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THE ROLE OF NANOMATERIALS IN ENHANCING FABRIC PROPERTIES

Kaviya Manikandan[1], Poomani Prakash[2], Sadhana Anthony Raj[3], Keerthiga K[4], Aniskumar Mani[5]

[1,2,3,4,5]V.S.B. Engineering College, Karur, India.

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ABSTRACT

A review on Nanotechnology in the textile industry is associated with its properties and characterization. This study deals with the manufacturing and production of textiles by using nanomaterials, which is used in several industries for various purposes. Nanomaterials were characterized by UV-Visible Spectroscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Fourier Transform Infrared Spectroscopy, X- Ray Diffraction, Energy Dispersive X- Ray Analysis and more spectrometric analysis. Nanoparticles in textile industries has the peculiar properties, which includes Water repellances, Anti- static, Anti- microbial, Flame retardancy, Wrinkle resistance. This paper reveals that the entire study of nanotechnology used in textile industries. It enables smart fabrics with functions such as health monitoring and temperature control, benefiting sectors like healthcare, sports, and military. While offering sustainable solutions, further research is needed to address the environmental and safety concerns of nanomaterials in textiles.

1. INTRODUCTION

Nanotechnology is a revolutionized discipline in the world. There is a various role in the the application of industries. It's strategy is adopted towards the incorporation of research data in science platform[1]. The manipulate and manufacture the materials and devices on nano scale of atoms or small group of atoms. The nanoscale is typically measured in nanometers. The nano is a word which came from Greek means "Dwarf". They are build at nanoscale which as specific physical and chemical properties due to its quantum mechanical effects.

The nano engineering is a discipline which is used to produce the materials using engineering techniques at nanoscale is called as nano engineered products. They are lighter, stronger and programmed materials to reduce the wastage to the environment and harmless to the environment [2].

Nanomaterials must have the least dimension of nano scale from 1 to 100nm. They have properties which are different from those of micromaterials and bulk materials, due to its size and surface defects they fall under characterizations of inorganic based nanomaterials, organic based nanomaterials, carbon based nanomaterials, composite based nanomaterials [3]. Inorganic based nanomaterials are used widely which are made up of inorganic molecules such as oxide hydroxide, chalcogenide or phosphate compound are less toxic, hydrophobic, bio-compatible and highly stable. ie., metal and metal oxide nanoparticles. Organic based nanomaterials are made up of organic molecules which are aggregated molecules or polymers are easily biodegradable, bio-compatible and less toxic in nature ie., liposome, lipid bodies, emulsions [4]. Carbon based nanomaterials are made up of high amount of carbon atoms which are highly flexible, high electrical conductivity and less toxic ie., graphenes, fullerene. Composite based nanomaterials are made up of one or more nanomaterials which are highly strength, flexible and heat resistance ie., quantum dots [5].

Nanotechnology is a rapidly developing field in textile industry which has high potential to revolutionize its performance and function in textiles the incorporation of nanomaterials and nanofibers into textile structures for the enhancement of the properties like physically strength, chemically durable and various multi-functions which lead to the development of the products with high performance textile materials [6]. In recent years the emergence of "smart textiles" which is derived from conventional materials with smart nanomaterials in which they can sense the change in the environment and responds to the modified parameters to perform a function. The incorporation of a nanotechnology in textile enables as to manufacture the smart and multi functional textiles with the innovative applications in the field of health, pharmaceutical, fashion, sports, military and transportation [7].

SYNTHESIS OF NANOPARTICLES

The nanoparticles can be synthesized by Top down or bottom up techniques. Top down methods involves fragmentation of bulk materials into nano-structured materials by physical methods approach like mechanical machining, physical vapour deposition, lithography and pyrolysis by thermal evaporation method [8]. Bottom up methods includes chemical and biological approach like sol-gel method, chemical vapour deposition, chemical co precipitation, micro-emulsions, hydro thermal methods, sono chemical methods and microwave methods [9]. By biological methods we can synthesis large amount of nanoparticles which are eco-friendly and sustainable. Plants, microbes can be used to synthesis. In plants we use leaves, fruits,

peels, stem, root. Agriculture waste, vegetable waste, egg shell, algae. Intracellular enzymes, metal ions which are trapped and extracellular products present mycelial of microbes like bacteria and fungi are involved in synthesis [10].

NATURAL FIBRES FOR TEXTILE INDUSTRY

The natural and plant fibers are widely used in textiles namely tannins, polysaccharides and some tissues are used [11]. Tannins from parts like bark wood, fruits, rind, leaves are important in textile finishing, preservation of leather, they show anti microbial properties and act as strong antioxidant against tissue damage from UV radiation for aroma finished cotton. In clothing *Pelagonium graveolans* leaf extract are used. Polysaccharides are actors thickeners for textile printing of patterns and designs [12].

SYNTHESIZED NANOPARTICLES FOR TEXTILE INDUSTRY SILVER NANOPARTICLE

A novel nano-silver colloidal solution was prepared in one step by mixing AgNo3 aqueous solution and an amino-terminated hyper-branched polymers can be synthesized. The white coloured, silver content nanoparticles are synthesized by various methods using microbes like bacteria, fungi and plant extracts.The microbes intracellular, and extracellular products of bacterias like lactobacillus which are reported the silver nanoparticles using bio-mass, supernatants, cell-free extract and also delivered components which are used to recovery [13]. Chemical methods like solid-state decomposition which is very simple method to synthesis the Ag particles in the shape of cubes obtained after annealing process known as photoluminosence [14]. The demonstration using silver ions may be reduced in extracellularly using fusarium oxysporum leads to produce stable silver nanoparticles in water. This incorporated cloths are sterile and can be useful in hospital for the prevention from the pathogenic bacteria such as staphylococcus aureus [15]. The incorporation of synthesized silver nanoparticles provides a sterile property, antimicrobial activity and washing durability [16].

GRAPHENES

Graphene is composed of a single-atom thick sheets of sp2 bonded carbon atoms which are arranged in a perfect (2D) honey-comb lattice like structure [17]. The

noble metal decorated graphene nanosheets can be synthesised by template of graphene oxides by one-pot solution based method through the run of mild reduction of graphene oxides using metal nanoparticles as catalyst for the hydrolysis reaction of NaBH4 at room temperature [18]. Multifunctional wearable E-textiles has a attention due to there great potential in healthcare, sports wear, fitness, space and military applications. Electro conductive textile yarns are used for next generation flexible sensors and composite textile. They are flexible , washable, wearable and bendable textiles [19]. Smart textile are based on graphene because they are owing to its superior electrical conductivity, high thermal conductivity. It covers mechanics, material development, fabric designs on body applications for thermal management and flame retardancy [20]. Ink-jet printing of graphene ink is very promising for wearing E-textile application. The functionalised organic nanoparticles present a hydrophobic breathable coating on textiles which has extra-ordinary electronic, optical and mechanical properties [21].

TITANOUM OXIDE

Titanium oxide can be synthesised in a biological way using plant ,bacteria and fungi extracts. By using low-pressure pyrolysis method at high temperature and concentrations using organic precursors [22]. Over 1000 years more than 100 different dyes, pigments has been used worldwide in different industries for the synthesis of dyes. Suspended TiO2 nanoparticles have been largely used has an effective catalyst for the degradation of organic contaminants present in water aqueous waste during the preparation of dyes in industries [23]. It can be also synthesized from plants naturally. Platinum doped nanoparticles has high potential towards microbes through the synergistic combination of photo-catalytic features of nanoparticles fabrics with novel properties are produced with self cleaning and stability against UV rays among new prominent properties obtained on textiles [24]. Titanium oxide deposited in the form of coating on the surface of the cotton fibers in the form of aggregated nanoparticles with average size dimension does not exist 50mm. Titanium oxide loaded with cotton fibers exhibit a bacterial reduction of more than 95% which are sustainable after washing cycles, display a excellent UV production before or after washing [25].

CARBON NANOTUBES

Carbon nanotubes are tube-like materials which are made up of carbon with a diameter at nano-scale . they are originated from graphene sheets and these graphite layers which are similar to a rolled-up non-stop breakable hexagonal mesh like structure based on the number of carbon layers [26]. They may be made up of singled -layered known as single walled carbon nanotubes(SWCNTs) or double- walled known a as double walled carbon nanotubes(DWCNTs) or multilayers known as multi walled carbon nanotubes(MWCNTs) [27].

Carbon nanotubes integrated with carbon filaments are used in the direct method such as growing on fibre, chemical grafting and nanostitching or like indirect methods such as mixing with matrix and applied via lay-up and dip coating [28]. It can be syntheised by chemical vapour deposition over patterned catalyst arrays leads to nanotubes grown on a specific sites on the surfaces. It also can be synthesised by Arc

-discharge, Laser Ablation and chemical vapour deposition method(CVD) based on the necessity of shapes ,structures and types the suitable methods are used. Among all CVD is a most promising synthesis route because economically less expensive, yield

,reaction time , size and simple method for purifying and heating [29].

They exhibit high elasticity, high thermal conductivity, low density and chemically inert in nature with high tensile strength, ultralight weight. Treatment of textiles with nanoparticles leads to produce a variety of conducting textiles materials [26]. The fabricated CNTs has the ability to produce composite materials for conventional and innovative applications which are from apparels and sports-wear to protect clothing, heating equipment, automobile textiles, building covering, geo-textiles and bio- medical textiles [30].

LIPOSOMES

Liposomes are a nano-carrier which are potentially against hydrophobic and hydrophilic cationic, anionic, or neutral molecules .they are highly bio-compatible ,bi- degradable and low-immunogenesis [31]. They are single-layered or multi-layered spherical vesicles of phospholipids molecules which are prepared by thin-layer hydration method, reverse phase evaporation method, solvent injection method, detergent removal method and heating method etc and they were charecterized by XRD, TEM, SEM [32].

The dyeing properties of fibres are influenced by lipid which acts as solvents. The two types of dyes called hydrophobic or hydrophilic acid dyes are present in liposomes. According to the ecapsulating and sustaining release properties of liposomes,they were used in costume , smart and medical textiles as they act as active agent to deliver across the membranes [33]. They are amphipathic in nature hence used in washing and scouring process. As a surfactant it removes contaminants nearly 14.7% and during preparation it does not form any foam [34].

DENDRIMERS

Dendrimers are nano-sized, rapidly symmetric molecules. They has biological and chemical properties such as polyvalency , self-assembly, electrostatic interactions, chemical stability, low cytotoxicity and solubility [35]. they are hyperbranched molecules first discovered by Fritz Vogthe In 1978 by Donald Tomalia and his co-workers . It is also called as Cascade molecules . The basic cascade or iterative methods are currently employed for the synthesis of dendrimers by convergent or divergent approach [36]. The material are prepared by sequestering metal ions within dendrimers followed by chemical reduction to yield electrovalent metal nanoparticles in a acqueous or non-acqueous media [37]. They includes 3-D architecture, mono dispersivity, highly branched macromolecular characteristics and tunable terminal functionalities [38].

Dendrimers are acts as polymeric stabilizers used in the preparation of silver nanoparticles in acqueous medium as finishing agent to produce anti-microbial textiles [39].They are introduced as amine-terminated dentritic materials has the potential to improve dyeability, salt free dyeability, anti-microbial activity, long- lasting fragment fabric, ultra-violet property, drug delivery through fabric , flame retardancy and waste water treatment [40]. To improve wash and wear properties poly dendrimers (amido amine) can be modified and used as new material for wrinkle resistance towards cotton [41].

ZINC OXIDE NANOPARTICLES

The synthesized zinc oxide nanoparticles are less expensive and can be synthesised very efficiently [42]. Green synthesis is a method for the synthesis of zinc oxide nanoparticles by using the plant extracts of leaves , stem, flowers ,root , barks. The plants like *Laures nobilis* , *Nyctanthes arbortristis* , *Azadirachta indica* extracts

are used for the synthesis which are sustainable ,eco-friendly and less toxicity, using salts like zinc acetate and zinc nitrate as precursors[43]. Also proteins and enzymes are used for the bio-synthesis of zinc oxide nanoparticles for multifunctions. By chemical methods like chemical vapour deposition (CVD)has been used for the synthesis pf zinc oxide nanoparticle with controlled morphology of spherical or rod- shaped particles [44]. It has been used largely due to the large bandwith length and high excitation energy and it's anti-fungal, anti-diabetic, anti-inflammatory , wound healing and anti- urothiatic Activities [45]. Zinc oxide nanoparticles were applied on the cotton and wool samples to impart sunscreen activity, physical tests were conducted to the fabric materials before or after the treatement [46]. They are strongly influenced by UV- filters , high catalysis, semi-conductor or piezoelectric coupling characteristics hence effectively applied in textile industry [47]. Utilization of this increase the structure by improving properties such as anti-microbial, water repellence, soil-resistant, anti-static, anti-infrared, flame retardant, dyeability, colour fastness, and strength of textiles [48].conventionally they are applied onto the textiles directly by pad-dry cure method as binders to hold the surface of fibres inturn they improves the wash fastness without use of any binders. Medical textiles have become the most essential and developing part in human healthcare discipline [49].

PROPERTIES OF SYNTHESIZED NANOPARTICLES MECHANICAL PROPERTY

The mechanical properties of nanomaterials involve their behavior under various conditions and loads. It focuses on enhancing the properties by adding nanoparticles to non-nanomaterial matrices.. Detailed properties of metal nanomaterials, such as Vickers hardness, fracture toughness, fracture strength, ultimate tensile strength, and impact strength, are discussed [50]. Nanomaterials, with their small size and unique effects such as surface and quantum tunneling, are gaining significant attention for applications in traditional materials, medical devices, electronics, and coatings. This review explores how factors like nanoparticle selection, production methods, grain size, and grain boundaries affect their mechanical properties. It highlights current research progress and the broader potential of nanomaterials compared to traditional materials, underscoring their promising future in material science [51].

ELECTRICAL PROPERTY

Thermoelectric materials have unique properties that allow energy conversion between thermal and electrical forms, with performance measured by the figure of merit (ZT). Despite significant research, ZT values are generally below 1, falling short of the target of 3 or more. Achieving high ZT remains challenging due to the difficulty of optimizing high electrical conductivity (σ), high Seebeck coefficient (S), and low thermal conductivity (κ) simultaneously. Inorganic nanomaterials often show high S and σ [52].

CHEMICAL PROPERTY

Characterizing nanomaterials requires more comprehensive physico-chemical data and testing techniques compared to traditional chemicals. While regulatory assessments for chemicals typically focus on specific toxicological traits, these may not directly translate to nanomaterials. The possible physico-chemical parameters and testing methods to establish a regulatory framework for nanomaterials [53]. It examines testing approaches for fifteen physico-chemical attributes of eleven nanomaterials under the OECD's Testing Programme and evaluates their significance and limitations. Findings highlight the critical roles of size distribution and shape in defining nanomaterials, while the octanol-water partitioning coefficient remains undefined for these substance [54].

MAGNETIC PROPERTY

Magnetism is crucial in many biological systems, but its weak forces require highly sensitive tools for accurate detection. Magnetic force microscopy (MFM) excels in lateral resolution and single-molecule studies, making it valuable for biological applications. This review highlights MFM's key benefits and inherent limitations. Magnetosomes, natural magnetic nanoparticles from magnetotactic bacteria, can serve as alternatives to synthetic nanoparticles for hyperthermia treatments. Additionally, understanding how magnetism influences biochemical reactions and biomolecular catalysis is crucial for advancing magnetic control in biological systems [55].

OPTICAL PROPERTY

Light scattering caused by angular reflectance is a key optical phenomenon widely measured and modelled across various fields, from materials science and medical imaging to 3D computer graphics and animation. This phenomenon underpins analytical methods in remote sensing, target detection, and radiance signature evaluation for both passive and active sensors. Accurate modeling of reflectance requires sophisticated formula processing across a broad spectrum of wavelengths, from ultra-violet to infrared [56]. Nanomaterials exhibit unique optical properties due to quantum confinement and high surface-to-volume ratios, differing significantly from their bulk counterparts. By adjusting parameters like size, shape, and surface characteristics, their optical properties can be tailored for various uses [57].

CHARACTERIZATION OF SYNTHESIZED NANOPARTICLES

The characterization of nanoparticles is performed by analyzing various physicochemical attributes such as molecular mass, identity, composition, purity, stability, and solubility. Additionally, unique characteristics of nanomaterials, like particle size, surface structure, and surface energy, are examined [58]. Techniques for characterizing nanomaterials are used, including electron microscopy, FTIR, UV-Vis spectroscopy, scanning probe methods such as atomic force microscopy, EDX analysis, X-ray diffraction, neutron diffraction, X-ray scattering, XRF spectrometry, acoustic wave methods, contact angle analysis, and various other spectroscopic techniques [59].

EDAX

Energy dispersive X-ray analysis (EDX) is a method used for examining near- surface elements and estimating their proportions at various locations, thus providing a comprehensive map of the sample [60]. This technique is employed in conjunction with SEM, where the surface of a conductive sample is struck by an electron beam typically ranging from 10 to 20 keV. It has high sensitivity to determine the elemental composition for overall mapping to characterize the surface [61].

SEM

A scanning electron microscope (SEM) is used to scan a sample's surface with a high-energy electron beam, resulting in high-resolution images (1–5 nm) [61]. This

makes it ideal for the examination of nanofibers and nanocoatings on polymeric or textile substrate. SEM generates detailed 3D images at high magnifications (up to 300,000), though only in black and white. It provides clear views of the surface structure and texture of nanofibers, nanocomposites, nanoparticles, and nanocoating [62].

TEM

Transmission electron microscopy (TEM) is a technique in which a beam of electrons is transmitted through an ultra-thin specimen, enabling interactions as it passes through [61]. Because polymeric nanocomposites and textile samples are softer than metals, they are cut into thin films (< 100 nm) using an ultra-microtome with a diamond knife under cryogenic conditions.They are accomplished by very accurate information like size distribution analysis that ensembles the elemental composition of biomaterials [63].

AFM

The atomic force microscope or atomic forced microscopy is utilized to measure nanometer-scale surface roughness and to visualize nano-texture on a variety of materials, such as polymer nanocomposites and nanocoated textiles [61]. In this technique, a probe with a sharp tip (around 10 nm in radius) scans the surface of the specimen in a raster pattern using piezoelectric scanners. The size can be determined by measuring the nanoparticles image height to investigate the influence of the substrate rougness and particle agglomeration on the statistical analysis of nanoparticles [64].

NMR

NMR has high resolution molecular architecture at the surface of the solid phase nanoparticles which elucidate the core and shell of the ligand with spatial and chemical. NMR can be employed to verify the immobilization of ligands on nanomaterials in both qualitative and quantitative terms [65]. A notable drawback of using NMR for nanomaterial characterization is its need for larger sample sizes compared to those required for small molecules. The distribution of mobile versus immobile polymer segments was determined from the exponential decay curves of T2

protons in both bound and free states, indicating that 55% of the segments were tightly wrapped while 45% were loosely bound [66].

XRD

A common method for the characterisation of sample purity, crystalline size and morphology. XRD provides crucial information on crystalline structures and grain sizes but is ineffective for amorphous materials and broadens peaks for particles under 3 nm, yielding volume-averaged results when applied to dried powders. It emphasize the inorganic and organic size ,shape and dimensionalities [67].

UV-VIS SPECTROMETRY

UV-Vis reflectance spectroscopy offers a refined non-invasive method for uncovering dyes and lake pigments in cultural heritage pieces, delivering remarkable sensitivity and precision. Ultraviolet (UV) spectroscopy, often referred to as UV-visible (UV-VIS) spectrophotometry, evaluates how samples with chromophores absorb ultraviolet and visible light [68]. This cost-effective method is widely employed in chemistry and biochemistry for identifying and quantifying a range of compounds. In this process, a UV-VIS spectrophotometer transmits light through the sample, measuring absorbance at various wavelengths, which reflects the concentration of the absorbing materials. Important parameters encompass absorbance (A), transmittance (%T), reflectance (%R), and their temporal variations, along with the wavelength used for measurement [69].

INNOVATION IN TEXTILE INDUSTRY USING NANO-MATERIALS

NANO-FINISHING

Nano-finishing is the application of surface of textile materials with nno- particle to have a active surface with enhanced properties. Zinc-oxide, silver oxide , titanium oxide are popularly used in nanofinishing in textiles. Metal oxides are preferably acceptable [70] .Mostly they are non-toxic and chemically stable under temperature. They show anti-bacterial , UV blocking , self-cleaning, anti-static and fight against odour. They are prepared by chemical vapour deposition (CVD), sol-gel method and ball-milling. Nowadays the nanotechnology in textile finishing are high

finishing are high performance sky wax, breathable water proof, sky jacket , strain repellent garments, LED digital camera etc. “Wrap nano sheets” wraps the covers to make fabric strong and durable [71].

NANOCOATING

Nanocoating increase the synthesis particles with unique properties like high hardness, toughness, wear-resistance , optical transparency. They are are classified into multilayer and hard nanocomposite coatings [72]. Also applied to textiles by padding, spraying , or dip-coating. Nanocoating techniques are sol-gel, layer by layer

, spin coating , vapour -deposition techniques, magnetron sputtering. These techniques are powerful for introducing various functionalities in textiles industries [73]. Nano structured surface coating of textile substrate for the enhanced functionalities to develop the fine and uniform nanofibers the fibers has high surface fabric performance and higher functionality including silica coating for photochromatic textile , superhydrophobic surface coating and transparent zinc oxide coatings for the reduction in colour fadings during this process the breed fibres are eliminated without increasing the average diameter of electrospun nanofibers [74].

NANOFIBRES

Nanofibres are one -dimensional materials which are in fibre shape with diameter in nanometer range . They have smaller pores and higher surface areas than regular fibres. It has unique properties such as high-surface -volume ratio which effects a large surface area, nano-porosity, mass-transport, they are permeable to water, stand with high thermal , and also has high mechanical strength [75]. It is also prepared by drawing method, phase separation, self-adhesion, electrospinning and centrifugal spinning [76]. Electrical spinning process is suitable for producing a variety of bio-polymers, engineering plastics, conducting polymers, block polymers, ceramics and composite materials to produce the nanofibers . Nanofibre yarns become available to textile industries process like weaving, knifing, and embroidery [77]. Technically applied as filter fabric, antiabacterial patches , chemically protective suits.Protective garments for soldiers to reduce the chemical exposure produced from elecrospace nanofibers [61].

NANODYEING

Dyes are utilized for various purposes includes for straining ,and even also for therapeutic medicines . Azo and Nitro dyes ,phthelocyanide, and acrl methane dyes are used. In India the dyes and pigments business helps to produce 80,000 tonnes of dyestuff and pigments [78]. In a wet shower which contains electrolytes and ionic salts applied to colour cotton and cellulosic strands regularly. The word “fibre reactive “ which means to the coloured fibre particles and fibre reactive dyes which are in covalent bonds. The controlled nanoparticle dyeing of cotton can ensure low cytotoxicity risk with multifunctional enhancement [79]. It can be achieved if the nanoparticles can be reduced to small enough size and particles can be easily dispersed in dye baths. They has out standing electric , mechanic, thermal properties and flexibility [80].

APPLICATION SWIMMING SUIT

The shark-skin suit worn is used during world-record breaking Olympic swimming champions is a suit ,which includes plasma layer enhanced by nanotechnology to repel water molecules to which helps to glide on the water [81]. The polymeric fabric are coated with silica nanoparticles to achieve required functions . they are light weight ,thickness, burning strength, stiffness, air permeability and water repellancy. The suits are specialized structure of shark which is long lasting and more durable. They show the specific functions in clothing like water repellancy and antimicrobial action, conductivity, , anti-static and anti-wrinkle characteristics [82].

SPORTS GOODS

Nanomaterials are used in sports equipment like racing bicycles, baseball bats, hockey sticks, tennis and badminton racquets, golf balls , archery arrows, skis, fly fishing rod ,etc. these are used in to increase the stiffness, durability , abbression resistances and to reduce weight [83]. Silver, silica, titanium, Zinc oxide nanoparticles are used for the drug delivery of the sports supplements to the required parts in the sports person [84].

FLEXIBLE ELECTRONICS

Nanomaterials helps us to increase the performance ,solution, processibility, and processing temperature requirements and to make flexible electronic systems. nanotubes , nanowires, and carbon -based thin films which are used in conductors

,transparent electrodes, semiconductors, and dielectrics . we can develop the wide range of flexible electronics such as displays, sensors, RFID tags and other transistors, interconnects, memory cells, passive components, and other sorted devices [85]. Nowadays printing techniques for flexible electronics were adopted because of it’s efficiency, low chemical ink transfer and compatible with various substrates making ideal wearable applications [86]. The materials is tuned to generate an electrical response on the textile surface when subjected to external stimuli by resistivity. The introduction of Sensors and automators in the textile industry is mainly inducted on the conductive materials [87]. The conductivity serials are has a wide range of applications in this field. The polymers are modified to its desired property by incorporating a variety of nano materials into a matrix like nanostructured Polyaniline (PAN) ,polypyrrole (PPy) are widely used for conductivity polymers with enhanced mechanical strength optical and conducting properties [7].

LIFESTYLE APPLICATION

Nanotechnology is very commercialised application in lifestyles including cosmetics and textiles. Bulletproof vests are very famous one materials among nanotechnology future developments include them usage of nanotechnology in creating smart and interactive textiles capable of sensing the magnetic , chemical , thermal , electrical and other stimuli [88]. Military dresses which has light weight but show a high degree of resistance to extreme temperature, durable antibacterial activity

, improved water resistance embedded with multi purpose nano sensors. They are also high anti ballistic, flame retardant and UV shielding properties [89].

WATER-REPELLANT

Water Repellent impregnation is applied in textiles to impart water and chemicals, oils and stain resistance to the textiles. The water repellence of the external fabric is achieved by the modification of hydrophobic polymers, dendrimers to wet-out can be comfort tissues [90]. To obtain the super-hydrophobic water-repellent properties cotton fabrics were treated with silica-nanoparticles [91]. The new type of water repellent for oven cotton fabrics is explained by using eco-friendly non-toxic

polymers. It means cotton fabrics show resistance to water penetration due to hydrostatic pressure buildup. A treatment namely sequentially coating the fibres with a polymer nanocomposites comprising a 6-perflourinated acyrilic co-polymer and silica resins (PDMS), hence the water is repelled easily on "roll-off" angles below 20* at hydrostatic pressure of 2.6 kpa [92]. Nanosilica was extracted from rice husk and applied on eri-silk to impart water repellent which enhances the whiteness and brightness of Eri-silk fabrics. SEM, FTIR, EDAX technique were used for the conformation of presence of nanosilica on silk fabrics [93].

WRIKLE-RESISTANCE:

Nano-Tex's innovative Fortify DP technology enhances wrinkle resistance by thoroughly infiltrating fibers with a flexible cross-linking structure. This method preserves the fabric's integrity and prevents the significant strength reduction linked to traditional wrinkle-free techniques. While wrinkle-resistant textiles suit time- constrained consumers, some lightweight materials and tailored garments may not work well with standard treatments.Cotton fabric tends to crease during use, and conventional techniques often depend on resin-based treatments for wrinkle resistance. Test findings revealed that direct dyeing improved the wrinkle resistance of cross-linked fabrics. Furthermore, flax fabrics infused with aluminum oxide nanoparticles exhibited enhanced flame retardant and wrinkle-resistant characteristics. Some researchers utilized nano-titanium dioxide and nano-silica to enhance the wrinkle resistance of cotton and silk fabrics, respectively.

FLAME RETARDANT

Important additive capable of lowering risk by either stopping and ignition are slowing down the flame spread rate and combustion [96]. Textile materials are one of the important cause for the fire-accidents .So we need to develop flame retardant textiles for protecting clothes in home and industrial textiles. Nanotechnology has developed for the flame retardant finish fabrics by utilising the colloidal antimony pentoxide (Sb_2O_5) by using this nano materials in clothes along with halogenated blaze preventive substances so that the physical and chemical properties are enhanced [7]. Nanoclays, Zinc oxide , Titanium dioxide nanoparticles can import flame retardant finish to fabrics and also found that zinc oxide nano particles with bleach

jute fabrics are good at the flame retardancy Flame retardancy of textiles are an emphasising fire safety characteristics [97].

The phosphorus-based flame retardants specially designed and developed for a fabrics and fibers which includes cotton polysters and blends which improves the effectiveness and replacement of toxic chemicals with low in environmental impact. The phosphorus -based compounds play a lead role with the combination of silica and nitrogen containing structures to design the efficient flame retardant fibres [98]. Fabrics with the flame retardant polypropylene filaments for carpet pile yarns were prepared by incorporating silver oxide nanoparticles into polymers [99].

UV-PROTECTION

Skin cancer is become a major disease under sun related cancer due to the ultra-violet radiation so that nanotechnology has come out as a crucial field which improves and provides a potential solution providing apt mechanics, optics, sunscreen and UV-blocked textile solutions on fabrics, yarns or even fabric aided nanoparticles are applied in UV-shielding and imparts sunscreen activity [100]. The harmful rays of the sun are danger so the garments use to protect the wearer from the weather using UV-blocking agents like Zinc oxide nanoparticles- a metal oxides are more stable which increase the intense absorption in the UV-region [101]. Photo-yellowing can be reduced by the help of organic and inorganic UV-blockers like TiO2, ZnO, Al2O3 are very effective in UV-protection [102]. TAs the intensity to ultra-violet radiation increases every year as it was very effective method to block UV-rays to human skin plastics timbers and other plant materials. The up's to textile materials has been aimed to produce finished fabrics with high performance [103].

ANTI-MICRBIAL ACTIVITY

Anti-microbial textile are functionally active textiles, which may kill the microbes and inhibit the growt. The application of different synthetic and natural anti-microbial compounds to prepare the anti-microbial textiles which includes anti- bacterial, anti-fungal, anti-viral which literally means the object which resist the gorwth of bacteria , fungi and viral particles. These are used in variety ranging from households to air filters, tool packaging, health care, hygiene, medical, sportswear, storage, ventilation and water purification system [104]. Gram (-)ve bacteria like E.coli and Gram (+)ve bacteria Staphylococcus aureus were demonstrated by meeting

with nanoparticles by pad-dry method [105]. Imparting curable anti-microbial properties to cotton fabrics using Alginate-quaternary ammonium complex nanoparticles. The anti-bacterial guard to the textile is very interesting and beneficial for health of humans. The nanoparticles like TiO2, CuO2, Polymeric fibres and metal fibres has been incorporated into fabrics for the the enhancement of bactericidal activity [7]. Silver nanoparticles were treated to the fabrics against the growth of the bacteria. The treatment of fabrics were involved in steps of complex processes, required a surface post treatment , lacked durability and altered a desirable properties which were related to the comfort of fabric [106]. Silver nanoparticles are very active against on membranes of Candida parapsilosis and Xanthomonas axonopodis pv citris [107].

ANTI- STATIC

The buildup of static electricity the typically arises from the triboelectric effect actually eliminated or reduced by an anti-static agent which is a compound design to treat the surfaces and materials. The traditional anti-static materials can be used as an innovative structure efficiently prohibit the voltage spikes and isolation of charged regions development [108]. A resilient conductive network was formed by an electrical conductive nanoparticles which are securely embedded with an fibrils of Teflon membrane. The display of larger static charge are hydrophobic due to the nylon and polyester .The parade of anti-static properties of zinc oxide nanoparticles coatings while silver nanoparticles can reduce the static voltage in polyester fibers by

60.4 % combining with gold nanoparticles further improving them effect by achieving

97.7 % reduction additionally Sb doped SnO2 has been shown to import anti-static characteristics to polyacrylonitrile fibres by forming conductive channels within the material [7]. The accumulation of static charges are prevented by the cellulosic fibres which contain more moisture conversely. The synthetic fibres are often falls short in an anti-static performance so we aimed to improve the anti- static properties of synthetic textiles with the use of materials such as oxide whiskers, nano antimony- doped tin dioxide and silane nanosol and they provide antistatic benefits due to their conductive nature facilitated by advanced nanotechnology [102].

ANTI-ODOUR

Body odour is controlled by bactericidal ,antimicrobial and self sterilising nanoparticles containing silver, zinc and copper . When the nanoparticles are added to fabric they protect them material against all microbes that causes unpleasant odour which enhance the resistance to washing temperature and abresion [109]. We can use of clothes in direct contact of skin fabrics like regular clothing, sports apparels, bedsheets and military uniforms as they are anti-allergic agents.Tourmaline nanomaterials based nanofinishing on textiles contributes a odour-resisting proper which has the ability to separate till 75% sticky moisture, 99.99% of bacteria and 90% of odour. The inclusion of fragrant material in antiodour or antimicrobial finishing by nano-encapsulation in synthetic fibres might assists to release fragrance [110].

2. CONCLUSION

Nanotechnology is revolutionizing the textile industry by enhancing fabric performance, durability, and functionality, offering features like water resistance, UV protection, and antimicrobial properties. As innovation progresses, nanotechnology is expected to drive sustainable solutions and advanced materials. However, environmental concerns regarding nanoparticle safety and disposal remain key challenges.

3. REFERENCE

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