

Synthesis and characterization of non-fluorinated copolymer emulsions for hydrophobic finishing of cotton textiles

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Non-fluoro copolymers containing a hydrophobic alkyl acrylate monomer (butyl acrylate/2-ethylhexyl acrylate/ lauryl acrylate) and a reactive monomer (maleic anhydride) have been synthesized using emulsion polymerization technique. The copolymer emulsions have been applied on to cotton fabric by a pad-dry-cure process and the water repellency of the fabrics before and after vigorous washes compared. The effect of chain length of hydrophobic monomer on the water repellency has been compared and the comfort properties of the coated fabrics such as air permeability and bending length evaluated. It is observed that the copolymers prepared using long alkyl chain acrylates show promising alternatives to the repellent agents based on perfluoroalkyl chains for water repellency.

Keywords: Air permeability, Cotton, Emulsion polymerization, Hydrophobic coating, Water repellency

1 Introduction

In the recent years, there has been an increased interest in the hydrophobic¹ and self-cleaning²⁻⁶ finishes because of their wide-ranging importance in all areas of the textile market such as clothing, home and technical textiles. Hydrophobicity of the surfaces is controlled by the chemical composition and geometry of surface. Many methods of imparting hydrophobic character to fabric surface have been reported that include the use of aluminium and zirconium soaps, waxes and wax like substances, metal complexes, pyridinium compounds, hydrophobic polymer films and attachment of hydrophobic monomers via physical or chemical sorption processes⁷. But the problems with some of these finishes are their poor durability and/or low breathability.

To overcome above problems, chemical modification that lowers the surface energy can be used as an effective method. The application of fluoro finishes on textiles to impart water and oil repellency has shown considerable growth during last decade. However, the use of fluorocarbon finishes⁸ is also a major environmental concern. There are some evidences concerning possible persistence, bioaccumulation, and/or toxicity of these types of fluorocarbon chemicals in the environment⁹. In practice, the hydrophobicity of the fabric surface can be imparted from plasma treatment of the surfaces¹⁰, chemical deposition, layer-

by-layer deposition, hydrogen bonding and colloidal assemblies. There are also methods based on casting of polymer solution and phase separation and electrospinning¹¹. In order to provide preferable durability of water repellency for textile treated with polymers, the introduction of a reactive/crosslinking group in the polymer is advantageous. The crosslinking group can react with cellulose under certain conditions. Soane *et al.*^{12, 13} have patented a variety of multi-functional polymers such as modified poly (maleic anhydride), which is modified by the covalent attachment of a hydrophobic molecule having the formula R-X (where R = hydro and fluoroalkyls having C₈-C₂₄ atoms) by means of an ester or amide bond that can be non-covalently or covalently attached to a material to impart hydrophobicity.

In this study, a series of copolymers of hydrophobic alkyl acrylate and maleic anhydride has been designed and synthesized by changing the number of carbon atoms in the alkyl chain of acrylate comonomer. The water based non-fluoro hydrophobic copolymer latexes, thus obtained, have been applied on cotton fabrics by conventional pad-dry-cure process, and the water repellency and the physical properties of the treated fabric investigated.

2 Materials and Methods

2.1 Materials

Butyl acrylate (BA) and 2-ethyl hexyl acrylate (EA), procured from Fluka, and lauryl acrylate (LA), purchased from Sigma-Aldrich, were used as

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hydrophobic monomers. Maleic anhydride (MA) and potassium peroxydisulphate (AR grade) obtained from Merck were used as reactive monomer and thermal initiator respectively. The chemical structures of these monomers are shown in Fig. 1. Sodium lauryl sulphate (SLS), procured from Qualigens Chemical Ltd., was used as an emulsifier. All the chemicals were used as received. Deionized water was used for all the experiments. The cotton fabric after scouring by the conventional procedures was used.

2.2 Synthesis of Copolymer Emulsions

The hydrophobic monomers BA, EA & LA and reactive monomer MA were used to prepare different copolymer emulsions (i) BM₁₀– BA/MA (90:10); (ii) BM₂₀–BA/MA (80:20); (iii) EM₁₀–EA/MA (90:10); (iv) EM₂₀–EA/MA (80:20); and (v) LM₁₀–LA/MA (90:10).

In a typical procedure to prepare the acrylate copolymers, an appropriate amount of pre-dissolved maleic anhydride (10 or 20 mole %), hydrophobic monomer (alkyl acrylate) (90 or 80 mole %), 50 % of SLS (2.5-5.0 % on the weight of water) and the required amount of deionized water were homogenized using Micra D-8 Si homogenizer at a speed of 10,500 rpm. The pre-emulsion thus obtained was then fed to a 500 mL four-necked glass reactor containing a precharge of water and the balance 50 % of surfactant. The glass reactor was equipped with a reflux condenser, a nitrogen inlet, a feed inlet tube with a dropping funnel (used for feeding the pre-emulsion), and a mechanical stirrer under N₂ purging. The pre-emulsion was fed drop-wise in about 30 min. The reaction temperature was raised to 60 °C, and pre-dissolved initiator (potassium peroxydisulphate, 0.02 mole % w.r.t. the monomers) was added to the reactor. The mixture was then stirred vigorously at 60 °C for 6 h to complete the polymerization. The total monomer-to-water ratio of 1:4 and the surfactant concentration of 2.5-5.0 % (on the weight of water) were used. The emulsion was cooled to 30 °C before being poured out. The copolymer emulsion was precipitated with cold methanol, washed several times, filtered and finally dried in vacuum to constant weight. The polymer yield obtained was 80-90 wt %.

2.3 Characterization of Copolymers

2.3.1 Calculation of Solid Content of Copolymer Emulsion

The solid content (SC %) of emulsion was determined gravimetrically using the following formula:

$$SC\% = \left(\frac{X}{Y} \right) * 100$$

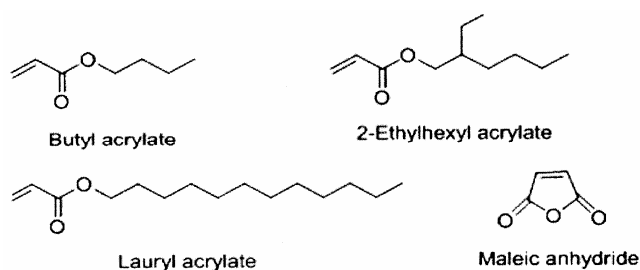


Fig. 1 — Chemical structure of monomers

where Y is the weight of copolymer sample taken initially; and X, the constant weight of copolymer sample obtained from Y gram of the copolymer emulsion.

2.3.2 Characterization of Copolymers by FTIR Spectroscopy

The FTIR spectra of the powdered dry copolymers were recorded using a Perkin Elmer FTIR spectrometer (Model Spectrum BX). In order to investigate the durability of the finish, the ATR spectra of the selected treated sample (BM₂₀) and control sample were also compared. The spectra were recorded over the range 4000-600 cm⁻¹. The resolution was 4 cm⁻¹, and the number of scans was 100 for each spectrum. Before the measurement, the studied samples were dried free of moisture.

2.4 Treatment of Cotton fabric with Polymeric Emulsion

The scoured cotton fabric samples were treated with five different finishing formulations (BM₁₀, BM₂₀, EM₁₀, EM₂₀, and LM₁₀) containing varying amount of the copolymer emulsion (1 wt%, 2 wt%, 3 wt% and ~ 20 wt%) and sodium hypophosphite. Samples were padded through a laboratory padder with two dips and two nips to give a wet pickup of 85±5 % (owf). The padded samples were then dried at 90 °C for 5 min and cured simultaneously at a temperature of 150 °C for 3 min.

2.4.1 Evaluation of Hydrophobicity

Water absorption time for each surface was evaluated to measure the hydrophobicity of the treated samples. In this test, the time for a water droplet to disappear/be absorbed totally on the sample was measured. The average volume of water droplet was about 30 µL. The drops were plunged from the same height (~ 2 cm) above the fabric for all the observations and the time taken by the water drop to spread on the sample was noted accurately. The measurement was carried out on different locations of the fabric specimen and an average of 10 readings was recorded for each test sample.

The efficiency of the treatment was also evaluated by measuring the water contact angle using a drop method. A 3.7 μL droplet of water/ Solophenyl Green BLE (Direct dye with medium light fastness) dye solution (%) was dispensed using a syringe assembly onto a 3-axis stage. With the help of a backlight source and an eyepiece the droplet was observed on the fabric sample and a tangent at the point of contact of the air-liquid-solid interface was aligned. The average contact angle was obtained by measuring the angles on the left- and right-hand sides of each droplet and taking the average of four droplets on different regions of the fabric sample. The measurements on cotton fabrics were performed 30 s after the water droplet was placed on the fabric. Each contact angle presented was the average of those measured at five different locations of each fabric specimen.

2.4.2 Evaluation of Durability of Finish

Durability of the finishes on the cotton fabric was evaluated by subjecting the samples to vigorous washing using AATCC Test Method 61-1996, as stated below.

Samples were washed under specified conditions to replicate 5 home washings. The samples were cut in to a specific size (6 inch \times 2 inch), put into a beaker and then 150mL of water was added followed by the addition of 0.225g detergent to the beaker and then 50 steel balls. The samples were subjected to washing in the launder-O-meter at 49 $^{\circ}\text{C}$ for 45 min. Each test specimen was rinsed three times in beaker using de-ionized water for 1 min with occasional stirring or hand squeezing. The specimens were dried in an oven (71 $^{\circ}\text{C}$ /160 $^{\circ}\text{F}$) and then they are allowed to conditioned at standard humidity and temperature for at least 1 h before the evaluation of properties.

2.5 Effect of Curing Temperature on Durability of Finish

The samples coated using 1, 2 and 3 wt% of BM_{10} copolymer emulsion were cured using three different sets of curing conditions (temperatures and time) and then subjected to washing by using the same washing conditions as mentioned above for curing conditions.

2.6 Surface Morphology

The morphology of treated samples as well as vigorously washed samples was observed using scanning electron microscopy (SEM) (Zeiss EVO 50) to compare the surface features of the treated and treated + washed fabrics.

2.7 Evaluation of Comfort Properties of Fabric

2.7.1 Air Permeability

The samples were tested to observe the effect of coating on air permeability by TEX TEST FX 3300 (Luftdurchlassigkeits-Prüfgerät) model. The specimen was clamped over the test head opening by pressing down the clamping arm which automatically started the vacuum pump. The pre-selected test pressure was automatically maintained, and after a few seconds the air permeability of the test specimen was digitally displayed in the pre-selected unit of measure. Thus, air permeability was measured at different position, representing a broad distribution across the length and width (ASTM D 737-96).

2.7.2 Fabric Handle

Bending length is the length of fabric that bends under its own weight to a definite extent. It is a measure of stiffness that determines the draping quality. The bending length was measured using a bending length tester (Paramount stiffness tester) based on the cantilever principle. Each specimen was tested four times at each end and again with the strip turned over. Mean values of bending length in warp and weft directions were then calculated.

3 Results and Discussion

3.1 Synthesis and Characterization of Acrylate and Maleic Anhydride Copolymers

Aqueous free radical emulsion copolymerization of hydrophobic monomers (BA, EA and LA) and a reactive monomer (MA) was performed to prepare a series of copolymer latexes (BM_{10} , BM_{20} , EM_{10} , EM_{20} and LM_{10}). The presence of maleic anhydride group introduces crosslinks with the hydroxyl groups of cellulosic substrate and thus provides a durable treatment. Three different monomers of varying alkyl chain length (BA<EA<LA) with pendant group butyl, 2-ethyl hexyl and lauryl acrylate respectively were investigated. The durability of the finish to washing was also compared for selected copolymers prepared by using two different feed compositions (10 and 20 wt%) of the hydrophobic and reactive monomer. The various process sequences and parameters that affect the yield, molecular weight and latex stability have already been studied¹⁴. Figure 2 illustrates the synthesis procedure for copolymer emulsions.

Pre-emulsification of the monomer with emulsifier results in better stability of the copolymer emulsion. For the pre-emulsification of butyl and 2-ethyl hexyl monomers, an emulsification time of ~15 min was

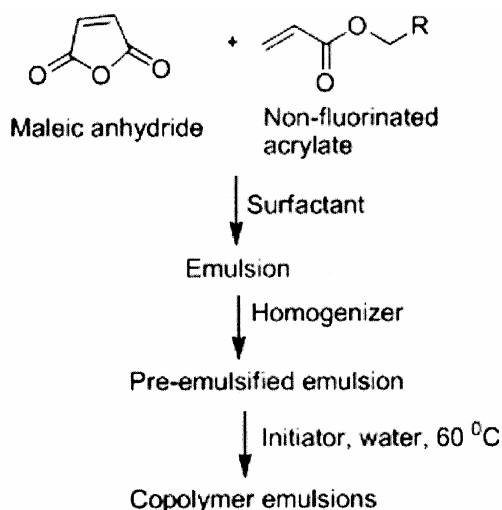


Fig. 2— Schematic diagram of copolymer preparation methodology sufficient, while for emulsification of lauryl acrylate monomer nearly 30 min was required. This increased emulsification time may be necessary due to long length of alkyl chains in the lauryl acrylate. Further, controlled feeding of the pre-emulsified monomer along with vigorous stirring was helpful in obtaining an emulsion with better latex stability. For the copolymers containing 10 mole % of maleic anhydride (BM₁₀, EM₁₀ and LM₁₀), 2.5 wt% of emulsifier (on water) was required while for copolymers containing 20 mole % of maleic anhydride (BM₂₀ and EM₂₀) higher emulsifier concentration of 5 wt% (based on water) was necessary for obtaining a stable emulsion. The emulsions obtained were stable for more than two months. Polymerization proceeded exothermically producing stable emulsions. The solid content of the copolymers obtained was 18-20 wt%.

The structure of copolymers was confirmed by FTIR analysis. In the spectra of the copolymer, the following characteristic absorption peaks were observed: 2957 cm⁻¹ (C-H stretching), 1733 cm⁻¹ (C=O groups), 1381 & 1386 cm⁻¹ (bending of CH₃ group), and 1168 cm⁻¹ {-C(=O)-O}. The incorporation of maleic anhydride in the copolymer was confirmed by the presence of absorption at 1851 and 1780 cm⁻¹ characteristic for asymmetric and symmetric stretching vibrations of anhydride group respectively.

3.2 Finishing of Cotton Fabric with Non-fluoro Copolymer Emulsion

As discussed earlier, the conventional water repellent finishes are mostly based on the use of long C_nF_{2n} (n=6-10) perfluoroalkyl groups to modify the physical properties of surfaces. However, fluoroalkyl chemicals have some economical and ecological

Table 1—Effect of finish add-on on the water drop spread time for samples treated with different copolymer emulsions [Water drop spread time for control (scoured) sample, 2s]

Polymer conc. wt%	Add-on, wt%			Water drop spread time, s		
	BM ₁₀	EM ₁₀	LM ₁₀	BM ₁₀	EM ₁₀	LM ₁₀
1	0.83	0.80	0.59	58±2	110±2	1221±2
2	1.39	1.29	1.29	82±2	167±2	1999±2
3	2.33	1.33	2.48	133±2	227±2	3170±2
~20	10.31	9.93	13.41	177±2	428±2	3447±2

disadvantages, such as high cost and potential risk for human health. In this study, the performance of finish based on alkyl (C₄-C₁₂ atoms) acrylates was compared. The fabrics were treated with 1 wt%, 2 wt%, 3 wt% and ~20 wt% of the copolymer latexes to investigate the effect of finish add-on on hydrophobicity. The finish was applied on cotton fabric by pad-dry-cure method.

In order to evaluate the hydrophobicity of the treated cotton fabric, a water drop was put on the sample and the nature of the water droplet as well as time taken by the water drop to spread/absorb was observed. The effect of the chain length of the hydrophobic monomer and finish add-on on the water drop spread time (or drop disappearance time) is shown in Table 1.

The treatment with 1 wt% of different copolymer emulsions results in very low add-on values. Table 1 shows that despite using the same dilution and same conditions of padding, the add-on values of the finish on the treated samples varies (0.59-0.83 wt% o.w.f) significantly. This variation may be ascribed to the variation in viscosity of the emulsions because of the nature of hydrophobic monomer.

The cellulosic surface by itself is highly hydrophilic. The untreated fabric absorbs water droplet quickly (within 2s) due to a combination of hydrophilic surface and capillary effect. However, the water drop remains stable on the treated fabric for varying time, depending upon the add-on and nature of hydrophobic monomer. Also, the shape of the 30 µL water drop remains nearly circular. It is evident from Table 1 that the time taken for water drop to spread is 58s for the cotton fabric treated with 1 wt% emulsion of copolymer BM₁₀ and 177s for the samples treated with 20 wt % of the same emulsion. This increase in the hydrophobicity may be ascribed mainly to the higher add-on of copolymer emulsion, resulting in complete coverage of cotton fibre.

However, despite this low add-on value, the water drop spread time of the treated fabrics increases from 58s to 1221s on increasing the chain length of hydrophobic monomer (from butyl to lauryl acrylate). The deposition/reaction of the copolymers probably causes the alignment of nonpolar segment upwards to orient away from polar forces, thus forcing itself toward the air interface. This lowers the critical surface tension of cotton fabric, thereby imparting a hydrophobic character to the treated fabric. The heat in the drying and curing step may facilitate the orientation by increasing molecular motion. Further, as evident from the above data, the time taken for the water drop to spread also increases with the increase in add-on of 2 wt% copolymer emulsion. Such an increase is expected because with the increase in concentration of the copolymer, the interaction between polymer chains is also enhanced. In case of LM₁₀, the time taken for water drops to spread is 3170 s for the fabric with 3 wt% emulsion and is 3447 s (~ 1 h) for the samples treated with 20 wt% emulsion. This observation indicates that when the concentration of the copolymer emulsion is increased over ~3 % (using copolymer LM₁₀), the increase in hydrophobicity is not proportionate to the finish add-on. This means that beyond a particular concentration (necessary for uniform application/treatment), further increase in the copolymer concentration does not improve the surface properties of the substrate significantly. Moreover, the lower add-on is also desirable to retain the physical and comfort properties of the substrate. This data clearly shows that significant degree of hydrophobicity can be imparted using ~ 3wt % of LM₁₀ copolymer emulsion, a non-fluoro finish.

The findings clearly show that the water droplet can stay on the treated fabric surface for a longer period. The results of water contact angle (WCA) values for various concentrations of hydrophobic finishes were also measured (Table 2). These contact angles do not change with time for more than 30 s and can be considered as equilibrium contact angles. In all the cases, the water contact angles (WCA) observed on the treated fabric are higher than 100°. In contrast, the control untreated fabric sample could not support the formation of a spherical droplet and all the water is penetrated/spread onto the porous structure of the fabric within 2 s. Therefore, the surface contact angle cannot be measured and is essentially zero.

Table 2 shows that for the same copolymer concentration, the contact angle value increases from

Table 2—Contact angle and air permeability values of samples treated with different copolymer emulsions

[Air permeability of control scoured sample, 18.92 cc/s/cm²]

Polymer conc. wt%	Air permeability cc/s/cm ²			Contact angle, deg		
	BM ₁₀	EM ₁₀	LM ₁₀	BM ₁₀	EM ₁₀	LM ₁₀
1	17.95	18.85	20.10	104 ±3	110±3	120±3
2	18.12	18.74	22.26	120±3	120±3	134±3
3	14.74	18.14	21.26	125±3	122±3	134±3
~20	14.03	13.22	18.88	126±3	124±3	138±3

BM₁₀ to LM₁₀. With 1 and ~ 20 wt% copolymer concentration, the contact angle increases from 104° to 120° and 126° to 138° respectively. An increase in the contact angle value with the increase in chain length of hydrophobic monomer is observed. These results are attributed to the lower surface energy of the fabric treated with alkyl acrylates containing longer alkyl chain. It is believed that the chemical structure of the finish has a strong influence on the hydrophobicity of the fabric. On treatment with even 2 wt% of all the three emulsions, the hydrophilic cotton surface turns to hydrophobic with contact angles >120°. More importantly, a high contact angle of nearly 134° is exhibited by the fabric treated with ≥ 2wt% of emulsion based on lauryl acrylate.

To understand the possible fixation /attachment of the copolymer finish on the cotton substrate, the ATR spectra of both control and treated cotton fabrics were compared. The fabric treated with 20 wt % of BM₂₀ and washed vigorously was selected. The ATR spectra of pure cotton exhibit O-H stretching absorption at around 3440 cm⁻¹, C-H stretching vibration at around 2800-3000 cm⁻¹, and C-O-C stretching absorption at 1056 cm⁻¹. After modification with the ~ 20 wt% copolymer, the treated and washed samples exhibit an increase in the peak intensity at 2920 cm⁻¹. This can be attributed to the introduction of -CH₂- groups. These observations together with the hydrophobic nature of the treated fabric confirm the chemical modification of cellulose surface with the described treatment. However, the intensity of the peak at 1700 cm⁻¹ due to the presence of -COOH groups is found to be very small. This is due to the very low concentration of finish present on the fabric.

Figure 3 shows a schematic diagram for the attachment of finish on the cotton textile. It is believed that at the time of curing cross-linking occurs between the reactive monomer and the hydroxyl groups of

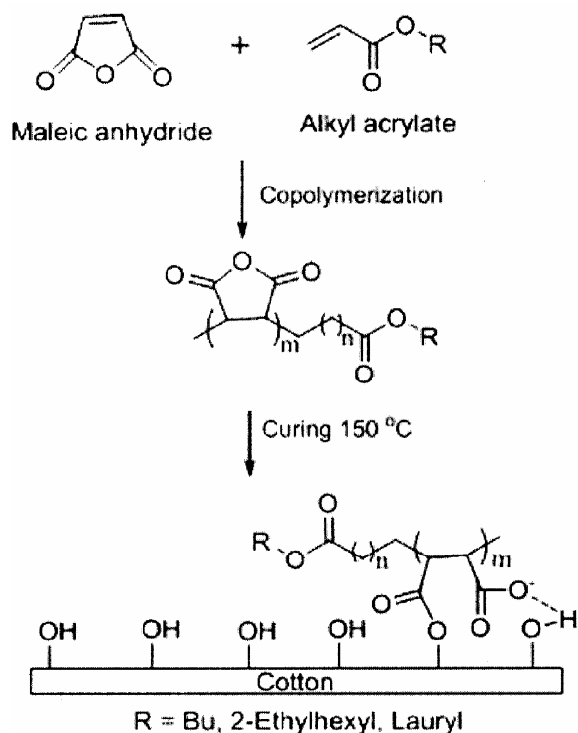


Fig. 3—Scheme showing chemical reaction of copolymer with cellulose

cellulose cotton which results in covalent attachment of the finish on the fabric.

3.3 SEM Analysis of Coated Fabric

SEM technique was used to investigate the surface morphology of the untreated and emulsion treated fabrics. Through SEM observations, one can get direct information about the nature of coatings, the compatibility between the surface of fabric and the coatings, and the distribution of the coatings along the surface. Figure 4 shows SEM micrographs of the samples coated with BM₁₀ emulsion copolymer before and after washing treatment. The particles of the coating are distributed continuously along a wide area of the surface and are visible on the cotton surface after washing cycles. These findings are in agreement with water repellency properties.

3.4 Evaluation of Comfort Properties of Fabric

The properties of the fabric, like air permeability and fabric handle, were evaluated in order to observe whether the application of the finish has affected the comfort properties or not.

3.4.1 Air Permeability

Table 2 shows the air permeability of samples treated with different copolymer emulsions. It is observed that the air permeability of the fabric is not

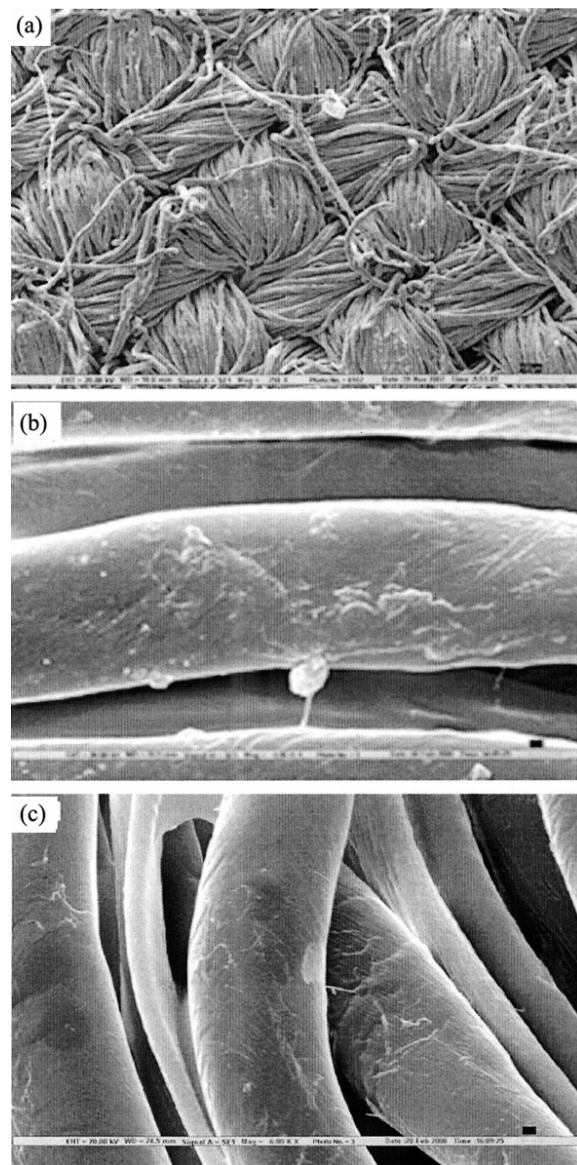


Fig. 4—SEM micrographs of cotton fabric treated with 3 wt % of BM₁₀ copolymer emulsion [(a) before washing at low magnification, (b) before washing at high magnification, and (c) after vigorous washing]

significantly affected, except for the fabrics treated with 20 wt % copolymer emulsions. The samples treated with LM₁₀ copolymer (1-3 wt %) exhibit a small increase in air permeability in comparison to the control fabric. This shows that the modification has taken place truly on the yarn/fibre surface rather than as a continuous coating on the fabric.

3.4.2 Fabric Handle

To observe the effect of finish on the handle of fabric, the bending lengths of the fabric treated with BA/MA, EA/MA and LA/MA copolymer finishes were measured.

Table 3—Bending length of samples treated with different copolymer emulsions

Polymer conc., wt%	Average bending length, cm					
	BM ₁₀		EM ₁₀		LM ₁₀	
	Warp	Weft	Warp	Weft	Warp	Weft
Control	5.5	4.4	5.5	4.4	5.5	4.4
1	4.9	4.1	4.8	3.9	4.4	4.0
2	4.9	4.2	4.5	3.9	4.6	4.0
3	5.1	4.3	4.8	4.1	4.9	4.1
~20	5.1	4.2	5.0	4.0	4.9	4.1

Table 3 shows that the values of bending length (both warp way and weft way) of the fabric decreases as compared to control till 2 wt% and then there is a slight increase in the bending length values for fabric treated with 3 wt% and direct emulsion (20 wt% copolymer). The trend is found to be the same for fabrics treated with other two copolymer finishes also. So, there is no significant effect of the copolymer finish on the handle of the fabric. It may be due to the fact that the application of finish acts as a lubricant between the fibres and hence provides a softening effect. The softening effect may be produced by the long alkyl group in the copolymer.

3.5 Evaluation of Durability of Finish

The treated samples were subjected to vigorous washing (AATCC test method-61, 1996) to find out the durability of finish on the fabric after washing.

It can be concluded from Table 4 that the time taken for the water drop to spread (hydrophobicity) decreases after the samples are subjected to vigorous washing; the value decreases drastically after 5 vigorous washing. This indicates that the removal of finish during vigorous washing treatment results in poor durability. This may be due to the improper/inadequate reaction of the copolymer with the substrate. The inadequate /improper fixation may either be due to the improper fixation conditions or lower/ insufficient number of available groups to react with the fabric.

The effect of curing conditions on the durability was also investigated by subjecting selected samples to more severe curing treatment. The samples treated with BM₁₀ copolymer emulsion (1-3 wt%) were cured under three different sets of conditions.

Table 5 shows that the curing temperature does not have any significant effect on the durability of finish.

Table 4—Effect of washing on durability of finish on cotton fabric

Polymer conc. wt%	Water drop spread time, s					
	Treated samples			Treated & washed samples		
	BM ₁₀	EM ₁₀	LM ₁₀	BM ₁₀	EM ₁₀	LM ₁₀
1	58±2	110±2	1221±2	14±2	37±2	35±2
2	82±2	167±2	1999±2	27±2	33±2	45±2
3	133±2	227±2	3170±2	30±2	38±2	46±2
~20	177±2	428±2	3447±2	45±2	58±2	61±2

Table 5—Effect of curing conditions on durability of finish BM₁₀

Polymer conc. wt%	Water drop spread time, s			
	Without wash	Cured at 50 °C for 5 min	Cured at 165 °C for 3 min	Cured at 180 °C for 3 min
1	58±2	14±2	8±2	14±2
2	82±2	27±2	22±2	24±2
3	133±2	30±2	36±2	37±2

Table 6—Effect of hydrophobic monomer and reactive monomer composition of copolymer emulsions on the time of water drop spread

Polymer conc., wt%	Time of water drop to spread, s			
	BM ₁₀	BM ₁₀ (Washed)	BM ₂₀	BM ₂₀ (Washed)
1	58±2	14±2	74±2	17±2
2	82±2	27±2	96±2	25±2
3	133±2	30±2	157±2	46±2
~20	177±2	45±2	196±2	63±2

This implies that the curing at 150 °C for 5 min may be sufficient for the covalent attachment of the finish, but the number of available reactive groups may not be sufficient.

Further, the fabrics were treated with both 90:10 and 80:20 of BA/MA copolymer emulsion and the effect of relative ratio of hydrophobic monomer and reactive monomer on hydrophobicity was observed. Table 6 shows the variation in hydrophobicity as the ratio of the hydrophobic monomer and the reactive monomer changes. The time taken for water drop to spread (hydrophobicity) for both treated and washed samples increases marginally with the increase in reactive monomer ratio from 10 mole % to 20 mole %. It is observed that though an increase in reactive monomer content in 80:20 BA/MA copolymer causes a relative decrease in hydrophobic comonomer, the hydrophobicity of the treated fabric is not adversely affected. This may be attributed to the increased degree of covalent attachment of the copolymer with

the fabric. Thus, it is suggested that 80:20 ratio of hydrophobic monomer to reactive monomer is more likely to result improved/durable hydrophobicity with lauryl and higher carbon chain acrylate monomers. These copolymers can provide molecular level hydrophobic finish to cotton substrate.

4 Conclusions

A durable molecular level non-fluoro hydrophobic finish with good latex stability has been developed. The latex prepared using lauryl acrylate as hydrophobic monomer and maleic anhydride as reactive transforms the very hydrophilic cellulosic surface into hydrophobic surface. While observing the effect of finish add-on on the hydrophobicity, it is found that the water droplet can stay on the treated fabric surface for a longer period. The contact angle measurement indicates that the treated fabric has a water contact angle $> 120^\circ$. The SEM analysis of the coated samples indicates the coating of copolymer finish on cotton fibre. The comfort properties of the coated fabrics such as air permeability and bending length are not significantly altered. The current approach is versatile and can be used for a variety of substrates with hydroxyl/amino group functions.

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