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DEVELOPING SELF CLEANING SURFACES OF TEXTILES BY NANOTECHNOLOGY

Dr.Jaya Pandey[1]

[1]Assistant Professor, Amity School of Applied Sciences, Amity University, Uttar Pradesh, Lucknow Campus, Uttar Pradesh, India.

Dr.D.K.Awasthi[2]

[2]Associate Professor, Sri J. N.P.G. College Lucknow,UttarPradesh, India

ABSTRACT

Self-cleaning materials have a great deal of attention both in research and commercial applications. Conventional methods used to impart different properties to fabrics often do not lead to permanent effect, and they tend to lose their functions after laundering or wearing. Nanotechnology however provides high durability for fabrics due to the fact that nanoparticles have a large surface area-to-volume ratio and high energy. Another advantage is that these can be permanently attached to garment's fibers without altering its texture or feel. The need for these materials is obvious and the applications are endless.[1-2]

KEYWORDS: *Nanotechnology, superhydrophilic surfaces, self-cleaning and sustaining system, and eco-friendly manner.*

INTRODUCTION

Self-cleaning materials have a great deal of attention both in research and commercial applications. Conventional methods used to impart different properties to fabrics often do not lead to permanent effect, and they tend to lose their functions after laundering or wearing. Nanotechnology however provides high durability for fabrics due to the fact that nanoparticles have a large surface area-to-volume ratio and high energy. Another advantage is that these can be permanently attached to garment's fibers without altering its texture or feel. The need for these materials is obvious and the applications are endless.[1-2]

IMPORTANCE

The challenge and importance of maintenance of hygiene and sanitation at the most heavily exploited public transport system mainly "The Indian Railways", need not be overemphasized. The fact that pathogens retain on the surface of textile for more than the period of three months and sputum of an infected person can infect many others further alarm the need to design, develop and discover a self-cleaning and sustaining system indigenously in economically viable and eco-friendly manner. The self cleaning textiles, mentioned in the project do not only pertain to the technological advancement but these would also techno economically benefit to the society. The ultimate consequence in developing the self cleaning fabrics is that use of things like chemicals, energy, manpower and water can really be limited. It could take about half a decade for the retail market for self-cleaning cloths and linens to launch as the technology developed so far still needs refining and tremendous amount of research work is still underway.[3-5] ***It is anticipated that self-cleaning technological advancement due to this effort will provide benchmark for the future textile and other commonly used materials to maintain hygiene and prevent the spreading of pathogenic infections avoiding the life threatening epidemics.***

Compared with traditional advanced nanotechnological processes the chemical sol-gel process and use of biogenic material technology of nanoparticles is cost effective in terms of industrial production as the use of chemicals and its quantity will be less and synthetic process would require only "soft" and "green" chemistry considering a low cost material as a photo catalyst. A wide spectrum of organic contaminants can be converted to water and CO_2.

The products are highly valuable because of following features:

- Ease of maintenance
- This would help to make textiles long lasting and scratch resistant
- Helps to maintain hygiene and prevent the spread of pathogenic infections
- Eco-friendly and sustainable as it allows to reduce cleaning efforts avoiding chemical reagents which are required in the washing and no byproducts are produced.
- Provides improved aging behavior by extended surface purity effect
- Aesthetically, garments will stay bright and are more durable than ordinary material.

TYPES OF SELF CLEANING MATERIALS

To realize self-cleaning material surfaces two alternative principal ways are been applied: the development of super hydrophobic or the development of superhydrophilic surfaces

i) Superhydrophobic surfaces; "the lotus effect": The technology for developing hydrophobic self cleaning surfaces is popularly known as "the lotus effect", coined by the discoverer and the developer of this effect, Wilhelm Barthlott of University of Bonn in Germany. The lotus self-cleaning effect stems from its surface being extremely hydrophobic. Paradoxically, the surface of lotus is not smooth as it has a microscopic roughness. In addition to this, the innumerable bumps on the surface of the lotus leaf allow to have physicochemical characteristics that define the lotus leaf to be super hydrophobic. The air trapped between the water and the leaf surface in the spaces around the bumps increases the contact angle to 150°, and water on it forms nearly spherical droplets with very little surface contact that roll across it mimicking the ball bearing.

On super hydrophobic surface, a drop rolls across, picking up dirt and carrying it away, as the water and dirt have greater affinity for each other than either it does for the surface. The wetting of a solid with water, where air is the surrounding medium, is dependent on the relation between the interfacial tensions (water/air, water/solid and solid/air). The ratio between these tensions determines the contact angle between water droplets on a given surface. A contact angle of 0° means complete wetting, and a contact angle of 180° corresponds to complete non-wetting.

The self-cleaning effect is related to the contact angle, the angle formed at the ternary phase boundary (liquid/solid/vapor). Water on a more hydrophilic, substance spreads across it to maximize the contact area. For a hydrophilic surface, the contact angle with the surface is less than 30°; a hydrophobic surface has a contact angle greater than 90°.[6]

ii) Superhydrophilic surfaces: Interestingly, the exactly opposite phenomenon, superhydrophilicity concept has also been exploited to develop self-cleaning surfaces. For the preparation of these thin layers mainly photo catalytic active metal oxides or sulfides have been applied. Since last few years TiO_2 coated materials are of increasing interest. If TiO_2 anatase type (Figure 1) is exposed to UV light very low contact angles are obtained (less than 1°). These materials have the unique property of "attracting" rather than repelling water. The water lies flat on the surface sheets instead it forming droplets. Furthermore, UV illumination of titanium dioxide leads to the formation of powerful agents with the ability to oxidize and decompose many types of bacterial organic and inorganic materials.[7]

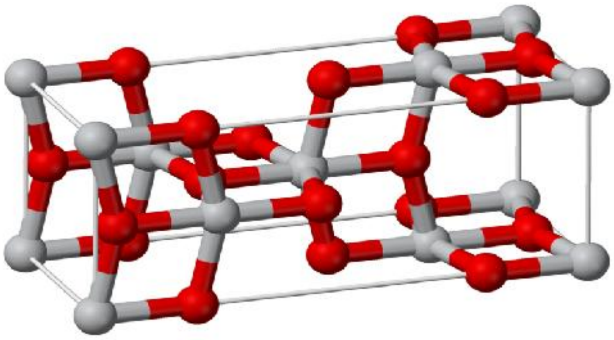

Figure 1. Crustal Structure of Anatase[17]

Due to their electronic structure, which is characterized by a filled valence bond and an empty conduction band, semiconductors (metal oxides or sulfides such as ZnO, CdS, TiO_2, Fe_2O_3 and ZnS etc.) can act as sensitizers for light-induced redox processes. The energy difference between the lowest energy level of the conduction band and the highest energy level of the valence bond, so called band gap energy corresponds to the minimum energy of light required to make the material electrically conductive. When a photon with energy of *hv* exceeds the energy of the band gap an electron is promoted from the valence band to the conduction band leaving a hole behind (Figure 2).

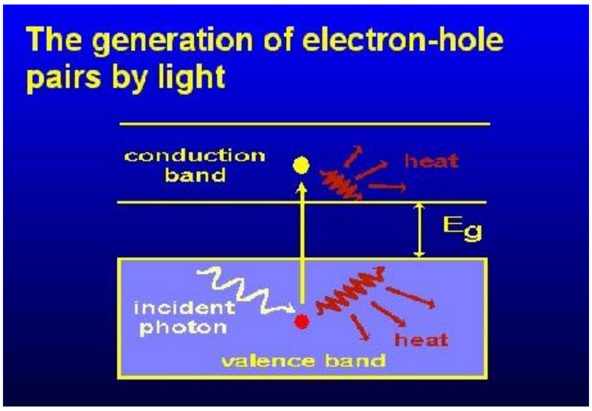

Figure 2. Generation of Electron-hole pairs

In electrically conducting materials, i.e. metals the produced charge carriers are immediately recombined. In semiconductors a portion of this photo excited electron–hole pairs diffuse to the surface of the catalytic particle (electron –hole pairs are at the trapped surface) and take part in the chemical reaction with that absorbed donor or acceptor molecules. The holes can oxidize donor molecules whereas the conduction band electrons can reduce appropriate electron acceptor molecules.[8-9]

A characteristic feature of semi conducting metal oxides is the strong oxidation power of their holes. They can react in a one-electron oxidation step with water to produce the highly reactive hydroxyl radical. Both the holes and the hydroxyl radicals are very powerful oxidants, which can be used to oxidize most organic contaminants. In general, air oxygen acts as electron acceptor by forming super oxide ion radical. Super-oxide ions are also highly reactive particles, which are able to oxidize organic materials.TiO_2 is semiconductors with the energy gap = 3.2 Ev. If this material is irradiated with photons of the energy >3.2 Ev [(wavelength) <388 nm], the band gap is exceeded and an electron is promoted from the valence to the condition band consequent, the primary process is the change-carrier generation.

The ability of a semiconductor to undergo photo induced electron transfer to adsorbed particles is governed by the band energy positions of the semiconductor and the redox potential of the adsorbent. The relevant potential level of the acceptor species is thermodynamically required to be below the conduction band of the semiconductor.[10] Otherwise, the potential level of the donor is required to be above the valence band position of the semiconductor in order to donate an electron to the empty hole. The band-edge positions of several semiconductors are featured in Table 1.

Table1. Band-Edge positions of Semiconductors

S.No.	Semiconductors	Band-Edge Positions
1	CdS	2.5
2	CdSe	1.7
3	TiO_2	3.0
4	Nb_2O_5	3.4
5	ZnO	3.2
6	Fe_2O_3	2.2
7	SnO_2	3.5

Technical details:-

A revolution in self cleaning surfaces is underway. The brilliant applications of nanotechnology to obtain self cleaning textile substrate, floors, walls, windows etc could be undertaken by controlling wet ability and surface interaction. Engineering a superhydrophobic surface using polymers and superhydrophilic surfaces using nanocatalysts can be designed, discovered and developed by synthesizing nanoparticle and then it has to be made to stick to the object for its usefulness. Chemistry would contribute in developing the nanomaterials for these applications.

Preparation of self-cleaning textiles with hydrophobic coatings based on bifunctional polymer film (one type that can interact with the substrate and the other with photocatalytic oxidizing nanaocatalyst mixed with nanoparticles from biogenic origin, imparting nano-roughing and self-cleaning effect to the surface will be undertaken in this project. By transferring the microstructure of selected plant surfaces to practical chemical materials, super-hydrophobic surfaces could be developed. It is well known that the materials with nanoscale grain size show different properties from the same material in the bulk *form. These unique properties are related to the large number of surface or interface atoms.*

Over the past several years, a number of technologies have been developed for the production of nanoparticles. Chemical methods have an important place among the experimental methods applied on pilot scale.

This is so called "soft chemistry" which uses relatively non-aggressive diluted solutions at moderate temperatures. The sol-gel method and co-precipitation from solutions form, together with oxidation-reduction reactions, hydrolysis, colloidal processes and hydrolysis of organometallic complex substances, come under the chemical methods category. The sol-gel method is based on molecular synthesis of nanoparticles wherein the particles are built up by molecule-by-molecule addition. Sol-gel method involves formation of 'sols' in a liquid and then connecting the sol particles to form a network. By drying the liquid, it is possible to obtain nanoparticles. Sols can be obtained by hydrolysis, condensation and polymerization of monomers to form particles. After the formation of sols, formation of network which extends throughout the liquid medium is obtained to form a gel. Synthesis of sol-gel involves hydrolysis of precursors, condensation followed by polycondensation to form nanoparticles, gelation and drying processes by various routes. Precursors are to be chosen such that they have a tendency to form gels. Rate of hydrolysis and condensation reactions is governed by various factors *viz* temperature, pH, molar ratio, nature of material, concentration of catalyst and process of drying. Finally, at proper conditions spherical nanoparticles are produced.

CURRENT STATUS OF SELF CLEANING MATERILAS

A variety of approaches have been followed in order to create a hydrophobic surface with microrough reatures to impart superhydrophobic prpperties to the surface. Hydrophobic materials developed so thus far are based on polymeric systems such as poly 9 phytanyl methacrylate), a copolymer of 2-isopropenyl-2-oxazonine and methyl methacrylate, other acrylic –siloxane based systems, silica and aluminium based polymer systems, organofoloro components on glass substrate etc.. Some of these surface coating can also be applied to fabric using various methods.[11]

Because many untested claims have been made to support nanotechnol;ogy products, standards institutions are beginning to set stringent tests for self-cleaning clothing that are based on these innovations. In October 2005 the German Hohenstein Rresearch Institute, which offers tests and certifications to trade industries around the world, announced the nanosphere textiles were the first to pass the whole range of tests, including those examining water repellency and the ability of the fabric to maintain its performance after ordinary wash cycles and other wear and tear tests.[12]

Easy-clean cloth cloths are becoming widely available, but buyers of marquees awnings and sails are expected to constitute the biggest market for the lotus effect finishes so far

Preparation of nanoparticles:-

Preparation of nanoparticle can be done in two ways. The first step is done to identify the best possible nanoparticle (unpatented for this purpose, mainly metal oxides or sulphides such as ZnO, CdS, Nb_2O_5, SnO_2, SiO_2, TiO_2, Fe_2O_3 and ZnS etc.) for the use in self-cleaning reactions synthesized by a new synthetic route (again unpatented) and the second step is done in parallel to identify the possibility of the nanoparticle obtained from the biogenic origin for the use in the above processes.

Sol-gel chemical techniques:-

The sol-gel process (mainly "soft" and Green" methods), also known as chemical solution deposition, is a wet-chemical technique widely used in the fields of materials science and ceramic engineering for the fabrication of both glassy and ceramic materials. In this chemical procedure, the 'sol' (or solution) gradually evolves towards the formation of a gel-like biphasic system containing both a liquid phase and solid phase whose morphologies range from discrete particles to continuous polymer networks. The sol-gel approach is a cheap and low-temperature technique that allows for the fine control of the product's chemical composition.[13]

Extraction of nanoparticles from biogenic origin:-

It is quite surprising that from microbes to bacteria to plants it is possible to get nanoparticles. The production of nanoparticles is eco-friendly because this involves natural phenomenon that take place in biological systems. Moreover biologically fabricated nanostructures offer substantially different properties. The biogenic method for nanoparticle production is simple, eco-friendly and allows for getting controlled nanoparticles which can be used as a catalysts with specific composition, which is however difficult to synthesize by classical methods. Living organisms can form highly structured nanoparticles network from cheap sources, in biocompatible conditions and in impressively short times. These have proven to be important for several biotechnological and biomedical applications. Plants and other biological organisms make nanoparticles in amounts of gigatons per annum, whereas industrial processes only produce mere megatons.[14]

Coating of nanoparticles on prepared hydrophobic material:-

The precursor sol can be either deposited on a substrate to form a film (e.g. by dip coating or spin coating), cast into a suitable container with the desired shape (e.g., to obtain monolithic ceramics, glasses, fibers, membranes, aero gels), or used to synthesize powders. The technology of surface coating is a post process surface technology, done on the final product material, so a range of possible reaction combination can be tried and tested for example rubber, plastics and others. A polymer film mixed with nanoparticles can be permanently integrated into any common fabric natural as well as synthetic, including silk, polyester and cotton etc.[15-17]]

CONCLUSION

A revolution in self cleaning surfaces is underway. The brilliant applications of nanotechnology to obtain self cleaning textile substrate, floors, walls, windows etc could be undertaken by controlling wet ability and surface interaction. Engineering a superhydrophobic surface using polymers and superhydrophilic surfaces using nanocatalysts can be designed, discovered and developed by synthesizing nanoparticle and then has to be made to stick to the object for its usefulness.

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