



# Plasma Treatment as Green Technology for Dyeing of Textile Fabrics



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## Abstract

Use of synthetic dyes for dyeing of textile fabrics are most problematic environmental concerned for textile industry owing to their toxic effect on ecosystem. Thus, sustainable novel technologies for textile dyeing are needed that utilize enhanced dye uptake and improved performance characteristics of fabric. Such technology may reduce dye concentration in waste-water effluents from textile sector and ultimately become energy efficient and cost effective. Plasma technology has proven to impart enhanced dye exhaustion, dye penetration, dyeing in shorter time with minimal of chemical auxiliaries and energy usage. The potential attributes of plasma on textile dyeing is discussed in this article..

**Keywords:** Plasma technology, Textile fabric; Dyeing; Applications

## Introduction

Textile sector is facing an increased global competition in current decade owing to changing market conditions. The utilization of novel technical skills is thus forced for fabricating textile products for high quality performances [1]. This aspect is further accelerated to employ such technologies due to high level of hazardous chemicals in large quantities and volume of waste water textile effluents. Thus extra purification methods are needed to purify these effluents. As alternative to conventional chemical treatments, radiation has potential to tailor surface characteristics of polymeric, micro and nanostructures [2]. Among all available surface treatment methods, Plasma irradiation is observed a remarkable significance. This is a green, dry, worker friendly and ecofriendly method that can alter surface properties without major change in bulk performance of textile materials. Owing to heat sensitive nature of textile polymeric materials, non-thermal plasma is particularly suitable [3,4].

## Plasma treatment Vs chemical modification

Surface morphology of fiber greatly influences the choice of processing method for it. For example, a fiber having scales on its surface may exploit unwanted phenomenon like barrier of diffusion or felting. Therefore, many fiber degradation effects as well as environmental issues are concerned by using chemical treatment for modification of such fibers [5,6]. Thus a number of green processes have focused due to ecological and economical awareness to deal these issues.

As comparison, low yield of dyeing and more than 50% dye lost in waste water effluent, some esthetic and environmental issues can

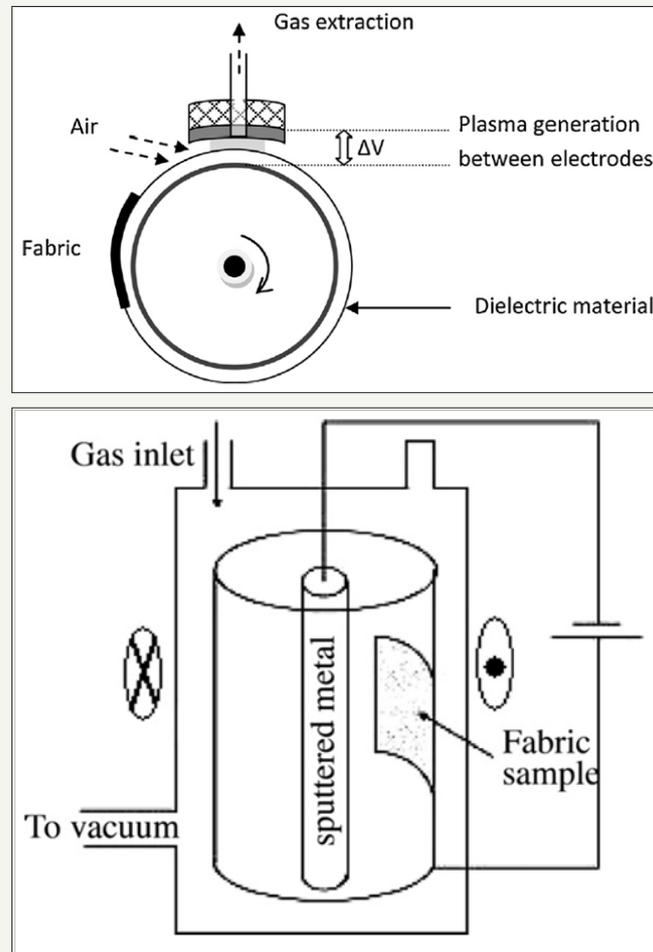
minimized by plasma treatment before, during dyeing or finishing processes. Advantageously, this technology can operate at ambient conditions with lesser of no chemical auxiliaries are needed. Thus, this technology is attributed green textile technology.

## Plasma treatment

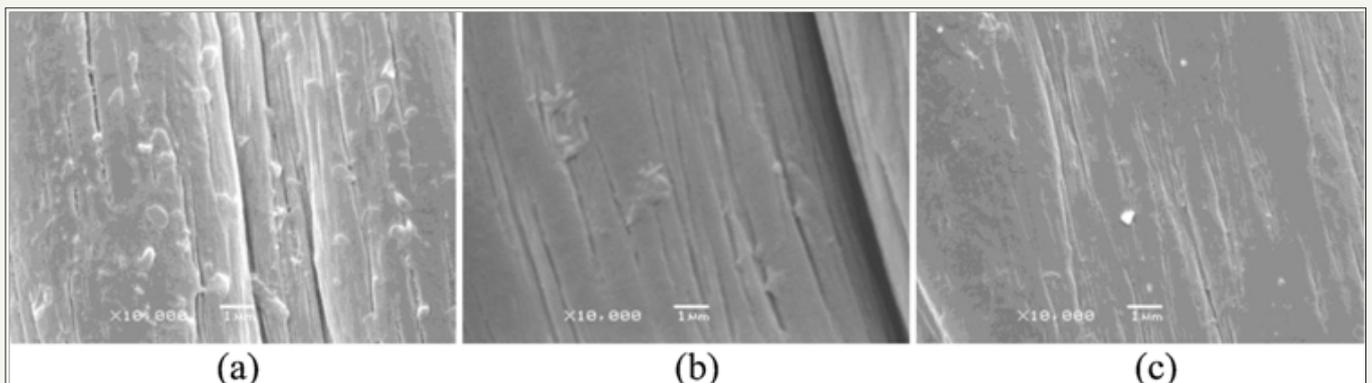
Various characteristics have developed for textiles e.g., high level of shrink resistance [7-10] wet ability [11,12]. Low temperature plasma (LTP) treatment has shown significant plasma-polymer surface interactions to tailor process and performance characteristics of dyeing wool fiber including improved dye uptake, lesser felting dispute, increased electro negativity on fiber surface [7,13-16]. In this way, penetration of dye become more penetrated in treated fiber and ultimately enhance coloration achieved. Exocuticle A-layer of wool fiber is expected to under gone cytokine oxidation under exposure of sputtering results of plasma. Ultimately, partial swelling of A-layer at fiber surface occurred owing to decrease in cross-linkages and improved fiber-dye affinity. Comparatively, Acetone/argon plasma is favored in place of helium/argon plasma to improve dyeing ability of wool at room temperature towards acid dyes [14]. Furthermore, coupling enzymatic treatment along with low temperature plasma pre-treatment is significant to further increase dyeing rate of cotton and wool fabrics toward milling acid dye [17]. This performance achieved by simultaneous effect of enzymatic and plasma treatments which attack in interior and exterior of fiber respectively. Nature of plasma gas also contribute its significant effect for modifying fiber surface. For example, chrome dyeing of wool fabric is favored to use nitrogen plasma in place of oxygen plasma [18]. Thus, mordant treatment of wool fabric

in textile processing can be substituted with plasma sputtering of which gives better performance characteristics of fabric and enhanced antibacterial properties advantageously [19]. Different schematic view of plasma sputtering setup for fabric is depicted

in Figure 1. The performance of air plasma pre-treated fabrics is dependent to optimized process parameters [20,21]. Unwanted results may achieved at prolonged plasma exposure of fiber such as change in appearance of fabric and heavier weight loss.



**Figure 1:** Schematic view of (upper) corona plasma equipment used for acrylic fabric treatment [19] (lower) the DC magnetron sputtering setup [19].



**Figure 2:** SEM micrographs of acrylic fiber.

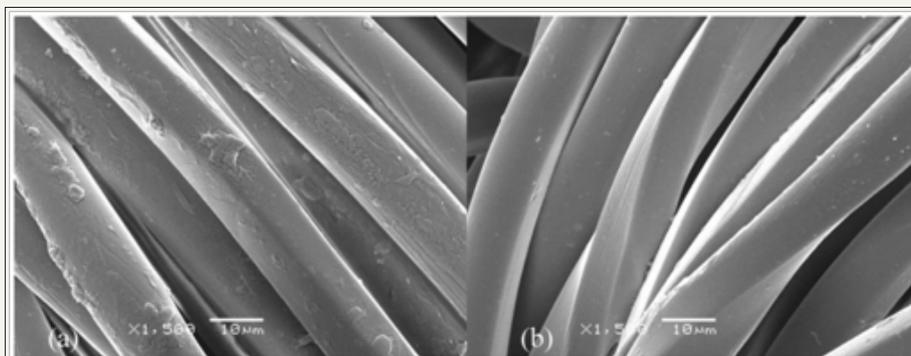
(a) Untreated

(b) After corona treatment for 7s

(c) 28s. Evidence of the effect of matter removal by plasma etching observed in (b) and (c) [26]

In place of natural fibers, plasma technology is shown extraordinary results for synthetic fibers as well. PET fabric treated by cold plasma exhibit enhanced dyeing performance owing to enhanced surface area and surface roughness induced by plasma treatment [22,23]. Enhanced dye exhaustion is also may be due to greater affinity and enhanced water swelling ability of PET fiber

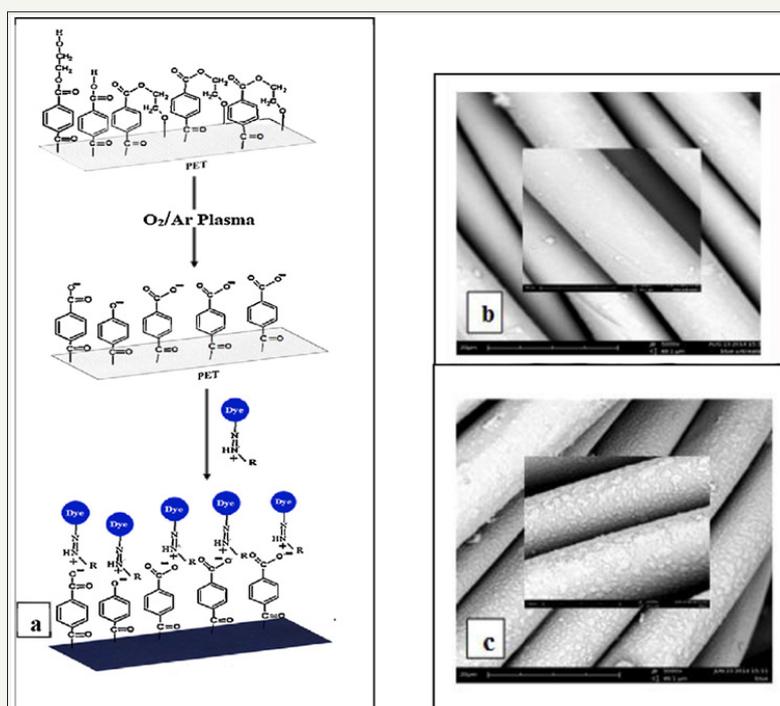
towards polar parts of dyes during dyeing process of treated PET fabric [24]. Anti-reflective coating of PET with better coloration is achieved by plasma sputter etching of organo-silicon compounds on surface of PET [25]. Corona plasma is able to remove unwanted matter substance from surface of acrylic [26] and polyamide [27] fibers as depicted in Figure 2 & 3.



**Figure 3:** (a) untreated PA 66 fibers and (b) plasma-treated PA 66 fibers at 100W, 3min, 10L.min<sup>-1</sup>, and 1 Torr [27].

Furthermore, characteristic functional groups may develop on surface of fiber by plasma technology along with specific carriers for fabricating various functional and high performance applications. As a result, hydrophilicity and capillarity achieved e.g., enhanced dye diffusion in the amorphous region of PET/Viscose [28-30].

Plasma technology introduced oxidized anionic polar groups (i.e., C=O, COOH) on fiber surface with increased hydrophilicity which enhances the interactions of fiber with dye [30,31]. The mechanism of disperse dye with treated PET fabric surface is shown in Figure 4.



**Figure 4:** (a) The mechanism of disperse dye with treated PET fabric surface and SEM images (b) untreated after dyeing (c) treated after dyeing [30].

Another significant approach of utilization of Plasma technology is aim at grafting of suitable functional group on surface of fiber which also improves interaction of dye and fabric surface [32]. Introducing oxygen atoms onto surface of fabric by double barrier

discharge (DBD) plasma from atmospheric oxygen is another example of this approach. Thus, plasma technology is a versatile technique having a number of advantages over conventional treatment methods. Plasma treatment has tested with a number

of natural and synthetic fabrics such as silk [33,34], wool [35-41], cotton [16,42-51], polyethylene [52], polypropylene [53-55], polyester [22,56-60], polyamide [61-64], ramie [65] and viscose fibers [66].

## Conclusion

This article is an attempt to exploit and summarize potential aspects of plasma technology for textile dyeing to be employed in textile sector. Plasma treatment is a dry and clean technique operates at ambient temperature which is able to improve coloration and to develop characteristic functionalities on surface of textile fabric without altering the performance of bulk fiber. Furthermore, plasma treatment can couple with other natural treatment methods which further improve the performance of treated fabric. This results insignificant reduction of toxic chemicals and auxiliaries in effluent load which diminish energy usage and cost and environmental impact.

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