Study of Physical Properties of Nano-Silica Coated Cotton Textiles

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ABSTRACT

This research was aimed to investigate the effect of silica sol-gel coating on air permeability, stiffness and tensile properties of dyed cotton fabric. Various concentrations of silica nanoparticles were applied on dyed cotton substrate using two different cross-linkers through sol-gel method. The homogenous sol-gel coating dispersions were prepared by using an ultrasonicator. Coated samples were tested for mechanical and comfort properties such as tensile strength, stiffness, crease recovery and air permeability. It was found that tensile strength and crease recovery of coated substrate were slightly improved. On other hand, it was observed that fabric stiffness and air permeability were affected slightly by increasing concentration of silica nanoparticle. It was also observed that type of cross-linker has strong influence on coated fabric's strength and flexural rigidity.

Key Words: **Woven Cotton, Silica Nano-Sols, Tensile Strength, Crease Recovery, Air Permeability.**

1. INTRODUCTION

Sol-gel coatings are widely used for surface functionalization of textiles and are prepared through different methods especially hydrolysis and poly condensation of TAOS after that these sols are converted into gels [1-4]. Surface finishing by using sol-gel coating not only enhance technical properties such as water repellency, flame retardancy, UV resistance and self-cleaning but also improve durability of finishes and dyes due to the presence of alkyl cross-linker [2-7]. Functional and technical garments are products that should still meet consumer expectations like looks, comfort, hand, care/maintenance, and health issues, but should offer other properties like protection against: physical, thermal, chemical, and biological attacks or stress. Functionalization of technical products can offer superior properties in markets such as automobiles, aerospace, construction, and home furnishings [8].

Arkles, et. al. [9] found that increase in viscosity rate and temperature of curing is primarily control by the morphology and composition of the gel. Finishing of textiles, hydrolysis of solutions and drying situations govern the density, porosity, mechanical properties, and the significant thickness for enhancement of durability of treated goods. Silica nanoparticle when mixed with silane hydrophobes and silane cross linkers, applied through sol-gel route not only enhance water

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repellency but also improve fastness properties of reactive dyed cotton fabric with a little effect on shade [10].

Daoud,et. al. [6] observed that untreated cotton substrate is smooth under a scanning electron microscope, whereas, substrate treated with silica nanoparticles and cross-linker GPTMS appeared uneven and rough [11]. The results of the physical testing show that the slight enhancement in the bursting strength and abrasion resistance was achieved at a cost of slight reduction in the tensile and tear strength and air permeability [11-13]. These researchers have used different metal precursors and undyed fabric except Alongi,et.al. [12].

Sol-gel coatings are mostly focused due to their good durability even after five industrial washes [10, 14].These surface functionalized fabrics have been mostly tested for hydrophobicity but mechanical and comfort properties have not been fully explored. This paper presents the results of tensile and comfort properties of dyed 100% cotton woven fabric, surface functionalized for hydrophobicity by Silica nano particles mixed with silane hydrophobes (i.e water repellent agent) and silane cross linkers applied through sol-gel method.

2. MATERIALS AND METHOD

2.1 Materials

A commercially prepared woven cotton fabric (60 ends/inch and 60 picks/inch) with both warp and filling yarns having 22 tex was supplied by M/S Lucky Textile Mills Pvt: Ltd Karachi. TEOS (Tetraethoxysilane) and TMOS (Tetramethoxysilane) as shown in Fig. 1 (a-b) and n-octyltriethoxysilane were provided by Hangzhuo Feidian Chemical Co. Ltd Shanghai, China. Silica nanoparticals (Aerosil® 200) was supplied by Pharmacare Industry Lahore, Pakistan. Ethanol (95%) and hydrochloric acid (37%) were used as solvent catalyst respectively.

2.2 Dyeing of Fabric

Indosol Red-BA (direct dye) and Drimarene Reactive Blue-BR (Reactive dye) along with dyeing auxiliaries were applied by using standard recipe of Clariant [15] on Rapid High Temperature exhaust dyeing machine. Afterward these samples were washed and dried for nano-sols coating.

2.3 Preparation of Nano-Sols

The silica nano-sols were prepared by using ethanol 96 ml, HCl 24 ml, cross linkers TEOS/TMOS 20 ml, n-octyltriethoxysilane 4 ml and different concentration of silica nanoparticles [1, 16]. Four sols were prepared A, B, C and D having Zero, 0.02, 0.1 and 0.2% silica nanoparticles respectively while all other chemicals remain same. Firstly all ingredients except hydrophobe were mixed in a beaker; after two hours silane hydrophobe (n-octyltriethoxysilane) was added to the solution. It was then subjected to ultrasonic treatment for 30 min in chilled or ice bath using an ultrasonic probe (FRT-200B) to make the sol ready for application.

2.4 Application of Nano-Sols

A number of nano-sol solutions were prepared with TEOS and TMOS cross-linkers. These coatings were applied on dyed samples manually by dip and dry method, fabric may be dipped thoroughly more than one time for even application. After application samples were dried at room temperature and cured at 100°C for 1 hour in laboratory oven [16]. The treated samples were then stored in air tight polyethylene bags till they were tested.

2.5 Measurements

The treated samples were tested for tensile strength on Uster Tenso Rapid 4 according to standard test method (BS-2576), for fabric stiffness British standard test method (BS-3356) was used. Fabric crease recovery was measured according to guidelines given in test

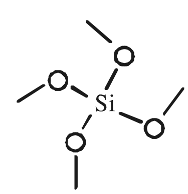


FIG. 1(a). TETRAMETHOXYSILANE

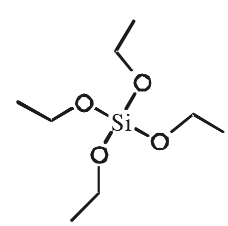


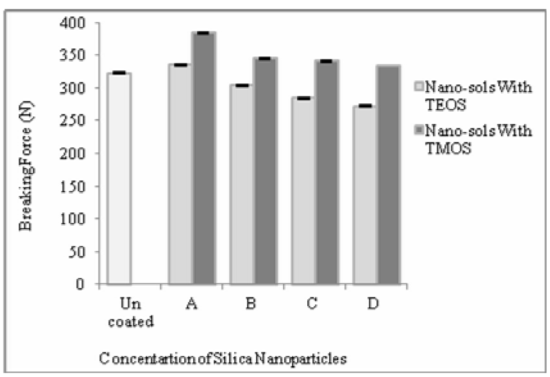
FIG. 1(b). TETRAETHOXYSILANE

method (BS EN-22313) whereas air permeability was determined by (ASTM D-737).

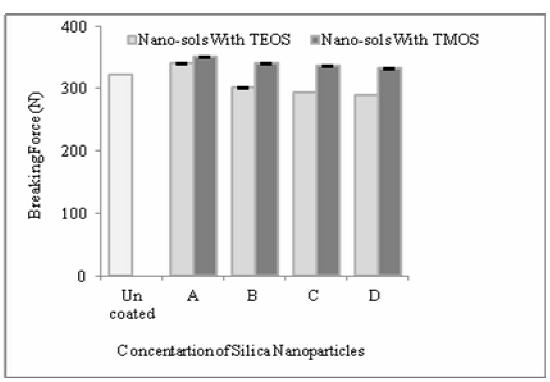
3. RESULTS AND DISCUSSION

3.1 Effect of Silica Nano-Sols on Tensile Strength

Fig. 2(a-b) show that tensile strength of coated fabric initially increases with a sol having no silica nanoparticles (Recipe-A) as compare to untreated sample but thereafter it decreases gradually. It is also evident that, tensile strength decreases more with TEOS as cross-linker and leads to below the un-treated sample's strength while it is still greater when treated with TMOS. It is because, these coatings are much homogenous which helps yarn binding in first instance but their higher amount make fabric surface rough and rigid [10]. The potential standard deviations from the mean values are also presented in the graph in the form of error bars, which depict no any significant deviation from mean.



(a) DIRECT DYED SAMPLES



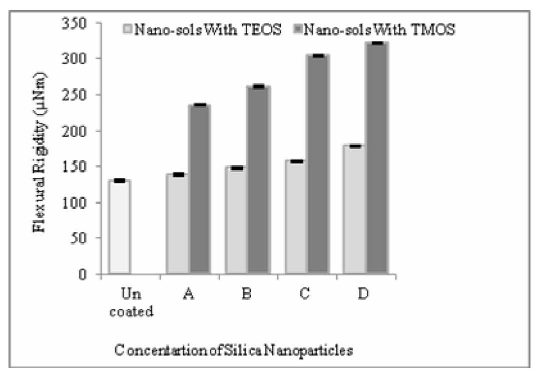
(b) REACTIVE DYED SAMPLE

FIG. 2.EFFECT OF SILICA NANO-SOLS ON TENSILE STRENGTH

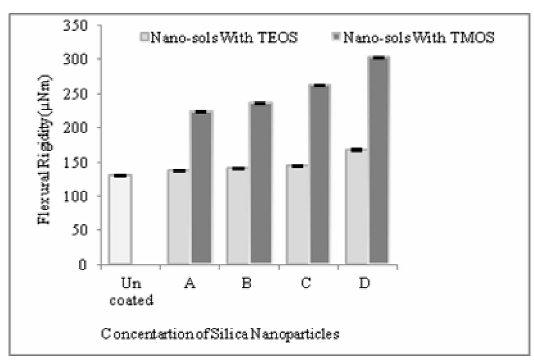
These findings are also confirming [12,13] which states that effect of sols on tensile properties is negligible. Dye type has no effect it was expected.

3.2 Effect of Silica Nano-Sols on Stiffness

Chemical coatings make fabrics stiff due to their rigidity. Silica nanoparticles when applied through sol-gel method in presence of silane cross-linkers - form 3D network on fabric surface, which in turn enhance the fabric stiffness. Fig. 3(a-b) show that flexural rigidity of treated samples increases gradually with silica nanoparticle concentration and fabric became three times stiff by using 0.2% silica (of the weight of bath) in the recipe (recipe D - nano-sols with TMOS). The cross linkers are also showing the same effect as in previous section –Fabric treated with TMOS is stiffer than one treated with TEOS. This may be caused by the chemical structure of TMOS as stated in Fig. 1. The side chain of carbons is longer in case of TEOS than TMOS, hence causes the molecules to slide over and results more flexible surface. Therefore it is suggested that cross-linker should be selected according to fabrics



(a) DIRECT DYED SAMPLES



(b) REACTIVE DYED SAMPLES

FIG. 3. EFFECT OF SILICA NANO-SOLS ON FLEXURAL RIGIDITY

intended end use. Furthermore, the error bars as the standard deviations were also applied to the graphs to check the distribution of data and precision, which reveal that there is perfect precision in measurement.

3.3 Effect of Silica Nano-Sols on Crease Recovery

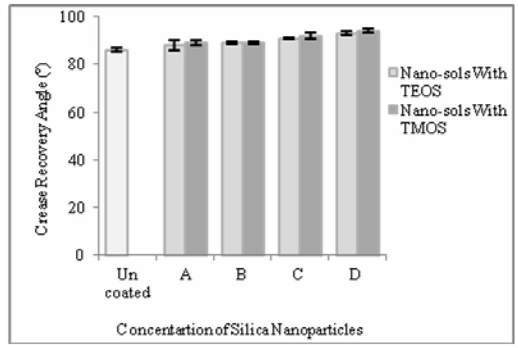
Fabric crease recovery is a complex phenomenon involved compressive, torsional, flexural and tensile forces. It depends upon fabric and yarn parameters and measured as fabric recovery angel after crushing if 0° means no recovery and 180° means full recovery. It was observed that, the increase of concentration of silica nanoparticles contributes to increase the crease recovery angle of the dyed cotton fabric due to restriction of the molecular movement in the fiber structure. Results of silica sol coated fabric's crease recovery are shown in Fig. 4(a-b) which depict that crease recovery angle has improved slightly by addition of silica nanoparticles in nano-sols.

Previous research [9,17] show that nano-metal oxides such as SiO_2 when used as a water repellant and fire retardant and thermal stable agent along with non-formaldehyde cross linking agents also improve the crease recovery properties of cotton fabric. Error bars depict the acceptable overall distribution of data with minor deviation of individual measurement from mean value, which is evident that mean represents true measurement.

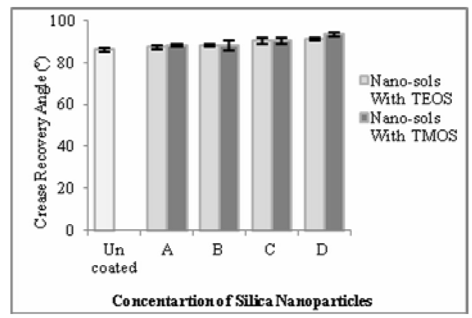
3.4 Effect of Silica Nano-Sols on Air Permeability

Air permeability of fabric is one of the main comfort properties of coated fabrics. Fig. 5(a-b) reveal the effect of different concentration of silica nanoparticles.

Air permeability of nano-sol coated cotton was slightly affected by sol coatings. It was observed that as concentration of silica nanoparticle increases permeability of fabric slightly decreases. This slightly reduction is not only due to the introduction of silica nanoparticles and hydrophobe, which make fabric surface rough by depositing [18] but also their deposition in the fabric pores results in bridging mechanism that reduces pore size [14,19]. Furthermore, untreated fabric shows more deviation in permeability readings from mean value (Fig. 5(a-b)) as compare to coated samples. It may be due deviation in pore morphology but these are acceptable.

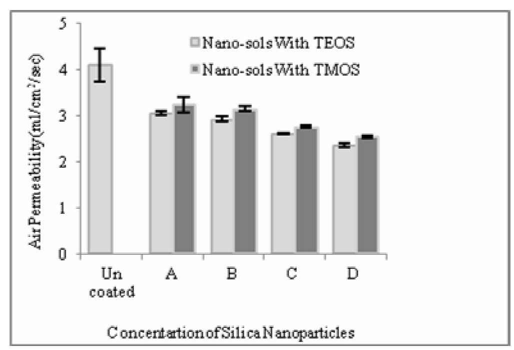


(a) DIRECT DYED SAMPLES

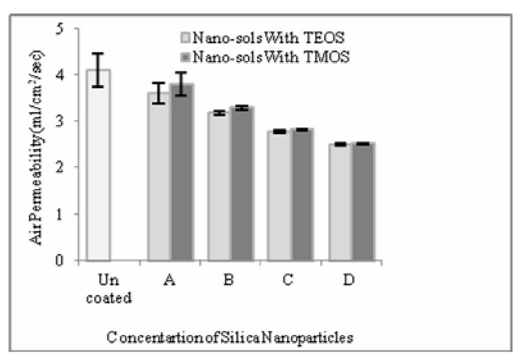


(b) REACTIVE DYED SAMPLES

FIG. 4. EFFECT OF SILICA NANO-SOLS ON CREASE RECOVERY



(a) DIRECT DYED SAMPLES



(b) REACTIVE DYED SAMPLES

FIG. 5. EFFECT OF SILICA NANO-SOLS ON AIR PERMEABILITY

CONCLUSIONS

In undertaken research, the physical properties of silica sol-gel coated cotton were investigated. Following conclusions are drawn:

(i) Tensile strength of fabric was improved at low concentration of silica nanoparticles and then gradually decreased but remain above the un-treated fabric strength with TMOS as cross-linker.

(ii) As it was expected, fabric flexural rigidity increased with each addition of silica nanoparticles in the solution. This effect was more prominent with TMOS cross-linkers.

(iii) Slight improvement in fabric crease recovery and reduction in air permeability was also observed, whereas dye type has no effect on coated fabric's properties.

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