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Developing Self Cleaning Clothes through Chemicals Inspired by Ancient India

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Abstract

It is quite true, nothing is impossible in the world that we are living in today. Things that seemed impossible and unachievable in the past have now been brought to our doorsteps by brilliant people. May it be space travel, underwater excavations, robotics or the electronic technology of smart devices; everything is attainable and has been attained. And now another concept which was seemingly impossible in the past has been achieved by the scientific means of nanotechnology: Self-cleaning clothe that involves fabric is a finely woven material used in textile industry found to display varied functions meant for fashion to protection. Durability of fabrics is one of the most important features. Ideal high quality fabric is considered to be resistant to moisture, stains, finger marks and dust. As mentioned, this is an example of an ideal fabric which is almost impossible to inbuilt all the qualities towards meeting customer needs. Advances made in the area of nanotechnology paved the way for high definition clothes. This article summarises fabric's connect with ancient practices the basic nature and properties, their plausible origin, manufacturing strategies, applications and their impact on environment and human health.

Keywords: Nano molecules, Flourocarbon, Tungusten oxide, Zinc oxide, Fabric.

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1. Introduction

Past has been the source of inspiration for mankind from as long as we have known it. History influences various aspects of our lives. May it be our culture, traditions, languages, ethics, ideals, morals, beliefs, fashion or inventions; our ancestral legacy has influenced it all immensely [1]. We learn and derive from our past, our history, our myths, our legends, our epics, our fictions. Most of our modern day inventions had origin in or were inspired by these tools of the past, may it be the helicopter (Leonardo Da Vinci's Model) or the submarine [2] (similar device first mentioned in the Peloponnesian War: 413 BC), cellular phones or rockets, every invention has some deep connection to the past (facts, myths and fictions). Similar, it seems, is the case with the concept of self-cleaning clothes.

India has one of the most ancient civilisations and also one of the most erudite of senses of environment. The 'Panchatantras' are an excellent example of this fact; the stories of the Panchtantras are not only inspiring and captivating, but also convey the message of 'keeping the environment clean and healthy' very efficiently [3]. Some other examples that depict the sophisticated environmental ethics of ancient India would be the Hitopadesa, teachings and stories of Gautam Buddha (Jatakamala) and that of Lord Mahavira, and of course, the great epics of Mahabharata and Ramayana.

The concept of self-cleaning clothes [4] is first seen in Ramayana when, during exile, Rama, Sita and Lakshmana visited Rishi Atri in southern periphery of Chitrakut whose wife Anasuya , a deeply pious woman, presented Goddess Sita with beautiful jewellery that never lost lustre or form [5], a cream that prevented aging and a saree that always remained clean, free of dirt or rather *a self-cleaning saree!* Was it the same technology that we have realised so many years later? [6] Did someone actually figure it out back then? We may never get to know the answers to these questions. However one thing that we do know is there definitely was a concept similar to that of the modern day nanotechnology of self-cleaning clothes.

Nanotechnology has been emerged as foremost front running technology aiming to advance all the sectors of society [6]. By virtue of high surface area of nanomaterials, there are myriad of applications surfaced in recent years. Since its discovery in 1973 by Wilhelm Barthlott, a renowned botanist from University of Bonn, Germany, scientists across the world started

understanding the potential application of nanotechnology almost in all fields of research including the self-cleaning clothes [7]. Nanotechnology based fabrics are considered to be much superior to the conventional ones because these fabrics do not compromise on their functions and properties due to exhaustive usage and laundering [8]. Nanotechnology is primarily based on surface area which is the prime reason behind high durability of fabrics [9]. High surface area leads to high surface energy that in turn enhances the functional tolerance during repetitive usage [10]. Moreover, nanotechnology does not allow the loss of basic functions e.g. breathability or hand feel that makes it as an ever evolving valuable technology in textile industry [11].

As far as clothes are concerned, we are ought to deal with these entities on daily basis. Considering the fast life and hygiene factor it is very important to have durable clothes. In particular, the requirements of hospitals, security forces and railways' clothing are practically impossible to meet in an ideal manner if the self-cleaning fabrics are not used in manufacturing of their clothes [12]. Thus, we believe that the development of self-cleaning fabric and clothes is almost a blessing for all humanity. Nanotechnology based self-cleaning surfaces are of two types: a) the one that has extremely minute rough surfaces (it has property to repel dusts and mere rinsing is enough to reuse) and b) the one that has nano-crystalline titanium oxide based photo-catalytic layer (it has property to destroy organic mass that causes fouling) [13].

2 The Flourocarbon Method

In addition to nanotechnology, fluorocarbon based clothes are also developed [14]. These materials on the surface of the clothes work on the principle involving reduced critical surface tension of solid and become less than that of water or liquid. Due to this surface tension difference, solid becomes replant to water or liquid [15, 16]. Despite of having remarkable properties, it had its own limitations as it does not lead to permanent effect on cotton fibre and in addition to this fluorinated compounds can cause skin irritation. Eventually, fluorocarbon based clothes are seemingly less popular than the one which is nanotechnology based [17]. There are various nanotechnology based manufacturing of self-cleaning clothes featuring concept of Lotus-effect, hydrophilic photocatalytic coatings, SLIPS, Silver nanoparticles, Metal oxide colloidal, chlorine halamine and microwaves reported [18].

3 Replicating the Lotus-effect Using Carbon-Nanotubes

For many years creating self-cleaning clothes seemed to be next to impossible, but once again a solution finally [19] emerged from the one source that had been our constant guide for finding solutions of complex problems: Nature, more specifically Lotus leaves. Lotus leaves are highly worshiped in Asia for their exceptional cleanness; even though the plant grows in muddy water and is surrounded by dirt its leaves remain immaculately clean [20]. It is well precedented in the literature that the as Lotus leaves exhibit the remarkable property of being highly hydrophobic. Scientifically, it is evaluated that the even and smooth surfaces have unique roughness by virtue of having nano-scale hair like structures [21]. Nano-size wax crystals attributing to three-dimensional conical structures that also impart in uniqueness of Lotus leaves [22]. All these salient features offer self-cleaning properties and termed as Lotus Effect [23].

Exceptional properties of Lotus leaf and sound understanding of science behind its function led to design fabrics by using controlled array of carbon nanotubes in order to manufacture self-cleaning clothes [24]. In particular carbon nanotubes (CNTs) and surface modified carbon nanotubes (PBA-g-CNTs) are considered as building blocks to simulate the surface of Lotus leaves at the nanoscale. These carbon nanotube manipulations in cotton offered a surface contact angle more the 150 degrees (characteristic feature of being hydrophobic), whereas in case of untreated cotton surfaces offer a contact angle less than 90 degrees (characteristic feature of being hydrophilic) [25]. It is also reported that the classical and modified carbon nanotubes have mechanical and electrical properties leading to find application in area of developing sensors, conducting and special textiles.

3.1. Limitations

Replicating the concept of Lotus effect at a scale is found to be challenging in textile industry. So far there are only few cost effective processes that have been concluded at large scale mainly for paints.

Although at research level carbon nanotubes can be embedded with cotton but the overall nanostructure is unable to withstand high pressure therefore apart from simple rinsing it may not be compatible to washing machines. Nevertheless, cleaning of some of the nano-textile entities are quite effective with water but the surface cannot be generalized to accommodate all organic liquid e.g. oil [26].

4. Using Hydrophilic Photo Catalytic Coatings

Nano-sized, titanium dioxide as a photo catalyst is used in coating of the objects. These coatings are found to display anti-bacterial properties. In particular, the fabric, before manufacturing the textile, is coated with a thin layer of titanium dioxide having a diameter of 20 nanometres [27]. Titanium oxide is hydrophilic in nature and acts as a catalyst in the event of chemical degradation of the organic material in dust in presence of light leaving being the objects self-cleaned. These hydrophilic titanium dioxide based coatings proved to be an excellent catalyst for the photo degradation of colorants and other organic pollutants [28]. There are several other metal oxides and sulphides, including WO_3, ZrO_2, ZnO, CdS, and

polyoxometallates are reported but TiO_2 is found to be industrially more viable.

4.1 Limitations

Nevertheless, titanium dioxide is termed as a good catalyst it takes a lot of time to expunge stains on the fabric as it is not very efficient in using sunlight. In order to use photo catalytic coating based clothes it may be considered ideal to recommend for military personnel and hikers who have primarily to continue working outside under sunlight for prolonged period of time and they also face difficulty in cleaning their clothes by other means.

5. Using Slippery Liquid-Infused Porous Surfaces (Slips)

SLIPS was discovered by a team of researchers at Harvard (Wyss Institute) and since 2011 scientists have demonstrated the many applications for the self-cleaning surface which seems to repel nearly all sorts of substances that comes in contact with it. Though previously the method was not used on fabrics, in 2014 SLIPS took that leap as well. It was tested out on everyday cotton and polyester fibres and the results were very successful.

A SLIP, like the 'Lotus Effect', was also derived from Nature. SLIPS stands for *Slippery Liquid-Infused Porous Surfaces.* Though both *The Lotus effect* and SLIPS are inspired by the Nature, both vary greatly [29]. *The Lotus effect* is based upon the super-hydrophobic property of lotus leaves. Moreover, SLIPS is designed based on the functioning of Pitcher plant, which creates a sleeper surface that causes insects fall into the plant and unable to come out. The SLIPS technology involves coating of a slippery lubricated film infused into a nano-porous solid surface yielding a material of significance tolerating the pressure or physical damage by virtue of being resistant to all kinds of liquids, including oil, blood and brine solution.

There are two chemical treatment methods for generating a SLIPS-fabric;

a) silica based coating (SiM);

b) sol-gel alumina based coating (SgB)

This is the one of the latest advancement in this area and found be much better than existing tools. A SLIP has capability to repel and resist variety of staining agents and it can withstand high pressure.

5.1 Limitations

All the SLIPS based fabrics cannot be created for conventional use but it is recommended for extreme environmental conditions and in a very challenging situations e.g. while dealing with biohazards. Clothes based on this technology can also be recommended for military, research lab coats, medical clothing, and clothing for construction, manufacturing personnel including tents as a cover for various podium and sport's stadiums.

6. Using Silver Nanoparticles

Silver nanoparticles are known to offer high degree of resistance to dust and water. In this technology silver nanoparticles are coated over fabrics and clothes made out of this along with hydrocarbons improve the water repellent property significantly. These nano whiskers are found to be 1/1000 part of the size of typical cotton fibre. These fibres are much stronger than the cotton fibre due to peach fuzz effect.

6.1 Limitations

This method found application only for producing self-cleaning fabric developed out of cotton.

7. Using Metal Oxide Colloidal

What basically happens in this process is that the fabric is treated with a metal oxide colloidal solution and then heat to obtain a characteristic surface roughness which pushes the angle of contact between the water and fabric surfaces to more than 150 degree, because of which the fabric becomes extremely water-repellent.

7.1 Limitations

Like silver nanoparticle based clothes, this method also found application only for producing self-cleaning fabric developed out of cotton.

8. Using Chlorine Halamine

This technology works by inducing textile fibres with chlorine containing compounds called halamines. These compounds have been found to show anti-bacterial properties therefore it has also been used to disinfecting pools by in large. So far, there are no side effects of using this method as chlorine in this form is reported. This material does not form any kind of toxic compounds by combining with other elements. This is great strategy that involves halamines embedded in cellulose fibres of the cotton which displays the anti-bacterial. Such kind of clothes can be reactivated with a wash in chlorine bleach. Considering halamine's properties, these can be recommended for railways and medical uses such as uniforms, wipes, bedding and towels.

8.1 Limitations

Like metal oxide and silver nanoparticle based clothes, this method also found application only for producing self-cleaning fabric developed out of cotton.

9 Using Microwaves

Microwaves have been used to anchor nanoparticles to the fabrics thereafter it gets treated with chemicals that found to behave like strong water, dust, oil and pathogen repellent thus this technology has found application in manufacturing of t-shirts and undergarments. This allows staying hygienic for few days without washing.

9.1 Limitations

Like other discussed techniques, this method also found application only for producing self-cleaning fabric developed out of cotton.

10. Self-Cleaning Wool and Silk

Nano titanium dioxide technology is used in this method but it requires chemical manipulations to install the carboxylic groups on the surface of silk (its surface is made up of inactive keratin protein). These carboxylic groups bind with titanium oxide when treated with titanium dioxide nano-crystal solution affording self-cleaning wool and silk. Red stain on clothes takes around 20 h to fade away and other colour stains disappear must faster. These clothes found application in hospital, sports, military, upholstery, under garments and smart textiles.

11. Environment and Health

There is no alarming evidence so far indicating that nanoparticles embedded in cotton fibres are eliciting harmful effect on environment and health. Lotus effect in the context of self-cleaning clothes might lead to weathering effect out of biodegradable materials. Titanium dioxide was found to leach out in the environment and it also assist in oxygen free radical leading to cause of concern but the impact of TiO_2 towards health and environment is not estimated. Weathering effect also leads TiO_2 getting into water stream and food chain. It is however recommended to design coating in such a way to reduce or prevent leaching of nano-coatings and nano-materials in the environment [30].

12. Significance of Self-cleaning Clothes

Nano-material can permanently be attached to the garments with compromising its texture. Considering its self-cleaning attributes, it helps in conserving considerable amount of water. In addition to this, it helps in maintaining the hygiene and avoiding the spread of pathogenic infections. Nano based textile products can keep allergens, dust, moisture and oil away from people helping us to lead healthier life. These products can also protect us from UV radiation considerably. Nano technology based textile industry has potential to impact wellbeing of the society [30].

13. The Economic Significance

Reduced cost of maintenance, reduction in usage of water thereby reducing resource utilization has high degree of potential to embrace economy in a big way [31, 32, 33].

14. Future

At the rate the technology of self-cleaning clothes is advancing, it seems that it won't be long before we won't have to worry about washing our clothes for staying hygienic, neither would we have to worry about laundry while travelling or on rainy or cloudy days. Nanotechnology is a rapidly growing technology, much like the electronic technology has developed over the last few decades same is the expectations with Nanotechnology. Ever increasing needs of textile products due to fast growing population, it is important for scientists to employ meaningful and safe technology to advance textile industry in a cost effective manner.

15. Conclusion

We are heading towards living on resource stressed planet and efforts on nanotechnology based research related to textile industry would contribute to society in a meaningful way. Nanotechnology in textile industry has certainly paved the way for using clothes in a sustainable manner. Self-cleaning properties, usage of nano-based clothes in challenging situation, managing the biohazards and other many applications of these smart textile would certainly help in bearable existence of human race and ecosystem by in large.

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