International Journal of Advanced Research in
IT and Engineering

ISSN: 2278-6244

WATER REPELLENCY OF TEXTILES THROUGH NANOTECHNOLOGY

Dr. Chinta S.K.*

Landage S.M.*

Jain Swapnal*

Abstract: *Novel and special finishing of coated textiles such as flame retardency, water repellency, antimicrobial, UV light ageing and encapsulated fragrances etc. has increased demand. Water and soil repellency are the major targets for textile fibres. Nanotechnology develops new techniques for finishing of textiles. Nanotechnology exhibits fibrous materials to develop "lotus-like" surfaces and characterize their morphology and the ability to repel water and self-cleaning without changing the handle and breathable properties of the fabric.*

Keywords: *Nanotechnology, water repellency, sol gel process*

*D. K. T. E. Society's, Textile & Engineering Institute, Ichalkaranji, India

1. INTRODUCTION

Trends in global textile industry reveals that the survival of the conventional textile business is very difficult in current scenario even after an enormous capital investment because the numbers of competitors are increasing at high speed, consequently, conventional textile products are available in the market at large with very competitive prices, and hence the profit percentage is reduced to the minimum level. So high-tech industrial revolution is directly needed for survival in such severe competition [1]. The global textile industry is moving towards new trends and most promising technologies to achieve functional and high performance characteristics which include specialized coating, plasma based products, smart/technical technologies and nanotechnologies [2]. Impact of nanotechnology on the textile industry and the application of nano-materials in textiles have dramatically improved the fibre and processing technology to fulfil the needs of society [3]. Drastic changes have been observed in the last five decades in the applications of textiles and there is no doubt that in the next few years nanotechnology will penetrate in every field of textile industry [4]. Nanotechnology is defined as the precise manipulation of individual atoms and molecules to create layered structures. One nanometer is defined as 1 billionth meter i.e. 1×10^{-9}m and involves developing materials or devices within that size[5] [6]. Nanosize particles can exhibit unexpected properties different from those of the bulk material. The small size of nanoparticles leads to particle–particle aggregation hereby making physical handling of nanoparticles difficult in liquid and dry powder forms. The basic premise is that properties can dramatically change when a substance's size is reduced to the nanometer range. In bulk form, gold is inert; however, once broken down into small clusters of atoms it becomes highly reactive [7]. It's the application of functional systems in the sub-micro range.

Nanotechnology is an interdisciplinary science which takes a role in the material science, mechanics, electronics, optics, medicine, plastics, energy, aerospace, textiles, optical coatings, antibacterial agents, physics, biology. Decreasing the size of particles to nanoscale dimensions fundamentally changes the properties of the material. For example, 50 kg of 1mm-size SiO_2 particles, with a surface of 120 m^2, when decreased to 1 nm would have a surface area of 120,000,000 m^2. In addition, as the particle size decreases the number of molecules in the surface relative to the bulk increases, giving new and unexpected properties [8]. This has been illustrated schematically in Fig. 1

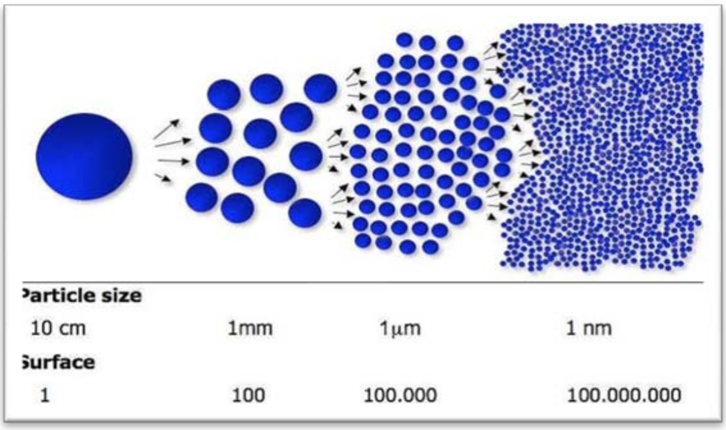

Fig.1 Schematic representation of particle size and surface at nanoscale.

It was demonstrated in recent years that nanotechnology can be used to enhance textile attributes, such as fabric softness, durability, and breathability, water repellency, fire retardancy, anti-microbial properties, and the like in fibres, yarns, and fabrics [9].

Fundaments of nanotechnology lie in the fact that the properties of materials drastically change when their dimensions are reduced to nanometre scale. Textile exports, for instance, are using nanotechnology for self-cleaning properties of the leaves of the lotus-flower for textile applications. This is the domain of intelligent textiles.

2. IMPORTANCE OF NANOTECHNOLOGY

Nanotechnology also has revealed commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. In contrast, nanotechnology can provide high durability for fabrics, because the nano-particles have a large surface area-to-volume ratio and high surface energy, thus presenting better affinity for fabrics and leading to an increase in durability of the function [10]. In addition, a coating of nano-particles on fabrics will not affect physical and mechanical properties such as hand, strength, air permeability and wetting [11]. The purposes of using nanotechnology in textile and apparel applications are low chemical usage; lower energy costs. Thus, nanotechnology is today's most preferred solution for the textile industry because of the techno-economic advantages.

3. APPLICATION OF NANOTECHNOLOGY IN TEXTILES

In order to understand clear overview of the concept of nanotechnology in the textile industry, the application of nanotechnology in the textile value chain has to be reviewed. There are two places in the textile value chain where nanotechnology can be applied; one is to apply at the production of fibres or the other is to apply the technology on the surface of yarn or fabric as coating at the finishing step. Techniques to incorporate nanotechnology in the manufacturing process include the integration of nanomaterials into fabrics (e.g. silver nanoparticle additives on fibres), use of nanosize fibres or use of various nanocoating processes to provide a particular surface resistance. The increased demand for textiles and fabrics that provide comfort with enhanced functionality and improved appearance is driving the demand for nanotechnology in this sector [12]. Moreover, natural textile fibres are also complex nano structures and ultimately, the natural world can only be understood by analysis at the molecular level [13].

Among the most interesting nanotechnology application in the textile industry are those which offer the possibility of reducing the use of harsh chemical (such as in antimicrobial application), improve the long term performance and durability of textile generates product which are more ecofriendly and greener, as well as application which deliver performance enhancing features.

- Antimicrobial and antibacterial applications with silver compound
- Nanoparticles to test the efficiency of protective textile and other materials.
- Nanomaterial to reduce the quantity of harmful chemicals in finishing recipes.

- Nanocoating for oil, flame and heat resistance.
- Use of nanotechnology for biomimics, such as recreating the surface of a lotus leaf on textiles at the nanoscale in order to reproduce its resistance to oil and water for potential use in self cleaning textile applications [14].

Some of the other applications of nanotechnology are:

i. Colour fastness
ii. Colour changing
iii. Water repellent
iv. Abrasion
v. Fire retardant
vi. UV absorption
vii. Energy storage
viii. Data storage
ix. Communications
x. Controlled release of additives [15].

The automotive industry is potentially a major beneficiary of nanotechnology developments which promise improvements and benefits at various levels providing lighter, stronger, harder materials, improved engine efficiency, reduced fuel consumption, and reduced environmental impact, improved safety, and comfort. People spend ever more time in their cars and therefore safety and comfort become increasingly important. Textile materials have an important role here, for their use spans from interior panels for doors and pillars, seat coverings and padding, parts of the dashboard, to cabin roof and boot carpets, headliner, safety belts, air bags, air filtration, tyre cord, and trimmings. Moreover, the use of textiles, in particular natural-based materials thanks to their easier recyclability, contributes to reducing car weight by replacing many conventional hard-surface structures.

Advantages of nano enabled automotive textile:

- Both in terms of passenger needs and environmental impact.
- Nano-enabled textiles provide new and innovative solutions for car upholstery with moisture wicking, self-cleaning, antimicrobial and antistatic properties, or tear/wear resistance and noise reduction features.

- Safety can also be enhanced with nano-enabled textiles possessing valuable flame retardant/ resistance properties.
- In the more distant future, "smart textiles" that can monitor variables such as the driver's condition; however, privacy issues may arise. The increased use of textiles in the car contributes to the reduction of the car weight and hence fuel consumption and CO_2 emissions [16].

Rising health and safety concerns for those exposed to dangerous environments or high risk professions has increased demand for improved protective apparel and accessories. Protective textiles are part of the Personal Protective Equipments (PPE) family and represent a specific area of the advanced technical textiles sector, a strongly growing market for the textile industry, satisfying an increasing demand for high performance requirements. Personal protective textiles are produced with the aim of eliminating or minimising the risk of injuries, accidents and infections, acting as shields against chemical, biological and nuclear hazards, high temperatures and fire, sharp objects, and ballistic projectiles.

Novel surface treatments and coatings, nanocomposite and nanoscale fibres, and functional nanoparticles offer textile products providing improved levels of protection together with a lower weight, higher comfort, new or multi-functionalities, or more environmentally friendly processes.

Advantages offered by nanoenabled technical textiles in the protective textiles sector.

1. Personal Protective Equipment (PPE) is increasingly important in the quest to eliminate or minimise the risk of injuries, accidents, and infections arising from a variety of threats and environments.
2. Protective textiles have been selected by the European Commission as one of the areas of the Lead Market Initiative for Europe, aimed to create an innovation-friendly market framework and to re-invigorate and increase competitiveness of traditional industries.
3. Nanotechnologies can play a fundamental role in the development of improved or novel multifunctional protective textiles by providing higher levels of protection, lower weight and bulkiness, and higher levels of comfort. Moreover, nanotechnologies, by facilitating the integration of electronics into garments, make

possible the development of smart/intelligent textiles that allow tracking, monitoring and control of physiological parameters, generation of energy for powering wearable equipments and communication functions [17].

4. PROGRESS TOWARDS THE FABRIC FINISHING BY USING NANOTECHNOLOGY

Finishing of fabrics made of natural and synthetic fibres to achieve desirable hand, surface texture, colour, and other special aesthetic and functional properties, has been a primary focus in textile manufacturing. In the last decade, the advent of nanotechnology has spurred significant developments and innovations in this field of textile technology. Fabric finishing has taken new routes and demonstrated a great potential for significant improvements by applications of nanotechnology. The developments in the areas of surface engineering and fabric finishing have been highlighted in several papers [18-21]. There are many ways in which the surface properties of a fabric can be manipulated and enhanced, by implementing appropriate surface finishing, coating, and/or altering techniques, using nanotechNanotechnology provides plenty of efficient tools and techniques to produce desirable fabric attributes, mainly by engineering modifications of the fabric surface. For example, the prevention of fluid wetting towards the development of water or stain-resistant fabrics have always been of great concern in textile manufacturing. The basic principles and theoretical background of "fluid-fabric" surface interaction are well described in a recent manuscript by Schrauth et al [22]. They have demonstrated that by altering the micro-and nanoscale surface features on a fabric surface, a more robust control of wetting behaviour can be attained. They also showed that such an alteration in the fabric's surface properties is capable of exhibiting the "Lotus-Effect, “which demonstrates the natural hydrophobic behaviour of a leaf surface. This sort of surface engineering, which is capable of replicating hydrophobic behaviour, can be utilized in developing special chemical finishes for producing water-and/or stain- resistant fabrics.

5. PROBLEM ASSOCIATED WITH NANOTECHNOLOGY

Nanofinished fabrics would have to be classified as hazardous wastes were not confirmed. They can be recycled or thermally utilised using conventional methods. There are still questions about the mass land filling of nano finished fabrics (possible impairment of water and soil). Here we believe there is a need for research and action prior to their market introduction in order to avoid any damage to humans and the environment from the very outset. If pure nanomaterials are manufactured or there is the mass use of materials finished with nano particles, then the recycling systems must be upgraded to keep pace with these technological developments [23].

6. WATER REPELLENT TEXTILES

Finishing of coated textiles such as flame retardency, water repellency, antimicrobial, UV light ageing and encapsulated fragrances etc. has increased demand. Water and soil repellency has been one of the major targets for fibre and textile scientists and manufacturers for centuries. Water repellent textiles, by definition, repel water from the surface of the fabric. However, there are multiple methods by which water can be repelled from the fabric surface. A fabric surface can repel water by resisting adsorption, absorption, or penetration of water. When functionalizing a fabric for water repellency, it is important to keep in mind the end use of the textile. Rendering a textile water proof implies that the fabric will be repellent to water in both the liquid and vapour forms. The distinction between waterproof and water repellent textiles becomes important when considering the end use of the textile. Water proof textiles are valuable when creating barriers to eliminate the penetration of water of all forms, such as tenting. In contrast, textiles that are both water repellent and breathable are necessary for end uses such as performance clothing.

When measuring the repellency of a textile, it is important to maintain differentiation of the terms: water repellency and contact angle. Water repellency describes how well a fabric resists the absorption, adsorption, and penetration of water on a fabric surface. The measurement of the contact angle of a liquid on the surface of a fabric is a method of quantitatively describing the surface energy of the substrate [24].

The contact angle of a liquid on the surface of a material is an indirect measurement of the wettability, and directly relates to the interactions of the solid, liquid, and gas phases.Thus, the differences between the surface energies of the solid-vapour and solid-liquid phases strongly affect the resultant contact angle formed between the solid and liquid.It should be noted that Young's Equation is based upon a perfect system where the solid surface is smooth and homogeneous. As textile surfaces are not smooth, and uniform application of finishes is extremely difficult, there is large variability in repellency data based upon fabrics [25].

6.1 Contact Angle

The contact angle of a droplet on a substrate is the angle formed between the solid-liquid interface and the liquid-vapour interface, and is shown in Figure 3.

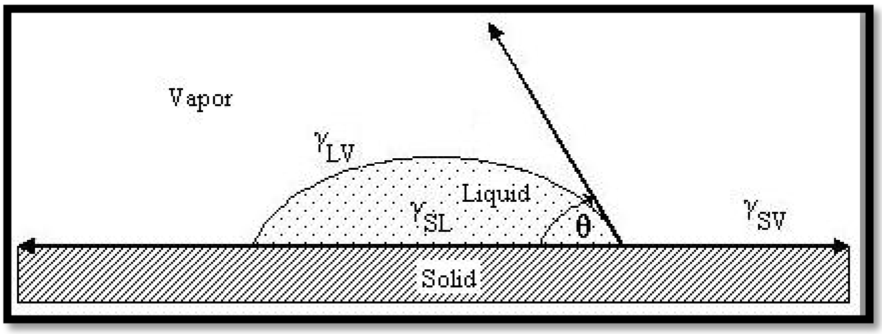

Fig.3 Contact angle measurement

When θ≤ 90°, the surface is said to be hydrophilic and the drop wets the surface. If the contact angle is 0°, then the solid-liquid interaction is greater than or equal to that of the liquid-liquid interaction. Conversely, if the contact angle is 180°, then there is no interaction between the solid and liquid phases. When the contact angle exceeds 90°, wetting of the substrate does not occur, and the substrate is said to be hydrophobic. In this case, the interaction between the liquid and gas phases is greater than the interaction between the solid and liquid phases. When surfaces have contact angles greater than 90°, the fluid and surface are unable to efficiently form secondary bonds. Increasing surface roughness have also been shown to positively impact the water repellency of smooth surfaces [26-28]. The lotus leaf, occurring naturally in nature, is an example of a system where surface roughness has a large effect on water repellency. The lotus leaf surface is covered in paraffin crystals on the scale of 1-10 micrometers, and can achieve contact angles greater than 155° [29]. The use of the sol-gel process is one method that has been used to increase surface roughness through the introduction of nanoparticles [30-32].

7. CHEMICALS USED FOR WATER REPELLENT FINISHING OF TEXTILES

Water repellent finishing on the fabrics is mostly imparted by the incorporation of low surface energy compounds. Water repellency can be achieved by using following chemicals.

1. Wax dispersions free of metal ions
2. Metallic salts and soaps
3. Wax dispersions containing Zirconium salts and Pyridinium compounds.

4. Silicones
5. Organo chromium compounds
6. Fluorochemicals.

Products falling under 1 to 4 categories were purely temporary and lasted only a few washes. Methyl Hydrogen Polysiloxane was very popular water repellent finish and had a lot of risks associated with it. Methyl Hydrogen Polysiloxanes are reactive in nature and great care had to be taken while handling these materials. These materials came in many forms such as fluids, emulsions and resins. These products evolve hydrogen upon contact with strong bases, amines, primary alcohols. These compounds rapidly evolve hydrogen gas and form flammable and explosive mixtures in air. The inherent risk involved with these compounds made them unpopular and unattractive for water repellent finishing operations. Moreover compounds based on paraffin oil with silicone water repellent finishing agents were not sufficient to protect textiles from grease and oil stains. This led to the development of fluorocarbon polymers. Fluorocarbons are both oil and water repellent. Fluorocarbon polymers also form a film where the fluorocarbon radicals are perpendicular to the fibre axis thus prevent wetting of the fibre surface. The most commonly used chemicals for hydrophobization are fluoroalkylsilanes owing to their extremely low surface free energy and the simple reaction of the silane groups with the hydroxyl groups on coatings. Also, most superoleophobic surfaces are created by the hydrophobization of a perfluorinated material [33-34].

8. NANOTECHNOLOGY IN WATER REPELLENCY:

Hydrophobic finishes lower the surface energy and can give a maximum water contact angle of roughly 120^0. To get higher contact angle and to have the self-cleaning ability, Surfaces with contact angle between 150^0 to 180^0 are required [35]. This type of finish cannot be obtained by a surface coating. Super hydrophobicity increases with an increase in surface roughness which provides larger geometric area. The roughened surface generally takes the form of a substrate membrane with a multiplicity of microscale to nanoscale projections or cavities. Water repellency of rough surface was due to the air enclosed between the gaps in the surface. This enlarges the air/water interface while the solid/water interface is minimized. In this situation, spreading does not occur and the water forms a spherical droplet. SiO_2, Al_2O_3 nanoparticles are mainly used for super water repellent finishes.

Wettability is one of the most important properties of a solid surface and the contact angle has been commonly used to characterize the surface wettability. A surface with a water contact angle larger 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. Superhydrophobic surfaces have attracted much interest because of their potential practical applications such as anti-sticking, anticontamination, and self-cleaning coating. Attracted by their potential industrial applications, numerous attempts to preparing artificial superhydrophobic surfaces have been done by mimicking the lotus leaf structure. Porous structures, nano fibres and carbon nanotubes have also been used to develop superhydrophobic surfaces. Nanosphere impregnation involves a three-dimensional surface structure with gel-forming additives which repel water and prevent dirt particles from attaching themselves. The mechanism is similar to the lotus effect occurring in nature. Lotus plants have superhydrophobic surfaces which are rough and textured. Once water droplets fall onto them, water droplets bead up and, if the surface slopes slightly, will roll off. As a result, the surfaces stay dry even during a heavy shower. Furthermore, the droplets pick up small particles of dirt as they roll, and so the leaves of the lotus plant keep clean even during light rain [36].

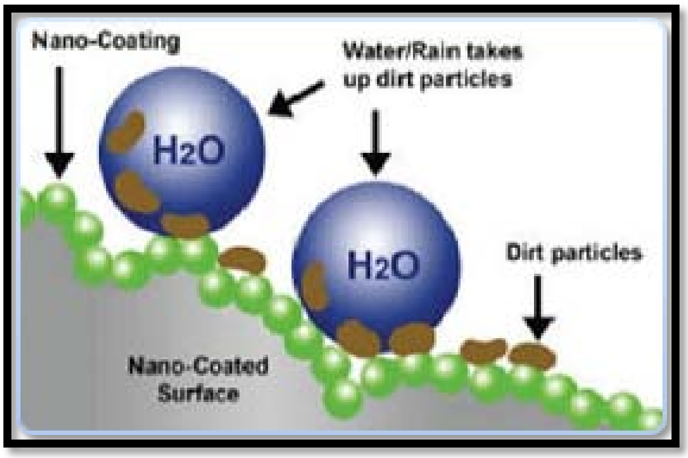

Fig. 4 Nanocoated self cleaning textile

9. NANOSOLS

Nanosols are colloidal solutions of nanometre sized metal oxide particles in aqueous or organic solvents. Due to the very high surface area of such small particles the nanosols are metastable, thus, for example, during a coating process the particles will aggregate due to the evaporation of the solvent, easily forming a three-dimensional network. Nanosol particles exhibit diameters in the range from a few nanometres up to 100 nm, while coatings formed by nanosols can reach a thickness of up to several hundred nanometres. The length scale of a nanosol coating can therefore cover a broad range of the structural elements starting from molecules up to three-dimensional, large-scaled objects such as fibres forming a textile. Depending on the curing parameters the inorganic metal oxide based networks will be mainly amorphous after moderate heat treatment (so-called xerogels), if a treatment at high temperatures of, e.g., 500°C and more is carried out the networks from increasingly crystalline structures.

The basic nanosols can be modified in a wide range, leading to numerous new functionalities that can be applied to various surfaces in comparably simple coating processes. The nanosol coating is therefore a suitable tool for modifying a large number of materials, such as glass, paper, synthetic polymers, wood, metal and, of course, textiles.

Coating textiles via the sol-gel process provides the textile substrate with a desired functionality while maintaining the physical properties of the textile. The application of sols containing metal oxides has the following benefits:

- Use of particles with diameters < 50 nm form durable transparent oxide layers.
- Heat, light, chemical and microbial stability.
- Augmented properties such as mechanical strength, wear and abrasion resistance.
- Oxide coatings can carry embedded functional additives such as biological compounds, inorganic particles, and polymers.
- Application can be carried out at room temperature and atmospheric pressure, and applied using conventional textile processes such as padding, and dip-coating [37].

In addition to being able to apply these coatings at room temperature and atmospheric pressure, curing nanosol coatings can be carried out at temperatures as low as 120°C, which is lower than that of traditional fluorochemicals (as high as 180°C).Thus, when applying a nanosol coating on a cotton fabric, which discolours at relatively high temperatures, the curing temperature can be lowered to avoid the negative impact on the performance of the coating. Silanes and other ceramic nanoparticles have been prepared in the sol gel process to create thin films that can be applied to surfaces such as natural fibres, synthetic fibres and solids, metals, wood, and glass [38-44]. Depending on the chemistry of the applied coating, surfaces can be modified to be hydrophilic or hydrophobic, and additional functionality can be added to a surface, such as flame resistance [45-49]

Sol-gel coating on textile				
↓	↓	↓	↓	↓
Textile properties	Surface properties	Optical properties	Bio-active systems	Further properties
↓	↓	↓	↓	↓
Stiffness/drape Handle Absorbency Permeability Felt-free	Hydrophobicity Hydro-oliophobicity Abrasion stability Barrier function Photocatalytic activity	Colour Photochromic effect UV absorption	Biocidal coating Controlled release system Therapeutic system	Heat resistance Magnetic properties Conductivity Odour management

Examples for the improvement of textile by application of sol gel coating

As a result of the particular properties of textile materials, e.g. high flexibility or low heat resistance, the nanosol process has to be adapted for the treatment of textiles.

9.1 Preparation of nanosols

9.1.1 General aspects of the preparation of nanosols

Nanosol coatings are usually prepared by using the sol-gel process.This process can be basically divided into three steps: formation of the nanosol by hydrolysis of the precursor material and subsequent condensation reactions, the coating process, then drying or curing. The precursors are either inorganic metal salts or metal organic compounds such as metal alkoxides or acetylacetonate. Alkoxy derivatives of metals or semimetals are most widely used, whereby hydrolysis transform them into the corresponding hydroxides. These hydroxides are mostly unstable in higher concentrations and therefore tend to undergo subsequent condensation reactions. The condensation reactions lead to the formation of particles with sizes in the nanometre range [50].

9.1.2 Conditions for preparation of nanosols

The conditions used for the preparation of the sols (e.g. solvent, pH-value, temperature, concentrations, salt concentration) determine the development of the particles as well their size. Hydrolysis can be carried out under acidic as well as alkaline conditions. Nanosols hydrolyzed under acidic conditions usually result in weakly cross-linked condensation products with a dense layer structure after coating, whereas alkaline-catalyzed sols tend to particle aggregates with larger pores Frequently used precursors are, for example, tetraethoxysilane Si(OC2H5)$_4$ (TEOS), titanium (IV) isopropoxide Ti(OC3H7)$_4$ or Al(OC4H9)$_3$. The product of the reaction described is the so-called nanosol, which is a liquid dispersion of low viscosity (usually in the range of 1 to 6 mPas) containing nanosized particles. This nanosol can be easily applied to numerous substrates, forming dense layers after the evaporation of the solvent. The main steps for preparing sol-gel derived coatings are depicted below.

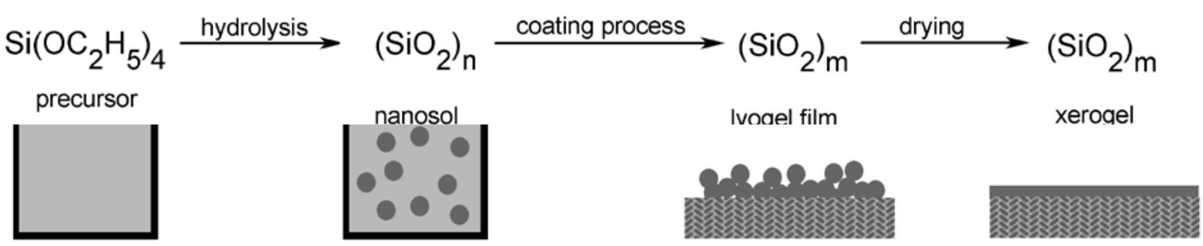

Fig.5 Main steps for the preparation of nanosol coatings (sol-gel process)

Due to the small size and the high surface area the particles tend to aggregate, so the nanosol it is metastable. The aggregation can either lead to a gelation process or to precipitation of metal oxides. In both cases the sol cannot be used as a coating material any more [50].

9.1.3 Affecting parameters

The stability of a sol is affected by many parameters; most important are the type of particle and the solvent composition. Furthermore the pH-value, the amount of water, the solid content or the presence of salts determine whether a sol is stable. Certain sols are stable for several years while others will gel within minutes, or even seconds.

A significant stability enhancement can be for example achieved by dilution of nanosols with ethanol or other alcohols. In certain cases the gelification process will be accelerated by dilution with water. Organically modified silanes can increase the storage time. Ageing means not only a continuous agglomeration and gelation of the sol, but also the precipitation of aggregates is possible. The ageing can have a significant influence on the properties of the resulting coatings, especially on coating thickness, roughness and porosity.

TEOS can also be used as precursor for the hydrolysis in pure water, since ethanol is released during the hydrolysis reaction. In the latter systems the precursor and water have to be stirred vigorously because TEOS and water are immiscible. Furthermore the TEOS concentration has to be kept at a comparatively low level to achieve stable nanosol. An alternative method to prepare aqueous nanosols is the removal of the organic solvent by evaporation by passing air through the sol while simultaneously substituting it with water. Using this method the resulting mean particle size in the aqueous nanosol is quite similar compared with that the originally ethanol containing sol [50].

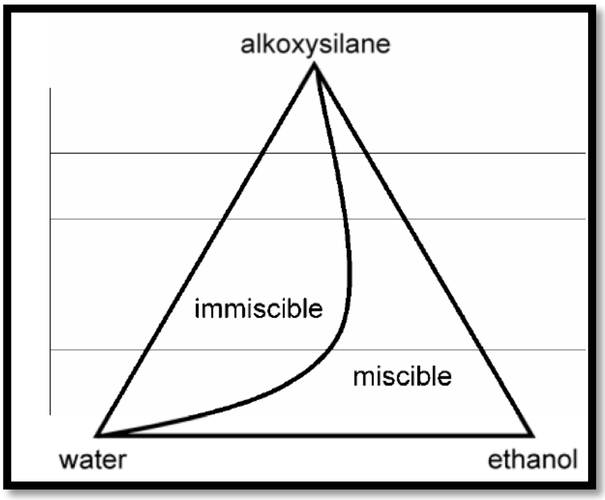

Fig. 6 Phase diagram of the system alkoxysilane, water and ethanol.

9.2 Modification of nanosols

Nanosols can be modified in many ways to achieve new or additional functional properties. By adding new properties to a sol, the sol coated surface will be suitably provided with the corresponding functionalities. The modifications can be carried out by adding particular compounds, either to the precursors before hydrolysis, or to the prefabricated nanosols.

In principal two main types of modification of nanosols are defined: chemical and physical modification.

The chemical modification is performed with additives which are able to form covalent bonds with or within the metal oxide particles during the preparation process. Such chemical modifications could be the result of a co-condensation of different types of metal alkoxides, for example of tetraethoxysilane (TEOS) with other metal alkoxides (Me(OR)n). Following this approach metal oxide compound composed of different metals in a variable ratio can be produced. The most frequently used metals are silicon, aluminium, titanium, zinc and zirconium.

The modification of nanosols can also be carried out with additives that are homogeneously incorporated and immobilized into the metal oxide matrix without forming covalent bonds. These additives are usually larger molecules such as polymers, pigments, dyestuffs, active substances or biomolecules. The incorporation can occur by adding the additives either before, or after hydrolysis of the precursors.

Both routes will lead to comparable composite structures and immobilization behaviour since it is assumed that encapsulation actually occurs during the formation of the network. The immobilization of additives within the inorganic matrix is very efficient and can be controlled by several means, for example, the composition and structure of the oxide matrix, by the additive content or, for example, by the addition of the pore forming agents [50].

9.3 Application process

The application of nanosols of the textile materials can be carried out by conventional procedures used for textile finishing. Such procedures are mainly simple dipping, padding or spraying processes. Even printing processes using nanosols can be realized on textiles. Probably the simplest method is dipping of a textile sample into the nanosol. The fabric is immersed in the sol, remains there for a certain time, it is taken out and it either dries under the ambient conditions or it is thermally cured in an oven or a stenter frame.

Other curing procedures may also include a plasma treatment, the use of lasers, IR or UV radiation. Comparable procedures can also be carried out with fibres or yarns instead of fabrics. Since the solvent uptake of a textile fabric is extremely high compared with polymer film padding, the latter process is more common in the textile industry. The solvent uptake of a textile is in the range of 100 % (depending on the fabric as well as the fibre material).

The padding process is a dipping process, followed by squeezing. The squeezing process is advantageous for several reasons; on the one hand the amount of liquor absorbed by the fabric can be reduced drastically. On the other hand the squeezing guarantees uniform distribution of the sol covering the complete product. This is particularly important when using aqueous nanosols for the treatment of hydrophobic fibres that show a comparably low wettability. High amounts of sol absorbed by the fabrics might be disadvantageous for different reasons.

- The production speed would be decreased

- The energy consumption would be increased since more solvent has to be evaporated.
- The amount of solvent necessary would be larger.
- In addition to these economical and ecological disadvantages a higher amount of sol absorbed means an increased coating thickness.

The coating thickness is of tremendous importance for the resulting textile properties. To achieve a certain coating thickness either the concentration of the sol has to be adjusted or the pressure applied by the squeezing rolls [50].

9.3.1 Nanosol finishing of textiles by conventional applying techniques

i. Padding
ii. Casting
iii. Spraying

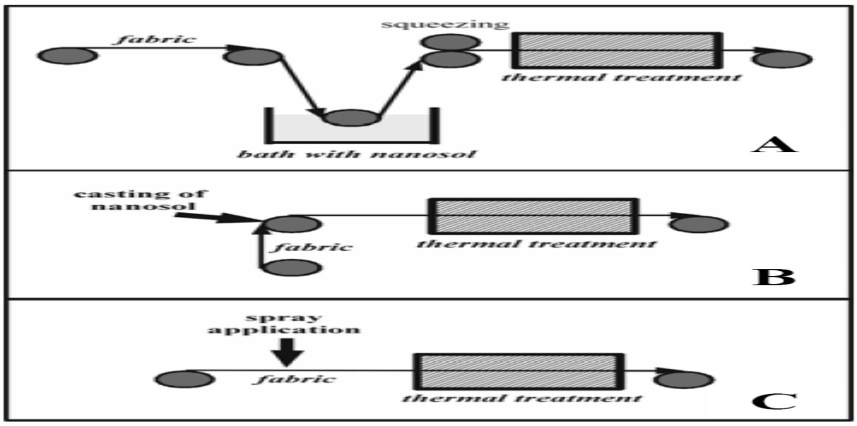

Fig.7 Nanosol finishing of textiles by conventional applying techniques, A: padding, B: casting, C: spraying.

For certain applications or finishing full penetration of the textile by the sol is not necessary. As an example, repellence might only be needed on one side of the product. In these cases the sol application cannot be carried out by dipping or padding. For this the casting of the nanosol or a spray application treating only one side of the textile fabric is useful methods. Possibly the use of sols with higher concentrations might be required or be advantageous [50].

10. EVALUATION OF TEXTILES TREATED WITH WATER REPELLENT FINISHES

i. Spray Test for Water Repellency Rating
ii. Air Permeability
iii. Hydrostatic Head Pressure Test
iv. Tearing Strength
v. Bending length
vi. GSM
vii. Surface Characterization by Scanning Electron Microscope (SEM)

11. CONCLUSION

Nanotechnology holds an enormously promising future for textiles. The development in functional finishes based on nanotechnology has endless possibilities and at present the application of nanotechnology merely reached the straight line. The new concepts exploited for the development of nano-finishes have opened up exciting opportunities for the further research and development. Nanotechnology does not affect other properties of the fabric which gets affected in other types of finishes. Nanotechnology involves a three-dimensional surface structure on the textile surfaces which is very beneficial and does not affect the properties of the substrate like the handle and breathability and does not add more extra weight to the treated textile. When nanosols technology is used for water repellency then finish involves a three-dimensional surface structure with gel-forming additives which repel water and prevent dirt particles from attaching themselves. The mechanism is similar to the lotus effect occurring in nature. With this technology we can achieve super hydrophobic surfaces which are rough and textured.

REFERENCES

1. How to catch up with latest textile market trends Pakistan, Dawn News, July 17, 2006.
2. Hussain T., *Textile Education in Pakistan*, Pakistan Textile Journal, 2008.
3. Qian, L., Hinestroza J.P., *Application of nanotechnology for high performance textiles*, Journal of Textile and Apparel Technology and Management, Vol.4, 2004, p. 1-7.
4. Sinha A., N.V.T., Kelvin Y., *Textile Industry review and outlook,* Adsale ATA Textile Online - Journal for Asia on Textile & Apparel, Feb., 2011.

5. Vijaya S., Mrudula T., Naga Deepth CH, Sree V., *Novel Applications of Nanotechnology in Life Sciences*, J Bioanal Biomed S11, 2011.
6. Menaa B., *The Importance of Nanotechnology in Biomedical Sciences*, J Biotechnol Biomaterial, 2011.
7. Liu Y.C., Lin L.H., Chiu W.H., *Size-controlled of gold nanoparticles from bulk gold substrates by sonoelectrochemical methods*, J. Phys Chem,Vol.108, 2004, p. 19237-19240.
8. Kathirvelu, D'Souza L., Bhaarathi D., *Nanotechnology applications in textiles,* Indian Journal of Science and Technology, Vol. 1(5), Oct, 2008.
9. Sawhney A.P.S, Condon B., pang S.S., Li G., *Modern Applications of Nanotechnology in Textile,* Textile Res. J., Vol.78, 2008, P. 731-739.
10. Wong Y.W.H., Yuen C.W.M., Leung M.Y.S., Ku S.K.A., Lam H.L.I. *Selected applications of nanotechnology in textiles*, AUTEX Res. J., Vol. 6(1), 2006.
11. Carfagna C., *Nanomaterials in fibres and textiles*, Nanotechnology for the Italian Textile, Milano, Italy, July, 2005.
12. Anon, *Nanotechnologies and the textile sector*, http://webarchive.nationalarchives.gov.uk/+/interactive.bis.gov.uk/nano//sections/nanotechnologies-and-the-textiles-sector/.
13. Tayler, D.J., *Report on Present Status and Future Potentila of Nanotechnologies in the Textile Industry TechniTex Conference,* 30th April 2004, http://www.hollings.mmu.ac.uk/~dtyler/Nanotechnology1.html.
14. *Texman, Application of nanotechnology in developing technical textile, New cloth market, June, 2010.*
15. Van Heeren H., *Nanotechnology and Lifestyle,* Nanotechnology Aerospace Applications, P. 1-4.
16. *Anon, Nanoenabled automotive textiles,* http://ebookbrowse.com/observatorynano-briefing-no-24-nano-enabled-automotive textiles-pdf-d26784083*., Dec., 2011.*
17. *Anon,Nano-enabled protective textiles,* http://www.observatorynano.eu/project/files/briefing%20no.7%20nono-enabled%20protective%20 textiles.pdf *, Dec., 2010.*

18. Sudarshan, T. S., Surface Eng*.,* Vol. 19(1), 2003.
19. Kathiervelu, S. S., Synth. Fib*.,* Vol. 32, 2003.
20. Harper, T F., Ind. Fahr Prod*.*,Vol. 89, 2004.
21. Amberg-S., Weber U., Mt. Text. Bull*.,* 2004.
22. Schrauth, A. J., Saka. N., Sub, N. P., *Nano Ma,if.* (Daejeon, Korea), Proc. of the SecondIn!. Symp, 2004.
23. Anon, *Consumer Conference on Nanotechnology in Foods, Cosmetics and Textiles,* BfR, Nov. 2006, p. 1-11.
24. Halbur, Chandler J., *Co-Presence of Durable Flame Retardant and Repellent Nano-Finishes*, Thesis, 2010, P. 1-126.
25. Gilman J. W *, New flame retardants consortium,* National Institute of Standards and Technology, 1999, p. 6357.
26. Bottcher H., Mahltig B., *Modified silica sol coatings for water-repellent textiles*, J. Sol Gel Sci. Techno, Vol. 27(1)*,* 2003, p. 43-101.
27. Chang K., Wu K., Tsai Y., Lu J., Chen H., Chen Y., *Fabrication of superhydrophobic silica-based surfaces with high transmittance by using tetraethoxysilane precursor and different polymeric species*, Appl. Surf. Sci, Vol. 255(20), 2009, p. 8634.
28. Larmour, Saunders, Bell, *Assessment of roughness and chemical modification in determining the hydrophobic properties of metals,* New Journal of Chemistry,Vol. 32(7), 2008, P. 1215.
29. Ma C., Wang F., Kuan H., Chiang C., *Thermo-oxidative degradation of novel epoxy containing silicon and phosphorous nanocomposites*, European Polymer Journal,Vol. 39(4), 2003, P. 825.
30. Schindler W. D., Hauser P. J., *Chemical Finishing of Textiles,* Net Library and Textile Institute, 2004.
31. Soeno S., *Ultra-water-repellent surface: Fabrication of complicated structure of* SiO_2 *nanoparticles by electrostatic self-assembled films,* Applied surface science, Vol. 237(1-4), 2004, P. 539.
32. Toselli M., Pilati F., Fabbri E., P., Busoli S., Messori M., *Flame retarding poly(methyl methacrylate) with nanostructured organic-inorganic hybrids coatings.* Polymer, Vol. 44(16), 2003, P. 4463.

33. Leadley J., Sermon P., *Fluoroalkylsilane modification of sol-gel SiO2-TiO2 coatings,* Journal of Sol-Gel Science and Technology, Vol. 32(1-3), 2004, P. 293.
34. Holme I., *Water repellency and waterproofing,*in *Textile Finishin,* Society of Dyers and Colourists D Heywood, Ed. West Yorkshire, Uk, 2003, P. 137-213
35. Bhushan B., Nosonovsky M., Jung Y.C., *Towards optimization of patterned superhydrophobic surfaces* , J. R. Soc. Interface,Vol.4, 2007, P. 643-648.
36. Russell E., *Nanotechnologies and the shrinking world of textiles,* Textile Horizons, 2002, 9/10, P.7-9.
37. Haufe H., Bottcher H., Mahltig B., *Functionalisation of textiles by inorganic sol-gel coatings,* Journal of Materials Chemistry, Vol. 15(41), 2005, P. 4385.
38. Ash M., Ash. I., *An International Guide to More than 1000 Products by Trade Name, Chemical, Application, and Manufacturer,* The Index of Flame Retardants, 1997.
39. Beaucage G., Pratsinis S., Hyeonlee J., *Aero-sol-gel synthesis of nanostructured silica powders,* Chemistry of Materials, Vol. 9(11), 1997, P. 2400.
40. Laachachi, Cochez, Ferriol, Leroy, Cuesta, Oget., *Influence of Sb_2O_3 particles as filler on the thermal stability and flammability properties of poly(methyl methacrylate) (PMMA)*. Polym. Degrad. Stab.,Vol. 85(1), 2004, P. 641.
41. Kirtay S., Gunay V., Sam. E., *Hydrophobic (water repellant) silica films having high heat resistance by sol-gel dip coating,* Key Engineering Materials, 2004, P. 264-268.
42. Soga M., Nakagawa T., *A new method for fabricating water repellent silica films having high heat-resistance using the sol-gel method,* J. Non Cryst. Solids, Vol. 260(3), 1999, P. 167.
43. Yeadon, *Durable fire retardant systems for outdoor cotton fabrics*, Journal of coated fabrics, Vol. 8(3), 1979, P. 234.
44. Yoneda, *Mechanical durability of water repellent glass,* Thin Solid Films, Vol. 351(1-2), 1999, P. 279.
45. Hirashima H., Rao A., Latthe S., *TEOS based water repellent silica films obtained by a co-precursor sol-gel method,* Smart Materials Structures, Vol. 18(9), 2009.
46. Laachachi, *Effect of ZnO and organo-modified montmorillonite on thermal degradation of poly(methyl methacrylate) nanocomposites,* Polymer degradation and stability, Vol. 94(4), 2009, P. 670.

47. Seddon ,Harper., *Influence of flame retardant additives on the processing characteristics and physical properties of ABS,* Macromolecular Symposia Vol. 169, 2001, P. 109.

48. Soeharto, Goynes, Salame, Lambert, Blanchard, Ramaswamy, *Performance of flame retardant and water repellent finishes for kenaf/cotton blend fabrics*, Text Chem Color, Vol. 29(12), 1997, P. 22.

49. Coradin T., Livage J., *Aqueous Silicates in Biological Sol-Gel Applications:New Perspectives for Old Precursors,* Acc. Chem. Res., Vol. 40, 2007, P. 819-826.

50. Boris Mahltig, Torsten Textor, *Nanosols and textiles,* Publisher- World Scientific Publishing Co. Pvt. Ltd., 2008, ISBN-13: 978-981-283-350-1, P. 1-237.