Atmospheric Pressure Plasma Jet Treatment of Malaysian Batik Fabrics

Rizan Rizon Elfa[1], Umi Syazwani Rahizan[1], Mohd Khairul Ahmad[1], Chin Fhong Soon[1], Mohd Zainizan Sahdan[1], Jais Lias[1], Ahmad Shuhaimi Abu Bakar[2], Mohd Khairuddin Md Arshad[3], Uda Hashim[3] and Nafarizal Nayan[4]

[1]*Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400 Johor, Malaysia*

[2]*Low Dimensional Materials Research Centre, Department of Physics, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia*

[3]*Institute of Nano Electronic Engineering (INEE), Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia*

[4]*Microelectronic and Nanotechnology- Shamsuddin Research Centre (MiNT-SRC), Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400 Johor, Malaysia.*

elfa.rizan.r@gmail.com

***Abstract*—Atmospheric pressure plasma jet became very popular in plasma chemistry due to its properties which are applicable for surface treatment. In this work, a low-cost and in-house atmospheric pressure plasma jet using argon gas, neon transformer power supply and quartz tube has been developed. The atmospheric pressure plasma jet system can be used for textile applications. The low temperature of plasma treatment is environmentally friendly technology which has been proposed to change the topographical properties of the textile surface, besides its popularity that can be used to improve the surface wettability and dying properties of the textiles. Malaysian batik fabric has been used in this work to study the treatment effect of plasma jet on fabrics. Contact angle measurement is used to observe the water contact angle and absorption time under various treatment conditions. Results show that the fabric surface became hydrophilic just after the treatment of plasma jet. The water absorption time became faster when exposed to longer treatment time and higher flow rate of argon flow. This understanding is essential to optimize the usage of atmospheric pressure plasma jet for textile treatment and modification.**

***Index Terms*—Atmospheric Plasma; Textiles Wettability; Water Contact Angle; Plasma Jet.**

I. INTRODUCTION

Nowadays, the textile industry uses conventional fabric treatment which is a wet chemical process that uses a high amount of water for the preparation of fabrics including dying, printing and finishing of fabrics. Those processes using a chemical substance that is applied to textiles [1–3]. The chemical process consumed a lot of time besides involved high pollution of water resources. In addition, the cost of the chemical process is very high. Therefore, this study will give a method to overcome this problem and save more energy besides consuming less cost for the treatment of textile [4–7]. Fabric treatment is important to improve the feel or touch of the fabrics and make the fabric suitable for a specific used [8–10]. To overcome this situation, an atmospheric pressure plasma jet treatment is proposed to be one of the methods that can be used without using the chemical substance for textile treatment. However, the conventional plasma that usually uses is low-pressure plasma which is not applicable for the textile application. The atmospheric pressure plasma has been invented recently and applied for various applications, including biomedical, agricultural and textile industries [8]–[12]. During plasma treatment, the specific surface area will be increased and the hydrophobic area on the surface will be oxidized and partially removed [3]. Then, due to the chemical and physical surface modifications, the shrinkage behaviour of the textile will decrease. The surface modification from plasma treatment depends on the type of gaseous used [3]. The presence of reactive and inert gas is able to bring the chemical change on the surface of textiles [3]. Moreover, with the plasma treatment, it can enhance the printability that can be used when colouring the textiles. There are many types of fabric that can be used for atmospheric pressure plasma jet treatment such as wool, cotton, nylon and others.

There are many advantages of atmospheric pressure plasma such as cost-effective process because it does not need vacuum system which is a high cost to develop it. Moreover, the plasma treatment for atmospheric pressure plasma is a continuous treatment for textile applications and it is faster and easy process compare to low-pressure plasma. On the other hand, atmospheric pressure plasma system has its own disadvantages whereas it is difficult to sustain the glow discharge of the plasma. Then, it needs a higher voltage for gas breakdown and atmospheric pressure plasma is hard to produce uniform plasma throughout the reactor volume. There are many types of atmospheric pressure plasma such as corona discharge, dielectric barrier discharge, and plasma jet system. In this work, atmospheric pressure plasma jet (APPJ) is produced using a neon transformer power supply, quartz glass tube, two copper sheet electrodes and argon gas.

II. ATMOSPHERIC PRESSURE PLASMA JET SETUP

In this study, atmospheric pressure plasma jet consists of a neon lamp power transformer that acts as a power supply is connected to two copper sheet electrodes and commercial quartz glass tube which act as a dielectric material. This configuration allows the distance between the two electrodes to be varied between a few centimeters depending on the diameter size of quartz glass tube. For this experiment, the outer diameter of the tube is 5 mm, and the inner diameter is 3 mm. The maximum gap between two electrodes is kept around 3.0 cm to generate plasma discharge under influence of argon gas.

If the distance between the gaps is wider than 3.0, the plasma is not generated due to the low power of the neon lamp power transformer.

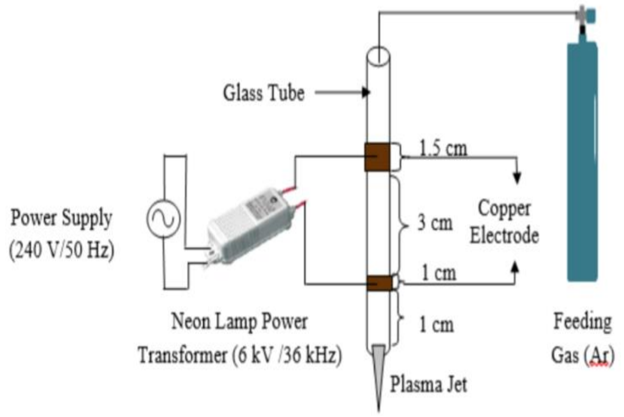

Figure 1: Configuration of atmospheric pressure plasma needle jet using copper electrodes and neon transformer power source. Argon gas flow is fixed at 50 L/min.

The APPJ is generated by using a power supply from the neon lamp power transformer. The voltage of electrodes was measured using high voltage probe, and it is found that the output is 10.69 kV for top electrode and 11.50 kV for the bottom electrode. On the other hand, the frequency of top electrode is 37.313 kHz and the bottom electrode is 45.455 kHz as shown in Figure 1 the configuration of the plasma jet.

High voltage and high frequency are essential to generate atmospheric pressure plasma with better uniformity since the atmospheric pressure plasma jet requires high breakdown voltage. Then, high purity (99.999%) argon is used as a discharge gas. The flow rate of argon can be adjusted from 10 to 60 liter per minute (L/m). Figure 2 photo image of the atmospheric pressure plasma jet system.

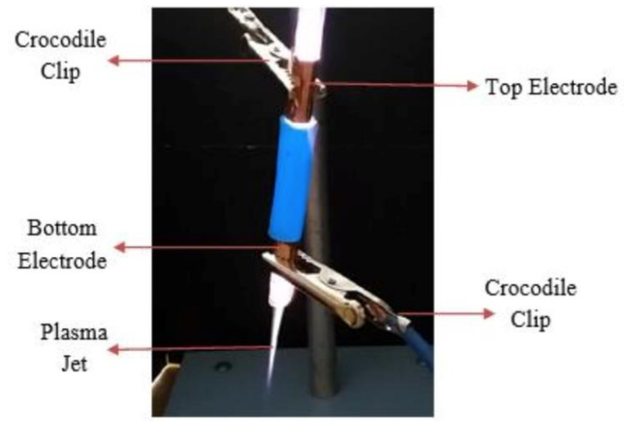

Figure 2: Photo image of atmospheric pressure plasma needle jet. Length of plasma jet is about 2 cm from the tube orifice.

III. Results and Discussion

Contact angle measurement is a method of measurement to study the wettability on surfaces of the fabric. On top of that, it can determine the hydrophobic and hydrophilic properties of the materials. Hydrophobic is a property of a substance that does not absorb water while hydrophilic is a substance that absorbs water. If the contact angle measurement has a small angle that is ≤ 90°, it has high wettability properties, while if the measurement has a large angle that is ≥ 90°, it has lower wettability properties. The instrument that used to measure contact angle is VCA (Video Contact Angle) Optima. The VCA Optima can capture a static or dynamic image of the droplet and determine tangent line for contact angle measurement. The absorption time of the water droplets on the fabrics was considered as the wettability characteristics of the fabrics [13]. A sessile drop of 1 µl distilled water from microliter syringe onto Batik surface. The process of droplets contact to samples was recorded by high-resolution cameras that give magnification up to 51:1. Figure 3 shows a hydrophobic property of Batik fabric before APPJ treatment at approximately 131.50° angle of water droplets. The water liquid is completely absorbed by fabric at 19.2 seconds after the water dropped.

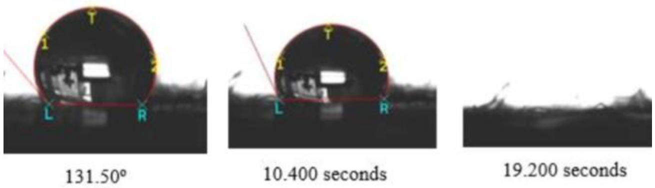

Figure 3: Contact angle measurement and time taken for Malaysian batik fabric to absorb water before plasma treatment.

Then, Batik fabric is placed at 1 cm from the tube orifice and exposed to APPJ for 5 seconds. The contact angle measurement results and time taken for water absorption after undergoing plasma treatment can be seen in Figure 4. The contact angle measurement just after plasma treatment in 5 seconds is 76.00°. Figure 3 and 4 indicate that there is changing in hydrophilic properties of the fabric before and after treatment of APPJ. The duration of the fabric to absorb water after plasma treatment in 5 seconds is 0.924 seconds, as shown in Figure 4.

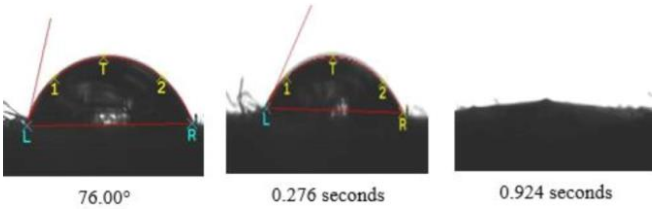

Figure 4: Contact angle measurement and time taken for Malaysian batik fabric to absorb water for 5 seconds of APPJ plasma treatment.

In addition, when the fabric is exposed for 10 seconds, the duration of the fabric to absorbs water become faster. This is because the hydrophilic properties of the fabric increase when the fabric is exposed to the plasma for a longer period of time. This is because the plasma treatment has increased the grooves and roughness of the Batik fabrics that will lead to enhance the absorption and wetting area upon contact to liquid [14]. The effect of treatment distance between the plasma plume and fabrics are also studied. This is important since the energetic and ionized particles in plasma and heat of the plasma could damage the fabric. Meanwhile, the plasma treatments could also affect the roughness of the fabrics due to etching process [15]. Hence, these can contribute to enhancing the wettability properties of the fabrics [16]. Figure 5 shows that the absorption time increased when the treatment distance increased. The treatment time was fixed at 5 seconds. This result shows that the APPJ treatment is applicable for the distance between 0.5 and 2.0 cm. When the distance is too short, the fabric was damaged with dark black spot was observed. On the other hand, when the distance is too far, the effect of APPJ became less efficient and minimum surface modification is achieved [17]. This probably due to plasma plume unable to brush the fabric surface [14]. The 0.5 cm distance between orifice to plasma shows the absorption time is 1.13 seconds. The absorption time keeps on longer 1.73 seconds, 2.31 seconds and 3.00 seconds as the distance between plasma orifice and treated Batik fabrics is increasing 1 cm, 1.5 cm and 2.0 respectively.

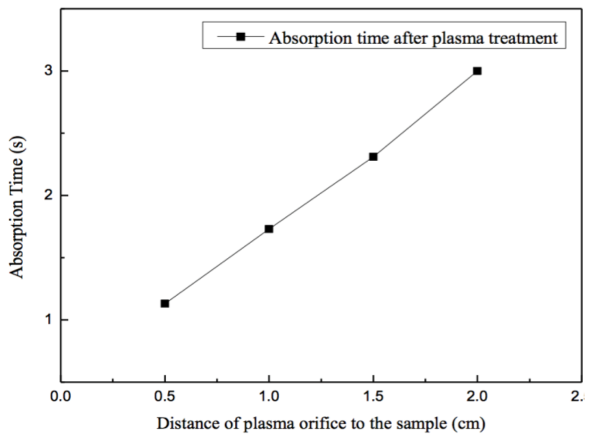

Figure 5: Effect of the distance of plasma tube orifice to fabric sample against time of water absorption after APPJ treatment for 5 seconds.

In addition, the APPJ is produced at various argon flow rates. When the flow rate was below than 10 L/min, the plasma was not stable and produced a spark which is not applicable to fabric treatment. Figure 6 shows the absorption time of fabric treated with APPJ. The argon gas flow rates are between 20 and 60 L/min and the treatment times are 5 and 10 seconds. As shown in Figure 6, water absorption of batik fabrics becomes faster when the higher argon flow rate is used. This may be due to the longer plasma plume when the argon flow rate is high. In addition, the water absorption is improved when the APPJ treatment time is longer. As shown in Figure 6, the 10-second treatment exhibit 100% shorter times of water absorption than that of 5 seconds treatment.

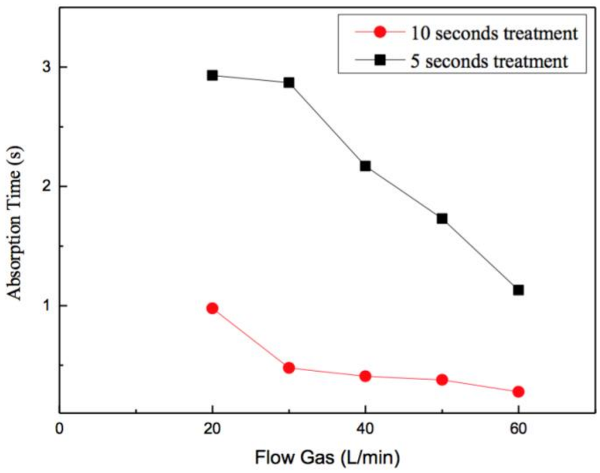

Figure 6: Water absorption time after APPJ treatment for 5 seconds and 10 seconds and various argon flow rates.

For the 10 seconds treatment, 20 L/min required only a second to dissolve the water droplets and shows the reduced time taken to 0.5 seconds, 0.43 seconds and 0.40 seconds to dissolve the water droplets for 30 L/min, 40 L/min and 50 L/min Ar flow rate. In case of 60 L/min feeding Ar, it shows magnificent improvement of Batik fabrics wettability as it only needs 0.3 seconds to dissolve the distilled water droplets for 10 seconds plasma treatment and 0.43 seconds longer time to dissolve the droplets for 5 seconds treatment. As mentioned before the plasma treatment could increase the surface roughness and at the treated Batik fabrics appear more grooves as increases the Ar flow rate. This could be because on the liquid-fabrics interface the water droplets are ‘sliding’ the rough surface of the fabrics [18].

IV. CONCLUSION

The effect APPJ towards Malaysian batik fabric is described in this paper. Water contact angle measurement is used to discuss the effect of APPJ treatment at various conditions. The results clearly showed that the hydrophilic properties of fabric increased when exposed to APPJ. In addition, the water absorption time became faster when exposed to APPJ. When longer treatment time of APPJ was used, the water absorption became faster. These results indicate that APPJ significantly affects the surface properties of batik fabric. The distance between the plasma plume and fabric should be longer than 0.5 cm to prevent fabric from damage.

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