To Impart Lotus Effect on Cotton Fabric Using Combination of Silica Nanoparticles & Water Repellent Agent

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***Abstract* - As cotton material is hydrophilic in nature. In this study the lotus effect was imparted on cotton fabric by using combination of silica nanoparticles and water repellent agent. The silica nanoparticles were synthesized by using typical Stober method with tetraehthyl orthosilicate as raw material. The surface morphology of treated fabric was characterized by using scanning electron microscope. The properties of finished fabric such as water spray rating, hydrostatic head pressure, air permeability, tearing strength, was checked. The spray rating of 100 found in case of 40 gpl concentration of water repellent agent and all the concentration TEOS.**

Keywords- TEOS; Lotus effect; SEM.

I. INTRODUCTION

Textiles with hydrophobic surfaces have many uses in industrial, consumer, and apparel market. Generally, superhydrophobic surfaces are created through the combination of surface roughening and lowering of the surface energy. It is well known that a fluorinated polymer has a low wettability due to its low surface energy. [1, 2]

Hydrophobicity of the surfaces is controlled by the chemical composition and geometry of surfaces. 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 process. But the problems with some of these finishes are their poor durability. [3]

Conventional methods used to impart different properties to fabric often do not lead to permanent effects and will lose their functions after laundering or wearing. Nanotechnology can provide high durability for fabrics, because nanoparticles have a large surface area-to-volume ratio and surface energy. [4]

The leaves of lotus have epidermal cells on their rough surface covered with wax crystals. The wax crystals provide a hydrophobic layer and the double-size structure gives the surface high roughness. [5, 6, 7, 8]

Cotton, a cellulose-based material that is greatly hydrophilic, is more benefited when made hydrophobic. Modification of cotton to make it superhydrophobic extends the use of cotton even further o various other end-uses, like water-repellent, self-cleaning fabric or it could even be used in oil-spill clean-up. Also the water repellency is essential and potential applications of highly water repellent textile materials include rainwear, upholstery, protective clothing, sportswear, and automobile interior fabrics. [9, 10, 11]

II. EXPERIMENTAL

A. Materials

1. Fabric: Desized, scoured bleached cotton fabric is used for study.

2. Chemicals and Auxiliaries: Tetraethyl orthosilicate [Si (OC2H5)4 (TEOS)] as a raw material for the synthesis of silica nanoparticles. Auxiliaries such as ethanol, ammonia solution were used. The distilled water was used for the synthesis of silica nanoparticles. The commercially available as a water repellent agent TUBIGUARD was used.

B. Characterization

The surface morphology of cotton fabric treated with silica nanoparticles and combination of silica nanoparticles & water repellent agent was checked on scanning electron microscope (SEM) (JSM-6360 JEOL/EO). The water repellency and hydrostatic head pressure properties of treated fabrics were measured according to AATCC 22, ISO 4920 & ISO 811, AATCC 127 test methods respectively. The air permeability and tearing strength properties of treated fabrics were measured according to ASTM B 737 & IS 6359:1971SP-15 respectively.

C. Synthesis of Silica Nanoparticles

The silica nanoparticles were synthesized by the alkaline hydrolysis of the tetraethyl orthosilicate followed by the dehydration, condensation reaction through a typical Stober method. [12, 13, 14, 15]

The mixture of tetraethyl orthosilicate and ethanol was prepared, and then it was mixed with the mixture of distilled

water, ethanol and ammonia solution with continues stirring. The synthesis was carried out for 3 hours at 300C.

D. Application of Silica Nanoparticles & the Water Repellent Agent on cotton fabric

The previously desized, combined scoured & bleached fabric was dipped in the silica sol & then padded using two dips & two nips to achieve the wet pick up of 80 % with a pressure of 4 Kg/ Cm2 of a padding mangle. The sample then dried at 800C for 3 minute & cured at 1600C for 3 min with a laboratory stenter. Then this fabric was again treated with the water repellent agent with varying concentration of 15 - 40 gpl & dried at 800C & cured at 1600C. The composition of chemicals for the synthesis of silica nanoparticles & the composition for nano water repellent finish has shown in the following tables 1 & 2 respectively.

TABLE 1. **Composition of Chemicals for the Synthesis of Silica Nanoparticles**

Sr. No.	TEOS (Mol)	Ethanol (Mol)	Water (Mol)	Ethanol (Mol)	Ammonium hydroxide (Mol)
1	*0.2*	*2.5*	*2.0*	*2.5*	*0.10*

TABLE 2. **Composition of water repellent agent and silica nanoparticles for water repellent finish**

Sr. No.	TEOS (Mol)	Ethanol (Mol)	Water (Mol)	Ethanol (Mol)	Ammonium hydroxide (Mol)	Water Repellent Agent (gpl)
Recipe 1	*0.2*	*2.5*	*2.0*	*2.5*	*0.10*	*15*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*20*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*25*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*30*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*35*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*40*
Recipe 2	*0.2*	*2.5*	*2.0*	*2.5*	*0.10*	*15*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*20*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*25*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*30*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*35*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*40*
Recipe 3	*0.2*	*2.5*	*2.0*	*2.5*	*0.10*	*15*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*20*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*25*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*30*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*35*
	0.2	*2.5*	*2.0*	*2.5*	*0.10*	*40*

III. RESULTS AND DISCUSSION

A. Synthesis of Silica Nanoparticles

Silica nanoparticles were prepared through a typical Stober method including the hydrolysis of TEOS and the condensation of the hydrolyzed silica species in the presence of an ammonia catalyst.

B. Characterization

The surface morphology was characterized by scanning electron microscope (SEM). It was observed that the cotton fabric treated with silica nanoparticles showed the scaly appearance as on the lotus leaves surface, which made the surface rougher & enhance the water repellency. Also the scanning electron micrographs showed the change of the surface geometry of the cotton fabric. The following fig. 1 showed the SEM image of cotton fabric treated with silica nanoparticles & fig. 2 shows the SEM image of cotton fabric treated with both silica nanoparticles and water repellent agent (40gpl). The fig. 2 shows that the water repellent agent forms a waxy layer on the silica nanoparticles as like lotus leaves.

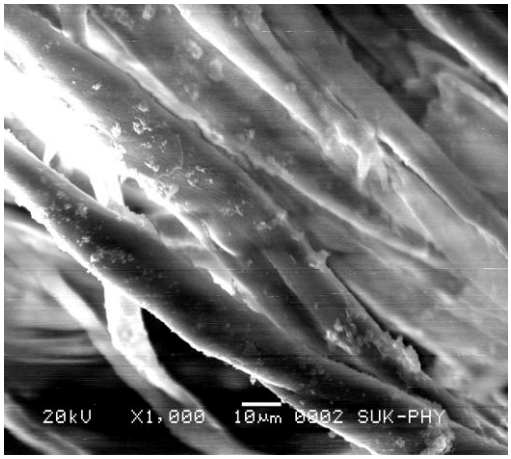

Fig. 1. SEM image of cotton fabric treated with silica nanoparticles.

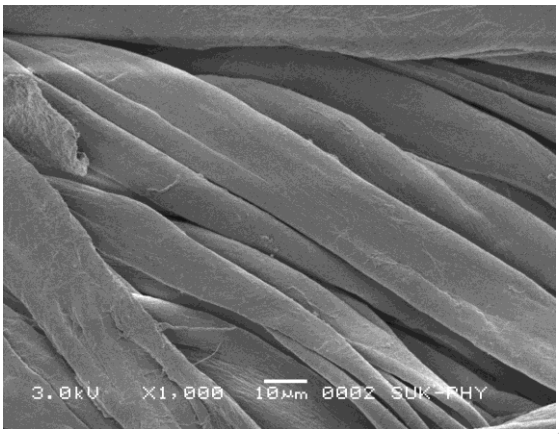

Fig. 2. SEM image of cotton fabric treated with both silica nanoparticles and water repellent agent (40gpl).

C. Effect of Concentration of Water Repellent Agent on Water Repellency Rating- Spray Rating

TABLE 3. **Effect of concentration of TEOS, water repellent agent on Water Repellency Rating- Spray Rating.**

	Values of Spray Rating at 0.10 mole Ammonia Solution catalyst																	
	TEOS-0.2 mole						*TEOS- 0.4 mole*						*TEOS- 0.6 mole*					
	Water repellent agent conc.						*Water repellent agent conc.*						*Water repellent agent conc.*					
	15 g/l	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*	*15 g/l*	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*	*15 g/l*	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*
Before Washing	*90*	*90*	*90*	*90*	*90*	*100*	*90*	*90*	*90*	*90*	*90*	*100*	*90*	*90*	*90*	*90*	*90*	*100*
After Washing	*90*	*90*	*90*	*90*	*90*	*100*	*80*	*90*	*90*	*90*	*90*	*100*	*90*	*90*	*90*	*90*	*90*	*100*

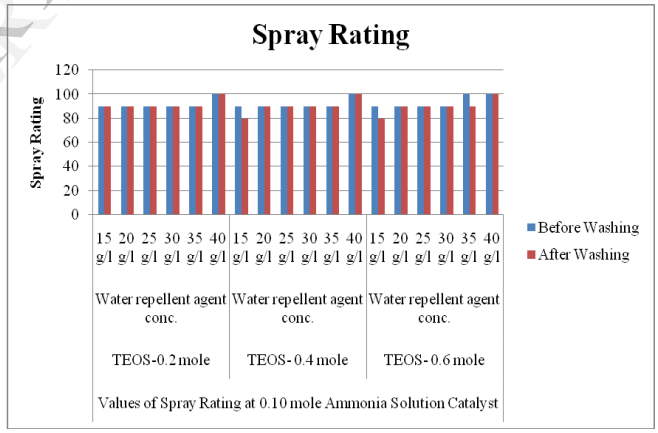

Fig. 3. Effect of concentration of TEOS, water repellent agent on water repellency rating- spray rating.

The above Table 3 and Fig. 3 shows that the concentration of water repellent agent increases from 15 gpl to 40 gpl, also the concentration of TEOS increases from 0.2 mol to 0.6 mol at fixed concentration ammonia solution of 0.10 mol. The fabric finished with 0.2 mol concentration of TEOS shows the spray rating of 90 at 15 gpl concentration and spray rating of 100 at 40 gpl concentration of water repellent agent, while the fabric finished with 0.4 mol concentration of TEOS shows the spray rating of 90 at 15 gpl concentration and spray rating of 100 at 40 gpl concentration of water repellent agent & the spray rating of 90 for 15 gpl and 100 for 40 gpl was observed in case of 0.6 mol TEOS.

In this the spray rating of 100 was observed for 0.2mol, 0.4 mol & 0.6 mol TEOS at 40 gpl concentration of water repellent agent. The maximum spray rating obtained may be due to the formation of layer of silica nanoparticles on the surface of fabric which helps in formation of rough surface which helps in increase in water droplet contact angle with the surface of the fabric and with increase in the water repellent layer on the fabric surface. The washing of fabric does not affect the spray rating was mostly observed.

D. Effect of Concentration of TEOS, Water Repellent Agent on Hydrostatic Head Pressure

TABLE 4. **Effect of concentration of TEOS, water repellent agent on hydrostatic head pressure.**

	Values of Hydrostatic Head Pressure (Cm) at 0.10 mole Ammonia Solution catalyst																	
	TEOS-0.2 mole						*TEOS- 0.4 mole*						*TEOS- 0.6 mole*					
	Water repellent agent conc.						*Water repellent agent conc.*						*Water repellent agent conc.*					
	15 g/l	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*	*15 g/l*	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*	*15 g/l*	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*
Hydrostatic Head Pressure	*14.66*	*14.66*	*14.83*	*15.00*	*15.50*	*15.50*	*14.66*	*14.83*	*15.16*	*15.16*	*15.50*	*15.66*	*15.00*	*15.00*	*15.00*	*15.00*	*15.16*	*15.66*

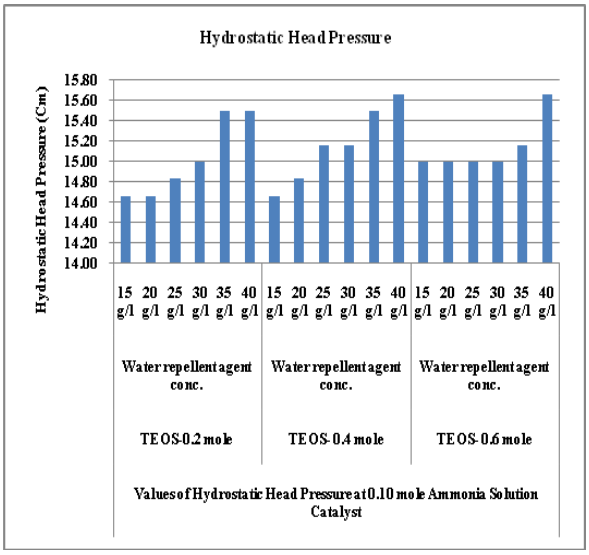

Fig. 4. Effect of concentration of TEOS, water repellent agent on hydrostatic head pressure.

The above Table 4 and Fig. 4 shows that the hydrostatic head pressure for the fabric treated with combination of silica nanoparticles and water repellent agent. The water repellent agent concentration increases from 15 gpl to 40 gpl, also the concentration of TEOS increases from 0.2 mol to 0.6 mol at fixed concentration ammonia solution of 0.10 mol. It was observed that for 0.2 mol TEOS the hydrostatic head pressure increases from 14.66 to 15.50 for water repellent agent concentration of 15 gpl to 40 gpl respectively, while for 0.4 mol TEOS the hydrostatic head pressure increases from 14.66 to 15.66 for water repellent agent concentration of 15 gpl to 40 gpl respectively & the hydrostatic head pressure of 15.00 to 15.66 was observed for 15 gpl to 40 gpl. This is may be due to the fact that silica nanoparticles along with increase in water repellent agent concentration help to resist the drop of water to come out from the fabric surface.

E. Effect of Concentration of Water Repellent Agent on Air Permeability

TABLE 5. **Effect of concentration of TEOS, water repellent agent on air permeability.**

	Values of Air permeability(Cm3/Cm2/Sec) at 0.10 mole Ammonia Solution catalyst																	
	TEOS-0.2 mole						*TEOS- 0.4 mole*						*TEOS- 0.6 mole*					
	Water repellent agent conc.						*Water repellent agent conc.*						*Water repellent agent conc.*					
	15 g/l	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*	*15 g/l*	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*	*15 g/l*	*20 g/l*	*25 g/l*	*30 g/l*	*35 g/l*	*40 g/l*
Air permeability	*16.99*	*15.81*	*14.89*	*14.74*	*14.70*	*14.40*	*16.31*	*16.15*	*16.01*	*15.84*	*15.01*	*14.88*	*17.62*	*16.50*	*16.32*	*16.18*	*14.70*	*14.55*

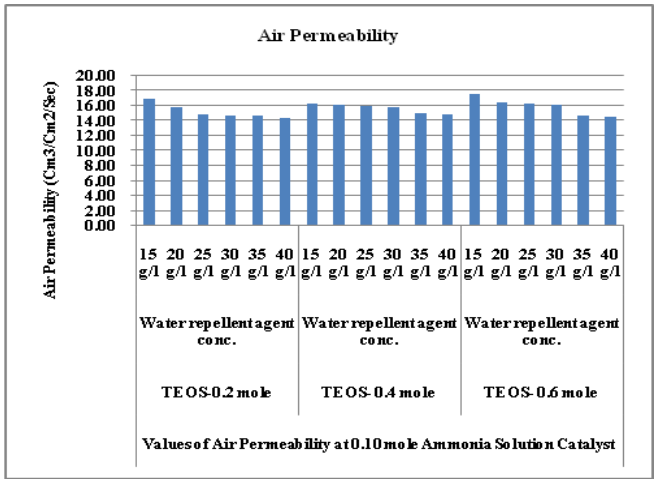

Fig. 5. Effect of concentration of TEOS, water repellent agent on air permeability.

The above Table 5 and Fig.5 shows that the concentration of water repellent agent increases from 15 gpl to 40 gpl, also the concentration of TEOS increases from 0.2 mol to 0.6 mol at fixed concentration ammonia solution of 0.10 mol. It was observed that for 0.2 mol TEOS the air

permeability decreases from 16.99 to 14.40 for water repellent agent concentration of 15 gpl to 40 gpl respectively, while for 0.4 mol TEOS the air permeability decreases from 16.31 to 14.88 for water repellent agent concentration of 15 gpl to 40 gpl respectively & the air permeability of 17.62 to 14.55 was observed for 15 gpl to 40 gpl in case of 0.6 mol TEOS. This is may be because as concentration of water repellent agent goes on increasing the film form goes on becoming continuous along with the silica nanoparticles, due to which air transmission rate decreases.

F. Effect of Concentration of Water Repellent Agent on Tearing Strength

TABLE 6. **Effect of concentration of TEOS, water repellent agent on tearing strength.**

	Values of Tearing Strength (gf) at 0.10 mole Ammonia Solution catalyst																	
	TEOS-0.2 mole						***TEOS- 0.4 mole***						***TEOS- 0.6 mole***					
	Water repellent agent conc.						***Water repellent agent conc.***						***Water repellent agent conc.***					
	15 g/l	***20 g/l***	***25 g/l***	***30 g/l***	***35 g/l***	***40 g/l***	***15 g/l***	***20 g/l***	***25 g/l***	***30 g/l***	***35 g/l***	***40 g/l***	***15 g/l***	***20 g/l***	***25 g/l***	***30 g/l***	***35 g/l***	***40 g/l***
Weft Way	*1472.00*	*1427.20*	*1280.00*	*1267.20*	*1260.80*	*1260.80*	*1049.00*	*992.00*	*979.20*	*953.60*	*953.60*	*947.20*	*1235.20*	*1203.20*	*1177.60*	*1139.20*	*1075.20*	*1036.80*
Warp Way	*1747.20*	*1619.20*	*1510.40*	*1504.00*	*1497.60*	*1478.40*	*1139.20*	*1126.40*	*1120.00*	*1113.60*	*1113.60*	*1107.20*	*1427.20*	*1286.40*	*1254.40*	*1254.40*	*1248.00*	*1203.20*

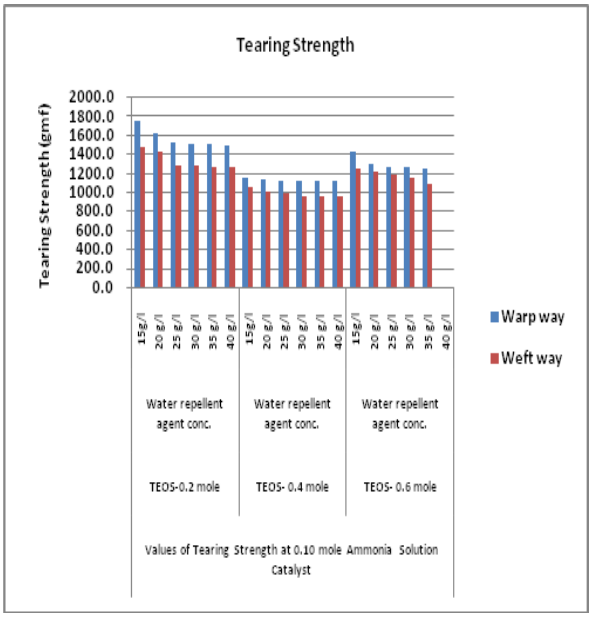

Fig. 6. Effect of concentration of TEOS, water repellent agent on tearing strength.

The above Table 6 and Fig. 6 shows that the tearing strength in both warp way and weft way for the fabric treated with combination of silica nanoparticles and water repellent agent. The concentration of water repellent agent increases from 15 gpl to 40 gpl, also the concentration of TEOS increases from 0.2 mol to 0.6 mol at fixed concentration ammonia solution of 0.10 mol. The fabric shows decrease in tearing strength in warp direction for 0.2 mol TEOS from 1747.20 to 1478.40 for water repellent agent concentration of 15 gpl to 40 gpl respectively, while the fabric shows decrease in tearing strength in warp direction for 0.4 mol TEOS from 1139.20 to 1107.20 for water repellent agent concentration of 15 gpl to 40 gpl respectively & the decrease in tearing strength in warp direction for 0.6 mol TEOS from 1427.20 to 1203.20 for water repellent agent concentration of 15 gpl to 40 gpl respectively was observed. The fabric shows decrease in tearing strength in weft direction for 0.2 mol TEOS from 1472.00 to 1260.80 for water repellent agent concentration of 15 gpl to 40 gpl respectively, while the fabric shows decrease in tearing strength in weft direction for 0.4 mol TEOS from 1049.00 to 947.20 for water repellent agent concentration of 15 gpl to 40 gpl respectively & the decrease in tearing strength in weft direction for 0.6 mol TEOS from 1232.20 to 1036.80 for water repellent agent concentration of 15 gpl to 40 gpl respectively was observed. This is may be due to increase in concentration of water repellent agent along with silica nanoparticles causing increase in the resistance for the slippage of fibers in both warp and weft direction.

IV. CONCLUSION

In this study the combine finish of silica nanoparticles & water repellent agent was applied on the cotton fabric. The surface morphology was observed using scanning electron microscope. The change in the surface

morphology was observed. The spray rating of 90 was observed for all the TEOS concentration and for water repellent agent concentration from 15gpl to 35gpl used. The spray rating of 100 found in case of 40gpl concentration of water repellent agent and all the concentration TEOS. This shows that the lotus effect imparted on cotton textile material using combination of silica nanoparticles & water repellent agent. Also there was decreased in air permeability, tearing strength and increased in hydrostatic head pressure was observed as the concentration of water repellent agent increased.

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