The acceleration ofwater absorption time innatural silk

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The acceleration of water absorption time in natural silk fabrics (Bombyx Mori) irradiated with positive and negative corona plasma discharges at atmospheric pressure

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The acceleration of water absorption time in natural silk fabrics (Bombyx Mori) irradiated with positive and negative corona plasma discharges at atmospheric pressure

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Abstract. This study aims to examine the acceleration of water absorption time in natural silk fabric irradiated with negative and positive corona plasma discharge generation at atmospheric pressure. The point-to-plane electrode configuration is made by one hundred point electrodes, equally distributed, in a 10 x 10 square plane and a plane electrode made of copper. The positive plasma discharge is generated by connecting the point electrodes to a high voltage power supply. In contrast, the negative plasma discharge is generated by connecting the power supply to the plane electrode. During the plasma discharge irradiation, the dyeing natural silk (Bombyx Mori) samples are placed on the plane electrode with varying irradiation duration and electrode spacing. Identification of irradiation effects on the fabrics was made using water drop test and SEM (Scanning Electron Microscope). Increasing the electrode's gap improves the stability of the corona discharge by reducing the discharge current. Moreover, longer irradiation time results in faster water absorption due to a significant interaction between the torn fabrics and water, especially at a broader electrode gap. In conclusion, both positive and negative corona plasma discharges irradiation alters water absorption time, with longer irradiation time results in faster water absorption by samples.

1. Introduction

Silk is a famous textile product globally due to its uniqueness and aesthetic value, making silk farms one of the essential household industries in some countries [1]. In its process, silk must be carefully prepared by dyeing before being sold to the market. This wet chemical processing is useful for removing natural impurities from the silk surface, making it suitable for added value coloring and functionality. Unfortunately, the dyeing process requires a large amount of energy and water because it involves a multi-step process. Moreover, the method also produces waste that often ends up polluting the environment [2,3].

One method that can serve as an alternative to overcome this problem is using plasma technology in preparing silk. Plasma treatment offers some advantages compared to its conventional chemical processes counterpart [4,5]. Another technology for fabric processing is needed to reduce (even eliminate) water use, namely plasma technology. The technology used for fabric processing is non-thermal plasma technology because textile materials are heat-sensitive polymers and can be applied continuously. Plasma technology applied to textiles is a dry, environmentally friendly, and worker-friendly method of achieving surface changes without changing different materials' bulk properties [4,5]. The generation of plasma for fabric processing is carried out under atmospheric conditions and is cold plasma. The types of atmospheric plasma that are applied to textiles are (i) plasma corona, (ii) dielectric plasma barrier discharge (DBD), (iii) Atmospheric Glow discharge plasma (APGD), and (iv) Atmospheric pressure plasma jet (APPJ). Corona plasma is the oldest type of plasma technology [5] that can generate atmospheric conditions without triggering a gas feed from noble gas elements. There are two types of corona plasma, namely positive corona and negative corona [6,7].

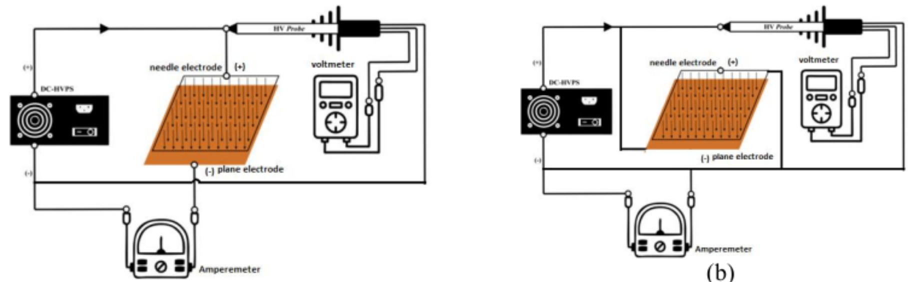
Corona plasma radiation on polyester fabrics impacts the increase of the fabric's water absorption rate [8]. The absorption also occurs for natural silk fabrics that are irradiated using corona negative [9]. Plasma treatment technology is a unique and innovative method to treat textile surfaces. Moreover, the generation of plasma spaces can be carried out under atmospheric conditions. The advantage of plasma technology in the silk industry is evident from physical and chemical aspects as plasma treatment does not involve water use, which means no waste whatsoever. Therefore, this study aims to compare the effects of positive and negative corona plasma discharges on Bombyx Mori, specifically for the water drop test and changes in the sample's surface. Comparing the corona's characteristics in the presence of natural silk fabrics is also investigated.

2. Methods

Both corona plasma discharges at atmospheric conditions were generated by connecting electrodes to a high voltage direct current power source. The electrodes used were arranged in point-to-plane geometry. One hundred point electrodes served as active electrodes placed in a 10 x 10 square plane. These electrodes are made of stainless steel, with the plane electrode is made of copper. Point electrodes were separated 1.3 cm from each other. Observation of potential difference and electric current during plasma generation at atmospheric conditions was made using a multimeter set in both parallel and series configurations. The electric current used to measure potential difference was set to run through a high voltage probe before being connected to a multimeter to convert the measuring order from kilovolt into volt.

The generation of positive plasma discharge is conducted by connecting point electrodes to the high voltage power supply's anode and the plane electrode to the cathode, as shown in Figure 1. The opposite arrangement was applied for negative plasma discharge generation with point electrodes attached to the cathode, whereas the plane electrode was connected to the anode. The material used in this research was natural silk (Bombyx Mori) which has undergone dyeing. Treatment samples were of 10×10 cm^2 dimension. Plasma discharge characterization was carried out by gradually applying a potential difference to point electrodes and varying the point electrode's spacing at atmospheric pressure. The characterization was also performed by placing the silk samples on the plane electrode for the previous setup. Irradiation treatment on the silk samples involved both variations in irradiation duration and electrode spacing. Identification of irradiation effects on the samples was made using waterdrop test and Scanning Electron Microscope (SEM).

Waterdrop test was carried out differently for positive and negative plasma discharge treatment. Measurement for water drop test on the samples during positive corona plasma discharge irradiation started when water was absorbed. Measurement for water drop test on the samples during negative corona plasma discharge irradiation was started when water drops begin to set on samples.



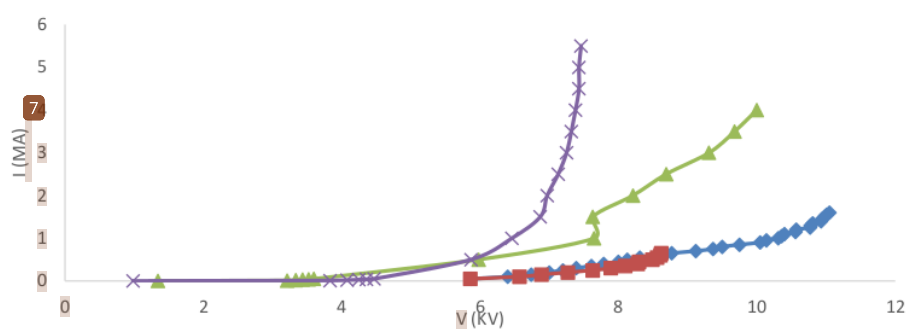
(a) (b)

Figure 1. (a) Electric circuit to generate positive corona plasma discharge. (b) Electric circuit to generate negative corona plasma discharge.

3. Results and discussion

Figure 2 shows plasma discharge characteristics generated using point-to-plane electrode configuration at both positive and negative polarity. These three different spacing indicate that the generation of negative corona plasma discharge requires lower potential differences than its positive counterpart. This relative ease of negative corona plasma discharge generation is due to the presence of free electrons at atmospheric condition, which is caused, among others, by cosmic radiation in the universe.

The presence of samples for both positive and negative plasma discharge generation affects discharge characteristics differently. For positive corona plasma discharge, the influence of sample placement in reducing current is minimum which is similar to that of cotton [6] and polyester [11]. The reduction is possible as the presence of the sample magnifies the dielectric constant of the plasma chamber. On the contrary, the sample for negative corona plasma discharge magnifies the corona discharge current observed during treatments for cotton and polyester [7].



(a)

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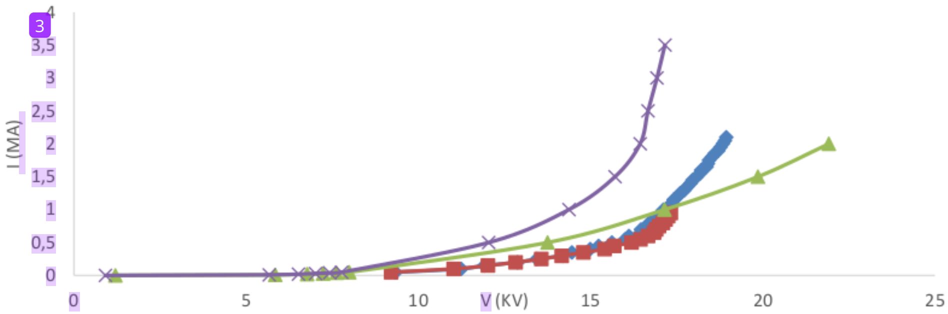

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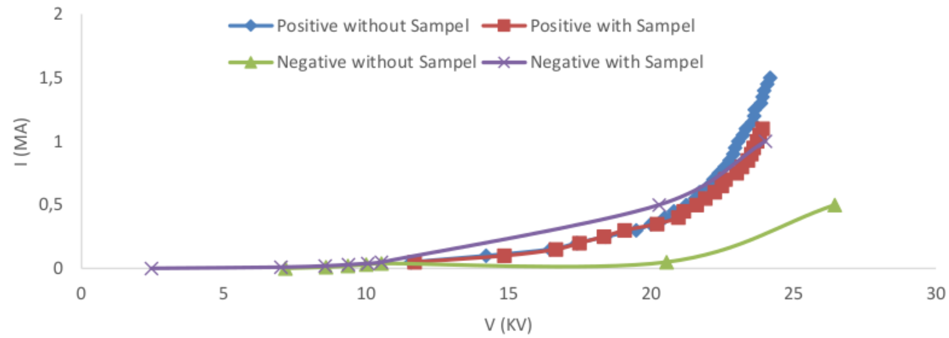


(c)

Figure 2. The characteristics of positive and negative corona discharge at atmospheric condition, both with and without samples, for electrode spacing of (a) 0.9 cm, (b) 2.1 cm, and (c) 3.0 cm

Increasing spacing between the point and the plane electrodes uniformly alters the presence of discharge by reducing discharge current on both positive and negative corona plasma discharges, with or without samples. The increase is reasonable as the wider spacing between electrodes allows for a larger dielectric chamber that, in turn, increases the dielectric constant.

Figure 3 shows water absorption characteristics by irradiated samples using positive (blue line) and negative (red line) corona plasma discharge. Both curves depicted in Figure 3 show that water absorption into the samples is faster when the irradiation time increases. According to a previous study, plasma radiation treatment in fabric samples can cause cloth's surface energy to rise in the emergence of hydrophilic groups [12]. That causes the silk fabric to absorb water faster, and the longer the irradiation time, the faster the moisture absorption in the silk fabric is.

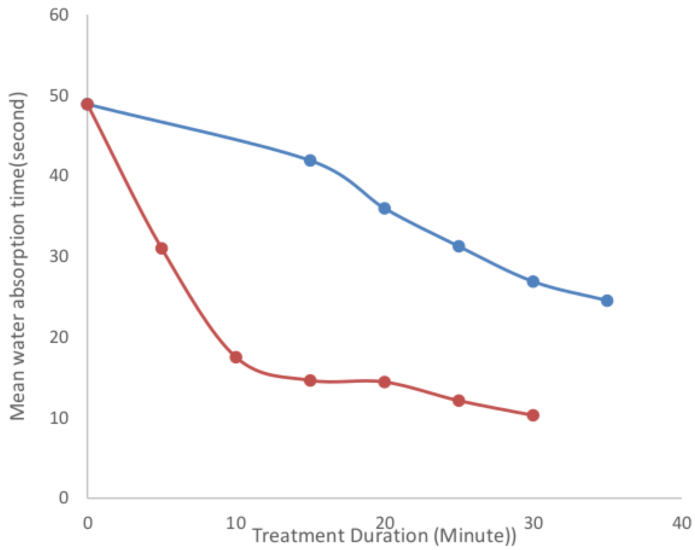
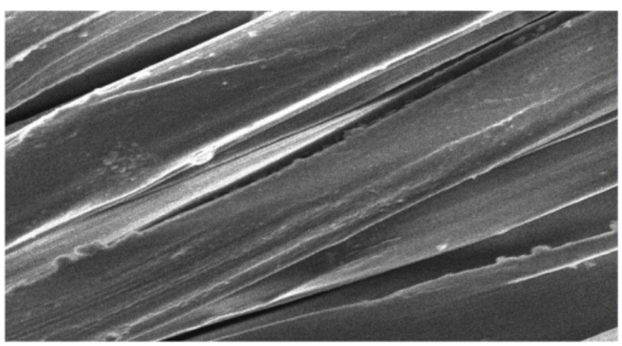
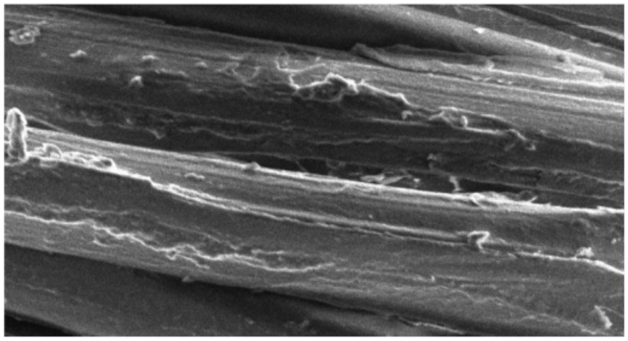


Figure 3. Curves showing relationship characteristics between water absorption and irradiation time of positive (blue line) and negative (red line) corona plasma discharge with point and plane electrode spacing of 2.4 cm.

Figure 4 shows samples at 2500× magnification before and after irradiation with positive and negative corona plasma discharges. Before irradiation, samples reveal threads of Bombyx Mori natural silk that are neatly arranged, as shown in Figure 4(a). In contrast, after irradiation using positive corona plasma discharge at 30 minutes, Figures 4(b) show that the irradiation has torn the silk surfaces. Figures 4(c) show the condition of samples after irradiation using positive corona plasma discharge for 30 minutes, where torn fabrics were found due to cavities and incisions that allow more significant interaction between samples and water. These two factors fasten water absorption in samples.



(a)



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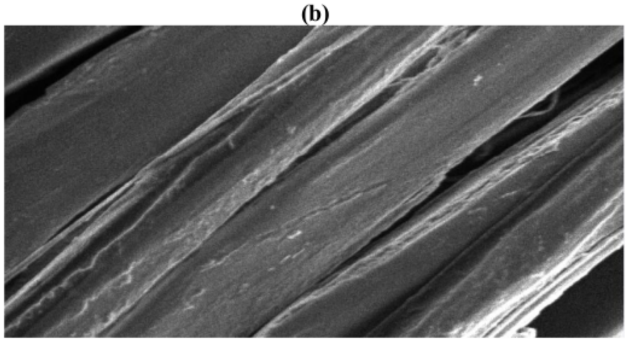

(c)

Figure 4. The microscopic image at 2500 times magnification for (a) samples without treatment, (b) samples with positive corona plasma discharge irradiation for 30 minutes, and (c) samples treated with negative corona plasma discharge irradiation for 30 minutes.

4. Conclusion

In conclusion, Bombyx Mori samples alter positive and negative corona plasma discharge characteristics at atmospheric pressure. More prolonged irradiation will tear the silk surfaces and damage fabric. Nevertheless, both positive and negative corona plasma irradiation alters the sample's water absorption time, with longer irradiation time resulting in faster water absorption.

Acknowledgment

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