (PEG), dimethylolpropionic acid (DMPA), and trimethylamine (TEA).[16]

Utilizing the thermoplastic polyurethane material from the polyurethane material category and new yarn covered in polyester yarn, the fabric was redesigned, and a new kind of leather-like environmental protection fabric was created using the material's ability to melt at high temperatures.[17]

UV-curable multifunctional waterborne polyurethane is used in the fabrication of polymeric dyes for textile coating. To get over the limitations of thermo-curing, three brand-new UV-curable polymeric dyes (UVPDs) based on multipurpose waterborne polyurethanes have been successfully produced. End-capping the UVPDs with 2-hydroxyethyl acrylate (HEA), pentaerythritol triacrylate (PETA), and dipentaerythritol pentaacrylate (DPEPA) allows for customized UVPD functionality.

PU in textile and clothing, especially in technical textiles, in addition to its traditional use as elastane/lycra in clothes due to its balanced qualities. PU fabric coatings give the base fabric excellent moisture permeability and water resistance. [18]

Chitosan inclusion has also been successful in chemically altering PU structure [19, 20]. In comparison to pure WPUs, the water-born polyurethane (WPU) based on chitosan exhibits superior antibacterial action against E. coli and Staphylococcus aureus. Chitosan has been widely used in the antimicrobial finishing of cotton and many other textiles because it is an effective antibacterial agent. Isophorone diisocyanate (IPDI), polyethylene glycol (PEG), 2,2-dimethylol propionic acid (DMPA), and chitosan (CS) were used to create a variety of water-dispersible polyurethanes dispersion (CS-PUs) with versatile performance profiles for textile applications.[21]

Polyurethane

A recurring urethane linkage is created when a diol or polyol reacts with a di/poly isocyanate to create polyurethane. When other additions, such as a chain extender, are present. Two mother components, a polyol, and an isocyanate, can serve as the basic building blocks of polyurethane. The final characteristics of the product are influenced by both these components. The qualities of polyurethane may be drastically altered by changing the polyol or the isocyanate. In the resulting polyurethane, the polyol and the isocyanate form various domains or regions, These areas are in charge of introducing characteristics like softness, flexibility, or hardness.[22]

Because of their greater mobility and consequent flexibility, polyols tend to have longer chains than diols, which gives polyurethane additional flexibility. The utilized isocyanates and chain extender, meantime, control the hard portions. Since isocyanates often have relatively short chains, they crystallize more readily and produce tightly packed segments that are extremely rigid and non-flexible.[23] Because it combines hard and soft parts, polyurethane has the property of being extremely adaptable and efficient in a wide range of applications.

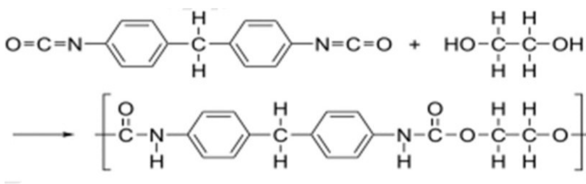

Fig. 1. Urethane formation

Polyols, Isocyanates, and PUs

Polyols are compounds with several functional hydroxyl groups. they can be broadly divided into polyester polyols and polyether polyols. Epoxide and an active hydrogen-containing molecule react to form polyether polyols. They are created by adding ethylene oxide or propylene oxide in the presence of catalysts to a polyhydroxy pre-cursor molecule. In addition, polymerization or ring-opening reactions of epoxy monomers can produce polyethers[24, 25]. Glycols, ethylene glycol, 1,4-butane diol (BDO), and 1,6-hexane diol are a few of the most basic polyols. The polyesterization of extremely diacids and glycols yields polyester polyols, which are obtained from virgin raw materials. When compared to polyether polyols, polyester polyols are typically more expensive and viscous. A high degree of hydrogen bonding in polyester contributes to the formation of solid bonds, increasing the material's tensile strength and hardness. However, they are crucial because PUs made from them have greater cut, solvent, and abrasion resistance. A different category of polyester polyols is created using recycled raw materials. They are made using recycled polyethylene terephthalate (PET) and a process called transesterification, sometimes known as glycolysis. And various polyols can be obtained from sustainable, all-natural sources like vegetable oils, Fatty acids, or dimer fatty acids may be these renewable resources[26, 27]. These diols can be made from a variety of crops, including castor, soybean, Pongamia glabra, neem, and cotton seeds [28].

Isocyanates are necessary components in the manufacture of polyurethane. These are two or more -NCO groups per molecule, di- or polyfunctional isocyanates. These can have an aromatic, aliphatic, or cycloaliphatic structure. Due to their high reactivity, isocyanates are absorbed into the polyurethane backbone by a reaction with hydroxyl-containing substances like various polyols, albeit the reactivity is sluggish at ambient temperature and depends on several additional parameters as well [29].

PU dispersions (WDPUs) In addition to being utilized as base coats for automobiles, topcoats for vinyl upholstery, footwear adhesives, and printing inks, PU dispersions (WDPUs) are frequently employed for coating a wide range of materials, including textile, leather items, plastics, furniture, and flooring [13, 14]. Numerous researchers have created various types of polyurethanes (PUs) based on numerous diols and diisocyanates and investigated them for a variety of applications [30, 31] due to the special characteristics of PUs. PUs are also extensively employed in the development of breathable, non-formaldehyde coatings, as well as to improve the quality, durability, and transient appearance of textiles [32, 33]. Water-dispersible polyurethanes' antistatic, hydrophilic, and anti-soiling finishing qualities are ideally suited for synthetic fibers [34, 35]. Textile goods have been the forerunners in the development of several functional qualities, including antibacterial, wrinkle resistance, softness, stain resistance, hydrophilicity, and UV resistance/blocking capabilities.

Application of PU in textile finishing:

PU has made considerable research advancements in the area of functional textiles and is widely employed in a variety of applications, including:

Utilizing cottonseed oil as a polyurethane-based textile finishing agent:

Many efforts are being undertaken to create polymers from vegetable oil using a renewable technique. Vegetable oil-based polyurethane was created and is used in numerous industries as a result of the simple preparation and potential uses of polyurethanes. Castor oil, palm oil, rapeseed oil, white mustard seed oil, tall oil, castor oil, and palm oil, as well as soybean, sunflower, and peanut oils, are used to create synthetic polyurethane foams. The production of waterborne polyurethane dispersions, which are used as a coating material for cellulosic fabrics, by converting cotton seed oil into polyol. [15]

Application of the waterborne-polyurethane dispersions to the fabric:

Washing the fabric in a solution containing 2 g/L Na_2CO_3 and 1 g/L Triton X-100 (nonionic surfactant) (BASF) before applying the polyurethane dispersions at 100 °C for 60 min. 11 g of unwashed fabric were washed twice in 1:30 w/v hot and cold water ratios, and then the fabric was dried at ambient temperatures of 37 °C.

Cotton seed oil epoxidation using 100 grams of cotton seed oil A round bottom flask was filled with 40 g of H_2O_2 (50%) and 15.2 g of HCOOH (95%) and swirled for 21 hours at 25 °C in a water bath. After 21 hours of reaction, cottonseed oil that had been epoxidized was washed with 0.5 M NaCl solution and ethyl acetate (3:1 ratio of the total weight) before being mixed with the epoxidized. After washing the epoxidized oil, $NaHCO_3$ was employed to maintain a pH of 7, followed by $MgSO_4$-based drying, and finally filtration. After vacuum filtering for 1 hour at 38 degrees Celsius, rotary evaporation was then applied to the epoxidized cottonseed oil.

Cotton seed oil was epoxidized to form polyols and 60 g of the epoxidized oil and 180 g of CH_3COOH were put into a flask with two necks while being stirred mechanically and allowed to condense for eight hours at 80 °C.

Polyurethanes (PUDs) made from polyol are prepared To create a homogenous mixture, the synthesized polyol and DMPA (dimethylol propionic acid) were placed into a four-necked flask with a mechanical stirrer and heated to 80 C for 30 min. IPDI (isophorone diisocyanate) was added drop by drop during the course of 30 min of stirring, and DBTDL (dibutyltin dilaurate), a catalyst, was also added at that period. The reaction was then allowed to proceed for 3 h. Methyl ethyl ketone (MEK) was added to the mixture as a solvent to control viscosity. After three hours, a pre-polymer had produced. To expand the polymer's chain, BDO (1,4-butanediol) was added and reacted for 30 minutes to an hour. After that, it was allowed to cool to 40 °C, neutralized with trimethylamine, and distilled water was added while being mechanically stirred at a high speed.

Applying PUDs on cotton/poly fabric the dispersions were produced in distilled water for 4.5 minutes at 10 g, 30 g, and 50 g per litre. For two minutes, each fabric—white, printed, and dyed—was submerged in a 200 ml solution. After that, it was dried for 3 minutes at 80°C and then cured for 5 minutes in an electric oven at 140°C.

After treatment, fabrics exhibit better results. This is because prepared coatings' solid contents rise as polyol mole ratios rise, bringing dispersed particles closer together and fostering powerful interactions. It results in a reduction in micelle size and prevents light from penetrating the cloth, which weakens the molecular structure of the dye.

The fabric was applied with dispersions to get improved pilling resistance. the pilling rate of the fabrics by varying the mole ratio of the cottonseed oil-based polyol (pilling resistance increases in the amount of polyol beyond 1.5 (10.62 g) moles).

Colorfastness properties of fabrics

- **Colorfastness against rubbing:** after applying 1%, 3%, and 5% dilutions of PUD dispersions to fabrics, swatches of printed fabric showed improved improvement in both dry (2/3 to 4) and wet rubbing ratings (2 to 3) ratings. The dyed treated fabric samples with dispersion solution improved from a wet rubbing rating of 2 to 3/4, a dry rubbing rating of 3 to 4/5, and a rubbing rating of 6 and 7. With 5% of a prepared pu dispersion, both materials' rubbing fastness improved the most.
- **Washing fastness:** The fabric samples treated with the 5% concentrated solution had higher washing fastness results. This may be because the dispersions were better inserted into the fabric and adhered to it, and because a stable and durable coating layer had formed on the fabric. The coated textile samples have stain ratings between 3/4 and 4/5 and shade changes between 3/4 and 4/5.
- **Colorfastness to perspiration:** Acidic and alkaline ratings of the treated dyed fabric have shown to be in the range of 4- 4/5 in terms of color fastness to perspiration. While the rating for printed treated cloth swatches was in the 3/4–4/5 range for both acidic and alkaline.
- **Colorfastness to light:** The application of a 5% diluted PUD solution to fabric swatches resulted in better results, increasing lightfastness. In contrast, the rating of dyed fabrics was observed in the range of 3/4–4, but coated print samples showed some improvement, rating 4 & 4/5.

Using aqueous polyurethane dispersions based on curcumin to treat textiles with antibacterial properties

Curcumin, a naturally occurring biomolecule, is employed as an antibacterial agent, and it has been effectively inserted into the backbone of water-dispersible polyurethane to create biobased antibacterial textile finishes. This curcumin-based water-dispersible polyurethane (CUR-WDPU) dispersions were created by mixing curcumin (CUR) in various molar amounts with polyethylene glycol (PEG), dimethylol propionic acid (DMPA), trimethylamine (TEA), and isophorone diisocyanate (IPDI).[16]

Curcumin is obtained from the Curcuma longa plant which imparts numerous pharmacological effects. Exceptional antibacterial, antifungal, antioxidant, anti-inflammatory, anticoagulant, and anticancer properties are displayed by this naturally occurring substance. Historically, it has also been applied to textiles as a dye or coloring agent [36, 37]. The polymeric chain of water-dispersible polyurethane is extended using curcumin.

Applying aqueous polyurethane dispersions based on curcumin to the fabric

Washing fabric: Before applying CUR-WDPU-IPDI finishes, samples of dyed and printed polyester cotton were washed at 100 °C for 30 minutes, rinsed, and then dried at room temperature with the pH of the fabrics kept between 6.5 and 7.5.

Preparation of CUR-WDPU

PU prepolymer preparation using NCO terminals:

- PEG (1.0 mol) and DMPA (0.8 mol) were added to the reactor first, and the reaction was conducted there for 30 min at 80–90 °C.
- Then, a single drop of the catalyst DBTDL (dibutyltin dilaurate) was added to the reaction mixture followed by the addition of isophorone diisocyanate (IPDI) (2 mol) under vigorous stirring.
- The reaction mixture was then allowed to continue reacting for an additional 2 hours at 70 to 80 °C, producing a hydrophilic PU prepolymer with NCO terminals.
- To neutralize the carboxylic (COOH) groups that are present in the PU polymeric chain, TEA (0.9 mol) was added to the NCO-ended PU prepolymer. This neutralization was carried out for the next 45 min at 55 °C.
- A very little quantity of methyl ethyl ketone (MEK) was added to the reaction mixture to reduce the viscosity of the polymer solution.
- Curcumin (dissolved in the required amount of MEK for 30 min, then the addition of deionized water at room temperature for the following 2 h) was used to extend the chain of the neutralised PU prepolymer. A reliable CUR-WDPU dispersion with 35% solids was created.

Finish application

One liter of distilled water was combined with 20 or 40 grams of CUR-WDPU dispersion. To create a 2% or 4% solution of the polymeric dispersion, this mixture was homogenized using a mechanical stirrer for 5–10 min. After that, textile swatches were squeezed, dried, and cured at 150 °C for 1 min.

Antimicrobial properties of curcumin water‑ dispersible polyurethane

The antibacterial activity of fabrics treated with synthetic CUR-WDPUs increases noticeably. Overall, 2% dilution of CUR-WDPUs produced the best results. This may be attributed to the fabric and CUR-WDPUs' superior compatibility and improved penetration. Additionally, it was noted from the findings that the antibacterial activity of the PU polymeric chain significantly increased when the molar quantity of curcumin was increased.

Gram-positive and gram-negative bacteria with impaired prokaryotic cell division have been inhibited by curcumin [38, 39].

Polyurethane (PU) for functional textiles applications

The application of PU in textiles and clothing, especially in technical textiles, in addition to its traditional use as elastane/lycra in clothes due to its balanced qualities.

PU fabric coatings give the base fabric excellent moisture permeability and water resistance. These materials make the greatest substitutes for synthetic leather textiles used in military and civilian foul-weather gear. The extremely hydrophobic textile surfaces exhibit anti-sticking, anti-contamination, and self-cleaning properties with the addition of PU coating.[18]

PU Coating in a breathable, water-resistant fabric

Breathability is the capacity of a substance to transfer sweat or moisture vapor. It is one of the industries because it explains how comfortable material is and how our bodies can keep their internal temperatures constant under a variety of circumstances and labor rates.

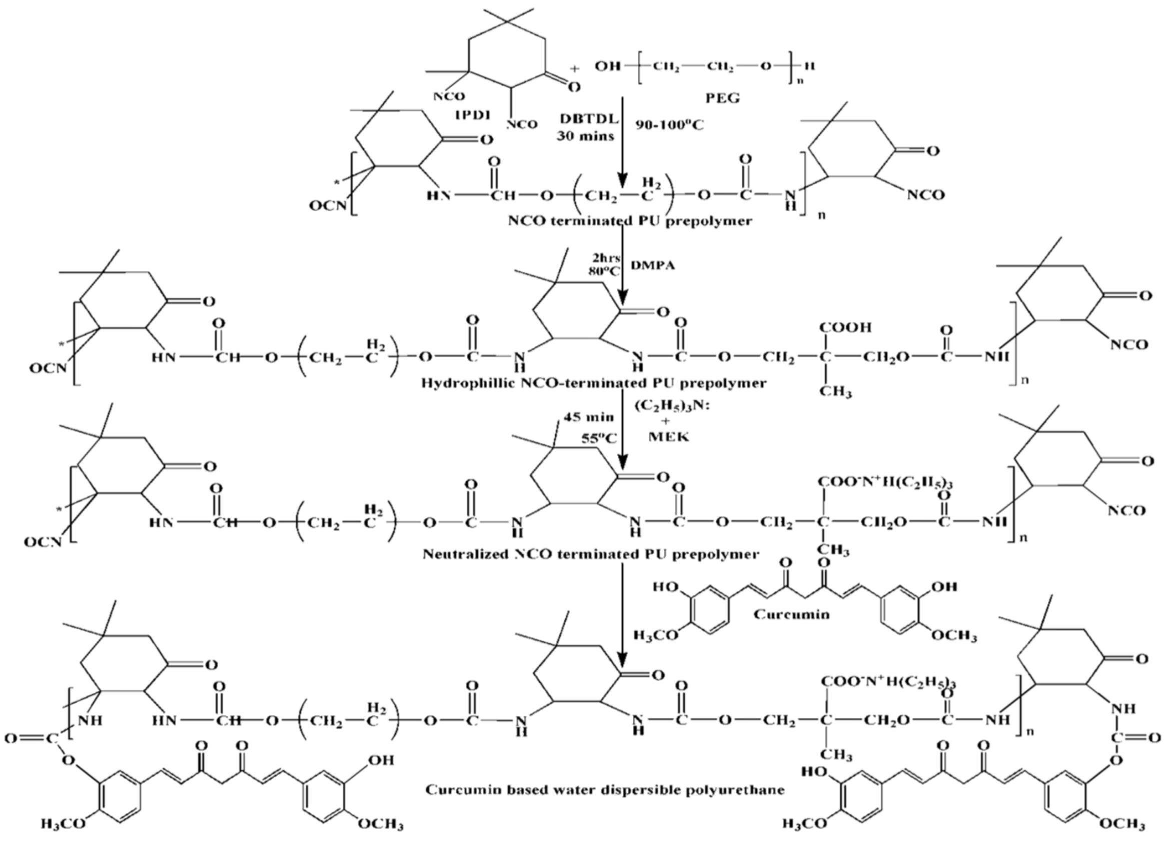

Fig. 2. shows how water-dispersible polyurethane based on curcumin was made.

Traditionally, waterproof fabrics are coated with PVC polymers, animal fat, wax, vegetable oils, or a combination of these materials. However, coated fabrics are uncomfortable to wear due to their rigidity and uncooperative attitude towards evaporating perspiration. Contrarily, **WBF's** unique feature is that it must be both waterproof (preventing water droplets from entering the fabric) and breathable, allowing moisture from the skin to evaporate through the spaces between the fibers and yarns. Due to its perceived attributes and physical characteristics, such as flexibility, adhesion, and abrasion resistance, which are superior to those of other polymeric materials, PU-coated WBF has become more and more popular as valuable soft coatings for textiles.[18]

Waterborne PU Coating for WBF

Due to the growing concern over lowering potential environmental contamination by reducing low volatile organic compounds produced by the solvent-borne synthesis technique, the application of waterborne PU (WBPU) coating in WBF has attracted attention.

Water resistance and water vapor permeability must be balanced for PU-coated WBF, which is accomplished by adjusting the hydrophilic and hydrophobic segments. Due to its hydrophilic character, the poly(ethylene glycol) (PEG) segment has historically been used as a hydrophilic soft segment to provide high WVP during PU synthesis. This hydrophilic PU lowers water resistance while increasing water vapor penetration.85When used as a textile coating, WBPUs made from hydrophobic poly (tetramethylene ether glycol) (PTMEG) and polypropylene glycol (PPG) a copolymer of ethylene oxide and propylene oxide with OH end groups achieved a balance of WVP and waterproof properties.

In synthesizing waterborne siloxane-containing PU from PTMG and PEG, Due to its hydrophobic property and high vapor diffusion rate, the polysiloxane can be employed as a modifier. The incorporation of 10%,-aminopropyl polydimethyl siloxane as mixing soft segments with PU resulted in the maximum moisture permeability and water resistance when hard segment, hydrophilic chain extender, and neutralization agent are present. WBTaffeta and Taslan base fabric laminated with PU coating increase the abrasion resistance and longevity of the electrospun nanoweb membrane.

Hydrophilic PU membrane for WBF

It is possible to create hydrophilic membranes, a thin polyester or polyurethane film that has undergone chemical modification, by including poly (ethylene oxide) in the polymer structure. By creating an amorphous region in the core polymer system, poly (ethylene oxide) in polymer aids in creating the hydrophilic portion of the membrane (Figure 1c). The solid aspect of the membrane prevents liquid water from penetrating, whereas its amorphous structure serves as the intermolecular gaps to allow water vapor to pass through. With the introduction of hydrophilic PU coating, the use of synthetic leather clothing in unfavorable conditions has decreased.

When nylon fabric is coated with hydrophilic PU, which is made from -caprolactam-4,4 diphenylmethane diisocyanate and hydrophobic polyols, it imparts characteristic water-repellant moisture-permeable qualities.

Application of PU for functional textiles

Fabrics and clothes insulators for thermal comfort

PCMs are the materials utilized in latent heat storage systems. During phase transitions between two solid states or between liquid and solid states, PCMs can absorb or release a significant quantity of heat. There are a variety of PCMs with countless melting points that can be classified as organic (such as paraffin, fatty acids, and polyethylene glycol), inorganic (such as salts, salt hydrates, hydroxides, and metals), polymeric, or a eutectic mixture of both. Incorporating PCMs into garments improves the wearer's thermal behavior, insulating them from adverse weather in addition to providing thermal comfort.[40]

application of PU-based PCMs in the textiles and clothing sector is one of the most important research topics and a plethora of approaches are practiced worldwide like, deposition of PCMs on PU films, incorporation of PCMs in PU films, PU-PCMs composite, and microencapsulation technique.[41]

PCMs embedded PU films

Giving basic fabric a coating of composite PU and PCM membranes results in the composite fabric having excellent thermal comfort, as shown by:

- Coated polyamide fabric is made by in-situ polymerizing WBPU-urea emulsions with 30% PCMs (hexadecane, octadecane, and eicosane) while thickening and hardening the mixture.
- Creating WBPUPCM from hexamethylene diisocyanate and PEG whilst utilizing a catalyst, chain extender, and neutralizer. When utilized in functional textiles, WBPU-PCM can offer great thermal stability with environmentally benign applications.

Microencapsulated PCMs-PU composite

In the microencapsulation technique, a tiny particle of the active ingredient or core material is encased in a coating or shell. The core substance may be in the form of a solution, dispersion, or emulsion. To enhance the thermal performance of PU foams, the first attempt at using microencapsulated PCMs (micro PCMs) was made in the 1990s. PCMs are increasing to expand their use in thermal energy fields like building heating and cooling, medical products, footwear, automotive interiors, and thermal insulation materials, mostly in thermal adaptable fibers, fabrics, coolants, and coatings.

The inclusion of thermo-regulating microcapsules with polystyrene (PS) results in a significant decrease in thermal conductivity and enhances insulating ability. The incorporation of PCMs can increase the PU Foam's thermal regulation capacity.

For example: combining PU with octadecane as PCM in the presence of emulsifiers to create a microcapsuleNylon fabric was coated with a coating combination that was prepared, and it was found that the WBPU/octadecane-coated fabric exhibits better heat transmission abilities.

PU for protective clothing

Protective textiles Due to their ability to protect in a variety of severe situations, protection is required for employees who are constantly in danger. Examples of protective textiles include those used in industrial, military, civilian, agricultural, medical, sporting, and space applications.

Application of PU-incorporated chemical protective textile materials

Chemically resistant textile fabrics are made to protect the wearer from various harmful substances, lowering the risk of bodily harm and illness, for instance:

1. Various polymers, including PU, PVC, PVDC, PTFE, and PE, have been successfully introduced the incorporation of PU binder to the hydrophilic natural fiber gives the composite its hydrophobicity and exhibits the greatest resistance to water and liquid chemicals, including acetone, ethanol, DMF, toluene, acetic acid, formic acid, n-decane, and hexadecane, penetrating it.
2. Investigating the thermal comfortability and protective capabilities of the composite specimen using PU binder and porous silica aerogel on the cotton fabric surface. Due to the hydrophobic PU, silica aerogel, and various concentrations of the roughness of the silica aerogel coated fabric, the PU-aerogel-cotton composite displayed good water resistance qualities.
3. In the PU-cotton composite, the use of sodium polyacrylic acid as a superabsorbent polymer (SAP) predicts a long-lasting resistance to liquid chemicals. By offering increased heat and vapor transmission, they increase air permeability while simultaneously providing the wearer with protection and thermo-physiological comfort.
4. Alkali-treated bamboo (Bambusa balcooa) fibers coated with PU/PS (50/50) exhibit greater resistance to water and various solvents, including acid, base, oxidizing agents, and organic and aqueous solvents than the PU coated one.
5. When applied to synthetic woven fabrics in the presence of a crosslinking resin and an organic fluorochemical, PU/acrylic latex-based IPN coating exhibits noteworthy resistance to stain, water, microbe, weather, light, and high temperature. This coated cloth demonstrates long-lasting outdoor uses, particularly for boat covers, lawn and patio umbrellas, and sun awnings.
6. When treated with 2-hydroxy-4-n-octoxybenzophenone (UV531) and fluorinated acrylic copolymer (FAC), electrospun PAN/PU/TiO2 nanofibrous membranes impose multifunctional features (UV resistance and waterproofness) in addition to chemical protection. Its benzene ring imparts hydrophobicity to stir up the waterproofing nature of the base fabric, which is used in high-altitude garments, protective clothing, covering materials, self-cleaning materials, and other medical products. UV531 absorbs light of the UV region directly to convert it into heat energy.
7. Acids, alkalis, and solvents won't harm PU coatings made of acrylic polyols and trimer of isophorone diisocyanate.

Fabric finishing through the synthesis of polymeric dyes based on UV waterborne polyurethane

To overcome the drawbacks of thermo-curing, which will result in significant energy consumption, high costs, environmental issues, a decrease in the mechanical properties, and yellowing of textiles, three novel UV curable polymeric dyes (UVPDs) based on multifunctional waterborne polyurethanes have been successfully developed.[42]

Ultraviolet (UV) curing technology is a mild instant curing approach that offers great efficiency, low energy usage, no volatile organic compound emissions, and high economic value.

Polymeric dyes are a group of self-colored polymers in which the chains of the polymer are chemically linked to dye chromophores. Most polymeric dyes lack reactive groups and are consequently challenging to cross-link with some fabrics, particularly textiles made of synthetic fibers. The majority of fabrics dyed with polymeric dyes may therefore require high-temperature curing to increase their fastness.

UV-curable waterborne polyurethanes WPUs are added to promote the UV curing efficiency and degree of cross-linking, which are mixed with pigments to obtain colorful coatings, due to the weak noncovalent interactions between pigments and WPUs. As a result, pigments will migrate and aggregate onto the coating surface, and then absorb UV light, which may reduce the UV light transmittance.[42]

UV-curable polymeric dye synthesis

- The acetone technique was used to create the UV-curable polymeric dyes.
- Soft section PEG and IPDI (isophorone diisocyanate) (0.05mol, 11.1 g) To create an

isocyanate-terminated prepolymer, polyethylene glycol (0.02 mol, 12 g) was put to a three-necked flask with a mechanical stirrer and heated to 70 C for one hour.

- Disperse Red, a chromophore, was introduced to the system after being dissolved in acetone (20 mL) and allowed to react with the isocyanate group (NCO) at 70 C for two hours.
- Chain extension was then added at 70 C for 2 hours using DMPA (dipentaerythritol pentaacrylate) (0.018 mol, 2.664 g) and DBTDL catalyst (dibutyltin dilaurate) (0.5 wt%).
- In addition, acetone (20 mL) was used to dissolve a photosensitive blocking agent (2-Hydroxyethyl acrylate (HEA), pentaerythritol triacrylate (PETA), and dipentaerythritol pentaacrylate (DPEPA)) and gently add it to the reaction system.
- At 70°C, the blocking reaction persisted for around 4 hours.
- A polymerization inhibitor called hydroquinone (0.5 weight percent) was added to the mixture to stop double bonds from polymerizing during the synthesis process.
- Following cooling of the reaction system to around 50°C, TEA (0.018 mol, 1.818 g) was added to neutralize the carboxyl group in the chain for 0.5 hours. Deionized water (20 mL) was then added to produce waterborne UVPDs.
- Acetone was then eliminated at 40 C using vacuum distillation.
- Finally, to eliminate unreacted Disperse Red, the viscous UVPDs were slowly put into anhydrous ether.
- The coated cotton fabrics were made from 30% UVPDs, 4% thickening agent PFL, and 5% photoinitiator. The coated cotton fabrics were then dyed with UV-curable polymeric dyes. The processes of drying and curing are comparable to the ones described above.

During treatment

- Occur due to the N-H, CQO, and C-O in the urethane group's hydrogen bonds, followed by the C-O-C group in PEG's absorbance, and finally The CQO and benzene-related absorption peaks in DR's anthra quinone structure. Additionally, the formation of NCO group-ended polymeric dyes is shown by the sharp absorption peak associated with the isocyanate group (NCO). Results show that the -OH groups in the acrylate blocking agents completely interacted with the NCO groups at the end of the polymeric dyes, resulting in the effective production of multifunctional UV-curable polymeric dyes. The formation of the polyurethane chain and the successful introduction of the dye chromophore into polyurethane are both indicated by all of these outcomes.

Properties after Treatment

Thermal properties

- According to the findings, adding a dye chromophore will increase thermal stability, and UVPDs with higher functionality have curing films that have better thermal resistance because they have higher crosslinking densities. After all, the blocking agents have more CQC groups, which results in a higher crosslinking density.

Color properties

- The structure of the UVPDs is not significantly impacted by UV radiation.
- As the UV curing period increases from 20 s to 100 s, the K/S values of all the coated cotton materials decrease by roughly 21%. The color value progressively decreases when the color brightness (L*) significantly increases.
- The color of the UVPD-coated cotton fabrics lightens a little bit.

Color fastness

The color fastness of the coated cotton fabrics that were exposed to 5% photoinitiator for varying times was tested. It was discovered that as the curing time was raised from 20 s to 60 s, the fastness against rubbing and washing of cotton fabrics coated with UVPDs could be improved up to grades 4-5. The most likely explanation is that more C=C bonds create a compact network structure as a result of the free radical polymerization reaction.

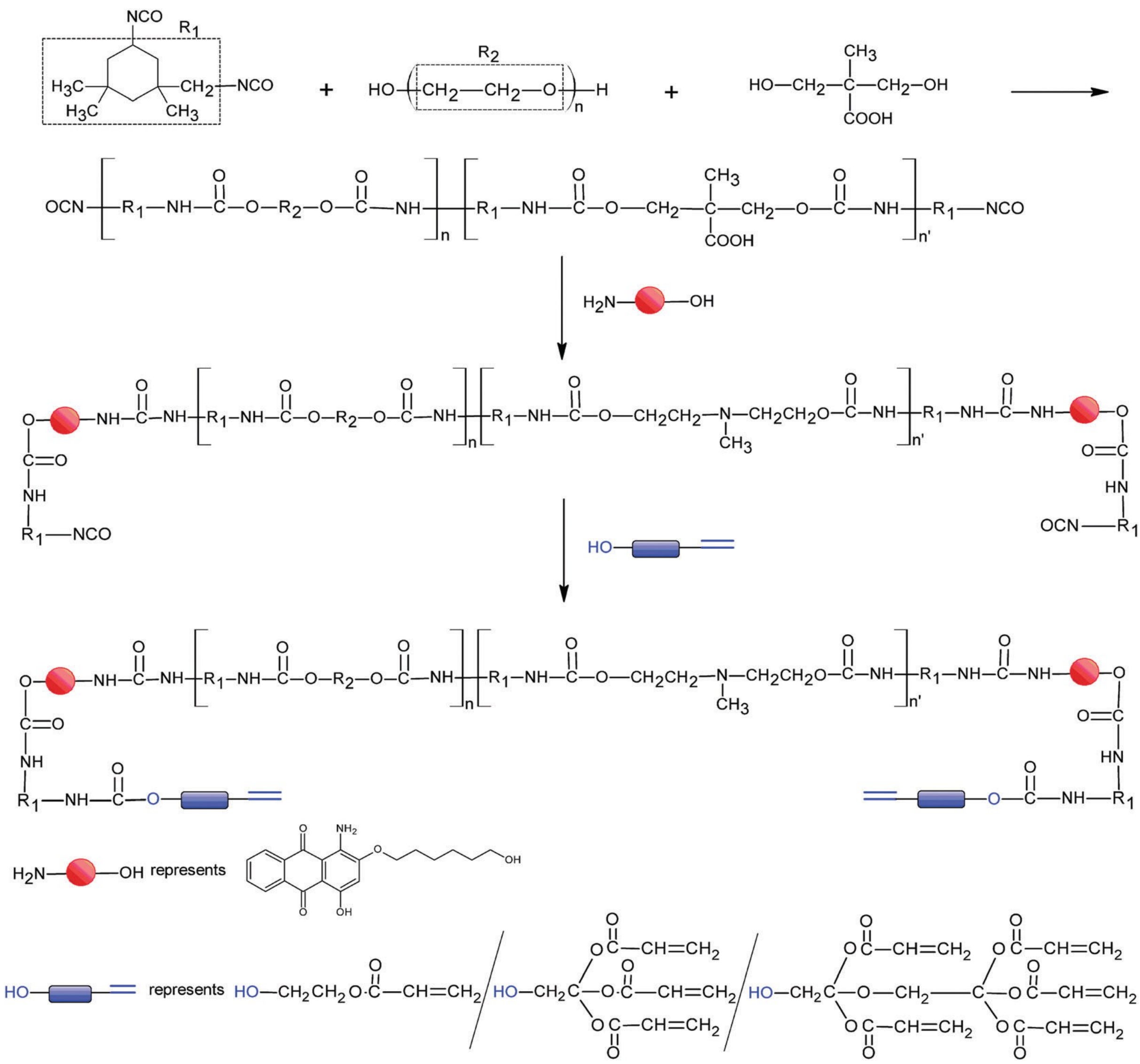

Fig. 3. UVPDs' process of synthesis

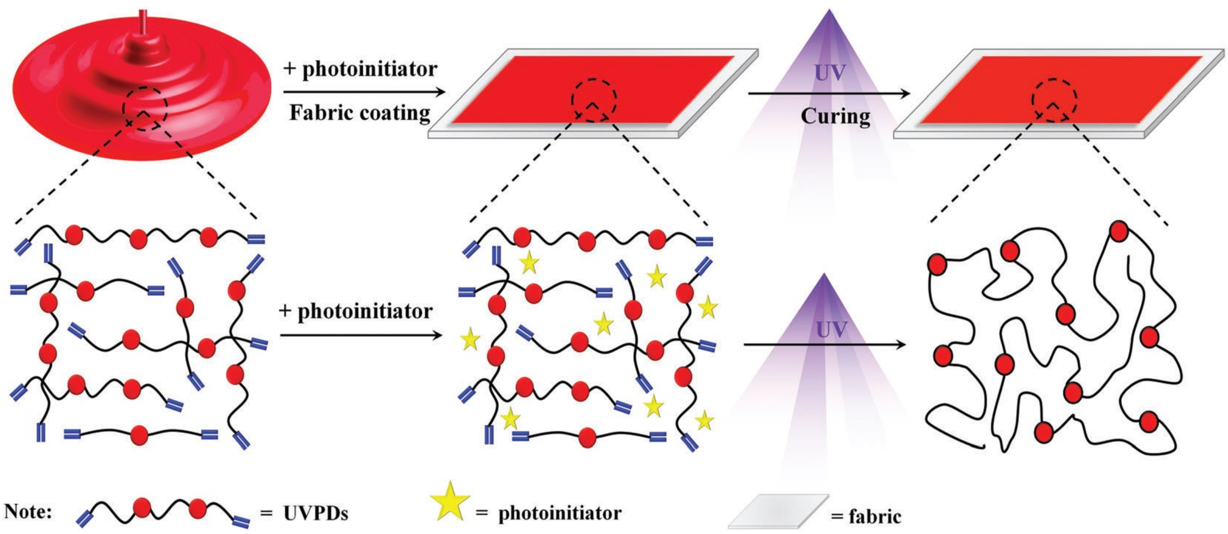

Fig. 4. UVPDs' curing procedure

Thermoplastic polyurethane to make an environmentally friendly leather-like fabric

Redesigning the fabric by covering polyester yarn with thermoplastic polyurethane and taking advantage of the material's ability to melt at high temperatures to create a new kind of leather-like environmental protection fabric.

Polyurethane can be divided into three categories:

Cast polyurethane elastomers (CPU), mixed polyurethane elastomers (MPU), and thermoplastic polyurethane elastomers (TPU). [17]

Thermoplastic polyurethane elastomer (TPU)

- is a form of solvent-soluble, heat-plasticized polyurethane. which can be separated into two sorts, polyester type and polyether type, based on their molecular makeup. This particular variety of polyurethane is non-toxic and environmentally safe. It can be recycled and degraded in the soil by being buried there, and it can also help the environment.
- It possesses traits such as melting and deforming when heated, transparency, good elasticity, mildew resistance, good warmth, and others. It also has traits such as resistance to abrasion, cold, oil, water, and tearing.

- Thermoplastic polyurethane can be used to make fibers and fabrics more resilient. It is a biocompatible and biodegradable elastomer [43, 44]
- The TPU yarn design technique allows for the usage of both covered and uncovered yarn. TPU raw yarn has a high yarn strength and good elasticity. However, because of its weak ability to absorb moisture and humidity, the hand feels astringent, which is easily the cause of snagging and pilling while weaving. It can be used with other yarns to create new, easier-to-spin yarns like covered yarns or core-spun yarns.
- Polyurethane yarn has single-strand and multi-strand fiber structures, with round and square cross-sections. The knitting industry has made extensive use of polyurethane yarn with a multi-fiber structure because of its high elongation, low linear density, transparency, and other physical and chemical features.
- For instance, 62% cotton, 30% rubber polyurethane, and 8% nylon are used to make the Cotton Latex Effect Yarn. This yarn has waterproof and wear-resistant qualities.
- The textile industry uses thermoplastic polyurethane elastomer (TPU) materials extensively. TPU film composite textiles and TPU chips are utilized to create spandex chemical fibers, which are frequently used as shoe materials, synthetic leather, etc.

Development of faux leather environmental protection fabrics

- Twisting polyester and TPU hot-melt raw yarn creates the raw material, which meets a variety of color requirements while also becoming stronger and more resilient. The melting point of heat is between 120°C and 145°C.
- The 150-count polyester yarn and 250-count thermoplastic polyurethane filament are used to create the imitation leather fabric.

Advantages of TPU imitation bio-leather fabric

- This brand-new style of imitation leather cloth decreases the use of leather products and achieves both animal and environmental protection. In addition, the fabric performs a variety of duties better than other leather items now on the market.
- It possesses the toughness and shine of genuine leather while also having the properties of being waterproof and breathable, windproof, abrasion resistant, heat preservation, and moisture permeable.
- It improved the application categories for fabrics used in furniture, clothing, and automobile interiors.
- The cloth handle is made softer, more pleasant thanks to the TPU resilience, which reaches 15%–25%.
- It offers strong tear resistance following repeated folding and high folding resistance at low temperatures.
- The apparel is kept dry and breathable because the moisture permeability of the material can reach more than 3500 g/(m224h), compared to less than 1000 g/(m224h) for standard imitation leather items.
- Other qualities include abrasion resistance, room-temperature foldability, and water repellency.

Synthesis of Aqueous Chitosan-polyurethanes Dispersion for Textile Finishing

Chitosan has been added to the PU structure to modify it chemically which, when compared to pure WPUs, exhibits superior antibacterial action against E. coli than Staphylococcus aureus. Chitosan has been used extensively to finish cotton and many other textiles with antibacterial properties. Chitosan is a common substance used in finishing textile fabrics because of its antibacterial, wound-healing, and moisture-retention qualities. It also significantly increases the antistatic effect of polyester.

Chitosan's antibacterial properties are crosslinked to cotton through hydroxyl groups utilizing glutaric dialdehyde, 1,2,3,4-butane tetracarboxylic acid (BTCA), citric acid, dihydroxy-ethylene urea (DMDHEU), and dimethylol .[21]

Washing fabric

- (48/52 and 55/45 polyester cotton blend ratio respectively)
- The poly-cotton fabrics were washed with detergent in a laboratory setting at 100 C for 30 minutes before being rinsed with hot and cold water. This was done before applying the CS-PU dispersion. The cleaned clothes were allowed to air dry at room temperature.

Synthesis of Chitosan-Based Polyurethane Dispersions (CS-PUs)

- PEG (1 mol), DMPA (1 mol), and IPDI (3 mol) were added to a four-necked, round-bottomed glass flask and charged for the synthesis of the -NCO functional PU prepolymer. The mixture was then heated at 60C in a nitrogen environment until the PEG-DMPA melted.
- To create an NCO-terminated hydrophilic PU prepolymer, a few drops of DBTDL catalyst were additionally added to the reaction media and polymerization was conducted for two hours at 80 C.
- To decrease the prepolymer's viscosity, an appropriate amount of methyl ethyl ketone (MEK) was added, and the temperature of the diluted prepolymer was lowered to 55C.
- To neutralize the carboxylic groups (-COOH) contained in DMPA, TEA (1.1 moles) was then added, and the reaction mixture was constantly agitated for 45 minutes while maintaining a temperature of 55 C.
- PU neutralization, then the temperature was raised to 65 to 70 C.
- To prevent gel formation for the final 4–8 hours of the reaction, a chain extender (chitosan powder mixed in an appropriate volume of DMSO (dimethyl sulfoxide) and BDO (1, 4-butanediol)) was gently added to the prepolymer.

After that, add distilled water and mix for a further 30 minutes at 35 C to get a uniform dispersion.

Application of CS-PU Dispersions on Poly-cotton Blend Fabrics

- The dyed and printed P/C textiles were coated with the 10% and 20% solutions of CS-PU dispersions using the pad-dry-cure process.
- Following the application of CS-PU dispersions to fabric samples, drying and curing were performed at 80°C for three minutes and at 140°C for five minutes consecutively.[21]

After treatment

Fabrics show better results such as:

Crease Recovery Angle (CRA)

It is evident that CRA rises as chitosan concentration in the finished polyurethane increases. When CS-PU dispersion is applied to fabrics, the surface of the fabrics become cross-linked. To break these ties, this network structure needs to be broken with the most energy possible. The cellulose molecules are maintained in their positions by these linkages. As a result, it prevents the cellulose molecules from breaking and sliding off of it. The crease healing angle increases as a result.

Tear strength

As the concentration of chitosan rises, more finish molecules attach to the fibers, thus limiting the fiber's ability to move when under stress. The low tear strength of treated fabrics is a result of the fibers' limited motions under tearing force.

Tensile strength

Tensile strength increases with an increase in the chitosan content in CS-PU dispersions. The CS-PU coating on the fibers is strengthened by polyurethane bonding to fibers of poly-cotton substrate through intermolecular dipole attractions, van der Waals forces and hydrogen bonding, and formation of two-dimensional network structure through hydrogen bonding, and occasional ether bridging of chitosan. The sticking effect of CS-PU dispersions strengthens the fibers in the direction of applied tensile loads and hence the fabrics can withstand higher applied tensile pressure.

Antimicrobial Activity

All of the colored and printed materials that were treated demonstrated antibacterial activity, which was boosted by the rising chitosan content.

Fabrics treated with CS-PU dispersions containing 0.4 and 0.5 molar chitosan exhibit even greater antibacterial activity, which can be explained by an increase in the quantity of -NH2 groups with chitosan concentration.

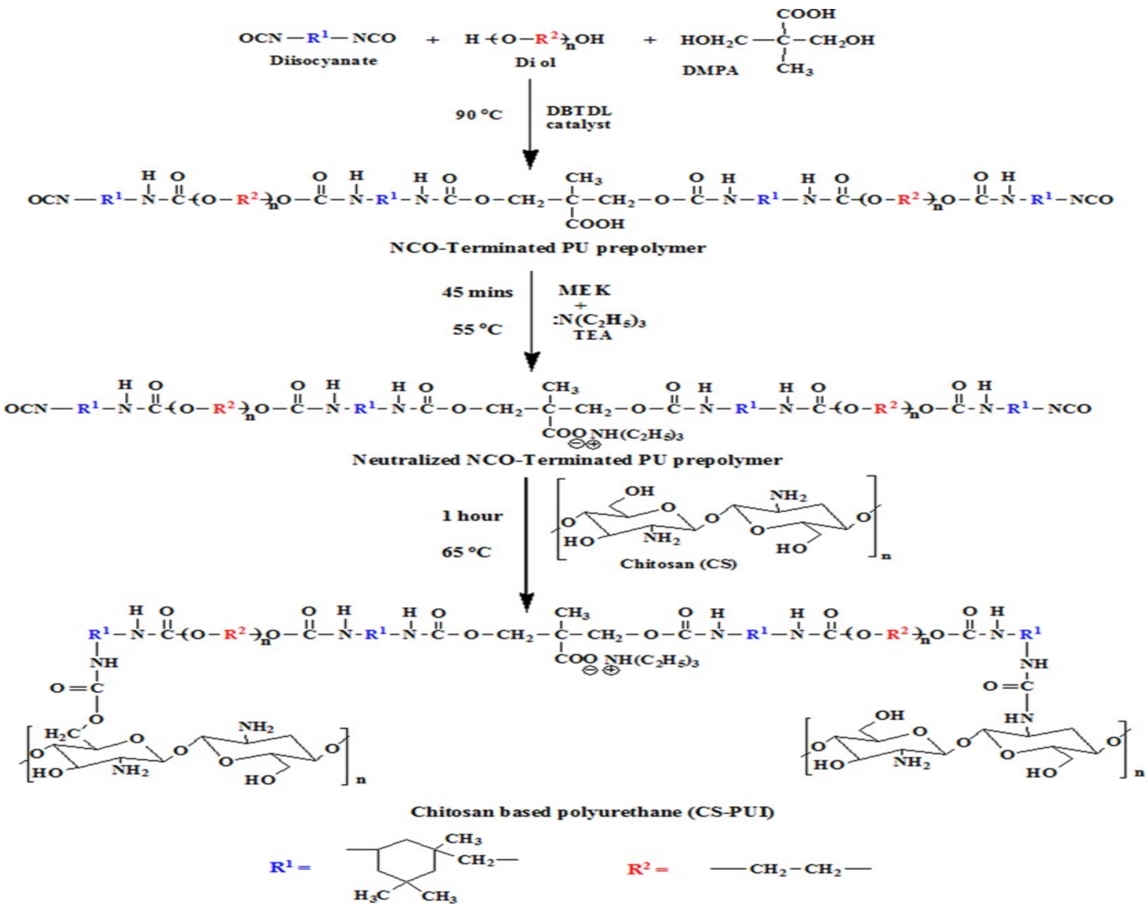

Fig.5. Synthesis of CS-PU dispersion with chitosan

Conclusions

In terms of performance and adaptability, polyurethane may now rank among the best materials we have ever encountered. In particular, water-dispersible polyurethane (WDPUs) coatings have attracted attention because of their exceptional qualities, including good stability at low temperatures, excellent flexibility, high levels of weather and water resistance, pH stability, excellent solvent resistance, and chemical and mechanical properties. Aqueous PU dispersions (WDPUs) are often used for coating materials like textiles, leather goods, furniture, footwear adhesives, and printing inks. A variety of diols and di-isocyanates serve as the basis for the synthesis of polyurethane. the modification of polyurethanes is the primary benefit that permits finishing fabrics, which are employed as textile finishing agents to improve the quality, and durability, and for the production of breathable coated fabrics and anti-soiling finishing capabilities for fibers.

Conflicts of interest

There are no conflicts to declare

Funding sources

There is no fund to declare

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البولي يوريثين (PU) في عملية تجهيز المنسوجات

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الملخص

عندما يتعلق الأمر بمجال تطبيقات تجهيز المنسوجات ، فإن البولي يوريثان هو عمليا مادة رائعة. إنها تمزج ليونة المطاط مع صلابة وصلابة المعادن والبلاستيك. أصبح البولي يوريثين المادة القياسية للعديد من التطبيقات بسبب هذا المزيج من خصائص المواد وصفاتها. تم استخدامه في مجموعة متنوعة من الصناعات ، بما في ذلك القطاع الطبي الحيوي ، والصناعة البحرية ، واللدائن ، والرغاوي ، والمنسوجات ، والطلاء ، والمواد اللاصقة ، ومانعات التسرب ، والمواد اللاصقة. يمكن استخدام مجموعة متنوعة من البوليولات والأيزوسيانات لإنشاء البولي يوريثان ، من أجل إنشاء منتجات عالية الأداء ، حل اليوريثان الذي يحمله الماء محل اليوريثان القائم على المذيبات في مجموعة متنوعة من تطبيقات التشطيب للمنسوجات. نتيجة لذلك ، تقدمت PU بشكل كبير في مجال المنسوجات الوظيفية بسبب تكلفتها المنخفضة ، وقدرتها على الإنتاج الضخم ، والخصائص الفيزيائية والكيميائية المثيرة للاهتمام.

الكلمات الدالة: الأقمشة المطلية ب PU قوية للغاية كهربائيا ولاصقا ، وأكثر مقاومة.