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A Review of Protective and Decorative Coatings on Polyester Fabrics

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Abstract

Fabrics are widely used in non-clothing applications such as construction, transportation, healthcare, electronics, sports, etc. Due to its remarkable mechanical qualities, including high tensile strength, abrasion resistance, and dimensional stability, polyester textiles are frequently employed in a variety of applications. Unfortunately, they are prone to poor breathability, water resistance, and other functional issues. In order to address these issues and improve the functional performance of polyester textiles, coating technologies have been developed. By adding new functional groups, nanostructures, or chemical treatments, coatings have the power to change the attributes of surfaces, enhancing things like water repellency, breathability, antibacterial activity, UV resistance, and other desirable qualities. The aesthetic appeal of polyester materials may also be enhanced by coatings by adding distinctive colour, texture, and print patterns. Protective coatings can help to increase the resilience of polyester textiles to various environmental conditions. Decorative coatings can be used to give polyester fabrics an aesthetically appealing surface finish. The purpose of this review is to offer a comprehensive overview of modern protective and decorative coatings for polyester fabrics. This review explores the benefits and downsides of each coating and assesses their impact on the physical and mechanical attributes of polyester textiles, such as colourfastness, tensile strength, and wear resistance. Overall, it has been determined that additional study is required to investigate the different uses that polyester textiles may serve.

Introduction

The first coated textiles were created more than a century ago. Oil was the first covering substance employed, and it was used as oilskins. They were created in the beginning in Scotland by painting oils onto these textiles then sun drying them. These coated materials were sticky and unattractive, but they were useful enough that an industry sprung up around them. Following World War II, the demand for coated textiles increased many fold. Development in Technology, robust consumer demand for better products, the environmental problem, and the aspiration to increase the application of such high-quality textile fabrics have propelled the textile industry to look for advanced materials. Surface modification of textile fabrics for creating materials with advanced functionalities has been extensively researched in recent years. Initially various techniques such as physical vapor deposition (PVD), chemical vapor deposition (CVD), plasma-enhanced vapor deposition (PECVD), dip coating, spray coating, roll-to-roll coating, etc. As time passed the interest of the textile industry in newer and more advanced techniques such as the layer-by-layer method[1,2], electrospinning[3], coaxial electrospinning[4], electrodepositing[5], atomic layer deposition (ALD), inkjet printing, sol-gel deposition, magnetron sputtering etc. increased. The effort of the industry is to use these novel techniques to incorporate these newer properties economically and effectively into the existing materials simultaneously.

Protective Coatings on Polyester Fabrics

In a research article published by Pongsathit, Chen, and coworkers tried to synthesize and test a novel type of coating that could provide multifunctional properties to a PET textile material and was also eco-friendly in nature[6]. For high-performance applications such as ski suits, it is extremely necessary for the fabric to have high Water Pressure Resistance (WPR) to resist the pressure of water or snow[6]. The Water Pressure Resistance of the fabric should be 1300-1500 mmH_2O depending on the extremity of the activity[6]. Apart from WPR for having clothing comfort it is necessary for the fabric to have Water Vapor Permeability (WVP) which is the amount of moisture that is transferred from one side of the fabric to another[6]. It is quite difficult to have both WPR and WVP in the same fabric[6]. Usually, solvent-based PU has been used to produce such fabrics because solvent-based PU has excellent WVP and reasonable abrasion resistance qualities[6]. However, the major drawback of using solvent-based PU on a large scale is that these solvents evaporate as Volatile Organic Compounds (VOCs) which are harmful to the surrounding environment and affect human health adversely[6]. Besides this PU is a petroleum derivative and is becoming expensive day by day owing to the depletion of petroleum resources[6]. Hence it became evident to create a material that was “green” in nature and had high WPR and WVP with good tensile strength and elasticity[6]. They found that Natural Rubber had good hydrophobicity and hence had good WPR along with excellent tear resistance[6]. However, the drawback of using a Natural Rubber polymer coating was that it had zero WVP[6]. They also found that WPU (Waterborne polyurethane) had good breathability and hence good WVP along with moderate abrasion resistance[6]. The disadvantage of using WPU coating was that WPU has zero WPR[6]. The idea was to vulcanize NR and then blend the NR with the WPU to create a coating that will fulfill the required properties[6]. The research was done to find the best possible combination of vulcanization time and amount of sulfur for the NR, the appropriate ratio of NR:PU blend, curing time, etc[6]. Finally, it was determined that a 60:40 ratio of NR:PU, a curing time of 15 minutes, and the sulfur content of 2 phr in a Conventional sulfur curing system (CV) give the best WPR and WVP combination[6]. This is a good example of how a novel coating turned the PET fabric into a special fabric with advanced properties.

Similarly, Nguyen, Chen, and coworkers have tried to use R2R-HIPIMS to coat multifunctional titanium oxide onto PET fabrics[7]. Hydrophobic and Hydrophilic textile materials have attracted a lot of attention from the scientific community recently owing to their versatility. Ti-O coating has been suggested for the coating application on various textile materials for decades[8]. Many processes can be used to deposit Ti-O thin films, like the sol-gel processes[9], micro-arc oxidation[10], chemical vapor deposition[11], thermal evaporation[12], RF Reactive Sputtering[13], inductively coupled plasma-assisted reactive DC magnetron sputtering[14], and High-Power Impulse Magnetron Sputtering (HIPIMS)[15]. In this paper, the author has discussed the process of applying a coat of Ti-O using a dry process of R2R-HIPIMS[7]. Here, we must first understand what magnetron sputtering is. Sputtering deposition is done in a vacuum chamber. The substrate we are going to use to do the coating here is a textile substrate. The source of the thin film material is a planar rotary sputtering target that is kept inside the sputtering chamber system can be made up of plastic, ceramic, or metal. A target is used to produce thin films. The air inside the chamber is continuously removed by vacuum pumps. High purity argon gas is continuously introduced to achieve a low-pressure argon atmosphere. A magnet array inside the cylindrical target generates a magnetic field. The target is filled with cooling water that dissipates the heat produced during the cooling process. The targets are rotating so that the material is utilized uniformly. A high voltage is applied to the molybdenum target to create a plasma that is concentrated along the magnetic field. The plasma contains Argon atoms, positively charged Argon cations, and free electrons. The Argon cations are continuously produced due to the bombardment of electrons on the atom. The sputtering target is negatively charged and the argon ions are attracted to its surface and eject the target atoms after colliding with the surface. Layer by layer the ejected atoms from the target are deposited onto the textile substrate opposite the sputtering target. The Ti-O coating was deposited on the fabric using HIPIMS by changing the O_2/Ar flow ratio[7]. The aim was to find out the perfect ratio of O2/Ar for having hydrophobicity and hydrophilicity properties of the textile materials[7]. During the experiment, it was found that keeping the O2/Ar flow ratio between 0/40 to 5/40 the PET fabric coated with Ti-O is hydrophobic in nature[7]. As the ratio increases from 10/40 to 40/40 the hydrophilicity increases and hence, we can get fabrics of specific wettability by carefully choosing the O2/Ar ratio[7]. The other properties of all these fabrics pertaining to the colorfastness, solar heat blocking capacity, and morphology of the coating were also observed to check the application of such a fabric in real-life conditions[7]. These fabric samples showed high color fastness with color differences $\Delta E < 5.5$ for all samples after 20 washing cycles[7].

Qi, Ma, and coworkers also worked on creating a waterproof breathable fabric (WBF) by using the Radio frequency magnetron sputtering technique[16]. In this research paper, the authors have described how a novel Waterproof Breathable Fabric (WBF) has been created by preparing a series of polymeric fluorocarbon coatings on the PET fabric[16]. In this experiment using RF sputtering technology, PTFE is deposited on the PET textile fabric[16]. The authors have studied various sputtering parameters and how they affect the quality of the textile material produced like the effect of the power of sputtering on the contact angle of the fabric, the effect of change of pressure on the contact angle, the effect of Target-Substrate distance (TSD) on the properties of the fabric and the effect of deposition time on the fabric properties[16]. Other tests that were performed to check the quality of the textile material created were the washing test, gas-moisture permeability test before and after sputtering, morphology test of PFCF and PFCFMs, and the contact angle measurement test[16]. It was found that an increase in the power of sputtering results in a decrease in the contact angle whereas an increase in the pressure led to an increase in the contact angle[16]. An increase in Target-Substrate Distance (TSD) led to a decrease in the deposition rate while an increase in the TSD makes the coating uneven[16]. The gas-moisture permeability of the fabric is almost similar to that of the uncoated fabric because the coating of the particles only settles on the fabric leaving the original pores vacant for ventilation[16]. Hence, the usefulness of the RF magnetron Sputtering technology for the coating of PET fabric for creating waterproof textiles was proved.

Due to the large surface area of nanoparticles and variety of physical and chemical properties, there has been a surge in the attraction of the textile industry to integrate these nanoparticles with the textile fabrics to increase their applications[17]. Silver Nanoparticles have excellent antibacterial, antiultraviolet, anti-static, optical, catalytic, conductive, and electrical properties that when integrated with textiles turn out to be an interesting material to be used[17]. There has been extensive research to determine an economic, environmentally friendly, and scalable way to deposit nanoparticles[17]. Some of these existing methods were electroless plating[18,19], electroplating, and vacuum deposition[20]. In this research paper Jiang, Qin, and coworkers have laid emphasis on the magnetron sputtering technology and the testing of the final fabric for various properties like UPF, antimicrobial properties, morphology, chemical composition, and Water Contact Angle (WCA)[17]. In the SEM it was observed that a uniform layer of silver nanoparticles was deposited by the magnetron sputtering and the average UPF increased substantially[17]. The fabric showed hydrophobic properties which were in contrast to the hydrophilic properties shown by the PET fabric[17]. The antibacterial properties of the fabric increased significantly as it was found that it had eliminated about 99.8% of *S. aureus* and 99.7% of *E. coli* on the textile sample[17]. This research paper showed that magnetron sputtering could be used as a technology to deposit nanoparticles on the surface of textile materials.

Another example of using a novel method for deposition of Ag nanoparticles on a piece of fabric was shown by Perelshtein, Applerot, and coworkers[21]. There has been a lot of research on finding out the mechanism of the antibacterial activity of the silver nanoparticles[22,23]. The bactericidal activity of Ag nanoparticles depends on the chemisorbed Ag^+, which is formed due to the interaction of silver with the oxygen in the environment[24,25]. But, the mechanism of how the silver ions go from silver nanoclusters go to the bacteria needed further investigation[21]. Nanoparticles of silver can be deposited using other methods such as magnetron sputtering[17], constant pressure padding[26], reduction of silver ions by ethanol or isopropanol, etc. In this research paper, the authors have tried to use the Sonochemical irradiation technique to produce and deposit nanoparticles on the fabric[21]. Sonochemical irradiation can be used for the synthesis of nanophased material[27] as well as for the deposition of nanoparticles on ceramic and polymer supports[28,29]. In this research paper, the real reason behind the bond between the substrate and the nanoparticle was found[21]. It was due to the point melting of the substrate due to the high rate and temperature of the silver nanoparticles thrown to the solid surface by the sonochemical microjets[21]. Apart from the spectroscopical tests, mechanical strength tests, antibacterial strength tests surface morphology tests along using SEM testing were also studied[21]. By studying all the properties, the potential application was found to be in wound dressing fabric, bed lining, and as a medicinal bandage[21].

Yuan, Xu, and coworkers have worked to improve the antiultraviolet and antistatic properties of the polyester fabric and opened a plethora of application opportunities for these materials[30]. It is a known fact that metal-semiconductor nanocomposites like Ag/ZnO can provide applications in electronics, optics, magnetics, biomedicine, medicine, and chemical sensors[31–34]. Silver/Zinc oxide Nanoparticles have a variety of applications owing to silver's outstanding optical, electrical, and chemical properties whereas zinc oxide has high photocatalytic activity, large excitation energy with a wide band gap, and has good chemical and thermal stability[35]. There are many methods to prepare Ag/ZnO nanocomposites and deposit them over fabrics like chemical bath deposition[36], sol-gel dip-coating method[37], hydrothermal method[38], photoreduction method[39], nonionic polymer assisted thermolysis[40], pulsed laser deposition[41], etc. The problem with these techniques is that they either require high temperature, high pressure, toxic reagents, long reaction time, or expensive equipment[30]. Hence, it was necessary to find a technique that would be dry, eco-friendly, fast, economic, and easily scalable[30]. Hence, the option of using magnetron sputtering seemed very viable to produce such a nanocomposite coating[30]. However, there was one problem with using magnetron sputtering for the deposition of both Ag and ZnO is that the Ag gets oxidized into Ag_2O and the final coating prepared is a nanocomposite of Ag_2O/ZnO which is not the coating we desire[30]. Hence, to solve this problem the Ag is first coated onto the fabric by DC magnetron sputtering and then a coat of Zn is applied which forms a layer of the Ag coating[30]. Finally, using RF magnetron sputtering ZnO is finally coated onto the fabric effectively protecting the underlying layer of silver from oxidation[30]. The efficacy of this system of the coating was tested in real-time and the antiultraviolet and anti-static properties of the fabric were tested[30]. These antiultraviolet and anti-static properties were compared with uncoated material and it was determined that these properties of the coated material were better than the uncoated ones[30]. Hence, this green method can be used to design and fabricate novel metal/metal oxide nanocomposites for advanced applications[30].

Photocatalysis is an attractive science in recent years and a lot of research is warranted in this area. The most widely used and studied material in the photocatalyst application is TiO_2 nanoparticles[42]. Some of the applications of TiO_2 in photocatalysis are in the development of self-cleaning glasses, ceramic, and textile materials[43–46]. A variety of techniques are available to deposit TiO_2 onto a textile fabric to achieve this photocatalyst activity like ionized beam cluster deposition[47], physical or chemical deposition[48,49], sol-gel process[50], etc. RF magnetron sputtering is the most widely used technique of all to deposit TiO_2 on the textile fabric[42]. However, the major drawback of using RF reactive sputtering is that there is a low deposition rate of the TiO_2 and the poisoning of the surface of the Ti target with the increase in O_2 /Ar ratio[51,52]. To increase the deposition, rate the energy used increases which increases the cost[42]. Ag is one of the most widely investigated dopants for TiO_2 photocatalyst[42]. In this research paper, the authors have coated the PET fabric with an Ag-Ag_2O-TiO_2 coating[42]. Initially, the PET fabric is coated with Ag by utilizing the DC magnetron sputtering over which a coating of Ag_2O is done by DC reactive sputtering[42]. Again, a layer of Ti is coated by using DC magnetron sputtering, and oxidation in the atmosphere oxidizes the Ti layer to TiO_2[42]. SEM morphology analysis along with XPS analysis was performed[42]. The photocatalytic degradation of the Rhodamine B was done and the rate was compared with that of TiO_2 coating[42]. The experimental results showed that Ag-Ag2O-TiO2-coated polyester fabric performed better than TiO2-coated polyester fabrics in the photocatalytic degradation of Rhodamine B, indicating that the Ag2O/TiO2 heterojunctions had a significant impact on the photocatalytic activities of Ag-Ag2O-TiO2-coated polyester fabrics[42]. This application of photocatalysis could be particularly helpful in the dye pollutant treatment[42].

The incorporation of newer properties into textile materials is increasing exponentially. Simultaneously, having properties like hydrophobicity, high flexibility, UV protection ability, electrical conductivity, photocatalytic activity, antibacterial activity, etc. in textiles have opened up applications in solar cells, photocatalysis, supercapacitors, and health[53–56]. Many of these coatings are prepared by dip-coating of textile fabrics with materials because of their advantages like reproducibility, high adhesion, and ease of scaling[57,58]. An important material that is widely recommended for such a wide range of applications is graphene which holds various qualities such as lightweight, high surface area, high transparency, high mechanical properties, compatibility, and excellent thermal properties[59–61]. Silver nanoparticles have attracted attention in their use in nanocomposites, electronics, and medical sectors[62,63]. In this research article, PET fabrics are coated with graphene, graphene oxide, and graphene/silver nanoparticles using the dip-coating method[64]. Various tests such as the XRD test, FT-IR spectroscopy test, Surface morphology using SEM, colour measurement test using CIE L*a*b* system, tensile strength test, elongation test, and the UV protection test were performed on the graphene, graphene oxide, and graphene/silver nanoparticle coated textile fabrics[64]. The final fabric contained excellent properties such as high flexibility, high stretchability, lightweight, and durability along with low electrical resistivity[64]. The UV protection factor increased drastically when silver nanoparticles were introduced into the fabric along with graphene[64]. Hence, it was finally found that these properties were more profound in graphene/silver nanoparticles than in other coatings[64].

The durable finishing of polyester fibre is difficult due to the presence of non-polar functional groups on the surface of the PET fibre[65] . This lack of functional groups to bind with the applied coating and the poor wettability of the PET fabric makes the role of a binder very important[66] . It has become important to have fabrics with multifunctionality like UV protection ability, self-cleaning ability, antimicrobial ability, photocatalytic properties, etc. Hence applying a coating of ZnO nanoparticles seemed to be the best available option[66] . There are 2 main approaches to immobilize the nanoparticles on the fabric surface one of which is the pre-synthesis of ZnO nanoparticles and then depositing them on the fabric, this is known as the ex-situ method[67] . The other method is the in-situ process in which the synthesis of the nanoparticle is done on the fabric itself in a one-step procedure[67] . In this paper the authors have used the in-situ synthesis method[66] . The surface of the PET fabric is depolymerized by aminolysis and to open the chain and give a hydroxyl and amino functional groups on the end which in turn would bind with the nanoparticles[66] . Triethanolamine (TEA) is used as the reagent that is capable of producing hydroxyl and amino functional groups by aminolysing the PET surface[68] . TEA is also required to provide an alkaline environment to produce the ZnO nanoparticles and is used as a capping agent that would monitor the size of the nanoparticles[68] . After the deposition of the ZnO nanoparticles the fabric was tested for its structural, UV protection ability, wettability, Self-cleaning ability, antibacterial ability, washing durability, strength and flexibility[66] . The prepared fabric gave better results than the PET fabric in all of the performed tests[66] .

There has been an increase in the application of electromagnetic waves in local networks, cell phones and radar systems in recent times[69,70] . This increases the problem of electromagnetic interference which can affect the functioning efficiency of various sensitive instruments[71,72] . The use of electromagnetic wave absorbers has been recommended to tackle this problem. As a result, producing garments that have electromagnetic wave absorbing properties has become more important. Carbonyl iron particle (CIP) is a conventional metallic magnetic loss absorber that is widely concerned due to its higher saturation magnetization and Snoke's limit[73,74] . Carbon black (CB) as a representative of the dielectric loss absorbers with small absorbance peak and narrow absorbance bandwidth[75] offers good dielectric loss with very low density[76] . In this research article, a polyester fabric with protective and magnetic properties is introduced using mixture of micro magnetic carbonyl iron powder and nano carbon black through the pad-dry-cure method and then sputter coating it with aluminium (Al) on one side[77] . The fabric was further analysed on the basis of morphology, X-ray diffraction, microwave absorbing properties and static magnetic properties[77] . The application of the mixture of NCB and CIP on the PET fabric enhanced the microwave absorbing properties in the range of 8.2– 12.4GHz enhancing RL value to _5.9 dB at the whole range of the tested frequency and the maximum RL achieved _7.7 dB at the frequency of 8.2 GHz[77] . Hence it was concluded that a coating of nano carbon black and carbonyl iron powder on PET fabric opens up another new application of X-band microwave absorbing properties[77] .

In another research article Ibrahim et al. performed research to develop multifunctional polyester fabric with diverse resilient properties by alkali pre-treatment to generate hydroxyl and carboxyl polar groups on the surface of the fabric as active centres and binding sites for nano-metal oxides, then eventually coating it with gelatin or polyacrylate as a binding agent and SiO_2, TiO_2, ZnO-NPs (MO-NPs) as functional materials[78] . The aim in this experiment was to find the best nanoparticle coating according to UV protection factor, antibacterial activity, self-cleaning ability, structural integrity, etc[78] . Initially these properties were tested for pre-treated and untreated PET fabrics[78] . It was determined that in every way the untreated fabric had weaker qualities than the pre-treated PET fabric[78] . Further, the impact of polyacrylate or gelatin as a binding agent in functional coating of pre-hydrolysed PET test specimens, as well as other paste components was determined[78] . Gelatin as a bio-binding chemical improved UV protection, antibacterial resistance, self-cleaning capability, and fabric stiffness and roughness, according to the research[78] . Then the 4 nanoparticles were tested for these properties. The fabric samples were influenced by the MO-NPs, according to the findings of the testing[78] . The following order was shown for the effect of the experiments by keeping the binding agent fixed:

UV protection functionality = TiO_2-NP > ZnO -NP >> SiO_2 -NP> ZrO_2 -NP >> Blank

Antibacterial Functionality = ZnO-NP > ZrO2-NP > TiO2-NP > SiO2-NP >> Blank

Self-Cleaning Efficiency = TiO2-NP > ZnO-NP >> SiO2-NP > ZrO2-NP >> Blank[78] . Hence it was finally concluded that a ZnO nanoparticle coating along with a gelatin binder showed a good overall[78] . As a result, it was determined that a ZnO nanoparticle coating in combination with a gelatin binder had good antibacterial, UV protection, and self-cleaning capabilities[78] .

We know that utilising magnetron sputtering to produce nano-film on the surface of textile materials allows them to have particular functions and increase their application range[79] . Cu coated fabrics are one of them, and they offer outstanding antibacterial, UV, electromagnetic shielding, and conductive qualities[80] . Zhang, Miao and co-workers in a study treated Cu-coated fabrics with a BTA(Benzotriazole) solution to improve the stability of copper film that was deposited on the fabric in synthetic perspiration[81] . Magnetron sputtering was used to deposit copper coatings with a thickness of 220 nm onto polyester fabrics[81] . Finishing agent BTA with concentrations of 0.1, 0.5, 1, 5, and 10 g/L were impregnated into Cu coated textiles[81] . The Cu-coated fabric's surface shape, electromagnetic shielding capability, FT-IR, UV absorption properties and conductivity were all studied in detail[81] . The BTA finishing is very efficient for Cu-coated fabrics to prevent sweat corrosion, as indicated in the results, and the optimal BTA concentration is 1 g/L[81] . After completing, the film displays no signs of perspiration corrosion and no discoloration[81] . The UV absorption capacity of fabrics treated with BTA increased as the concentration of BTA increased[81] . The BTA treatment for copper-coated fabrics has demonstrated to be an excellent protective strategy, which may enhance the use of copper-coated fabrics[81] .

In the development of electronic or e-textiles, selective metallisation of textiles is becoming increasingly significant [82]. To form e-textiles a non-conducting surface like PET is then electroless plated with Cu Strips that conduct electricity [82]. It has been observed that during washing, rubbing or in presence of sweat the Cu layer peels off [82]. Hence, it is necessary to coat the fabric. The effectiveness of polymer coatings for protecting copper (Cu) conductive tracks electroless plated on polyester (PES) fabric against laundering and rubbing was explored by Ojstršek, Virant and co-workers, without affecting the physical-mechanical and optical properties of the underlying material. The application of four regularly used polymers (polyurethane, acrylate, epoxy, and polydimethylsiloxane) to PES fabric and the subsequent characterization of the fabrics was studied. The goal was to examine the effect of individual coatings on the fabric's physical-mechanical properties, as well as the photo-stability of coatings under continuous UV irradiation, their abrasion resistance under rubbing and corrosion resistance against washing cycles. When compared to silicone elastomer, polydimethylsiloxane (PDMS) and epoxy resin, it was discovered that polyurethane resin (PUR) and modified acrylate resin (AR) had no effect on the air permeability, tensile strength, and breaking tenacity of the PES (ER). When compared to AR and ER, PUR and PDMS demonstrated greater abrasion resistance and photo-stability under sustained UV irradiation. PUR showed the best protection for Cu tracks on PES based on these findings, with the least influence on physical-mechanical qualities.

Decorative Coatings

The most popular textile materials are the fibres which are based on polyethylene terephthalate which is also known as polyester.[83] When PET filaments are blended with other yarns or fibres, in order to produce fabrics, the properties of the fabric changes and the final fabric will have beautiful decorative effects.[84] The process of coating of fabrics is a finishing process for textiles which improves many of its functions one of which is to improve the looks of the fabric and make it more attractive to the customer which is its decorative properties.

One of the methods to decorate the polyester fabrics is by coating metal on it. Metal coated fabrics are known as metallized fabrics. Metallized fabrics generally look more beautiful as those are more lustrous and reflect light. These reflective surfaces will offer great look to the polyester fabric which will attract the buyers in the marketplace. Metals such as Titanium, Aluminium, Stainless steel, Silver etc. are coated on the fabric to make it look attractive and enhance its other properties such as conduction. These are applied using various methods such as magnetron sputtering method, vacuum decomposition method.[85] The plating of products with a metal surface is not an easy process especially for the products in marketable form or the products that are made from plastic and hence the process of deploying a decorative coating for metallization of products is generally done by a method known as the magnetron sputtering method. In this method, the ionic-magnetron deposition can be operated optimally by bombarding ions at 3KeV of Argon energy for a duration of 5 minutes and at a pressure of around 4 to 4.5 Pa while at the power discharge capacity of the magnetron 10.5 KW and the pressure kept at 6.5×10^{-2} Pa, the deposition will take place for 10 minutes. As the discharge capacity of the magnetron increases, the deposition rate of coatings increases as well. The metallization of polymer surfaces has some challenges such as bad adhesiveness of metal films in the deprivation of superficial active bonds of the polymer. The adhesive properties can be improvised by forming on a surface of hydrophilic groups of several chemical natures. The adhesiveness of coatings can be increased by activating the polymeric surface of a material. The most popular method for metallization in vacuum technologies is that the process is made to take place in glow discharge of gas phase.[86]

Lanthanum hexaboride (LaB_6) is used at a large scale to coat the polyester fabrics due to many of its applications, one of which is that it acts as a decorative coating.[87,88] For our study, we take Poly Trilobal which is a kind of PET textile for being a substrate material which will help in making of the LaB_6 films. For coating nanostructured LaB_6 films on the flexible Poly Trilobal substrates of PET textiles, we need to carry out magnetron sputtering in the presence of a direct current which will act as a decorative coating and also will increase the polyester fabrics applications. The LaB_6 grains can be coated more easily by simply increasing the sputtering pressure. The deposition of nanostructure layer or layers on textiles can be done by many processes such as chemical plating, physical vapor deposition, in situ synthesis but the most widely used process still remains the magnetron sputtering deposition technology as it is useful for a large-scale preparation and has distinct advantages.[89]

Silver is another such metal which is metallizes on cotton and polyester fabrics. Silver, when metallized on the fabric, gives a unique look to the fabric and it has a great usage in the garment industry. Conventionally, chemical plating (which is an autocatalytic decomposition process) is used for the work which involves precision during the manufacture process. The recent developments in coating polyester fabrics with silver will definitely provide an enhanced tactile quality and an aesthetic appearance.[85] Polyester fabrics can also be coated with silver by the usage of a patented silver deposition method which was found out by a firm named Silvertech Ltd. The process of depositing silver is done UV reduction of a silver salt which is made to dissolve in a solution which is alcoholic and hence this solution will be used to impregnate the yarns.[90]

Copper is mostly coated on polyester fabrics to increase its conductivity but it also enhances the fabric's looks. In one of the recent investigations, electroless copper was metallized on polyester fabrics. It was plated by using $AgNO_3$ activator instead of the conventional $PdCl_2$ activator in order to reduce the plating process cost. The process of coating copper is electrochemical in nature.[91]

The materials that smartly respond to presence of an external environmental change such as humidity, pH, temperature, etc. by showing a visual colour change have developed a lot of interest for the researchers. The research work in this field has been bit slow because there are only a limited number of mechanisms available. When the decolouration takes place due to the changes in humidity, this decolouration is known as the humidity sensitive discolouration process and the material is known as humidity sensitive discolouration material. Proton transfer takes place with induction of a stimulus and the colour changes during the humidity induced pH discolouration process. With the increase in humidity, the polyester fabric will change its colour in many ways and the absorption will peak at 440nm-520nm even further to 550nm from 430nm in the visible light range of CRP and TBP. It is only after 25 cycles that a consistent performance in the discolouration process in the moisture absorption/drying is observed. The removal of the cresol red/thymol blue colour can be affected by Boric acid as it adjusts the system's pH while the system's humidity is changing.[92]

The property of a semiconductor material which pertains to light emission while responding to a strong electric field or an electric current is known as Electroluminescence (EL). Our sole purpose is to obtain a flexible and a lightweight EL device and in order to achieve that we do the following: Polyester fabric is coated with Poly(3,4-ethylenedioxythiophene):Poly(styrene sulfonic acid)-PEDOT:PSS-with ethylene glycol(EG) and in which NinjaFlex is being placed on the coated fabric by using a paste of phosphor and three dimensional printing. The thermal degradation behaviour of NinjaFlex was observed by conducting a Thermogravimetric analysis (TGA). A uniform surface appearance of the coated fabric is obtained. A huge number of decorative applications can be achieved using this particular coated polyester fabric such as entertainment, advertisements, nightlife industries, etc. And this will come under a category of decorative luminescent clothing and also other light emitting devices.[93]

People around the world are changing their aesthetical concepts because of which the coatings with a low gloss are grabbing more attention of the people. The low gloss coatings are widely loved due to their elegant yet simple appearance to the eyes. The low gloss coatings are divided into sub categories such as solvent based coatings, powder coatings and water-based coatings. We know that low gloss waterborne polyurethane (WPU) are single functional coatings and they do not meet the required environment for the complex applications. A special spraying device is used for powder coating which is very expensive and complicated whereas, the water-based coating technology easily achieves the low gloss with very minimum or no VOCs and it is also environment friendly.[94]

Metallic colouring has been achieved using vacuum evaporation dry coating with silver (Ag) or aluminium (Al) films, or wet coating metal film with metal powder. However, these two methods are not suitable for metallic coloration on textile fabric because vacuum evaporation with high temperature steaming is not suitable for textile with a low melting point, and wet coating fabrication produces significant pollution while the film layer is easily peeled off, causing the metal lustre formed to be not homogeneous and the colour unstable. Copper (Cu) is commonly utilised in conductive materials because it is less resistant than aluminium (Al) and less expensive than silver (Ag)[95–97]. In another study, Huang, Cai, and colleagues used a magnetron sputtering approach at room temperature to deposit copper films and copper oxide films on polyester fabrics to produce diverse colours on textile fabrics[98]. This research proposes an innovative method of avoiding the use of typical chemical colouring[98]. This research article discusses the colouring mechanism, the effect of sputtering parameters, and pertinent physical features[98]. The colour brightness of the coated fabrics is regulated by the copper/copper-oxide film thickness, which increases as the sputtering current increases, and the film thickness is governed by the sputtering current when no other parameters are modified[98]. Thus, by varying the sputtering current, multiple colours can be achieved. Colour fastness ratings range from 1 to 5, with higher grades indicating better colour fastness[98]. After testing, the colour fastness of both the dry and wet rubbing for copper oxide-coated fabrics is greater than 3, indicating good colour fastness[98]. Even the UPF of copper oxide-coated fabrics is significantly higher than that of blank uncoated cloth (Picture). As a result, an effective method for sputtering metal film or metal oxide film on the surface of textile textiles to generate absorption colour was described[98].

Similarly, Huang, Wu, and coworkers created metallic colours and diverse functions on polyester woven fabrics coated with a single layer of copper nitride films (CuN) and titanium nitride films (TiN) via nitriding reactive direct current (DC) magnetron sputtering at ambient temperature[99]. Copper nitride (CuN) films are dielectric materials having a high resistivity. They are brown-red or tan in colour at ambient temperature, nontoxic, and stable[100]. Titanium nitride (TiN) is an excellent thermoelectric conductor with a mature and stable fabrication technique, a low cost, and excellent corrosion resistance[101,102]. The authors investigated the relationship between the colour of the film and its micro/nanostructure, surface morphology, thickness, crystal structure, composition, electrical and static resistance, ultraviolet protection, and breathability.[99]. Light grey to pale yellow colours were obtained in this investigation, which were absorption colours rather than structural colours[99]. The layer thickness of the samples increased as the sputtering current increased; the absorption of visible light increased as the reflectivity decreased[99]. The composition and content proportion of the film impacted the hue of the samples, whereas the crystalline state, surface morphology, and bandgap of the films affected the absorption and reflection of visible light[99]. It was discovered that varied colours could only be obtained by varying the sputtering current. It was discovered that changing the sputtering current had no effect on the crystallisation and grain size of the films[99]. Crystallinity and particle size do not differ much between films, and their impact on film colour is minimal. The ultraviolet (UV) protection performance of the CuN series samples is much better than that of the immaculate fabric. According to the article, increasing sputtering current and film thickness enhances UPF while decreasing UVA transmission[99].

Conclusion

The textile industry has been exploring advanced materials through surface modification of textile fabrics to enhance their functionality. Novel processes like as electrospinning, the layer-by-layer approach, and electrodepositing have received a lot of interest in the industry. Researchers have endeavoured to develop materials having multifunctional qualities that are also eco-friendly in nature. A recent rise in research into specifically coated polyester textiles may be motivated by a growing need for textiles with better performance features in a range of applications such as sports and outdoor gear, medical textiles, and electronic textiles. Businesses have realised the true potential of coated fabrics and their widespread use in construction, automobile, medical, architecture, etc. Despite recent advances in coated fabrics, there is a growing need for research in the field of coated textiles because there are still numerous opportunities to improve the performance properties of coated textiles and develop new applications for these materials. Introducing newer coating technologies, developing sustainable coatings, developing multifunctional textiles employing specialised coating processes, and developing smart textiles are just a few of the areas where newer research is required. In conclusion, the topic of coated textiles provides a lot of development potential and research prospects. Coated textiles is an interesting rapidly expanding sector, and more study would not only lead to the creation of more sophisticated materials and technologies, but also to the enhancement of the production techniques used to apply coatings to textiles. This would allow for the creation of more efficient and cost-effective manufacturing methods capable of producing textiles with improved performance qualities. This would not only assist many businesses but would also contribute to overall technological development and sustainability.

References

(1) Tian, M.; Hu, X.; Qu, L.; Du, M.; Zhu, S.; Sun, Y.; Han, G. Ultraviolet Protection Cotton Fabric Achieved via Layer-by-Layer Self-Assembly of Graphene Oxide and Chitosan. *Appl Surf Sci* **2016**, *377*, 141–148. https://doi.org/10.1016/j.apsusc.2016.03.183.

(2) Tian, M.; Hu, X.; Qu, L.; Zhu, S.; Sun, Y.; Han, G. Versatile and Ductile Cotton Fabric Achieved via Layer-by-Layer Self-Assembly by Consecutive Adsorption of Graphene Doped PEDOT: PSS and Chitosan. *Carbon N Y* **2016**, *96*, 1166–1174. https://doi.org/10.1016/j.carbon.2015.10.080.

(3) Pant, H. R.; Bajgai, M. P.; Nam, K. T.; Seo, Y. A.; Pandeya, D. R.; Hong, S. T.; Kim, H. Y. Electrospun Nylon-6 Spider-Net like Nanofiber Mat Containing TiO2 Nanoparticles: A Multifunctional Nanocomposite Textile Material. *J Hazard Mater* **2011**, *185* (1), 124–130. https://doi.org/10.1016/j.jhazmat.2010.09.006.

(4) Chang, W.; Xu, F.; Mu, X.; Ji, L.; Ma, G.; Nie, J. Fabrication of Nanostructured Hollow TiO2 Nanofibers with Enhanced Photocatalytic Activity by Coaxial

Electrospinning. *Mater Res Bull* **2013**, *48* (7), 2661–2668. https://doi.org/10.1016/j.materresbull.2013.03.035.

(5) Pasta, M.; Hu, L.; la Mantia, F.; Cui, Y. Electrodeposited Gold Nanoparticles on Carbon Nanotube-Textile: Anode Material for Glucose Alkaline Fuel Cells. *Electrochem commun* **2012**, *19* (1), 81–84. https://doi.org/10.1016/j.elecom.2012.03.019.

(6) Pongsathit, S.; Chen, S. Y.; Rwei, S. P.; Pattamaprom, C. Eco-Friendly High-Performance Coating for Polyester Fabric. *J Appl Polym Sci* **2019**, *136* (39). https://doi.org/10.1002/app.48002.

(7) Nguyen, T. T. N.; Chen, Y. H.; Chen, M. Y.; Cheng, K. B.; He, J. L. Multifunctional Ti-O Coatings on Polyethylene Terephthalate Fabric Produced by Using Roll-to-Roll High Power Impulse Magnetron Sputtering System. *Surf Coat Technol* **2017**, *324*, 249–256. https://doi.org/10.1016/j.surfcoat.2017.05.082.

(8) Murray, J. L. The O-Ti (Oxygen-Titanium) System. *Bulletin of Alloy Phase Diagrams* **1987**, *8* (2), 165.

(9) Alam, M. J.; Cameron, D. C. *Preparation and Characterization of TiO 2 Thin Films by Sol-Gel Method*; 2002; Vol. 25.

(10) Fan, X.; Feng, B.; Di, Y.; Lu, X.; Duan, K.; Wang, J.; Weng, J. Preparation of Bioactive TiO Film on Porous Titanium by Micro-Arc Oxidation. *Appl Surf Sci* **2012**, *258* (19), 7584–7588. https://doi.org/10.1016/j.apsusc.2012.04.093.

(11) Maruyama, T.; Arai, S. *Titanium Dioxide Thin Films Prepared by Chemical Vapor Deposition*; 1992; Vol. 26.

(12) Zribi, M.; Kanzari, M.; Rezig, B. Structural, Morphological and Optical Properties of Thermal Annealed TiO Thin Films. *Thin Solid Films* **2008**, *516* (7), 1476–1479. https://doi.org/10.1016/j.tsf.2007.07.195.

(13) Bally, ´ A R; Hones, P.; Sanjines, R.; Schmid, P. E.; Levy´´, F. *Mechanical and Electrical Properties of Fcc TiO Thin Films Prepared by 11x r.f. Reactive Sputtering*; 1998; Vol. 108.

(14) Li, Z. G.; Miyake, S.; Makino, M.; Wu, Y. X. Microstructure and Properties of Nanocrystalline Titanium Monoxide Films Synthesized by Inductively Coupled Plasma Assisted Reactive Direct Current Magnetron Sputtering. *Appl Surf Sci* **2008**, *255* (5 PART 1), 2370–2374. https://doi.org/10.1016/j.apsusc.2008.07.108.

(15) Twu, M. J.; Chiou, A. H.; Hu, C. C.; Hsu, C. Y.; Kuo, C. G. Properties of TiO2 Films Deposited on Flexible Substrates Using Direct Current Magnetron Sputtering and Using High Power Impulse Magnetron Sputtering. *Polym Degrad Stab* **2015**, *117*, 1–7. https://doi.org/10.1016/j.polymdegradstab.2015.03.010.

(16) Qi H. Morphology and Discharge Parameter Dependence of Property and Structure of RF Sputter-Deposited Fluorocarbon Coatings on PET Fibers. *SEN'I GAKKAISHI* **2003**, *59* (9).

(17) Jiang, S. X.; Qin, W. F.; Guo, R. H.; Zhang, L. Surface Functionalization of Nanostructured Silver-Coated Polyester Fabric by Magnetron Sputtering. *Surf Coat Technol* **2010**, *204* (21–22), 3662–3667. https://doi.org/10.1016/j.surfcoat.2010.04.042.

(18) S. X. Jiang. Characteristics of Silver-Plated Silk Fabric with Plasma Pre-Treatment. *Fibers and Polymers* **2009**, *10* (6), 791–796.

(19) Jiang, S. Q.; Newton, E.; Yuen, C. W. M.; Kan, C. W. Chemical Silver Plating on Polyester/Cotton Blended Fabric. *J Appl Polym Sci* **2006**, *100* (6), 4383–4387. https://doi.org/10.1002/app.23895.

(20) Wang, H.; Wang, J.; Hong, J.; Wei, Q.; Gao, W.; Zhu, Z. Preparation and Characterization of Silver Nanocomposite Textile. *J Coat Technol Res* **2007**, *4* (1), 101–106. https://doi.org/10.1007/s11998-007-9001-8.

(21) Perelshtein, I.; Applerot, G.; Perkas, N.; Guibert, G.; Mikhailov, S.; Gedanken, A. Sonochemical Coating of Silver Nanoparticles on Textile Fabrics (Nylon, Polyester and Cotton) and Their

Antibacterial Activity. *Nanotechnology* **2008**, *19* (24). https://doi.org/10.1088/0957-4484/19/24/245705.

(22) Morones, J. R.; Elechiguerra, J. L.; Camacho, A.; Holt, K.; Kouri, J. B.; Ramírez, J. T.; Yacaman, M. J. The Bactericidal Effect of Silver Nanoparticles. *Nanotechnology* **2005**, *16* (10), 2346–2353. https://doi.org/10.1088/0957-4484/16/10/059.

(23) Sondi, I.; Salopek-Sondi, B. Silver Nanoparticles as Antimicrobial Agent: A Case Study on E. Coli as a Model for Gram-Negative Bacteria. *J Colloid Interface Sci* **2004**, *275* (1), 177–182. https://doi.org/10.1016/j.jcis.2004.02.012.

(24) Henglein, A. *Physicochemical Properties of Small Metal Particles in Solution: "Microelectrode" Reactions, Chemisorption, Composite Metal Particles, and the Atom-to-Metal Transition*; 1993; Vol. 97.

(25) Henglein, A. Colloidal Silver Nanoparticles: Photochemical Preparation and Interaction with O 2 , CCl 4 , and Some Metal Ions. *Chem. Mat*. **1998**, *10*, 444–450.

(26) Lee, H. J.; Yeo, S. Y.; Jeong, S. H. Antibacterial Effect of Nanosized Silver Colloidal Solution on Textile Fabrics. *Journal of Material Sciences* **2003**, *38*, 2199–2204.

(27) Gedanken, A. Using Sonochemistry for the Fabrication of Nanomaterials. *Ultrasonics Sonochemistry*. Elsevier 2004, pp 47–55. https://doi.org/10.1016/j.ultsonch.2004.01.037.

(28) Pol, V. G.; Wildermuth, G.; Felsche, J.; Gedanken, A.; Calderon-Moreno, J. Sonochemical Deposition of Au Nanoparticles on Titania and the Significant Decrease in the Melting Point of Gold. *J Nanosci Nanotechnol* **2005**, *5* (6), 975–979. https://doi.org/10.1166/jnn.2005.137.

(29) Pol, V. G.; Srivastava, D. N.; Palchik, O.; Palchik, V.; Slifkin, M. A.; Weiss, A. M.; Gedanken, A. Sonochemical Deposition of Silver Nanoparticles on Silica Spheres. *Langmuir* **2002**, *18* (8), 3352–3357. https://doi.org/10.1021/la0155552.

(30) Yuan, X.; Xu, W.; Huang, F.; Chen, D.; Wei, Q. Polyester Fabric Coated with Ag/ZnO Composite Film by Magnetron Sputtering. *Appl Surf Sci* **2016**, *390*, 863–869. https://doi.org/10.1016/j.apsusc.2016.08.164.

(31) Wu, F.; Tian, L.; Kanjolia, R.; Singamaneni, S.; Banerjee, P. Plasmonic Metal-to-Semiconductor Switching in Au Nanorod-ZnO Nanocomposite Films. *ACS Appl Mater Interfaces* **2013**, *5* (16), 7693–7697. https://doi.org/10.1021/am402309x.

(32) Chubenko, E. B.; Redko, S. v.; Sherstnyov, A. I.; Petrovich, V. A.; Kotov, D. A.; Bondarenko, V. P. Influence of the Surface Layer on the Electrochemical Deposition of Metals and Semiconductors into Mesoporous Silicon. *Semiconductors* **2016**, *50* (3), 372–376. https://doi.org/10.1134/S1063782616030040.

(33) Olekhno, N. A.; Beltukov, Y. M.; Parshin, D. A. A Theory of Spectral Properties of Disordered Metal-Semiconductor Nanocomposites. In *Journal of Physics: Conference Series*; Institute of Physics Publishing, 2015; Vol. 643. https://doi.org/10.1088/1742-6596/643/1/012118.

(34) Majumder, S.; Jana, S. K.; Bagani, K.; Satpati, B.; Kumar, S.; Banerjee, S. Fluorescence Resonance Energy Transfer and Surface Plasmon Resonance Induced Enhanced Photoluminescence and Photoconductivity Property of Au-TiO2 Metal-Semiconductor Nanocomposite. *Opt Mater (Amst)* **2015**, *40*, 97–101. https://doi.org/10.1016/j.optmat.2014.12.001.

(35) Bazant, P.; Kuritka, I.; Munster, L.; Kalina, L. Microwave Solvothermal Decoration of the Cellulose Surface by Nanostructured Hybrid Ag/ZnO Particles: A Joint XPS, XRD and SEM Study. *Cellulose* **2015**, *22* (2), 1275–1293. https://doi.org/10.1007/s10570-015-0561-y.

(36) Wang, Y. F.; Yao, J. H.; Jia, G.; Lei, H. Optical Prosperities of Ag-ZnO Composition Nanofilm Synthesized by Chemical Bath Deposition. *Acta Phys Pol A* **2011**, *119* (3).

(37) Thongsuriwong, K.; Amornpitoksuk, P.; Suwanboon, S. Photocatalytic and Antibacterial Activities of Ag-Doped ZnO Thin Films Prepared by a Sol-Gel Dip-Coating Method. *J Solgel Sci Technol* **2012**, *62* (3), 304–312. https://doi.org/10.1007/s10971-012-2725-7.

(38) Lu, W.; Gao, S.; Wang, J. One-Pot Synthesis of Ag/ZnO Self-Assembled 3D Hollow Microspheres with Enhanced Photocatalytic Performance. *Journal of Physical Chemistry C* **2008**, *112* (43), 16792–16800. https://doi.org/10.1021/jp803654k.

(39) Wang, J.; Fan, X. M.; Zhou, Z. W.; Tian, K. Preparation of Ag Nanoparticles Coated Tetrapod-like ZnO Whisker Photocatalysts Using Photoreduction. *Mater Sci Eng B Solid State Mater Adv Technol* **2011**, *176* (13), 978–983. https://doi.org/10.1016/j.mseb.2011.05.027.

(40) Sánchez Zeferino, R.; Barboza Flores, M.; Pal, U. Photoluminescence and Raman Scattering in Ag-Doped Zno Nanoparticles. *J Appl Phys* **2011**, *109* (1). https://doi.org/10.1063/1.3530631.

(41) Kim, K.; Lee, D. H.; Lee, S. Y.; Jang, G. E.; Kim, J. S. Effect of Ag/Al Co-Doping Method on Optically p-Type ZnO Nanowires Synthesized by Hot-Walled Pulsed Laser Deposition. *Nanoscale Res Lett* **2012**, *7*. https://doi.org/10.1186/1556-276X-7-273.

(42) Yu, H. L.; Wu, Q. X.; Wang, J.; Liu, L. Q.; Zheng, B.; Zhang, C.; Shen, Y. G.; Huang, C. L.; Zhou, B.; Jia, J. R. Simple Fabrication of the Ag-Ag2O-TiO2 Photocatalyst Thin Films on Polyester Fabrics by Magnetron Sputtering and Its Photocatalytic Activity. *Appl Surf Sci* **2020**, *503*. https://doi.org/10.1016/j.apsusc.2019.144075.

(43) Dastjerdi, R.; Montazer, M. A Review on the Application of Inorganic Nano-Structured Materials in the Modification of Textiles: Focus on Anti-Microbial Properties. *Colloids and Surfaces B: Biointerfaces*. August 2010, pp 5–18. https://doi.org/10.1016/j.colsurfb.2010.03.029.

(44) Li, S.; Huang, J.; Chen, Z.; Chen, G.; Lai, Y. A Review on Special Wettability Textiles: Theoretical Models, Fabrication Technologies and Multifunctional Applications. *J Mater Chem A Mater* **2017**, *5* (1), 31–55. https://doi.org/10.1039/c6ta07984a.

(45) Bozzi, A.; Yuranova, T.; Guasaquillo, I.; Laub, D.; Kiwi, J. Self-Cleaning of Modified Cotton Textiles by TiO2 at Low Temperatures under Daylight Irradiation. *J Photochem Photobiol A Chem* **2005**, *174* (2), 156–164. https://doi.org/10.1016/j.jphotochem.2005.03.019.

(46) Cedillo-González, E. I.; Riccò, R.; Montorsi, M.; Montorsi, M.; Falcaro, P.; Siligardi, C. Self-Cleaning Glass Prepared from a Commercial TiO2 Nano-Dispersion and Its Photocatalytic Performance under Common Anthropogenic and Atmospheric Factors. *Build Environ* **2014**, *71*, 7–14. https://doi.org/10.1016/j.buildenv.2013.09.007.

(47) Hidaka, H.; Asai, Y.; Zhao, J.; Nohara, K.; Pelizzetti, E.; Serponeg, N. *Photoelectrochemical Decomposition of Surfactants on a TiOflCO Particulate Film Electrode Assembly*; 1995; Vol. 99.

(48) Wang, Q.; Wang, X.; Li, X.; Cai, Y.; Wei, Q. Surface Modification of PMMA/O-MMT Composite Microfibers by TiO 2 Coating. *Appl Surf Sci* **2011**, *258* (1), 98–102. https://doi.org/10.1016/j.apsusc.2011.08.013.

(49) Parkin, I. P.; Palgrave, R. G. Self-Cleaning Coatings. *Journal of Materials Chemistry*. May 7, 2005, pp 1689–1695. https://doi.org/10.1039/b412803f.

(50) Tung, W. S.; Daoud, W. A. Photocatalytic Self-Cleaning Keratins: A Feasibility Study. *Acta Biomater* **2009**, *5* (1), 50–56. https://doi.org/10.1016/j.actbio.2008.08.009.

(51) Sproul, W. D.; Graham, M. E.; Wong, M.-S.; Rudnik, P. J. *Reactive d.c. Magnetron Sputtering of the Oxides of Ti, Zr, and Hfl*; 1997; Vol. 89.

(52) Martin, N.; Baretti, D.; Rousselot, C.; Rauch, J.-Y. *The Effect of Bias Power on Some Properties of Titanium and Titanium*

Oxide Films Prepared by r.f. Magnetron Sputtering; 1998; Vol. 107.

(53) Qi, J.; Xu, X.; Liu, X.; Lau, K. T. Fabrication of Textile Based Conductometric Polyaniline Gas Sensor. *Sens Actuators B Chem* **2014**, *202*, 732–740. https://doi.org/10.1016/j.snb.2014.05.138.

(54) Jiang, X.; Tian, X.; Gu, J.; Huang, D.; Yang, Y. Cotton Fabric Coated with Nano TiO 2 -Acrylate Copolymer for Photocatalytic Self-Cleaning by in-Situ Suspension Polymerization. *Appl Surf Sci* **2011**, *257* (20), 8451–8456. https://doi.org/10.1016/j.apsusc.2011.04.128.

(55) Xue, C. H.; Chen, J.; Yin, W.; Jia, S. T.; Ma, J. Z. Superhydrophobic Conductive Textiles with Antibacterial Property by Coating Fibers with Silver Nanoparticles. *Appl Surf Sci* **2012**, *258* (7), 2468–2472. https://doi.org/10.1016/j.apsusc.2011.10.074.

(56) Bedeloglu, A.; Demir, A.; Bozkurt, Y.; Sariciftci, N. S. A Flexible Textile Structure Based on Polymeric Photovoltaics Using Transparent Cathode. *Synth Met* **2009**, *159* (19–20), 2043–2048. https://doi.org/10.1016/j.synthmet.2009.07.019.

(57) Yamashita, T.; Takamatsu, S.; Miyake, K.; Itoh, T. Fabrication and Evaluation of a Conductive Polymer Coated Elastomer Contact Structure for Woven Electronic Textile. *Sens Actuators A Phys* **2013**, *195*, 213–218. https://doi.org/10.1016/j.sna.2012.09.002.

(58) Prasad, V.; Arputharaj, A.; Bharimalla, A. K.; Patil, P. G.; Vigneshwaran, N. Durable Multifunctional Finishing of Cotton Fabrics by in Situ Synthesis of Nano-ZnO. *Appl Surf Sci* **2016**, *390*, 936–940. https://doi.org/10.1016/j.apsusc.2016.08.155.

(59) Papageorgiou, D. G.; Kinloch, I. A.; Young, R. J. Mechanical Properties of Graphene and Graphene-Based Nanocomposites. *Progress in Materials Science*. Elsevier Ltd October 1, 2017, pp 75–127. https://doi.org/10.1016/j.pmatsci.2017.07.004.

(60) Novoselov, K. S.; Geim, A. K.; Morozov, S. v.; Jiang, D.; Katsnelson, M. I.; Grigorieva, I. v.; Dubonos, S. v.; Firsov, A. A. Two-Dimensional Gas of Massless Dirac Fermions in Graphene. *Nature* **2005**, *438* (7065), 197–200. https://doi.org/10.1038/nature04233.

(61) Novoselov, K. S.; Geim, A. K.; Morozov, S. v.; Jiang, D.; Zhang, Y.; Dubonos, S. v.; Grigorieva, I. v.; Firsov, A. A. Electric Field in Atomically Thin Carbon Films. *Science (1979)* **2004**, *306* (5696), 666–669. https://doi.org/10.1126/science.1102896.

(62) Li, Y.; Wu, Y.; Ong, B. S. Facile Synthesis of Silver Nanoparticles Useful for Fabrication of High-Conductivity Elements for Printed Electronics. *J Am Chem Soc* **2005**, *127* (10), 3266–3267. https://doi.org/10.1021/ja043425k.

(63) Lee, J. M.; Lee, Y. G.; Kim, D. W.; Oh, C.; Koo, S. M.; Oh, S. G. Facile and Novel Route for Preparation of Silica/Silver Heterogeneous Composite Particles with Hollow Structure. *Colloids Surf A Physicochem Eng Asp* **2007**, *301* (1–3), 48–54. https://doi.org/10.1016/j.colsurfa.2006.12.020.

(64) Ouadil, B.; Cherkaoui, O.; Safi, M.; Zahouily, M. Surface Modification of Knit Polyester Fabric for Mechanical, Electrical and UV Protection Properties by Coating with Graphene Oxide, Graphene and Graphene/Silver Nanocomposites. *Appl Surf Sci* **2017**, *414*, 292–302. https://doi.org/10.1016/j.apsusc.2017.04.068.

(65) Bech, L.; Meylheuc, T.; Lepoittevin, B.; Roger, P. Chemical Surface Modification of Poly(Ethylene Terephthalate) Fibers by Aminolysis and Grafting of Carbohydrates. *J Polym Sci A Polym Chem* **2007**, *45* (11), 2172–2183. https://doi.org/10.1002/pola.21983.

(66) Poortavasoly, H.; Montazer, M.; Harifi, T. Aminolysis of Polyethylene Terephthalate Surface along with in Situ Synthesis and Stabilizing ZnO Nanoparticles Using Triethanolamine Optimized with Response Surface Methodology. *Materials Science and Engineering C* **2016**, *58*, 495–503. https://doi.org/10.1016/j.msec.2015.08.065.

(67) Montazer, M.; Amiri, M. M.; Mohammad Ali Malek, R. In Situ Synthesis and Characterization of Nano ZnO on Wool: Influence of Nano Photo Reactor on Wool Properties. *Photochem Photobiol* **2013**, *89* (5), 1057–1063. https://doi.org/10.1111/php.12090.

(68) Singh, A. Synthesis, Characterization, Electrical and Sensing Properties of ZnO Nanoparticles. In *Advanced Powder Technology*; 2010; Vol. 21, pp 609–613. https://doi.org/10.1016/j.apt.2010.02.002.

(69) Sugimoto. S. GHz Microwave Absorption of a Fine α-Fe Structure Produced by the Disproportionation of Sm 2Fe 17 in Hydrogen. *Journal of Alloys and Compunds* **2002**, *330* (332), 301–306.

(70) Xiang, J.; Chu, Y.; Zhang, X.; Shen, X. Magnetic and Microwave Absorption Properties of Electrospun Co 0.5 Ni 0.5 Fe 2 O 4 Nanofibers. *Appl Surf Sci* **2012**, *263*, 320–325. https://doi.org/10.1016/j.apsusc.2012.09.052.

(71) Liu, X.; Zhang, Z.; Wu, Y. Absorption Properties of Carbon Black/Silicon Carbide Microwave Absorbers. *Compos B Eng* **2011**, *42* (2), 326–329. https://doi.org/10.1016/j.compositesb.2010.11.009.

(72) Aïssa, B.; Tabet, N.; Nedil, M.; Therriault, D.; Rosei, F.; Nechache, R. Electromagnetic Energy Absorption Potential and Microwave Heating Capacity of SiC Thin Films in the 1-16 GHz Frequency Range. *Appl Surf Sci* **2012**, *258* (14), 5482–5485. https://doi.org/10.1016/j.apsusc.2012.02.047.

(73) Li, W. P.; Zhu, L. Q.; Gu, J.; Liu, H. C. Microwave Absorption Properties of Fabric Coated Absorbing Material Using Modified Carbonyl Iron Power. *Compos B Eng* **2011**, *42* (4), 626–630. https://doi.org/10.1016/j.compositesb.2011.02.019.

(74) Qin, H.; Liao, Q.; Zhang, G.; Huang, Y.; Zhang, Y. Microwave Absorption Properties of Carbon Black and Tetrapod-like ZnO Whiskers Composites. *Appl Surf Sci* **2013**, *286*, 7–11. https://doi.org/10.1016/j.apsusc.2013.08.078.

(75) Dishovsky, N.; Grigorova, M. On the Correlation between Electromagnetic Waves Absorption and Electrical Conductivity of Carbon Black Filled Polyethylenes. *Mater Res Bull* **2000**, *35*, 403–409.

(76) Yuping, D.; Guangli, W.; Shuchao, G.; Shuqing, L.; Guojia, M. Study on Microwave Absorbing Properties of Carbonyl-Iron Composite Coating Based on PVC and Al Sheet. *Appl Surf Sci* **2012**, *258* (15), 5746–5752. https://doi.org/10.1016/j.apsusc.2012.02.082.

(77) Simayee, M.; Montazer, M. A Protective Polyester Fabric with Magnetic Properties Using Mixture of Carbonyl Iron and Nano Carbon Black along with Aluminium Sputtering. *Journal of Industrial Textiles* **2018**, *47* (5), 674–685. https://doi.org/10.1177/1528083716667261.

(78) Ibrahim, N. A.; Eid, B. M.; Khalil, H. M.; Almetwally, A. A. A New Approach for Durable Multifunctional Coating of PET Fabric. *Appl Surf Sci* **2018**, *448*, 95–103. https://doi.org/10.1016/j.apsusc.2018.04.022.

(79) Rani, K. V.; Sarma, B.; Sarma, A. Plasma Sputtering Process of Copper on Polyester/Silk Blended Fabrics for Preparation of Multifunctional Properties. *Vacuum* **2017**, *146*, 206–215. https://doi.org/10.1016/j.vacuum.2017.09.036.

(80) Jiang, S.; Miao, D.; Li, A.; Guo, R.; Shang, S. Adhesion and Durability of Cu Film on Polyester Fabric Prepared by Finishing Treatment with Polyester-Polyurethane and Aqueous Acrylate. *Fibers and Polymers* **2016**, *17* (9), 1397–1402. https://doi.org/10.1007/s12221-016-6254-9.

(81) Zhang, X.; Miao, D.; Ning, X.; Cai, M.; Tian, Y.; Zhao, H.; Jiang, S. The Stability Study of Copper Sputtered Polyester Fabrics in Synthetic Perspiration. *Vacuum* **2019**, *164*, 205–211. https://doi.org/10.1016/j.vacuum.2019.03.023.

(82) Ojstršek, A.; Virant, N.; Fox, D.; Krishnan, L.; Cobley, A. The Efficacy of Polymer Coatings for the Protection of Electroless Copper Plated Polyester Fabric. *Polymers (Basel)* **2020**, *12* (6). https://doi.org/10.3390/POLYM12061277.

(83) Prorokova, N. P.; Kumeeva, T. Y.; Kiryukhin, D. P.; Kichigina, G. A.; Kushch, P. P. Coatings Based on Tetrafluoroethylene Telomeres Synthesized in Trimethylchlorosilane for Obtaining Highly Hydrophobic Polyester Fabrics. *Prog Org Coat* **2020**, *139* (December 2019), 105485. https://doi.org/10.1016/j.porgcoat.2019.105485.

(84) Lai, K.; Sun, R. J.; Chen, M. yu; wu, H.; Zha, an X. Electromagnetic Shielding Effectiveness of Fabrics with Metallized Polyester Filaments. *Textile Research Journal* **2007**, *77* (4), 242–246. https://doi.org/10.1177/0040517507074033.

(85) Jiang, S. Q.; Newton, E.; Yuen, C. W. M.; Kan, C. W. Chemical Silver Plating on Cotton and Polyester Fabrics and Its Application on Fabric Design. *Textile Research Journal* **2006**, *76* (1), 57–65. https://doi.org/10.1177/0040517506053827.

(86) Yanovskii, V. P.; Kuzmin, O. S. Vacuum Installation of Magnetron Deposition of Decorative Coatings. *8* (3822), 2–4.

(87) Mitterer, C.; Stri, P. S. H. XUIifACE C 4TINGS Decorative Boride Coatings Based on LaB. *Surf Coat Technol* **1995**, *75*, 1020–1027.

(88) Derflinger, V. H.; Waldhauser, W.; Mitterer, C.; Schmölz, P.; Störi, H. LaB6-Based, Zr-Alloyed, Decorative Hard Coatings. *Thin Solid Films* **1996**, *286* (1–2), 188–195. https://doi.org/10.1016/S0040-6090(95)08517-3.

(89) Wu, Y.; Zhang, L.; Min, G.; Yu, H.; Gao, B.; Liu, H.; Xing, S.; Pang, T. Surface Functionalization of Nanostructured LaB 6 -Coated Poly Trilobal Fabric by Magnetron Sputtering. *Appl Surf Sci* **2016**, *384*, 413–418. https://doi.org/10.1016/j.apsusc.2016.05.062.

(90) Pollini, M.; Russo, M.; Licciulli, A.; Sannino, A.; Maffezzoli, A. Characterization of Antibacterial Silver Coated Yarns. *J Mater Sci Mater Med* **2009**, *20* (11), 2361–2366. https://doi.org/10.1007/s10856-009-3796-z.

(91) Guo, R. H.; Jiang, S. Q.; Yuen, C. W. M.; Ng, M. C. F. An Alternative Process for Electroless Copper Plating on Polyester Fabric. *Journal of Materials Science: Materials in Electronics* **2009**, *20* (1), 33–38. https://doi.org/10.1007/s10854-008-9594-4.

(92) Zhang, J.; Tan, J.; Chen, X.; Yin, Y.; Wang, C. High Humidity-Sensitive Discoloration Materials Fabricated with PH Indicator Ingredients. *Dyes and Pigments* **2021**, *195* (August), 109740. https://doi.org/10.1016/j.dyepig.2021.109740.

(93) Tadesse, M. G.; Dumitrescu, D.; Loghin, C.; Chen, Y.; Wang, L.; Nierstrasz, V. 3D Printing of NinjaFlex Filament onto PEDOT:PSS-Coated Textile Fabrics for Electroluminescence Applications. *J Electron Mater* **2018**, *47* (3), 2082–2092. https://doi.org/10.1007/s11664-017-6015-6.

(94) Ding, Z.; Li, J.; Xin, W.; Zhu, J.; Luo, Y. Matte Waterborne Polyurethane Fabric Nanocoating with Versatility via Mono-Layered Montmorillonite Nanosheets. *Prog Org Coat* **2021**, *159* (January), 106420. https://doi.org/10.1016/j.porgcoat.2021.106420.

(95) Akhavan, O.; Azimirad, R.; Safa, S.; Hasani, E. CuO/Cu(OH)2 Hierarchical Nanostructures as Bactericidal Photocatalysts. *J Mater Chem* **2011**, *21* (26), 9634–9640. https://doi.org/10.1039/c0jm04364h.

(96) Wang, Y.; Ghanbaja, J.; Soldera, F.; Migot, S.; Boulet, P.; Horwat, D.; Mücklich, F.; Pierson, J. F. Tuning the Structure and Preferred Orientation in Reactively Sputtered Copper Oxide Thin Films. *Appl Surf Sci* **2015**, *335*, 85–91. https://doi.org/10.1016/j.apsusc.2015.02.028.

(97) Du, Y.; Gao, X.; Meng, X. Preparation and Characterization of Single-Phased n-Type CuO Film by DC Magnetron Sputtering.

Physica B Condens Matter **2019**, *560*, 37–40. https://doi.org/10.1016/j.physb.2019.02.037.

(98) Huang, M. L.; Cai, Z.; Wu, Y. Z.; Lu, S. G.; Luo, B. S.; Li, Y. H. Metallic Coloration on Polyester Fabric with Sputtered Copper and Copper Oxides Films. *Vacuum* **2020**, *178*. https://doi.org/10.1016/j.vacuum.2020.109489.

(99) Huang, M. L.; Wu, Y. Z.; Liu, Z. K.; Lu, S. G. Metallic Coloration and Multifunctional Preparation on Fabrics via Nitriding Reactive Sputtering with Copper and Titanium Targets. *Vacuum* **2022**, *202*. https://doi.org/10.1016/j.vacuum.2022.111177.

(100) Nosaka, T.; Yoshitake, M.; Okamoto, A.; Ogawa, S.; Nakayama, Y. *Copper Nitride Thin ®lms Prepared by Reactive Radio-Frequency Magnetron Sputtering*.

(101) Maarouf, M.; Haider, M. B.; Al-Kuhaili, M. F.; Aljaafari, A.; Khan, J. Y. Negative Magnetoresistance in Iron Doped TiN Thin Films Prepared by Reactive Magnetron Sputtering. *J Magn Magn Mater* **2020**, *514*. https://doi.org/10.1016/j.jmmm.2020.167235.

(102) Lu, G.; Yu, L.; Ju, H.; Zuo, B.; Xu, J. Influence of Nitrogen Content on the Thermal Diffusivity of TiN Films Prepared by Magnetron Sputtering. *Surface Engineering* **2020**, *36* (2), 192–198. https://doi.org/10.1080/02670844.2019.1646964.