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STUDY IN APPLICATION OF NANOTECHNOLOGY TO ACHIEVE WATER REPELLENCY

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Abstract: *To obtain water repellent polyester non woven fabric. Fabric was treated with silica nano particle and commercially available water repellent agent. Silica nano particle was synthesized by using stobermethod, fabric was treated with silica nano particle and combination of both silica nano particle and water repellent agent and compare.For fabric treated with water repellent agent shows the rating of 80 for 35gpl and fabric treated with combination of both shows the rating of 100 for 35gpl that is super hydrophobic surface.*

Key words: *Nanoparticles, Nanosilica, Superhydrophobicity, Self-Cleaning, Surface Energy.*

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1. INTRODUCTION

For many years, people have been attracted by the self-cleaning property of the lotus leaf, and dream to develop man-made superhydrophobic surfaces. Superhydrophobic and self-cleaning surfaces exist widely in nature. Butterfly wings, legs of a water strider and leaves of some plants are good examples. Thanks to the innovation of scanning electron microscopy, today, scientists know the plant's ability to repel water and dirt results from the superhydrophobicity, due to the combination of micrometer-scale hills and valleys and nanometer-scale waxy bumps, in combination with the reduced adhesion between surfaces and particles. A surface with water contact angle large than 150° and a low sliding angle (the critical angle where a water droplet with a certain weight begins to slide down the inclined plate) is usually called a superhydrophobic surface. A combination of low surface energy and adequate surface roughness is necessary to obtain superhydrophobic and superoleophobic surface. High contact angles are achieved by reducing the surface energy of the solid surface and increasing its roughness in an appropriate manner, thus reducing wetting. Techniques involved in developing such surfaces include plasma treatment, chemical etching, chemical vapor deposition, lithography, and so forth. [1, 2, 3, 4]

Principle of Superhydrophobicity

Wetting of a solid surface is dominated by three interfacial tensions and can simply be evaluated by the spreading parameters(S).

$$(1)\quad S=\gamma_{SV} - (\gamma_{SL} + \gamma_{SV})$$

If the spreading parameter S>0, the liquid tends to spread completely on the solid. While for S<0, the liquid partially wets the solid and forms a spherical cap with a contact angle Θ_C, which is usually used for quantitative characterization of the wetting phenomena.The value of the angle is determined by three surface tensions where the chemical potential in the three phases should be at equilibrium. Therefore, the contact angle relationship Θ_C derived by balancing the three tension forces onto the solid surface

$$(2)\quad \cos(\theta_C) = \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}}$$

This is Young's equation for the determination of contact angles. [5]

2. MATERIALS AND METHODS

2.1. Materials

- **Fabric/substrate sample - 100% Polyester Spunlace Nonwoven fabric**

Table 1: Fabric specifications

	100% Polyester nonwoven fabric
Fabric thickness (mm)	0.40
GSM	40
Air-permeability ($cm^3/cm^2/s$)	73.2

- **Chemicals used:**

Chemical Name	Function
TEOS (tetraethyl orthosilicate)	Chemicals used for the synthesis of Silica Nanoparticles
Ethanol	
Ammonia	
TUBIGAURD	water repellent agent
Magnesium chloride	stabilizer for water repellent agent
Acetic acid	pH maintainer

2.2 Methods

Synthesis of silica nanoparticles:

The silica nanoparticles were prepared by the modified Stober method of hydrolysis, dehydration and condensation of TEOS as a precursor. Firstly a mixture of 0.2 mol tetraethyl orthosilicate and 2.5 mol ethanol was prepared, then it was mixed with the mixture of 2.0 mol distilled water, 2.5 mol ethanol and 0.05 mol ammonia solution. The synthesis was carried out for 3 hours at 30^0C. The following tables show the chemical composition for the synthesis of silica nanoparticles. [6]

Table 1.1: Recipe for the synthesis of silica nanoparticles

Sr. No	Chemical	Concentration (Mol)	Solution No.
1	TEOS	0.2	Solution 1
2	Ethanol	2.5	
3	Water	2.0	Solution 2
4	Ethanol	2.5	
5	Ammonium hydroxide	0.05	

Solution 1 + Solution 2 ⟶ Stirring at 30^0C for 3 hours.

Sr. No.	TEOS (Mol)	Ethanol (Mol)	Water (Mol)	Ethanol (Mol)	Ammonium hydroxide (Mol)
1	0.2	2.5	2.0	2.5	0.05

2.2 Application of Silica Nanoparticles and the Water Repellent Agent on polyester nonwoven fabric:

The polyester nonwoven fabric considered as the substrate to be applied is padded with the silica sol that was prepared earlierusing a laboratory padding mangle. The padded fabric samples were then dried at room temperature to maintain residual moisture content 8 – 10%. The dried fabric samples were cured at 140^{0}C for 3min. Then these fabric samples were again padded with the water repellent agent with varying concentration from 15gpl – 40gpl. The padded fabric samples were the dried at room temperature and cured at 140^{0}C for 3min. The following table shows the chemical composition for the water repellent finish.

Table 2: Recipe for Water Repellent finish

Sr.No	Chemical	Concentration
1	TUBIGAURD	15, 20, 25, 30, 35, 40 gpl
2	Magnesium chloride	12 gpl
3	Acetic acid	Add to maintain pH of 4.5 – 5

The following table shows the chemical Composition of water repellent agent and silica nonoparticles for water repellent finish.

Table 3: 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)
1	0.2	2.5	2.0	2.5	0.05	15
2	0.2	2.5	2.0	2.5	0.05	20
3	0.2	2.5	2.0	2.5	0.05	25
4	0.2	2.5	2.0	2.5	0.05	30
5	0.2	2.5	2.0	2.5	0.05	35
6	0.2	2.5	2.0	2.5	0.05	40

Each of the fabric samples treated with the silica nanoparticles as per the recipe mentioned above is further treated with the Water Repellent agent of concentrations ranging from 15 – 40 gpl as mentioned in table 2.

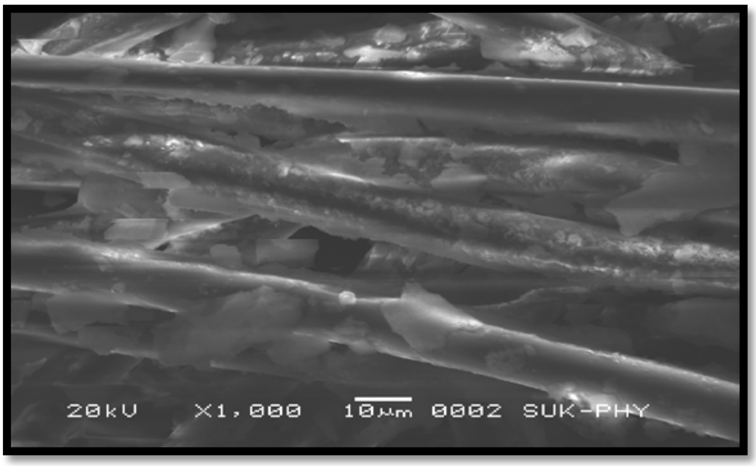
Test Standards

Spray Rating TestAATCC 22, ISO 4920	**Air-permeability**– ASTM 738-04
Hydro-static head pressure test	**SEM**– JOEL JSM 636

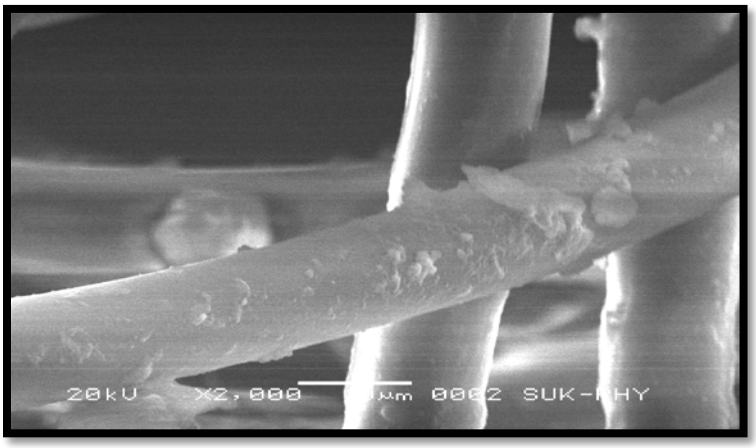
3. RESULTS AND DISCUSSIONS

3.1 Characterization:-

Scanning Electron Microscope (SEM) is used to characterized the surface morphology of treated fabric. It was observed that, due to the presence of silica nanoparticles fabric shows the scaly appearance on the surface, which made the surface rougher & enhance the water repellency. Figure 1 shows, the SEM image of polyester nonwoven fabric treated with silica nanoparticles & figure 2 shows the SEM image of Polyester Nonwoven fabric treated with both silica nanoparticles and water repellent agent . The figure 2 shows the water repellent agent forms an oily layer on the silica nanoparticles just like lotus leaves. Here silica nanoparticles act as an epidermal cells and water repellent agent as waxy bumps which results in superhydrophobicity on polyester nonwoven fabricfabric.



"Figur 1. SEM image of Polyester nonwoven fabric treated with silica nanoparticles"

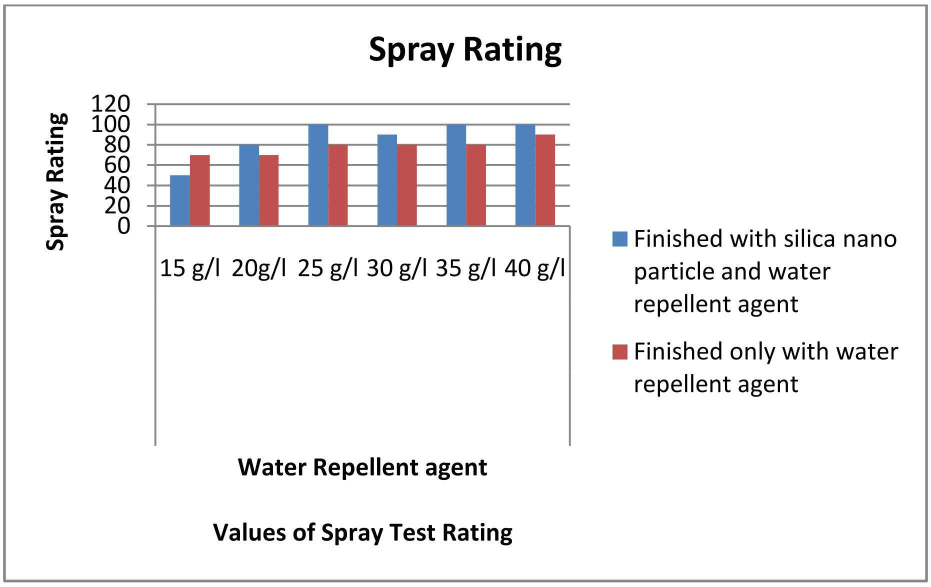


"Figur 2. SEM image of polyester nonwoven fabric treated with both silica nanoparticles and water repellent agent

3.2 Effect of concentration of water repellent Agent on Water Repellency Rating-SprayRating.

"Table 4. Effect of concentration of water repellent Agent on Water Repellency Rating-Spray Rating"

	Values of spray test ratings					
	Water repellent agent					
	15 g/l	20g/l	25 g/l	30 g/l	35 g/l	40 g/l
Finished with silica nano particle and water repellent agent	50	80	100	90	100	100
Finished only with water repellent agent	70	70	80	80	80	90



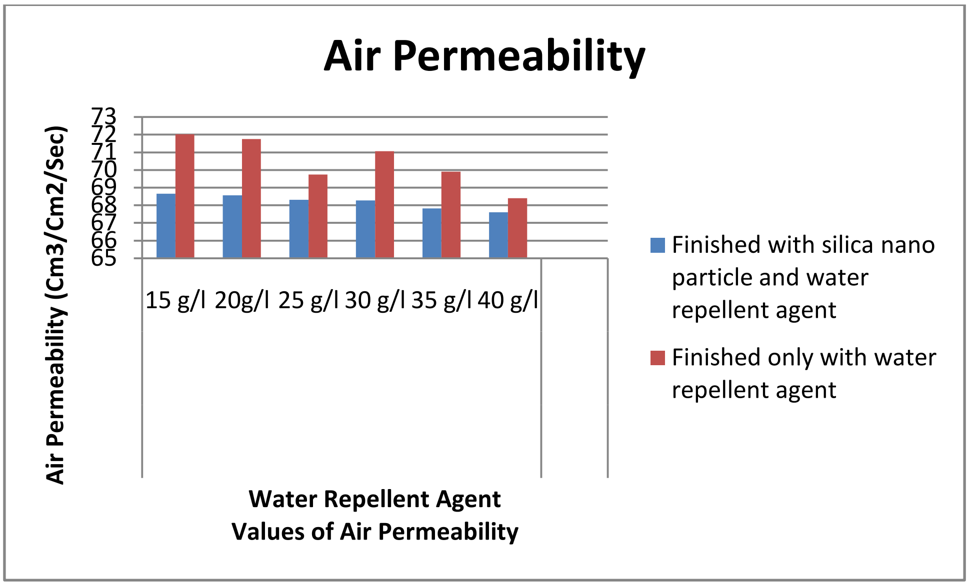
"Figure 4.Effect of concentration of water repellent Agent on Water Repellency Rating-Spray Rating"

From the above table 4 and Figure 4 it is observed that the fabric finished with only water repellent agent shows the increase in water repellency rating from 70 for 15 g/l to 90 for 40 g/l, while fabric finished with combination of water repellent agent and nano silica particle shows increase in spray rating from 50 for 15 g/l to 100 for 40 g/l. The fabric finished with combination of water repellent agent and nano silica particle shows the rating of 50 for 15 g/l, it is because of the random alignment offibres in non woven fabric. From the graph and table it is observed that 25 g/l gives optimum result.

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

"Table 5.Effect of Concentration of water Repellent Agent on Air Permeability"

	Values of Air Permeability ($Cm^3/Cm^2/Sec$)					
	Water repellent agent					
	15 g/l	20g/l	25 g/l	30 g/l	35 g/l	40 g/l
Finished with silica nano particle and water repellent agent	68.65	68.56	68.32	68.27	67.82	67.60
Finished only with water repellent agent	72.02	71.76	69.75	71.06	69.90	68.4



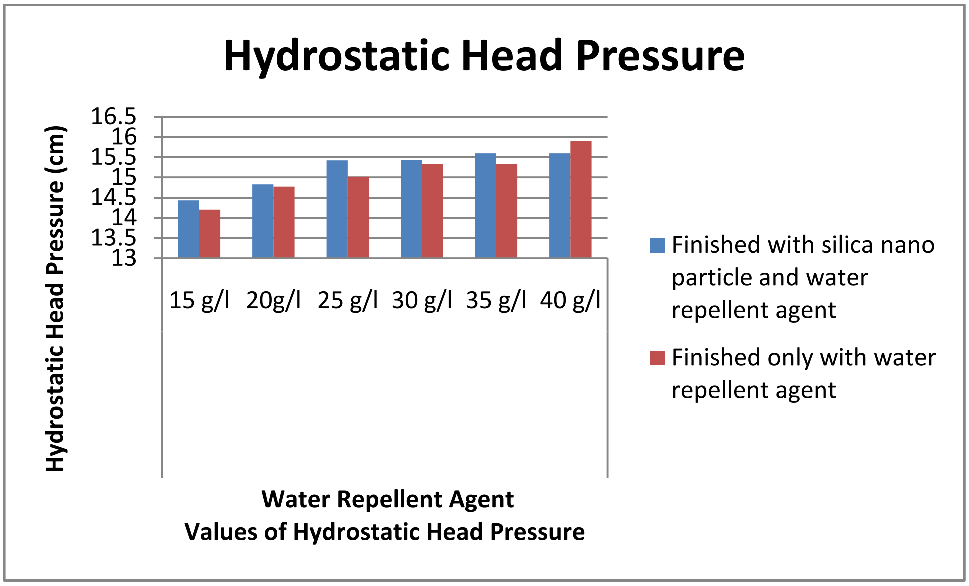
"Figure 5 .Effect of Concentration of water Repellent Agent on Air Permeability"

From the Table 5 and Figure 5, it is observed that, the fabric finished with only water repellent agent shows the decrease in air permeability from 72.02 to 68.4 for the concentration of 15 gpl to 40 gpl of water repellent agent respectively some values are fluctuate in between 20 g/l and 30 g/l this is because of random alignment of fibres in non woven fabric, while the fabric finished with combination of silica nanoparticles and water repellent agent shows decrease in air permeability from 68.65 to 67.60 for the concentration of 15 gpl to 40 gpl of water repellent agent respectively.This may be because; as concentration goes on increasing the film is going to become continuous, which causes decrease in air transmission rate& also the silica nanoparticles help in filling the interstices between fibres.

3.4 Effect of Concentration of Water Repellent Agent on Hydrostatic Head Pressure.

"Table 6. Effect of Concentration of Water Repellent Agent on Hydrostatic Head Pressure."

	Values of Air Hydrostatic Head Pressure (cm)					
	Water repellent agent					
	15 g/l	20g/l	25 g/l	30 g/l	35 g/l	40 g/l
Finished with silica nano particle and water repellent agent	14.43	14.83	15.42	15.43	15.60	15.60
Finished only with water repellent agent	14.20	14.77	15.02	15.33	15.33	15.9



"Figure 6. Effect of concentration of water repellent agent on hydrostatic head pressure."

The above Table 6 and Figure 6 shows that, the fabric finished with only water repellent agent shows the increase in hydrostatic head pressure from 14.20 to 15.33 for water repellent agent concentration of 15 gpl to 35gpl respectively. The fabric finished with combination of silica nanoparticles and water repellent agent shows an increase in hydrostatic head pressure from 14.43 to 15.60 for water repellent agent concentration of 15 gpl to 35gpl respectively. This may be because of silica nanoparticles helps to resist the drop of water penetrating inside fabric structure.

4. CONCLUSION

This study focuses on imparting water repellent properties on 40 gsm polyester non woven fabric. For this nano silica particle was synthesized by using stober method, fabric was then finished with both water repellent agent and combination of both water repellent agent and nano silica particle. It was observed that spray rating of 70 was observed for fabric treated with water repellent agent and spray rating of 80 was observed for fabric treated with combination of both water repellent agent and nano silica particle. This indicates that the nano silica particles helps in improving water repellent properties by roughening the fabric surface. Also there was decreased in air permeability and increased in hydrostatic head pressure and decreased in tearing strength was observed as the concentration of water repellent agent increased.

5. REFERENCES

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