# Recent advancements in textile finishing focused on eco-friendly and plasma technology approach

**Manisha Manasmita, Sumit Kumar and Deepak Mehra**

**NATIONAL INSTITUTE OF FASHION TECHNOLOGY**

**Fashion Technology Department**

**Bhubaneswar, Odisha**

**Corresponding author: Deepak Mehra, deepak.mehra@nift.ac.in**

## ABSTRACT :

Textile finishing refers to the final stage of fabric manufacturing processes. In this process, the textile is modified and its properties are enhanced to meet the requirements of customers. In two ways finishing on textile can be done. One is the dry finishing technique (physical), while the other is a wet finishing technique (chemical). As textiles are being converted into technical textiles, a growing concern is for the method that is used for finishing those textiles. With growing pollution and a rise in natural hazards, the textile industry needs to approach sustainable techniques. In recent years, the integration of plasma technology has emerged as a game-changer, particularly in the context of environmental sustainability. Recent developments in plasma technology have surpassed conventional finishing techniques, offering solutions to an array of challenges. These advancements include anti-static treatments, water-repellent coatings, flame-resistant modifications, wrinkle-resistant enhancements, anti-microbial properties, and many more. Moreover, they improve the functional aspects of textiles as well as address the growing need for sustainable and eco-friendly processes.

## 1. INTRODUCTION

The textile industry stands as one of the most significant contributors to global pollution, casting a substantial shadow on environmental sustainability. With that, the textile finishing processes employ a broad spectrum of chemicals to ensure the quality of the final product, which are major contributors to environmental pollution within the industry. So, there is a growing demand for innovative production techniques that can simultaneously enhance product quality and address environmental concerns. Textile finishing refers to the final stage of fabric manufacturing processes. In this process, the textile is modified, and its properties are enhanced to meet the requirements of customers. There are two ways in which finishing on textile can be done. One is the dry finishing technique (physical), while the other is the wet finishing technique (chemical). As textiles are being converted into technical textiles, there is a growing concern about the method used for finishing those textiles. With growing pollution and rising natural hazards, the textile industry needs to approach sustainable techniques. Eco-friendly finishes are the textile finishing methods that not only create eco-friendly finished textiles but also take care of harmful gas emissions and effluent water discharges. There are some recent developments in technologies which help in achieving this [1].

## 2. ECO-FRIENDLY FINISHES APPROACH

Eco-friendly finishes are the textile finishing methods which not only create eco-friendly finished textiles but also make sure to take care of the harmful gas emission and effluent water discharges. There has been some recent innovations in technologies which help in achieving this. Some examples of technologies that are used in eco-friendly finishing are Plasma technology, Nanotechnology, Biotechnology, Microencapsulation, Laser treatment, Biopolymer, and Ultrasonic finishing [2].

**2.1. Plasma technology** is rooted on ionized gases produced by electrical discharges. Electromagnetic power applied to a process gas produces a dynamic plasma medium consisting of ions, electrons, neutron, protons, free radicals and excited species. This facilitates various surface modification processes like surface activation, coating deposition, etching, etc. Plasma treatments have benefits of improving dyeing rates, colorfastness, micro-roughness, wash resistance and altering the surface energy of fibers and fabrics. Through plasma technology finishes like hydrophobization, wrinkle resistant, anti-microbial finishes, UV protection, etc can be done.

**2.2.** **Nanotechnology** deals with dimensions and tolerances less than 100 nanometres. In 21$^{st}$ century, it is one of the rapidly emerging technology. In textile industry, nano particles have the ability to be used as durable surface coating resulting in sustainable and cost-effective. It produces textiles with various functional properties such as water repellent, stain-resistance, flame retardant, antimicrobial, abrasion resistance, etc. These characteristics are achieved by nano-metal oxide coats by use of complex metallic compounds of copper or silver or zinc. The most widely used finishing method in this technology are padding, sol-gel and layer-by-layer processing.

**2.3.** In **Biotechnology**, enzymes play a greater role. Enzymes have a lot more of advantages over chemicals. They don't need any catalyst to increase rate of reaction or they do not alter the chemical equilibrium between reactants and products and most importantly, they are task specific. Since the 1980s Enzymes is being used in textile industry. They are used in various stages of textile processing such as desizing, scouring, bleaching or biopolishing. A variety of finishing can be done with the enzymes. These are anti-pilling, softening, improved hand feel and surface appearance. Cellulase enzymes along with pumice stones is used for denim stone wash effect. This process is known as bio-stoning.

**2.4.** **Microencapsulation** is a micro-packaging technique involved in thin deposition of polymeric coating on small particles of solid or liquid. This technique is widely used in textile industry. The material inside the microcapsule is known as core material whereas the wall is known as shell. Through this technique functional qualities such as fire retardancy, antimicrobial finishes, antistatic finishes can be achieved.

**2.5.** **Laser treatment** is a water free physical treatment that gives precision in processing textile. The textile to be processed is exposed to laser radiation using efficiency intensity. This process helps in making hydrophobic fibers hydrophilic to increase its dyeing capacity without damaging the textile. The most suited lasers for textile is carbon dioxide lasers which is constituted of gases such as carbon dioxide, nitrogen, hydrogen and helium. It has the ability to modify the surface and to impart functionalities such as textile adhesion, wettability and optical properties. Although reasearch are still going on this technique for textile finishing.

2.6. **Biopolymers** are obtained from agricultural feedstock and marine food resources. Some examples of biopolymers used for finishing are polysachharides, chitosan and sericin proteins. The advantage of using biopolymers is their availability in abundance and biodegradability. Through biopolymers antimicrobial, UV resistance, insect repellency and flame retardancy finishes can be achieved.

2.7. **Ultrasonic Finishing** uses ultrasonic that is the vibrations of frequencies greater than upper limit of audible range for human which is greater than about 20 kilo-hertz. This finishing process uses zinc oxide nanoparticles. The textile finished with ultrasonic, shows maximum sustainability, ease of maintenance and cost effectiveness. It provides long-lasting antimicrobial characteristics.

## 3. PLASMA TECHNOLOGY

Plasma is one of the four fundamental states of matter, alongside solids, liquids, and gases. It is characterized by its high energy state in which some or all the electrons have been removed from their respective atoms, resulting in a combination of positively charged ions and free electrons. This ionization process renders plasma electrically conductive, even though the overall plasma remains electrically neutral.

Plasma consists of ions, free electrons, photons, as well as neutral atoms and molecules, both in their ground and excited states. Plasma is used to do surface modification or activation, coating deposition on surface (known as plasma polymerization or grafting), and removal of waste from surface (known as plasma etching). The specific characteristics on substrate can be evoked by using different types of gases with plasma such as oxygen, fluorine, nitrogen, argon, etc.

In industrial plasma technology, two forms of plasma are used. They are thermal plasma and cold plasma. The thermal plasma is generated by direct and alternate current or by microwave source. The cold plasma has electron temperature higher than its ion and is considered as low-pressure plasmas (between 0.1pa and 100pa). In textile applications, generally cold plasmas are used. Cold plasma is further divided into vacuum plasma and atmospheric plasma.

Plasma can be induced in different ways. These are glow discharge method, corona discharge method, dielectric-barrier discharge method and atmospheric pressure plasma jet (APPJ) [3].

## 3. CHEMICAL SURFACE MODIFICATION USING PLASMA

There are ways in which surface modification can be done chemically using plasma. These are:

A. Radical formation: Here certain radical sites are formed by ionizing the polymer.

B. Grafting: It is a method to obtain mono-functional surface.

Using these techniques, polymerization and cross-linking can be done on textile. In polymerization by plasma, monomers are grafted onto the polymer surface to form a thin polymer film. The active species generated by the plasma source initiate polymerization reactions with the introduced monomers. As a result, a new layer or film of polymer is deposited on the polymer surface. This process allows for the incorporation of specific functional groups or properties onto the polymer surface without the need for a separate substrate. In cross-linking, two polymer molecules join together to form a single, larger molecule or network. This process is initiated when radical sites are created on the polymer surface during the plasma treatment. These sites which are radical in nature can react with other polymer chains, forming covalent bonds between them. Cross linking can enhance the mechanical properties, thermal stability, and chemical resistance of the polymer [4].

### 3.1. MECHANISM OF PLASMA ON THE SUBSTRATE

Plasma activation is a technique for modifying surfaces that uses plasma processing to improve the properties of a substrate. The key processes involved in plasma activation are:

3.1.1. Surface preparation : Plasma activation is employed to modify the material's surface before any finishes incorporate onto the surface. The key goal is to improve the surface adhesion properties.

3.1.2. Plasma activation at atmospheric pressure : This technique is performed at atmospheric pressure by using gases like hydrogen, nitrogen or oxygen.

3.1.3. Plasma functionalization : It involves introducing functional group onto material's surface. Then the material's reactivity is enhanced and its surface properties is modified.

3.1.4. Free electron activation : Through the imposed radio-frequency electric field, the free electrons in plasma gain its energy. These electrons impact with neutral gas molecules and transfer of energy takes place, hence the molecules dissociates into reactive species.

3.1.5. Interaction with solid surfaces : The excited species interacts with solid surfaces placed in the reactor. It results in the chemical and physical modification of the material surface [5].

## 4. TEXTILE FINISHES BY PLASMA TECHNOLOGY

### 4.1. ULTRAVIOLET PROTECTION FINISHES

The demand for textile apparel that shields against the harmful effects of ultraviolet radiation is increasing. Such clothing helps protect against the risk of skin cancer. Opting for protective garments with a high Ultraviolet Protection Factor (UPF) is regarded as a wise choice for a healthier lifestyle.

UV protection on cotton textiles can be achieved by exposing raw cotton fabrics to low-pressure, non-equilibrium gaseous plasma. This plasma is created in a glass tube through an electrode-less radio-frequency discharge either in oxygen or ammonia at a pressure of 50 Pascal.

The treatment not only enhance UV protection but also show improvement in adsorption of natural dyes [6].

### 4.2. ANTI-MICROBIAL FINISHES

In natural textiles, a major problems is microbial attack. The microbes in nature have the ability to degrade the textile made out of cotton or linen. So there is an importance of anti-microbial finishes on the textiles. Furthermore the rise in covid-19 in recent time makes it more important to use textiles which protects the user against the pathogenic germs.

On textiles that is of cotton, linen or viscose, anti-microbial resistance can be achieved using plasma technology. First, the requirement is of pre-surface modification using nitrogen or oxygen plasma on the substrate. This modification introduces new active and binding sites specifically NH2 groups on the fabric surfaces. Then silver nano-particles (AgNPs) with certain antibiotics are introduced to the modified surfaces, which results in significant improvement of anti-microbial activity of the treated material [7].

### 4.3. HYDROPHOBIZATION

Hydrophobization is the act of making something hydrophobic. Hydrophobization through plasma treatment offers a versatile approach with varied gas options. The application of hexamethyldisiloxane on cotton textiles yields a notable increase in the fiber surface's smoothness, elevating the contact angle to an impressive 130 degrees. Achieving a lotus effect on cotton textiles involves a process where the fibers are etched to create nano-sized peaks, which are then covered with a hydrophobic layer using gases like hexafluoroethane. It is important to note that, while these treatments enhance hydrophobicity, the water vapor transmission properties of cotton textiles remain unaffected.

### 4.4. FLAME RETARDANCY

Flame retardant textiles are much needed considering the hazard to life and property caused by fire. A flame retardant textile is characterized by its ability to protect the textile from quick-fire.

In cotton textile, plasma treatment is applied using atmospheric-pressure dielectric barrier discharge. The flame retardant finish is applied by pad-dry-cure method. In Polyester textiles, low-frequency oxygen plasma treatment conducted before padding polyester textile with alkyl phosphonate structured flame retardant agents. The hydrophilic characteristics of polyester fabric also get improved through this treatment.

### 4.5. ANTI-STATIC FINISH

The primary role of anti-static agent is to prevent the generation of static electricity within textiles. In polyester textiles, the anti-static property can be improved through low-temperature plasma treatment with oxygen. Low-temperature plasma treatment induces changes in the fibers leading to oxidation and degradation of fiber surfaces. Oxidation increases the surface energy while degradation modifies the surface morphology of fibers. As a result the fiber half-life is reduced. This reduction in half-life reflects the enhanced dissipation of electrostatic charges, making the fabric more anti-static.

### 4.6. CREASE RECOVERY FINISH

Textiles that are made up of cotton or linen are in constant need of crease recovery finishes. It can be done with plasma technology. The cross linking effect between cross linking agent and cellulose molecules can be increased with the pad- dry-plasma- cure process with argon as the working gas. The dry crease recovery angle and the wet crease recovery angle retention value of pad-dry-plasma-cure finished fabric are higher than those of the conventional finishing processes.

### 4.7. ADHESION IMPROVEMENT

Some textiles requires adhesive qualities in them. Plasma technology can help with that. The total number of functional groups on the surface can be increased in oxygen plasma, which then enhances the substrate's adhesion to other materials.

### 4.8. ANTIFELTING OF WOOL

Felting of wool is a natural process where wool fibers become entangled and compacted, leading to a dense, matted fabric formation. Anti-felting is necessary to get rid of this effect. The conventional anti-felting has negative effects on the environment while oxygen plasma helps in creating anti-felting wool without any issue.

The table provides a comprehensive guide linking various finishing treatments with specific materials and the corresponding plasma treatment needed to achieve desired properties [8]:

| PROPERTY | MATERIAL | TREATMENT |
|---|---|---|
| HYDROPHILICITY | SYNTHETIC FIBERS | OXYGEN PLASMA, AIR PLASMA |
| HYDROPHOBICITY | CELLULOSIC, WOOL, SILK, PET | SILOXANE PLASMA |
| FLAME RETARDANCY | COTTON, RAYON | PLASMA CONTAINING PHOSPHORUS |
| CREASE RECOVERY | CELLULOSIC FIBERS | NITROGEN PLASMA |
| ANTI-STATIC | WOOL, SILK, CELLULOSIC FIBERS | PLASMA CONTAINING DIMETHYL SILANE |
| ANTI-MICROBIAL | CELLULOSIC FIBERS | PLASMA CONTAINING DMDHEU |
| ANTI-FELTING | WOOL | OXYGEN PLASMA |
| UV PROTECTION | COTTON, PET | HMDSO PLASMA |

## 5. CONVENTIONAL TEXTILE PROCESSING (WET) V/S PLASMA TECHNOLOGY

The table offers a clear distinction highlighting how plasma technology diverges from and surpasses conventional/wet processing finishing methods [9,10]:

| | WET PROCESSING | PLASMA |
|---|---|---|

| | | TECHNOLOGY |
|---|---|---|
| **MEDIUM** | WATER-BASED | NO WET CHEMISTRY INVOLVED |
| **ENERGY** | HEAT | ELECTRICITY |
| **WATER CONSUMPTION** | HIGH | NEGLIGIBLE |
| **RAW MATERIAL CONSUMPTION** | LOW | HIGH |
| **REACTION LOCALITY** | SURFACE SPECIFIC | BULK OF MATERIAL |
| **SOLVENT REQUIREMENTS** | YES | NO |
| **NUMBER OF PROCESSES** | MULTIPLE | SINGLE |
| **ENVIRONMENT FRIENDLY** | NO | YES |
| **WASTE DISPOSAL** | HIGH | NEGLIGIBLE |
| **INNOVATION POTENTIAL** | MODERATE | VERY HIGH |

## 6. CONCLUSION

In conclusion, eco-friendly textile finishes mark a crucial stride towards sustainable and environmentally conscious practices in the textile industry. The adoption of biodegradable, non-toxic, and energy-efficient finishes contributes to reduced environmental impact, water conservation, and minimizing harm to human health. By prioritizing eco-friendly finishes, the textile industry can foster a harmonious balance between fashion and environmental responsibility, meeting the growing demand for sustainable and ethically produced textiles. Also, Plasma technology is considered to be a important technology for recent advancement in textile finishing. It is an alternative to achieve environmental friendly textiles and increase the sustainability of textile industry. Considerable studies have been conducted since the 1980s on advancing plasma technology within the textile sector. In conclusion, it is understood that this technology has a lot of potential in the textile industry.

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