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Modern Printing Techniques for Enhancing the Printability Performance of Synthetic Textile Materials Via Different Treatment Methods

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Abstract

Polymeric substrates are increasingly prevalent. Commercially accessible polymers include polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polypropylene (PP) Surfaces have less polar functional group density. As a result, these materials' adhesive properties are subpar by nature. As a result, creating a high-quality print on such polymer substrates has become difficult. Surface modification is now required for such surfaces as a result. The study covers the effect of different treatments dose on printability and the degree of surface modification.

Keywords: synthetic fabric, printing techniques.

Introduction

Printing on textiles predates civilization itself, without a doubt. The textile industry significantly affects the economics of nations. All civilizations have made extensive use of color through dyeing and printing techniques. A crucial step in the creation of textile material is the coloring of fabric. Textile printing is a traditional art form that has been practiced for a very long time. It is among the most varied and important ways to add colors and patterns to textile fabrics. Additionally, it involves using a technique to properly apply a design concept. [1]

Printing is commonly understood as "localized Dyeing". During printing, dyes are applied to particular areas of the fabric that make up the design. Similar to dyeing, printing requires certain reactions. In contrast to printing, when color is applied as a thick paste of dye, dyeing uses color in solution form. mixing a substrate (typical fabric) with a natural or artificial thickener and using a method for properly applying the colors The number of accessible colors was increased, and many procedures were employed. [2] The numerous methods employed in the textile-producing industry greatly increase pollution.

In the textile wet processing industry, significant volumes of complex effluents that change in quantity and form frequently occur. With a high concentration of suspended particles, pH fluctuations, high temperatures, and a high need for chemical oxygen processes, the available colors were doubled in the effluent from the textile industry, which is noted for its beautiful color. [3, 4]

The division of printing methods

In general, there is a distinction between printing methods and printing aesthetics. Direct printing and indirect printing are the two categories that traditional textile printing techniques fall under.

1- **Direct printing** is The most common way of including a color pattern. It can be done on white fabric or over fabric that has already been colored; in the latter instance, it is known as overprinting. [5] In which, printing pastes come into direct contact with the fabric surface without undergoing any extra processing modifications, and it is theoretically possible to employ the same dyes that were used to dye fiber for both dyeing and printing on it. The

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dye materials used in the printing paste are selected based on a variety of requirements, including the chemical composition of the fiber. The direct printing technique yields the desired result in a single operation, with the knowledge that fixing and washing may be necessary processes.

However, pigment is the most widely used colorant in textile direct printing and accounts for roughly 75–80% of all printing processes because it is an easy and inexpensive method that requires little equipment, doesn't call for washing, and generates only a small amount of waste. [6-8]
Examples of direct printing: are screen printing, block printing, burnout printing, Inkjet printing, and transfer printing.

2- **Screen printing** is a development of stenciling in which a colored image is produced by transferring color (printing paste) via openings in the silk screen placed on the fabric surface, which may produce deep shadows [8]A substance is applied to a mesh to fill up any gaps in the screen opening and stop dye paste from passing through the mesh except where it is intended to be printed according to the design requirements. Ink is forced through small pores in a screen mesh during the screen printing process.

screens made of polyester, nylon, or silk threads. [8] A flat-screens machine's speed is frequently lower than a rotary screen's. [8]The printing paste or dye is applied to the screen and pressed into the cloth through the screen's unblocked areas [8]There are two main screen printing techniques used for textile printing: flat screen printing and rotary screen printing. [9]

3- **Inkjet**: A digital printing technique called ink-jet printing enables printing on various textile substrates without coming into contact with the substrate or the ink. Technology for inkjet printing is used in many industries, particularly in the textile industry. owing to its straightforward procedure, accelerated process, and decreased material consumption with digital control and noncontact printing approach [10]
A key element of ink-jet printing technology that significantly affects printing quality is color ink. As a result, printing inks developed with printer technology. [10] The jetting ink is made up of a colorant (such as dye or pigment), a solvent (such as water), and other additives (such as a surfactant, salt, or a pigment ink binder). [11] Yellow, magenta, cyan, and black are the four fundamental colors used in digital printing, which creates new challenges for textile color mixing.

4- **Indirect printing**: compared to direct printing, indirect printing is different. Indirect printing techniques include resist and discharge printing. Since the beginning, these methods have been used in textile printing[8]. They will always be significant since the outcomes are more often unique and physically superior, even though contemporary technology has enabled the use of direct printing possible for many more designs and reduced the need to utilize these styles in recent years.

5- **Discharge printing** is a sort of printing that includes bleaching or eradicating particular colors in a pattern after it has been printed. It is also referred to as "extract printing" in some instances. [12-14]
Due to the predominance of designs with various colors on a dark backdrop, discharge printing is currently becoming more and more popular in both domestic and international markets. [12, 15] Regardless of current fashion trends, discharge printing, particularly on cotton, wool, and silk fabric, has always been significant.
There are two categories for discharge printing techniques. Bleaching is the first type of discharge, followed by color discharge. [8]

Polypropylene is a significant olefin fiber with the advantages of superior abrasion resistance, high stain resistance, and cheap cost. Currently, polypropylene fiber (PP) is a widely used polymer with a wide range of applications, including packaging, pipes, furniture for homes, and other technological areas. [16] Despite not being a renewable polymer, polypropylene is considered significant for various applications due to its good characteristics. [17] PP is essential in the fabrication of textiles because of its durability, affordability, and strength. PP is a material that is frequently used in the production of disposable surgical gowns, face masks, and head coverings in the field of medical textiles. [17]

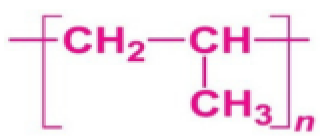

Fig. 1. Chemical structure of Polypropylene

Polypropylene (PP) is a low-cost fabric with great mechanical and chemical resistance. Hospital uniforms, bed sheets, surgical masks, diapers, burns, wound healing dressings, and hygiene bands are just a few of the hygienic and medical uses for PP. The hydrophobic property of PP makes it an inert synthetic fabric, and the lack of reactive functional groups in its molecular structure prevents it from being dyeable and printable.

For the aforementioned reasons, PP fiber is first altered using various irradiation techniques to generate free radical centers on the surface. Next, vinyl monomer graft copolymerization is performed, and finally, coloring is applied. There are several methods of irradiation employed, including plasma discharge, electron beams, ozone, UV, and -rays. [17] PP is dyeing using a dispersed dye with acceptable fastness and shades. [17]

PP treatments :

Effect of UV-Curable Inkjet on Polypropylene Fabrics by inkjet printing

UV-curable inkjet printing on PP materials is particularly interesting since it can replace conventional processes due to room temperature curing limitations.

Rapid development is being made in UV-curable inkjet printing methods for controlling fabric look during digital fabrication. Numerous sectors have expressed a great deal of interest in UV-radiation curing technology due to its many benefits. [18] UV-curable inkjet printing provides the benefits of high-quality printed pictures, outstanding color fastness, low energy consumption, room temperature curing, and low environmental contamination rate. UV-curable inks are a type of ink that can be cured by exposure to ultraviolet (UV) light. There are different types of UV-curable inks, including acrylic monomer inks, epoxy-based inks, polyurethane-based inks, hybrid inks, water-based UV-curable inks, glass-based UV-curable inks, thermal transfer UV-curable inks, silicone-based UV-curable inks, bio-based UV-curable inks, and nano-based UV-curable inks. Each type of ink has its unique characteristics and applications and can be used for printing on different surfaces, such as hard and soft surfaces, fabrics, paper, and biological surfaces.

It may be used to print on a variety of materials. Inkjet printing is paired with UV-curable ink in UV-curable inkjet printing. [18, 19] The photopolymerization of the binder, which is the chemical process that causes curing, is started when UV radiation of a certain wavelength from the UV light source installed on the inkjet printer's print head is absorbed. After being exposed to UV light, the binder, which contains pigment particles, creates a thin film that is placed on the printing substrate. The UV-curable ink printing technique is commonly utilized in different uses, including glass printing with bioinspired self-cleaning surfaces for liquid crystal displays and Applications of electromagnetic fields. Using the same UV-curable inkjet inks, found a significant difference between the printing quality of paper and polyvinyl chloride (PVC) plastic films. As an alternative to printing a white layer first and then doing regular printing with UV-curable ink, developed a technique to regulate the translucency of the 3D-printed item. Numerous research has examined different UV-curable pigment pastes and the impact of the ink's pigment-to-resin ratio on textile printing applications. [20] Compared to thermally cured inkjet-printed PLA textiles, found that UV-cured inkjet-printed biodegradable poly (lactic acid) (PLA) fabrics have a comparatively high color strength without altering the physical and mechanical qualities of the materials.

Four fundamental components are used to create UV-curable ink: a photo-initiator, a telechelic oligomer, a monomer, and a pigment [18]. When the quantities of the photo-initiator were altered, the color value of the UV-cured samples was dramatically altered. [21] Because each color's UV absorption/transmission intervals varied, the pigment color of the ink also had an impact on how well the printed films were cured. [22] According to research. on UV-curable inkjet inks for textile printing, the printed materials had smooth handling and desired fastness characteristics [20]. looked at the possibility of employing polyurethane acrylate as a UV-curable binder for ink preparation for pigment dye inkjet printing on a variety of fabrics. To create textile-based electronics with a low curing temperature, the UV-curable conductive inks were screen printed on nylon woven fabric. observed that after thermally cured inkjet printing, the bending rigidity, shear rigidity, and stiffness of heat-sensitive fabric increased [23]; however, this effect was less pronounced after UV-curable inkjet printing. Due to the jetting and curing of the photochromic ink on the photochromic textiles. the study discovered that the handle was stiffer than the unprinted fabric. This study looked at the impact of UV-curable inkjet printing on PP knitted fabric. Under different printing conditions, including the distance between the print head and the fabric surface, the number of overprints, and the color of prints, produced using UV-curable inks. The visual, physical, and low-stress mechanical features of UV-cured printed textiles were assessed and analyzed as performance attributes.

Inkjet Printing of Fabric with UV-Curable Inks

Using a Roland VersaUV LEF200 benchtop UV flatbed printer and a built-in UV-LED curing lamp with an emission wavelength range of around 200 to 400 nm, inkjet printing with UV-curable inks on heat-sensitive knitted fabric was carried out (Figure 2).

Hexamethylene diacrylate, exo-1,7,7-trimethy-bicyclo[2,2,1] hept-2-yl acrylate, diphenylphosphine oxide, benzyl acrylate, 2-methoxyethyl acrylate, and 1-vinylazepan-2-one are all components of Roland's UV-curable ink.

Six cartridges containing cyan, magenta, yellow, and black in CMYK color are included with the UV-curable ink. A second white cartridge adds splashes of vibrant color quality to transparent or dark surfaces, and a clear-gloss ink provides spot gloss or matte finishes.

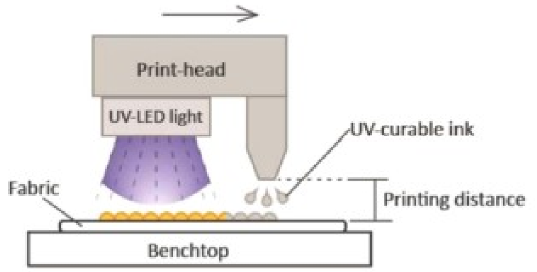

Fig. 2. UV-curing process using the overhead UV-LED curing system.

Preparation of Material Samples

PP textiles with circular knits were produced for UV-curable ink printing. One end of 20/20 100% Nylon/Lycra and one end of 75D/72F 100% PP were made with just one jersey stitch. Samples were printed in three colors: black (CMYK), basic magenta (PANTONE P115-4C), and pale blue (PANTONE P115-4C). The printing color was chosen in a range of brightness levels to examine how color affects the fabric's characteristics.

Fourier Transform Infrared (FTIR) Spectroscopy

Analysis of the dried ink film was done to verify UV-curing's incidence as a reduction and disappearance stretch peak at 810 cm-1 and the twisting peak at Following UV-curing, polymerization took place at a wavelength of 1410 cm-1 [21, 23, 24]]. It was UV-curable ink.

Pale blue PANTONE P115-4C (fabric samples B2), magenta (fabric samples M2), black (fabric samples BK2), cyan, and yellow were printed and cured on 2-mm acrylic plates using VersaUV LEF-200 printers with the appropriate print setting for the fabric.

FTIR (Nicolet 380 FTIR) spectroscopy was used to analyze the chemical alterations in the UV-curable ink. The ink's UV-curing was verified by the FTIR analysis of the ink film.

According to research on UV-cured acrylates, curing happens when the vibration peaks of the C=C double bonds drop and eventually vanish. The C=C double bond exhibits absorption peaks of vibration at 810, 840, and 950 cm^{-1}, spanning 1410 to 1420 cm^{-1}. [22, 24] The fact that the twisting peak at 810 cm^{-1} and the stretching peak at 1410 cm^{-1} have decreased and vanished in Figure 3 indicates that polymerization took place following the UV-curing procedure.

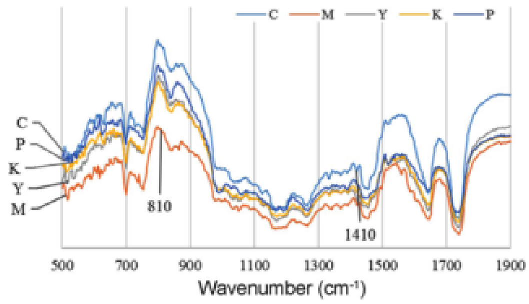

Fig 3: Fourier transform infrared analysis of the pigmented films prepared with C, M, Y, K, and Pantone P115-4C (P) formulations. [19]

Physical, and Mechanical Properties of the Printed Fabric

Using the Kawabata evaluation system for textiles (KES-F), the mechanical characteristics of the untreated and printed PP knitted fabrics were assessed. The system provides an objective evaluation of hand characteristics, including bending, surface, shearing, tensile, and compression analyses. [19]

Color Measurement and Resolution of Prints

The printed fabric's colors were measured using an X-Rite ColorEye 7000A spectrophotometer. [19]

The Leica M165C stereomicroscope and Adobe Photoshop CC software were used to examine the visual quality of prints on textiles at varied printing distances in terms of resolution. [19]

Results and discussion

Physical propertie

The outcome of the stepwise multiple regression analysis demonstrated that the fabric's mass per unit area and thickness rise as the number of overprints grows and are also influenced by the color of the print fig 4. [19] In general, as the lightness of the printed color dropped, the mass per unit area and thickness of the cloth grew.

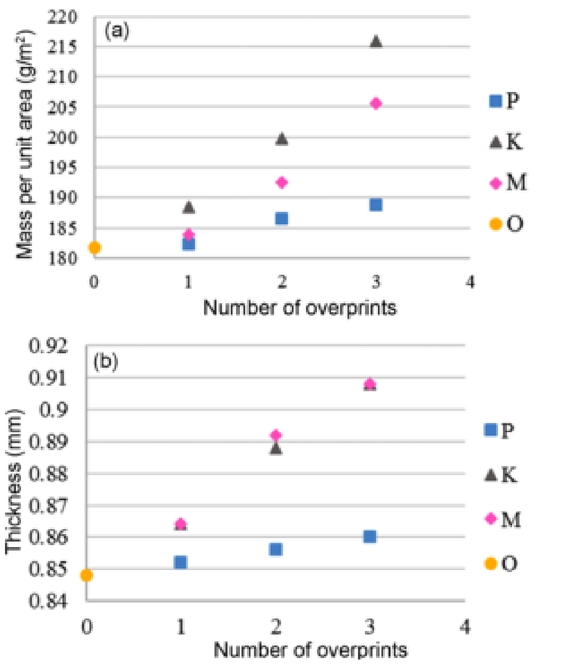

Fig 4: Changes in (a) mass per unit area and (b) fabric thickness by several overprints. [19]

Kawabata Evaluation of Printed PP Fabrics

Shearing properties

Figure 5 (a) shows that the G value of cloth printed with UV-curable ink was often greater than that of untreated fabric.

The fabric's capacity to resist sliding against one another under shear stress is indicated by the shear stiffness (G) value.

when illustrated in Figure 5, the fabric showed improved durability with a low number of overprints and higher mobility in the garment during physical activity when the G and 2HG5 values increased with the number of overprints. [19]

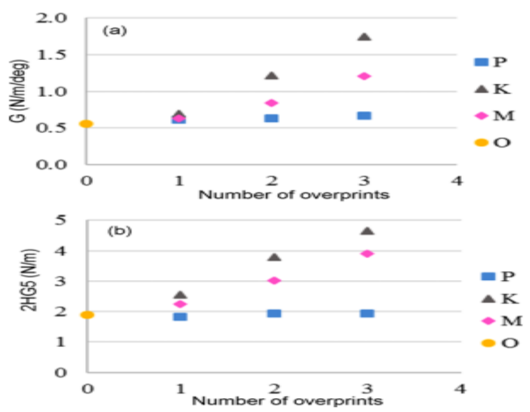

Figure 5. Changes in (a) shear stiffness (G) and (b) shear stress at 50 ° (2HG5) of fabrics by the number of overprints.

Tensile strength

The article discusses the impact of overprints and print color on the tensile properties of fabric. A lower LT value suggests greater fabric extensibility but less dimensional stability, while a higher RT value indicates a more durable fabric. A greater WT value implies more fabric stretchability. The study found that the number of overprints and print color had an impact on the LT, WT, and RT values, while WT also had an impact on the printing distance. The regression model indicated that more overprints were associated with higher LT values, while less overprints were associated with higher RT and WT values. A shorter printing distance was likewise associated with higher WT.[19, 25, 26]

Surface Properties (Coefficient of friction)(MIU)

Regardless of the number of overprints or the printing distance, the MIU value was greater in the fabric printed with the pale blue color and had a rougher surface than in the fabric printed with the magenta and black colors. It can be observed that more ink drops were equally distributed on the fabric surface when printed with magenta and black color than with pale blue by comparing the results of mass per unit area (lowest in pale blue color and greatest in black color) and MIU value. The UV-cured ink layer coated the whole surface of the fabric, equally distributing more inks, giving the cloth a smoother handle. [19]

Aesthetic Properties According to Color Measurement

The findings demonstrated that the printing device produced the best printing results when the number of overprints was set to one and the closest printing distance. When assessing the impacts of a fabric's characteristics by the printing distance in this study, the number of overprints was set at two.

As the printing distance increased, more ink was discharged, but not all of the ink droplets could be effectively deposited on the cloth surface and dried. As a result, the color that appeared on the cloth was paler than that with the closest printing distance and was closer to the reference color in terms of both brightness and color difference. Additionally, the ink droplet loss had a substantial impact on the color look but had little to no impact on the printed fabric's mechanical and physical qualities. [19]

Applying copper coating Polypropylene Fabric Surface to Use in Fog Collectors by screen printing, spray coating, and electroless coating:

Interest in depositing metallic layers on textile materials for various uses has recently increased. [27]

The creation of conductive textiles, electromagnetic interference shielding, wear protection, wearable displays, solar cells, actuators, data management devices, and biological sensors are the principal uses of these fabrics [28, 29]. Direct printing of metallic particles, vacuum deposition, flame and arc spraying, and electroless plating are a few common techniques that may be employed for this purpose.

electroless metal coating: is a mixture of the processes of oxidation and reduction.

Advantage

faster deposition, reduced cost, and low-temperature membrane production. Additionally, due to its oxidation-reduction properties, copper is ideal for wet processes. [30]

electroless plate fabric: has a multistep procedure that usually involves scouring, washing, etching, sensitization, activation, electroless plating, rinsing, and drying

The fabrics should be etched with KMnO4 or H_2SO_4 to get a highly adherent metallic coating. Even though, a weak van der Waals force causes the metallic layer to physically adsorb to the textiles. As a result, mechanical or ultrasonic cleaning can be used to remove the metallic coating layer.

Screen printing and wire arc spray coating are two more techniques that may be utilized to treat textile textiles with copper. [31]

Screen printing recipe :

The following ingredients were used to make a printing paste: 200 g/kg of copper powder (with an average particle size of 75), 100 g/kg of binder, 10 g/kg of diammonium phosphate, 350 g/kg of emulsion, and 20 g/kg of glycerin. The specimens were heated to a temperature of 100°C after printing with a no 200 mesh. [32]

Wire Arc Spray Coating :

The wire arc spray gun utilized in the current work was a Value Arc (Sulzer Metco Dewsbury, NY) gun with a converging nozzle. Two 1.6-millimeter-diameter consumable copper wires (Sulzer Metco, USA) were automatically supplied to meet at a certain location in an atomizing gas stream.

The gun's feed rate was 82 g/min, the spray distance was 100 mm, the current was 200 A, and the voltage was 33 V. [32]

Results

- The electroless copper plating has considerably altered the fibers' surface. SEM images of the electroless plated fibers revealed a coating of homogeneous copper particles. The micrographs clearly show that dense, metallic particles were evenly distributed on the surface of the fibers. [32]
- Screen-printed and spray-coated specimens had very diverse surface morphologies for the fibers. The printing paste was not evenly dispersed in the fiber gaps of the screen-printed and spray coated textiles. Due to the increased temperature applied to the specimens using this approach, distortion of the fibre cross section was seen in the spray coated textiles. The printing paste was inserted between the fibres and yarns of both screen-printed and spray-coated textiles. Polypropylene fibre distortion in spray-coated textiles was also noted, perhaps as a result of deterioration. [32]
- The weight gain was greatest (nearly 100%) in the printed textiles, whereas it was only between 1-2% in the electroless deposited materials. [32]
- The findings of electroless plating textiles showed that copper particles were effectively deposited on the surface of the fibres. For the E1 and E2 specimens, the deposition period was 10 and 20 minutes, respectively. [32]
- The research showed that the weight-based copper deposition rates were 0.0315 and 0.038 g/min, respectively. [32]
- After washing the textiles in the specified circumstances, the percentage of weight loss for fibres following ultrasonic cleaning remained unchanged, demonstrating the good washing fastness of electroless-coated materials. [32]

- Tensile strength
  The data collected demonstrate that the coating method reduced the breaking stress of all the textiles coated by utilizing all approaches. [32]
- Electrical conductivity :
  It was found that the electroless plated textiles (E2 and E1) had electrical conductivities that were about 100 times greater than those of printed and spray-coated fabrics. [32]
- Heat conductivity
  It indicates that electroless-coated textiles have a greater heat conductivity than untreated, printed, and spray-coated fabrics. [32]
- Air permeability
  As can be observed, the coated textiles' air permeability was reduced to varied degrees. In other words, compared to the other coated textiles, the air permeability of the electroless plated cloth was diminished to a lesser level. When examining the fabric's surface structure [32]
- Fog collection
  It was discovered that electroless plated textiles had more water collected than untreated, screen printed, or spray coated materials. [32]

Concolusion

When compared to textiles coated with screen printed and copper spray, electroless copper-plated fabrics demonstrated greater tensile strength, electrical conductivity, air permeability, thermal conductivity, and fog collecting capabilities.

The printing paste and/or copper particles filled the voids between the yarns and fibres in the printed or spray-coated textiles. Primary simulated studies shown that electroless plated polypropylene textiles may significantly improve the efficacy of polypropylene fabrics' fog collecting. [32]

PET" Polyethylene Terephthalate : It is an aromatic fiber One of the most adaptable materials utilised in the modern packaging and printing industries is polyethylene terephthalate (PET). [33]

Due to naturally occurring hydrophobicity caused by the non-polarity of the polymer materials, the adhesive characteristics are poor [33-35]. This makes it difficult for polar molecules to bind to the substrate.

In the printing business, adhesion depends on the properties of the ink-material interface and may be enhanced by increasing the hydrophilicity of the surface of the material [36]

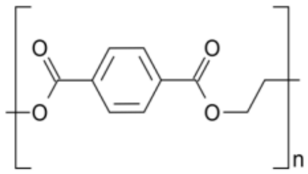

Fig : Chemical structure of "PET"

PET treatments

Atmospheric Cold Plasma on Polyethylene Terephthalate

This procedure tests the technical viability of polymeric material surface treatment methods based on cold plasma. The impact of plasma pre-treatment on the capacity to print on PET substrates was investigated. Using 80% N2 and 20% O2 as the input gas, several cold plasma treatments were performed on the surfaces of these polymer substrates. The study examines the impact of plasma dosage and intensity on the degree of surface alteration and printability. It identified the ideal plasma settings for high-quality and long-lasting prints.

Plasma, which consists of electrons, ions, neutrals, and free radicals in both their fundamental and excited states, is thought to constitute the fourth state of matter. Despite being electrically neutral, plasma is a chemically active medium because it contains free charge carriers. Through the process of exciting a gas mixture to a higher energy state using thermal, electrical, or radiation that upsets the species' electronic structure, excited molecules and ions are produced. [33]

DBD method

The dielectric barrier discharge method (DBD), among many atmospheric non-thermal plasma topologies, received positive feedback from most investigations for its stable plasma production and scalability.

Within the manufacturing process, it is renowned for modifying the surface qualities at a minimal cost without changing the bulk properties.

Studies demonstrate that surface-wetting characteristics can change as a result of DBD plasma treatment. As a result, conductivity, adhesive characteristics, print properties and quality might all change.

The energy from the electric field is transferred to the gas electrons, who subsequently, through collisions, transfer it to other natural species. The collisions that occur in high electric fields can be divided into two categories:

- Elastic collisions: natural organisms' internal energy remained unchanged despite a rise in their kinetic energy.
- Inelastic collision: When the electric field is strong enough, collisions produce excited species like ions.

Mechanism of DBD

- The majority of these excited states have shorter mean free pathways and transition to the ground state by producing photons, which are typically in the UV-visible region of the electromagnetic spectrum. Etching, adsorption, metastable ionisation, and secondary electron emission from the surface are effects of high-energy species striking a material [37]. The rise in the surface's hydrophilicity can be attributed to one or more of the aforementioned mechanisms [38]
- Terephthalic acid and ethylene glycol were esterified in the industrial PET synthesis process. Even though the PET polymer chain is made up of polar carbonyl oxygen groups, macromolecules can change their conformations to achieve a minimal interfacial energy state depending on the surrounding conditions. As a result of being exposed to air, PET material has a decreased surface energy, which results in less hydrophilicity on the surface. Unlike other surface modification methods, surface activation of PET material is effectively facilitated by high-energy species in the plasma [39].

Experimental

- For this experiment, the Dielectric Barrier Discharge (DBD) based Atmospheric Pressure Plasma Jet (APPJ) was created. As feed gases, the constructed jet is compatible with N2, Argon, and outside air.

In this investigation, plasma composed of 80% N2 and 20% O2 was applied to PET substrates. By adjusting the treatment period and the gap between the jet tip and the substrate, the plasma dosage was altered.

- All samples were put through a measurement procedure based on the enhanced sessile droplet method to determine the water contact angle of the control and plasma-treated samples [34, 35, 40, 41]. Digital photography was used to capture the picture of a water droplet on a PET substrate, which was then subjected to analytical software processing to determine the contact angle [40]. Based on the improvement in contact angle, two ideal parameters (treatment duration and distance from the jet tip to the substrate) were selected for screen printing.
- For both treated and untreated samples, a Fourier Transform Infrared- Attenuated Total Reflection Spectroscopic examination was performed to determine whether any chemical alterations occurred during the plasma treatment.
- Using the cross-cut technique tape test following ASTM D3359 standard, the ink adhesion impact on the PET surface was evaluated After the remaining print had been peeled off, it was photographed and its mean grayscale value was determined. On the remaining print, many tape tests were conducted to analyze the grayscale values. By performing the test three times for each treatment condition, the test's repeatability was confirmed.

Printing

One of the most popular printing methods that have been employed in both the textile and automobile industries is screen printing [37]

For printing on polymer surfaces, a screen with a mesh count of 110 was utilized, and commercial screenprinting ink was used for printing on both untreated and treated samples. On the surface, 25mm x 25mm squares were printed.

Results

The PET surface interacts with this very reactive mixture of ions and radicals, forming polar functional groups.

The improved polarity of the PET substrate aids ink adherence to the material. [42]

The relationship between plasma intensity and time can be used to establish the plasma dosage. In this experiment, the distance between the jet tip and the substrate was altered to alter the plasma intensity. The effects of plasma dosage on PET surface activation are therefore affected by differences in the aforementioned parameters, and this is evaluated by measuring the water droplet contact angles. Table 1 provides an overview of the interventions and the contact angle information gathered. [42]

Table i: contact angle variation with treatment time and distance from the jet tip

	Distance from the jet tip (mm)		
Treatment time (s)	***10***	***20***	***30***
0	67.17	67.17	67.17
1	36.85	44.55	58.69
3	35.33	38.31	40.95
5	34.79	36.29	39.72
10	30.55	35.10	37.05
	Contact Angle (°)		

According to the findings, plasma treatment enhances hydrophilicity by increasing the density of polar functional groups on the surface of the PET. [42] Fig. 6 visually illustrates the variances.

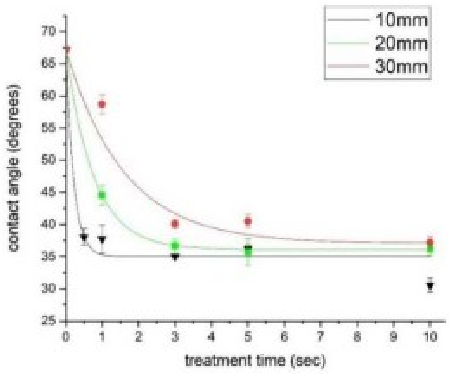

Fig. 6. Contact angle variation of different treatments [42]

- With time, the contact angle reduction per unit of treatment time decreases. The influence of treatment duration showed no discernible effect after 5 seconds. The samples treated at the shortest distance showed the highest surface activations. [42]
- the FTIR spectra were recorded for treated and untreated PET substrates in standard transmittance mode. The spectra of treated and untreated samples should be close to ideal. This suggests that the composition of the PET substrate has not been significantly changed by the plasma treatment. [42]

Print quality

The print quality of the treated samples was compared to the untreated samples' print quality. the cross-cut tape test per ASTM 3359 D

After five tape tests, treated surfaces show 51% and 41% ink removal compared to non-treated surfaces, which represents a 34% and a 44% increase in print quality for samples treated for 10mm 5s and 10mm 10s, respectively (Fig. 7). [42]

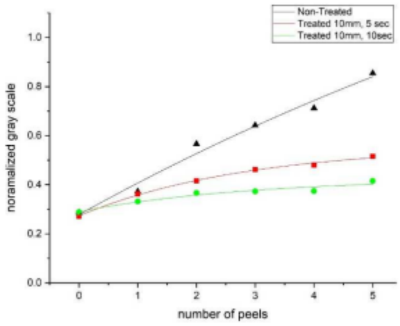

Fig 7 : Print quality improvement by atmospheric pressure plasma treatment [42]

Conclusion

The surface of PET substrates was activated using atmospheric pressure plasma based on N2/O2 input gases.

The water contact angle was lowered from 67.20 to 30.50 in just 10 seconds, demonstrating the treatment's efficacy.

A positive connection between the plasma dosage and the surface wettability was found, and it was asymptotic at the maximal dose level, showing that it had no influence on the wettability above that level.

Despite having a strong impact on surface modification, the atmospheric pressure plasma treatment did not alter the chemical makeup of the PET substrate. This suggests that, without altering PET's original chemical composition, the atmospheric pressure plasma may be successfully used to get improved surface attributes relating to surface wettability and stickiness. [42]

Discharge printing of (polyethylene terephthalate) fabric using Thiourea Dioxide

An efficient green reducing agent is thiourea dioxide (TDO, aminoiminomethanesulfinic acid). The extremely long C-S bond is broken during heating or in alkaline circumstances, releasing sulfoxylic acid or sulfoxylate ions, giving TDO its reducing potency, with the typical reduction potential of SO3 2 | S2O4 2 as high as -1.12 V [43, 44]

When dying PET fibers, nonionic dispersion dyes are used with thermos dyeing or high-temperature dyeing techniques. [45]

By examining the reductively discolored phenomena of the dispersed dyes treated on various substrates using various methods, such as dyes dispersed and dissolved in water, dyes treated on a glass surface, and dyes penetrated in PET fibers on a dyed PET fabric, the key factors affecting the discharge printing of polyester fabrics using TDO were studied. The findings contribute to the creation of a new, environmentally friendly discharge printing technique for PET textiles and give useful insight into the discharge printing of PET fabrics utilizing TDO as a discharge agent.

Evaluation of Effect of TDO on Disperse Dyes in Aqueous Solution :

By examining the absorption characteristics of a mixed solution, it was possible to examine how TDO affected dispersed colours in aqueous solution. Disperse dye, TDO, and distilled water totaling 0.1 l were combined, and the mixture was then heated at 80 o C for 20 min. A digital camera (EOS600D, Canon, Tokyo, Japan) was used to compare the initial and final solutions, and an ultraviolet-visible spectrophotometer was used to assess their spectrum characteristics in relation to the visible absorption qualities in N,N-dimethylformamide.

Evaluation of the Effect of TDO on the White Discharge of Polyester Fabrics Dyed with Disperse Dyes

The polyester textiles underwent exhaust dyeing with the chosen dispersion colors, followed by reduction cleaning. The white discharge paste was used to print on the colored polyester textiles, which were then dried and steamed in saturated steam at 105 o C for 10 min. The samples were steamed, then washed in cold water, and then allowed to air dry. The fabric's K/S values were then averaged after being tested three times. Table 2 displays the specific dyeing and white discharge printing settings.

Table 2. Parameters of dyeing and white discharge printing of PET fabrics

Dyeing		Reduction cleaning		White discharge printing	
Parameter	Amount	Parameter	Amount	Chemical	Amount (wt %)
Disperse dyes	1 % .owf.	Sodium hydrosulfite	1.5 g/l	Discharge paste TM-2 (50 % TDO)	10
Liquor ratio	1:30	Sodium carbonate	1.5 g/l	Thickening agent PTRV	3
Time	40 min	Liquor ratio	1:50	Urea	8
Temperature	115 °C	Time	20 min	Discharge-aid auxiliary HS-312N	x
pH	4.5-5.0	Temperature	80 °C		

Results

Reduction of TDO in Aqueous Solution

In general, the discharge temperature has a significant impact on TDO reducibility [46]

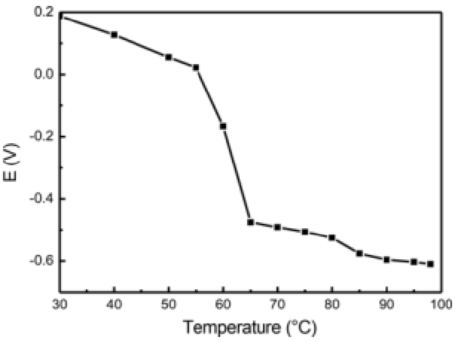

Figure 8. Effect of temperature on the redox potential of TDO.

From Figure 8, it is obvious that when the temperature rises, TDO's reduction potential lowers, resulting in an improvement in reducibility. Particularly, the redox potentials steadily drop between 30 and 55C, suggesting that TDO's reducibility is poorer at this point. The reduction potential rapidly decreases as temperature rises from 55 o C to 65 o C, demonstrating that TDO's reaction rate in the aqueous solution increases quickly and that its reducibility increases noticeably.

The curve changes less and the potential values are lower and gradually drop when the temperature is greater than 65 o C. It suggests that at this time, the TDO solution exhibits substantial reducibility. The curve continues to drop when the TDO solution is over 80 o C, indicating that the TDO solution at 80 o C has stronger reducibility.

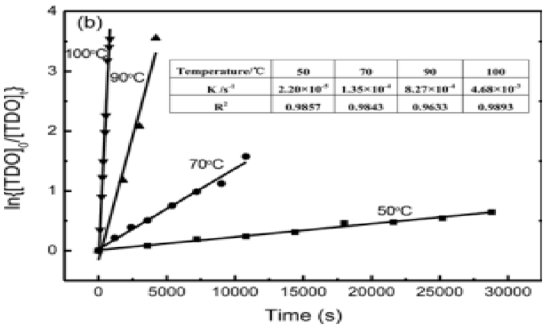

Fig 9: The corresponding decomposition reaction rate (K) values and curve linear relationship constants (R2) are tabulated in the inset of Figure 3(b).

Figure 9 shows the variations in ln[TDO_2]$_0$/[TDO_2]t over time, together with the accompanying decomposition reaction rate (K) values and curve linear relationship constants (R2).

At 100°C, TDO decrease is greatest. Generally, the linear relationship is more apparent when the R2 value is close to 1.00.

As can be seen from Figure 3(b), the linearity of ln[TDO2]0/[TDO2]t concerning time is excellent. In conclusion, TDO may be able to discharge print on polyester materials at temperatures of 100 o C or higher. [43]

Effects of TDO on Disperse Dyes Penetrated into Polyester Fibers:

To accomplish the discharge printing of polyester textiles, a discharge accelerant was incorporated into the white discharge pastes containing TDO. The TDO reaction and dye dispersion on colored PET textiles might be improved by the discharge accelerant by opening up compact polyester molecular structures. The K/S values of PET textiles colored with various ground colors were dramatically decreased after white discharge printing employing pastes containing TDO and dischargeaccelerant (Figure 9). [43]

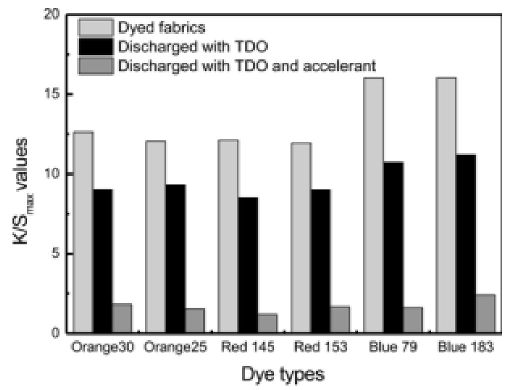

Figure 10. Effect of discharge accelerant on the K/Smax value of the sample treated by TDO discharged paste

Mechanism of discharge accelerant

The discharge impact of TDO was improved by the inclusion of a discharge accelerant. The glass transition temperature can be lowered as a result of the discharge-accelerating molecules entering the amorphous area of the PET fibers during the steaming process, which can assist swelling and the formation of gaps between intermolecular PET chains. [47]

Concusion

A lot of research was done on the use of TDO for PET fabric discharge. The rate of TDO breakdown accelerated with rising temperature, and TDO decrease intensified with rising temperature. The destruction of the chromogenic groups by TDO suggests that TDO may be appropriate for the discharge of polyester textiles coloured with certain azo-dyes. The chromogenic groups of the dyes deposited in aqueous solution and affixed to the surfaces of glass substrates were destroyed by TDO. The discharge effect is significantly influenced by the structure of PET fibers. To create a satisfactory discharge effect, a discharge accelerant was added to the white discharge pastes containing TDO, making the structure of polyester fibers significantly looser. This study offers useful information on discharge printing and may pave the path for TDO improvements. [43]

Conclusion

It was concluded that the treatment of polypropylene with UV-Curable Inks via inkjet printing improved the physical, aesthetic, tensile strength, color strength, and frictional stability of polypropylene fabrics

In addition, when comparing the various treatments' techniques that were employed on the polypropylene fabric's surface it was determined that the best techniques were the electroless plating procedure then screen printing, and arc-spray, respectively. Those coating techniques proved their efficiency in terms of improving the fabric's air permeability, heat, and electric conductivity, fog collecting, and the fabric's tensile strength.

The treatment of PET with cold plasma Using 80% N2 and 20% O2 as the input gas by screen printing showed an increase in the quality of the produced prints for samples that were treated for 10mm 5s and 10mm 10s, respectively. And the atmospheric pressure plasma was successfully used to improve the fabric's surface wettability and printability by inheriting several polar groups within the fabric's exterior.

The treatment of PET utilizing Thiourea Dioxide with the help of a discharge accelerant showed improved discharge printing.

Conflicts of interest

There are no conflicts to declare

Funding sources

There is no fund to declare

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References

[1]. Lacasse, K., Baumann, W., Lacasse, K., Baumann, W.J.T.c.E.d. and facts Environmental considerations for textile processes and chemicals, 484-647 (2004).

[2]. El-AAty, A., Mohamed, M., Hashad, A., Moawaed, S., Hassabo, A.G., Othman, H., Abdel-Aziz, E.J.J.o.T., Coloration and Science, P. Investigation of the discharge printing of cotton and silk fabrics dyed with reactive and natural dyes, 19(2) 203-210 (2022).

[3]. Zaied, M., Othman, H., Ghazal, H. and Hassabo, A.J.E.J.o.C. A valuable observation on natural plants extracts for valuable functionalization of cotton fabric (an overview), 65(4) 499-524 (2022).

[4]. El-Zawahry, M., Hassabo, A., Abdelghaffar, F., Abdelghaffar, R. and Hakeim, O.J.B.R.i.A.C. Preparation and use of aqueous solutions magnetic chitosan/nanocellulose aerogels for the sorption of reactive black 5, 11(4) 12380-12402 (2021).

[5]. Haggag, K., Ragheb, A., Abd El-Thalouth, I., Nassar, S. and El-Sayed, H.J.L.S.J. A review article on enzymes and their role in resist and discharge printing styles, 10(1) 1646-54 (2013).

[6]. Eldesoky, R.S.A. Novel approaches in textile surface modifications for better printability, The University of Manchester (United Kingdom), (2019).

[7]. Le Marechal, A.M., Križanec, B., Vajnhandl, S. and Valh, J.V. Textile finishing industry as an important source of organic pollutants, Organic pollutants ten years after the Stockholm convention-environmental and analytical update, IntechOpen Rijeka, pp. 29-54 (2012).

[8]. Ragab, M.M., Othman, H. and Hassabo, A.J.E.J.o.C. An overview of printing textile techniques, 65(8) 749-761 (2022).

[9]. Purushothama, B. Handbook of value addition processes for fabrics, Woodhead Publishing India PVT. Limited, (2019).

[10]. Javoršek, D. and Javoršek, A.J.C.T. Colour management in digital textile printing, 127(4) 235-239 (2011).

[11]. Shang, S. Process control in dyeing of textiles, Process control in textile manufacturing, Elsevierpp. 300-338, (2013).

[12]. Kašiković, N., Vladić, G., Novaković, D.J.G.o.C., Technologists and Environmentalists of Republic of

Srpska/Glasnik Hemicara, T.i.E.R.S. Textile printing–past, present, future, 35-46 (2016).

[13]. Seema, H., Deepika, L., Babu, A.J.J.o.T.i.T.E. and Technology, F. A comparative study on discharge printing using conventional and ecological recipe, (3) 245-261 (2018).

[14]. Hossain, M., Raman, M., Islam, M.J.J.o.p. and Engineering, T. Overview of piece printing process in textile industry, 12 (2015).

[15]. Thalouth, J., Abd-El, AA, E.-H.J.R.J.o.T. and Apparel Discharge printing on heat transfer printed cationised linen fabrics, 16(1) 58-67 (2012).

[16]. Ahmed, M. Polypropylene fibers, science and technology, Elsevier Science & Technology, (1982).

[17]. Abou Elmaaty, T., Sofan, M., Elsisi, H., Kosbar, T., Negm, E., Hirogaki, K., Tabata, I. and Hori, T.J.J.o.C.U. Optimization of an eco-friendly dyeing process in both laboratory scale and pilot scale supercritical carbon dioxide unit for polypropylene fabrics with special new disperse dyes, 33 365-371 (2019).

[18]. Bahria, H., Erbil, Y.J.D. and Pigments Uv technology for use in textile dyeing and printing: Photocured applications, 134 442-447 (2016).

[19]. Li, N.-w., Ho, C.-p., Yick, K.-l., Zhou, J.-y.J.F. and Polymers Effect of uv-curable inkjet printing parameters on physical, low-stress mechanical, and aesthetic properties of polypropylene knitted fabrics, 21 2788-2798 (2020).

[20]. Hakeim, O.A., Arafa, A.A., Zahran, M.K., Abdou, L.A.W.J.P. and Technology, R. Characterisation and application of pigmented uv-curable inkjet inks, (2018).

[21]. Baysal, G., Kalav, B. and Karagüzel Kayaoğlu, B.J.C.T. Colour and gloss properties of pigment- printed synthetic leather using an ultraviolet- curable water- borne polyurethane acrylate binder and two photoinitiators at different ratios, 135(2) 133-142 (2019).

[22]. Baysal, G., Kalav, B. and Kayaoğlu, B.K.J.C.T. Effect of pigment colour on the printing performance of synthetic leather using a ultraviolet- curable water- borne polyurethane acrylate binder, 135(4) 283-291 (2019).

[23]. Karim, M.N., Afroj, S., Rigout, M., Yeates, S.G. and Carr, C.J.J.o.M.S. Towards uv-curable inkjet printing of biodegradable poly (lactic acid) fabrics, 50 4576-4585 (2015).

[24]. Baysal, G., Kalav, B. and Karagüzel Kayaoğlu, B.J.C.T. The effect of ultraviolet- curable water- borne polyurethane acrylate binder concentration on the printing performance of synthetic leather, 135(2) 111-120 (2019).

[25]. Behera, B.K. and Hari, P. Woven textile structure: Theory and applications, Elsevier, (2010).

[26]. Tadesse, M.G. Quality inspection and evaluation of smart or functional textile fabric surface by skin contact mechanics, Högskolan i Borås, (2019).

[27]. Sha, W., Wu, X. and Keong, K.G. Electroless copper and nickel-phosphorus plating: Processing, characterisation and modelling, Elsevier, (2011).

[28]. Scholz, J., Nocke, G., Hollstein, F., Weissbach, A.J.S. and Technology, C. Investigations on fabrics coated with precious metals using the magnetron sputter technique with regard to their anti-microbial properties, 192(2-3) 252-256 (2005).

[29]. Guo, R., Jiang, S., Yuen, C. and Ng, M.C.F.J.J.o.M.S.M.i.E. An alternative process for electroless copper plating on polyester fabric, 20 33-38 (2009).

[30]. Gan, X., Wu, Y., Liu, L., Shen, B., Hu, W.J.J.o.A. and Compounds Electroless plating of cu–ni–p alloy on pet fabrics and effect of plating parameters on the properties of conductive fabrics, 455(1-2) 308-313 (2008).

[31]. Han, E.G., Kim, E.A. and Oh, K.W.J.S.M. Electromagnetic interference shielding effectiveness of electroless cu-plated pet fabrics, 123(3) 469-476 (2001).

[32]. Sarafpour, M., Youssefi, M., Mortazavi, S.M.J.F. and Polymers Copper functionalization of polypropylene fabric surface in order to use in fog collectors, 17 2041-2046 (2016).

[33]. Sandanuwan, T., Somaweera, D., Attygalle, D., Amarasinghe, S. and Weragoda, S.C. Improvement of toner printing on polyethylene terephthalate based transparency sheets using atmospheric plasma, 2019 Moratuwa Engineering Research Conference (MERCon), IEEE, pp. 345-348 (2019).

[34]. Rathnayake, W., Karunanayake, L., Samarasekara, A. and Amarasinghe, D. Chemical modification of microcrystalline cellulose using sunflower oil, 2020 Moratuwa Engineering Research Conference (MERCon), IEEE, pp. 215-219 (2020).

[35]. Samarasekara, A., Kumara, S., Madhusanka, A., Amarasinghe, D. and Karunanayake, L. Study of thermal and mechanical properties of microcrystalline cellulose and nanocrystalline cellulose based thermoplastic material, 2018 Moratuwa Engineering Research Conference (MERCon), IEEE, pp. 465-470 (2018).

[36]. Egodage, D., Jayalath, H., Samarasekara, A., Amarasinghe, D., Madushani, S. and Senerath, S. Novel antimicrobial nano coated polypropylene based materials for food packaging systems, 2017 Moratuwa Engineering Research Conference (MERCon), IEEE, pp. 88-92 (2017).

[37]. Wolf, R. and Sparavigna, A.C.J.E. Role of plasma surface treatments on wetting and adhesion, 2(06) 397 (2010).

[38]. Amarasinghe, D.S., Sunil, D. and Gafney, H.D.J.T.J.o.P.C.C. Effect of co pressure gradients on the photochemistry and thermal chemistry of fe (co) 5 physisorbed into porous vycor glass, 115(43) 20824-20831 (2011).

[39]. Dixon, D., J. Meenan, B.J.J.o.A.S. and Technology Atmospheric dielectric barrier discharge treatments of polyethylene, polypropylene, polystyrene and poly (ethylene terephthalate) for enhanced adhesion, 26(20-21) 2325-2337 (2012).

[40]. Kumarasiri, A., Attygalle, D. and Amarasinghe, D. Lead free solder compatibility improvement on nichrome alloy through contact angle modification, 2019 Moratuwa Engineering Research Conference (MERCon), IEEE, pp. 340-344 (2019).

[41]. Rathnayake, W., Karunanayake, L., Samarasekara, A. and Amarasinghe, D. Fabrication and characterization of polypropylene microcrystalline cellulose based composites with enhanced compatibility, 2019 Moratuwa engineering research conference (MERCon), IEEE, pp. 354-359 (2019).

[42]. Sandanuwan, T., Hendeniya, N., Attygalle, D., Amarasinghe, D., Weragoda, S.C. and Samarasekara, A. Atmospheric cold plasma to improve printability of polyethylene terephthalate, 2021 Moratuwa Engineering Research Conference (MERCon), IEEE, pp. 654-658 (2021).

[43]. Liu, X., Xie, M., Li, Y., Zhou, L., Shao, J.J.F. and Polymers Study on the reduction properties of thiourea dioxide and its application in discharge printing of polyester fabrics, 19 1237-1244 (2018).

[44]. Makarov, S.V., Horváth, A.K., Silaghi-Dumitrescu, R. and Gao, Q.J.C.A.E.J. Recent developments in the chemistry of thiourea oxides, 20(44) 14164-14176 (2014).

[45]. Karthikeyan, K. and Dhurai, B.J.A.R.J. New method of discharge printing on cotton fabrics using horseradish peroxidase, 11(2) 61--65 (2011).

[46]. Hu, Y., Feng, J., Li, Y., Sun, Y., Xu, L., Zhao, Y. and Gao, Q.J.S.C.C. Kinetic study on hydrolysis and oxidation of formamidine disulfide in acidic solutions, 55 235-241 (2012).

[47]. Murray, A., Mortimer, K.J.J.o.t.S.o.D. and Colourists Dye auxiliaries in the application of disperse dyes to man- made fibres, 87(6) 173-181 (1971).

تقنيات الطباعة الحديثة لتعزيز أداء الطباعة للمواد النسيجية الاصطناعية بواسطة طرق معالجة مختلفة

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الملخص

ركائز البوليمرية منتشرة بشكل متزايد. تشمل البوليمرات التي يمكن الوصول إليها تجاريا البولي فينيل كلوريد (PVC) والبولي إيثيلين تيريفثاليت (PET) والبولي بروبيلين (PP) الأسطح لها كثافة مجموعة وظيفية قطبية أقل. نتيجة لذلك ، فإن الخصائص اللاصقة لهذه المواد دون المستوى بطبيعتها. نتيجة لذلك ، أصبح إنشاء طباعة عالية الجودة على ركائز البوليمر هذه أمرا صعبا. تعديل السطح مطلوب الآن لمثل هذه الأسطح نتيجة لذلك. تغطي الدراسة تأثير جرعة العلاجات المختلفة على قابلية الطباعة ودرجة تعديل السطح.الكلمات الرئيسية: نسيج القطن / البوليستر تقنيات الطباعة