Journal of Fiber Bioengineering & Informatics 4:3 (2011) 267–276
http://www.jfbi.org | doi:10.3993/jfbi09201106

Effect of Atmospheric Plasma Treatment on Pad-dyeing of Natural Dyes on Wool

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Abstract

Plasma treatment is an emerging surface modification technique that alters dye uptake of wool without using chemicals or water for pre-treatment. Padding is an established continuous dyeing technique known for its efficient use of water, time and energy. This study combined these two techniques for colouration of wool fabric using two natural dyes derived from the Acacia plant family. The investigation focused on the effects of plasma treatment and obtaining unique patterning effects. Helium (100%) and a mixture of helium and nitrogen (95%/5%) were used as the plasma gases under atmospheric conditions. Plasma treated wool fabric was padded with the above natural dyes. Copper sulphate and ferrous sulphate were applied on the dyed fabric as mordant yielding neutral shades of beige and grey respectively. Up to a 30% enhancement of dye adsorption on plasma treated wool substrate was observed as compared to untreated sample for both gases used. This higher adsorption indicates the hydrophilic character of the natural dyes used. Key performance parameters such as fastness to washing, rubbing and light were tested and found to be satisfactory. A single process tone-on-tone pattern was achieved by controlling the plasma exposure of treated area. This study concluded that a merger of natural dyes with modern plasma treatment and padding techniques for wool colouration was feasible.

Keywords: Acacia Natural Dye; Atmospheric Plasma Treatment; Padding; Mordant; Wool Fabric

1 Introduction

Wool, used since the dawn of civilization, has to address present day issues in order to retain its pristine position as a preferred textile material. These issues may be classified as being broadly related to quality assessment, environment and competition from synthetic fibres [1]. Wool dyeing has a significant impact on the environment due to dyeing effluents which contain harmful chemicals and synthetic dyes for wool dyeing, and require pre-treatment before discharge

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[2]. A continuous effort is underway seeking benign substitutes [1]. The present study contributes to that effort by investigating a combination of pre-treatment with atmospheric pressure plasma and pad-dyeing with natural dyes.

Plasma technology is well known for imparting functional finishes to textile materials without the use of harmful chemicals or water [3, 4]. By plasma pre-treatment, the functionalities achieved include altered moisture relations (absorbance or repellence), anti-microbial, soil repellence, stain resistance, soft handle and improved dyeing [5-8]. This variety is possible by altering process parameters such as supply frequency, discharge power, treatment time, type and pressure of gas. For example oxygen or helium plasma increases moisture absorbance while fluorocarbon increases water repellence. Several surface phenomenon such as adsorption, desorption, etching, cleaning, surface activation and cross-linking occur singly or in combination on exposure to plasma [9, 10].

Plasma treatment has been found to affect the lipid layer and surface cuticle of wool without affecting its bulk properties. The treatment improved wettability and increased dye uptake, leading to an enhancement in the depth of shade and evenness. It has also been suggested that intrinsic dye hydrophilicity is a deciding factor for this improvement [11, 12].

Treatment of textile substrates is generally carried out by low temperature plasma of the vacuum or atmospheric pressure variety. Although the latter is a fairly recent development, the effects are comparable [12-15]. Atmospheric pressure plasma treatment is economical and convenient for continuous production as it avoids working in a vacuum.

Natural dyes, derived mostly from plants, were the mainstay of textile dyeing till the 1850's after which the synthetic dyes took over [16]. Synthetic dyes reign in the textile industry because of their low cost and brilliance while possessing excellent desirable properties, variety, and ease of application [17, 18]. Of late however, a subtle gap has been created by the restrictions placed on some carcinogenic and non-eco-friendly synthetic dyes [19]. Another factor could be the eco-conscious customer who wants to contribute by purchasing goods with the 'natural' tag even at premium prices. This has focused interest on the commercial viability of traditional natural dyes.

The new interest has highlighted a need for research to accommodate natural dyes in the present industrial scenario. Attempts at filling this need has resulted in literature pertaining to a review of sources [17, 20, 21], dye chemistry [22, 23], application methods [24, 25] and evaluation of desirable properties of natural dyes [26-28]. The findings may be summarized as:

- Natural dyes can yield a gamut of acceptable shades.
- A variety of application methods are amenable although exhaustion from water is the common method used.
- Present volume of demand obviates domination by natural dyes.

Research opportunities exist in areas such as:

- Evaluation and improvement of present and potential sources.
- Feasibility of combining developments in textile technology with natural dyes.
- Exploiting inherent properties of natural dyes for specialty applications.