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Surface Roughness Analysis of Cotton Fabric by Laser Speckle Technique

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Abstract: In the textile industry, disposing the waste products after dyeing causes a major environmental issue. The mordants used leads to adverse effect for the human and other living organisms. Plasma processing is ecofriendly and it does not produce any waste, pollution free on the environment. Therefore, low temperature plasma treatments are set to make a revolution in textile industry. The present work is to modify the surface of cotton fabric by oxygen plasma treatment with operating parameters such as exposure time, discharge potential and base pressure are kept constant as 5 min, 400V and 9 Pascal respectively. The surface roughness of the fabric is analyzed by laser speckle technique for plasma treated and mordanted fabric and then corresponding results were reported. Further, we observed the increase in surface roughness of the fabric after plasma treatment.

Keywords: Cotton fabric, Oxygen plasma, Hydrophilic, Surface roughness, Laser speckle.

1. Introduction

Nowadays the textile coloration using natural dyes is of great interest due to the toxic and allergic reactions of synthetic dyes. Natural dyes are biodegradable, eco-friendly and harmless to the environment. Metal mordants are used to enhance the fastness properties of the fabrics which is dyed with natural dyes[1]. The metallic mordants which themselves are pollutant and harmful causing the environmental hazard [2]. Plasma surface modification is a low temperature plasma technology which is a dry, ecofriendly and adds the functionalities such as hydrophilicity , antibacterial properties as well as biocompatibility[3][4]. The effect of plasma treatment can be altered by operating parameters such as discharge potential, treatment time , pressure and type of gas whereas the oxygen plasma treatment increases the hydrophilicity of the fabric [5]. By using the mordants extra purification method is needed to purify the effluents and plasma treatment is an alternate to the chemical methods which has observed a remarkable significance [6]. Glow discharge plasma consists of high energy electrons , positive and negative ions, excited atoms, free radicals, neutrals, UV radiation which interacts with textile surfaces and alters surface morphology, chemical composition without affecting the bulk properties [7]. Surface roughness assessment of textile fabric by fractal dimension is reported and the various methods existing to quantify the surface roughness are also described [8].

In this paper, the plasma treatment of cotton fabric was done by using DC glow discharge plasma. After treatment the fabric has been studied in order to evaluate the effect of glow discharge plasma treatment on the surface roughness of the cotton fabric. The conventional pre-mordanting method has also been studied for the comparison purpose. The treated fabric was assessed in terms of contact angle measurement and laser speckle technique.

2. Materials and Methods

2.1 Materials

The cotton fabric with dimension of 8×8 cm was cleaned with distilled water containing 8% of ethanol which is sonicated for 30 min at room temperature to remove the impurities. Then the fabric was dried and kept for plasma treatment.

2.2 Plasma treatment

A DC glow discharge plasma system was used to treat the cotton fabric [9]. The plasma treatment was carried out by placing the fabric inside the chamber with the help of the sample holder. Oxygen was used as a process gas and the exposure time, discharge potential and base pressure were kept constant as 5 min,400V and 9 Pa respectively. After plasma treatment the fabric was kept in an air lock cover for further studies.

2.3 Pre-mordanting treatment

Mordanting is the commonly used surface modification method for imparting hydrophilic property to the cotton fabric. In this study, ferrous sulphate is used to enhance the hydrophilicity of the cotton fabric. The cotton fabric was premordanted with ferros sulphate by dissolving the fabric in the solution for about 30 min. Then the fabric was dried and kept in an air lock cover for the analysis.

2.4 Contact angle measurement

The contact angle of the cotton fabric was measured by a goniometer at room temperature. Distilled water was used as a solvent. The droplet size of 2 µl, was placed on the fabric and the image of the liquid droplet on the fabric was recorded. The contact angle was measured immediately after the drop was delivered to the surface. The value of the contact angle was measured with an average of ten measurements for each specimen.

2.5 Laser speckle technique

The coherent laser beam from Semiconductor green diode laser (HLPS-1886) of wavelengths 532nm with 5Mw is allowed to fall on optically rough untreated fabrics and plasma treated fabrics. The reflected light captured by high resolution CCD camera produces the speckle pattern due to the composite effect of scattering and interference. The speckle pattern is recorded instantaneously in personal computer for further processing. The speckle images are converted in to equivalent binary images. Subsequently the fractal box counting is adopted to give quantitative description of surface roughness. The experimental set up used for the observation of speckle images is given in Figure 1.

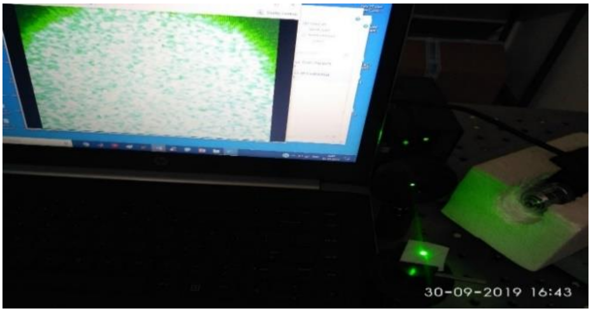

Figure 1. Experimental set up for Laser speckle technique

3. Result and discussion

3.1 Contact angle measurement

The contact angle measurement can quantitatively provide more information about the surface wetting properties of the untreated, mordanted and plasma treated fabric.

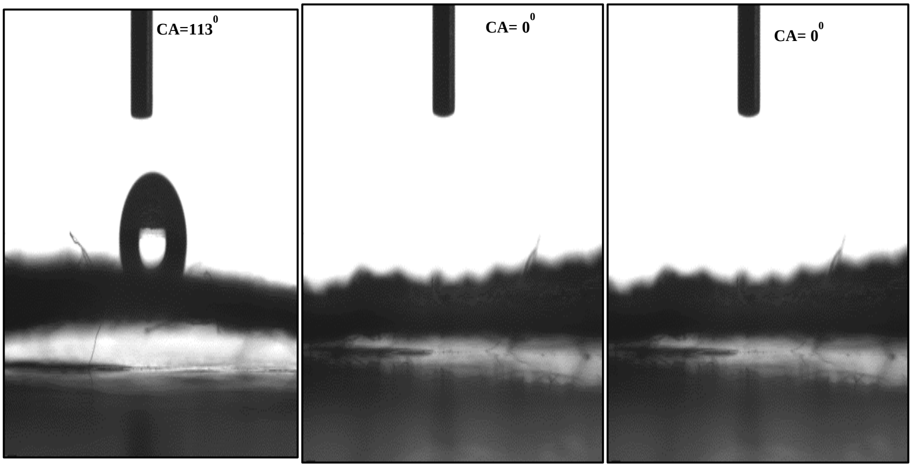

Figure 2. Contact angle image of untreated, mordanted and plasma treated cotton fabric

The contact angle of the samples was measured with distilled water and is shown in Figure 2. Surface energy was calculated from the contact angle values by using Neumann's method[10]. The contact angle of the untreated cotton fabric is 113^0 with surface energy 16.408 mJ/m^2, mordanted fabric is 0^0 with surface energy 72.8 mJ/m^2 and the plasma treated fabric is 0^0 with surface energy 72.8 mJ/m^2. The results of contact angle were given in the Table 1. By comparing the results it has been observed that the contact angle values were changed and reduced after plasma treatment. The changes were due to the variation of surface roughness of the treated fabric.

Table 1. Contact angle and surface energy of untreated, mordanted and plasma treated cotton fabric

Sample	Contact angle	Surface energy mJ/m^2
Untreated cotton fabric	113^0	16.408
Mordanted cotton fabric	0^0	72.8
Oxygen plasma treated cotton fabric	0^0	72.8

3.2 Laser speckle technique

3.2.1 Theory of fractal dimension:

The fractal dimension can be determined based on the box counting method where the binary images of a surface are covered with different grids (box length ε) and the number of boxes N(ε) required to cover the structures of the surface can be recorded. The speckle images are converted in to suitable binary images from which fractal dimensions are calculated.

If an object possess fractal, N (ε) increases according to the following equation:

$$N(\varepsilon) = C.\varepsilon^D \qquad \ldots\ldots(1)$$

Where, D is fractal dimension, C is constant value. The fractal dimension can be calculated from the equation [11]:

$$D = \lim_{\varepsilon \to 0} \left\{ \frac{log[N(\varepsilon)]}{\log(\varepsilon)} \right\}$$

The speckle images of untreated, mordanted and plasma treated fabric were shown in Figures 3 ,6&9 and the equivalent binary images of the speckle images were represented in Figures 4, 7&10.The fractal dimension of the untreated, mordanted and plasma treated fabric were observed from Figures 5,8&11 and the D values were 1.7149,1.8739 and 1.9140 respectively.

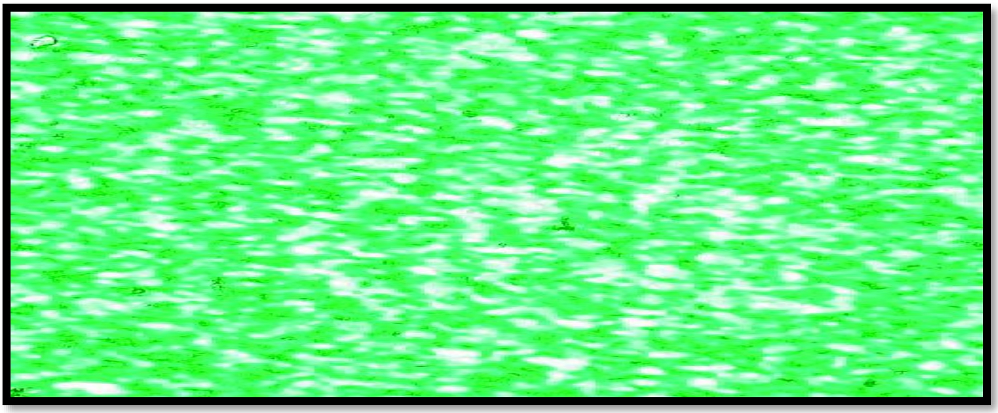

Figure 3. Speckle image of untreated fabric

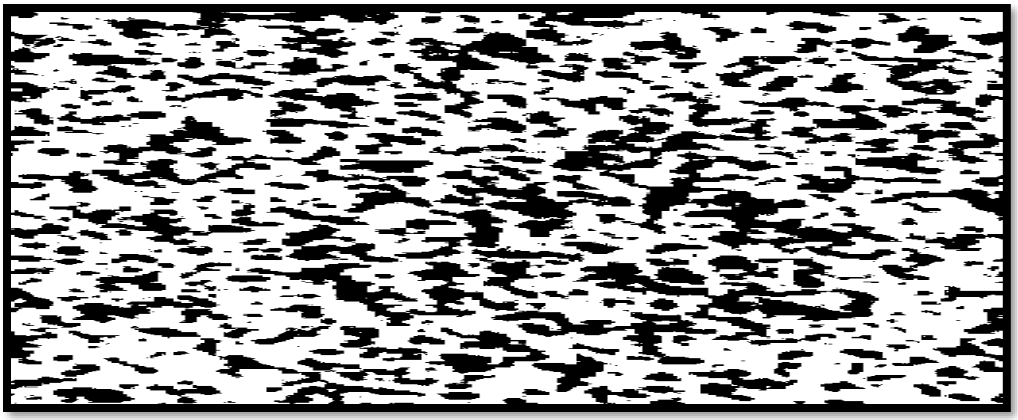

Figure 4. Equivalent binary image of untreated fabric

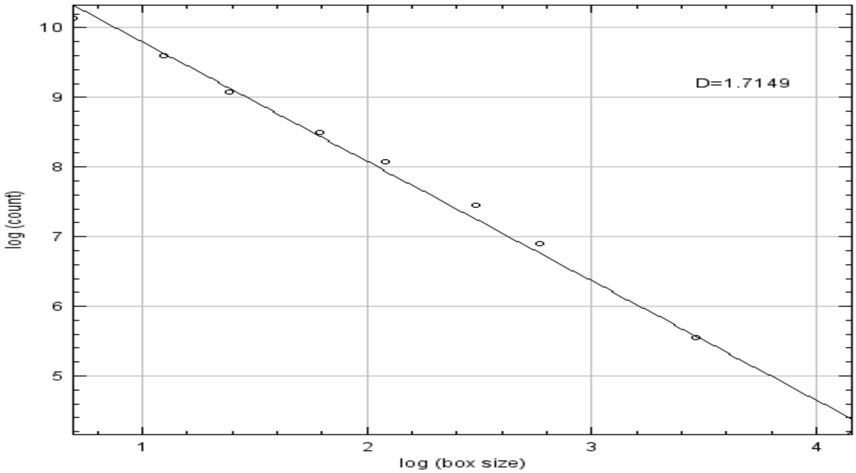

Figure 5. Fractal dimension of-untreated fabric

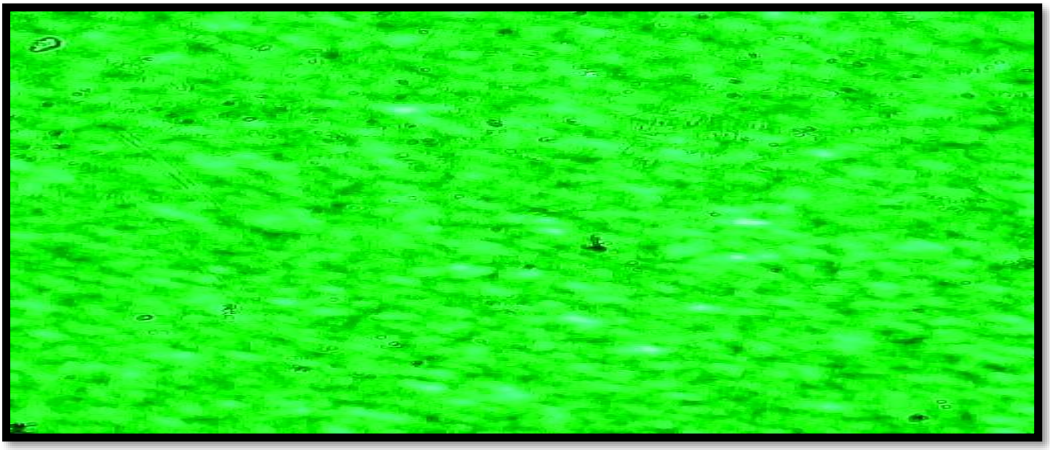

Figure 6. Speckle image of mordanted fabric

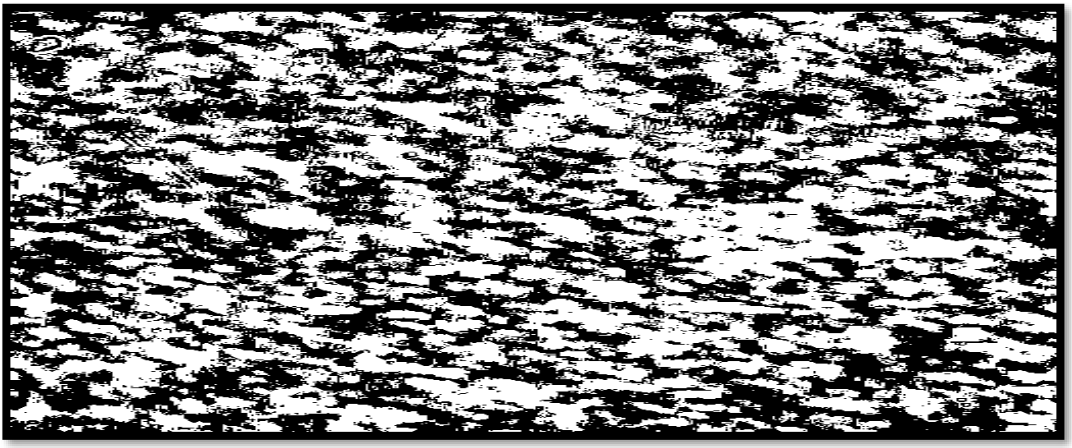

Figure 7. Equivalent binary image of mordanted fabric

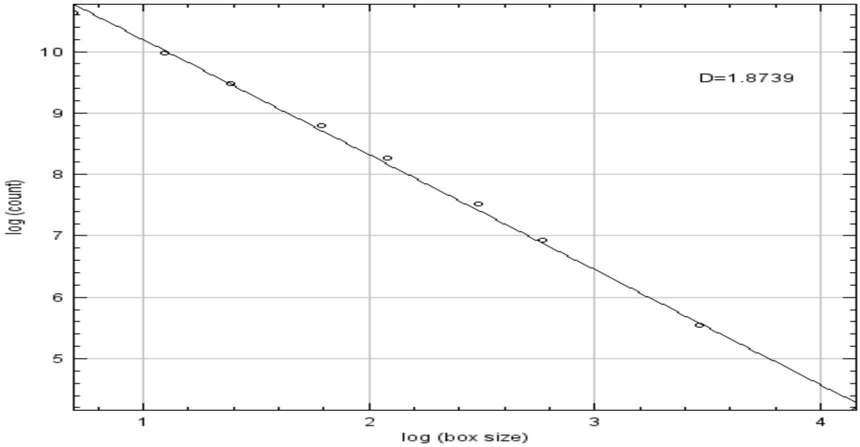

Figure 8. Fractal dimension of mordanted fabric

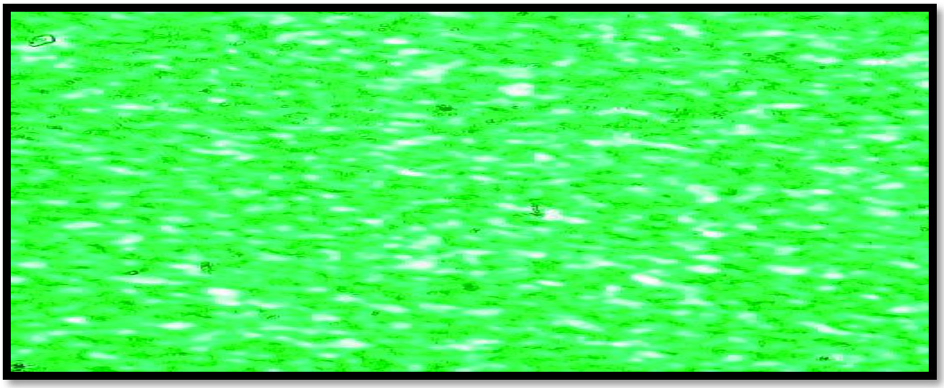

Figure 9. Speckle image of plasma treated fabric

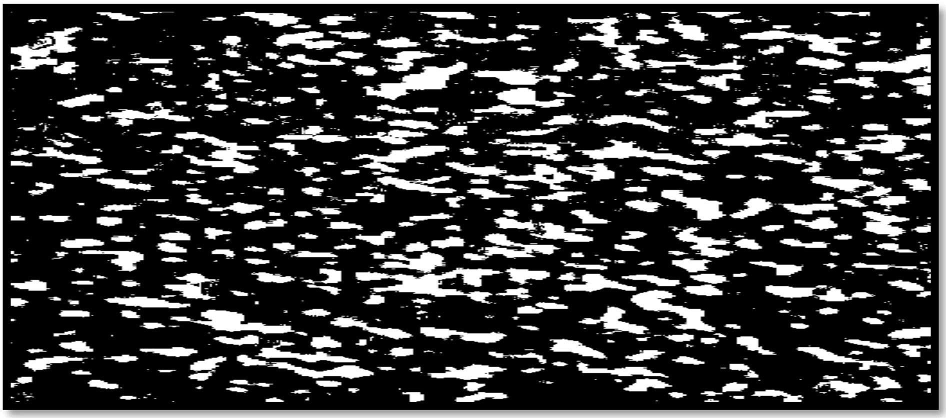

Figure 10. Equivalent binary image of plasma treated fabric

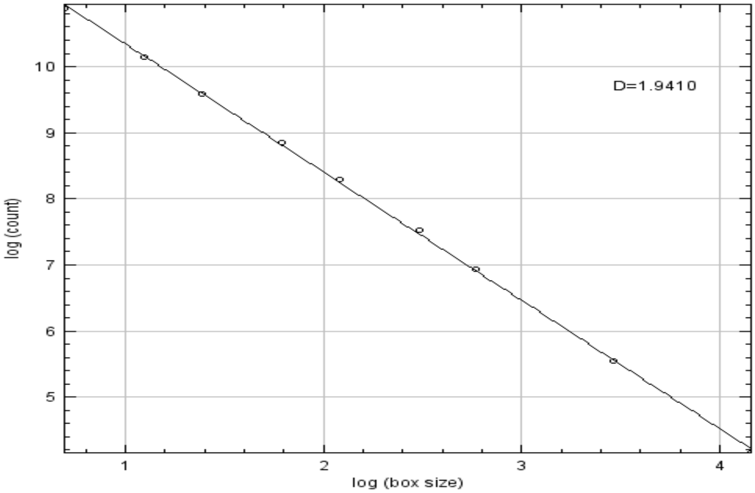

Figure 11. Fractal dimension of plasma treated fabric

3.2.2 Fractal Analysis

Calculated Fractal dimensions reveal that the increase in surface complexity of fabrics due to the influential parameters of pressure and voltage during surface modification process. The plasma treated fabric shows higher fractal values than the untreated and mordanted fabric. Hence plasma surface modification enhances the surface roughness. Fractal dimension is directly related to surface roughness and for extremely rough surfaces it has significantly higher values[12]. The value of fractal dimension is directly proportional to surface roughness. The fractal dimension is more for the rougher surface[13]. D is a suitable parameter to study the surface roughness. The value of D lies between 2.0 and 3.0 for 2D surfaces, where the value 2.0 indicates less rough surface, and 3.0 indicates highly rough surface[14]. Hence in this study the obtained value of 1.94 for textile shows the less complexity of the surface. The

4. Conclusion

In this study the surface roughness analysis of plasma treated and mordanted textile fabric was carried out by laser speckle technique. To improve the absorption of the dye the cotton fabric was mordanted with ferrous sulphate . Plasma treatment is an environment friendly alternative for metal mordants and pretreatment of the cotton fabric with oxygen plasma was employed. The quantitative surface roughness is estimated by means of fractal dimension. It is observed that the surface roughness increases for mordanted and plasma treated samples. Hence it is obvious that the surface becomes more complex due to treatment.

5. References

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Conflict of interest: NIL