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Low Density Fibrous Material Surface Light Reflectance Analysis

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ABSTRACT

The light based surface finishing of most product measurement is an important feature in the industries. In this paper, a lab fabricated tester for investigation on the quality of low density paper which was represent by tissue paper was done. Laser light is used as a light source to distinguish the quality of density paper and the light reflectance element was used. The photodiode was used as sensing element to detect the reflected light from the surface of tissue paper. The both of laser diode and photodiode were placed in a light box. The laser was used to emit light on the sample and the photodiode detects light intensity from the surface specimen in the light box. Different level of intensity correlates to different voltage output. The investigation on the different type of tissue paper including of high quality and low quality were done respectively. The result showed that the total ply high quality of low density paper has a higher reflected voltage output compared to low quality.

INTRODUCTION

Rapid growth within the microfluidic discipline has been seen in recent years. Microfluidic includes a vast field of applications including life sciences, industry, agriculture, and pharmaceuticals [1]. Unlike conventional equipment, the advancement of miniaturized devices to process and control diminutive volume of fluids has many advantages such as rapid and repeatable analysis [2], reaction time is shortened, more effective, and accurate by the increased surface-to-volume ratio, as well as reducing error rates by being more consistent during channels measurement [3].In microfluidic, wettability has direct influence to its fluid flow channels. Genrally, the most basic measure of wettability for a particular liquid/solid combination is the contact angle. As the contact angle changes, the device could be either in a hydrophobicity or hydrophilicity state [4,5].There were many researches done on the wettability characterization in microfluidic field. Fu and his co-workers grafted PNIPAAm onto porous anodic aluminum oxide. The results from the nanostructured surfaces displayed changes in wettability and surface roughness at the same time by alternating the temperature [6].To the best of the author's knowledge, there are minimal studies been done towards the relationships between the process parameters and the wettability effect, hence this paper studies the relationship between controllable process parameters and wetability of the etched Platinum metallization layer after Reactive Ion Etching (RIE).The reason that Platinum metallization is chosen is because of its high thermal coefficient resistance and inert characteristic to oxygen. Thus, it will help to overcome the corrosion problem that occurs in a device and withstand high operating temperature [7]. Light is an electromagnetic radiation and the visible wavelength to the human eye is in range of 400 nm to 700 nm [1]. Wavelength of visible light is in between the ultraviolet (UV) wavelength and the near infrared (NIR) wavelength. The reflection of light occurs when the wave meets with a surface or any boundary that does not absorb energy which comes from radiation therefore bounces the waves or changes the direction of the surface. As an example, when the laser light is directed to the mirror, the reflection of laser light can viewed on the wall. There are two types reflection of light which are specular reflection and diffuse reflection. The reflected rays are same and parallel to one another is known as specular reflection. Specular reflection happens when the light reflected from smooth surfaces, examples from the mirror. When the reflected rays are scattered in varying directions is known as diffuse reflection. The diffuse reflection is the reflection light from any rough surfaces example an rays

reflected from the rusty steel [2]. Light based surface finishing of most product measurement is an important feature. Surface quality evaluation by using the light is a fast measurement, low cost and non-contact device and reliable technique to achieve the best quality measurement method in the industries [3-14]. Visible and near infrared spectroscopy (VIS/NIR) based on the light as manipulator has been widely used in the food industry for food quality inspection [15]. The basic operating VIS/NIR spectroscopy method is based on sending light onto the test sample and then measuring the light reflected from the test sample at different wavelengths. The wavelength region for VIS/NIR spectroscopy is from 400 to 2500 nm. The reflection or a reflectance measurement occurs when the illumination and the detector is fixed on the same side of the sample. A transmission or a transmittance measurement, and the amount of light scattering and absorption of the sample detect by photo sensor occur when the VIS/NIR spectroscopy sending the light to the sample [16].In this work, a lab fabricated tester for simple surface characterization was built for the surface characterization of different low density paper quality based on the reflected light from the surface material. The laser light was used as source to distinguish the different type of low density paper is discussed. The reflected laser light from the surface of low density paper is detected by a photodiode, which functions as the light sensor. The signal from the photodiode is converted by Analog to Digital (ADC) converter and displayed on the Liquid Crystal Display (LCD) in which it is interfaced with PIC microcontroller board.

Methodology:

In this experiment, a lab module tester was designed and consist an emitting circuit, receiving circuit, light box, and specimen to be investigated inside. The light box is designed to locate the photodiodes. The light box was fabricated by using black colour acrylic with octagonal shape to provide better guide for photodiode arrangement. Besides that, the mat material such as sugar paper with black colour was used to cover all the walls inside the light box to reduce or minimal internal reflectance. By this method, it will provide a better experiment result in this research. The photodiode are positioned in a specific angle in the light box to receive scattering laser light that reflects from the surface specimens. The photodiode are arranged symmetrical in the following angles of 3°, 50°, 130° and 177° respectively. The stage to place the specimen in the light box is not fixed and can be adjusted to enable and ensures the intensity reflected to the photodiodes can be adjusted for various test specimen. In this research, the distance from top of laser source to the stage is 3 cm. For emitting circuit, the input of laser diode was connected to microcontroller. The laser diode model LDM 150 was used as a light manipulator to investigate the surface specimens in this experiment. The laser diode emits a red beam and has a wavelength in spectral region of 650 nm. The laser diode was operating in a low DC voltage which is +5.0 V. In this work, the laser pulse sustaining for 2 ms was set by the microcontroller and the time duration of laser pulse was controlled by the programming source code.The receiving circuit is build around the photodiode with microcontroller in this research. The peripheral interface controller (PIC) was used as microprocessor of the microcontroller, photodiode as photo detector, and Liquid Crystal Display (LCD) used to display the results. PIC16F887 chip was utilized as a processor in microcontroller with interface photodiode as light sensor to measure the intensity reflected for the surface specimens. The model of Si PIN photodiode S5972 from Hamamatsu was used in this research. The S5972 model is a high-speed Si PIN photodiodes designed for visible to near infrared light detection and the spectral response in region of 320 nm to 1000 nm. The signal obtained from the S5972 Si PIN photodiode was small, so the photodiode was connected to an operational amplifier (op-amp) in this circuit. The op-amp was used to amplify the output voltage from the photodiode before received by the microcontroller board. Meanwhile, the photodiode also requires a resistor to design a current to voltage converter circuit before connect to the PIC microcontroller. In this experiment, 15 readings were taken to ensure the accuracy of the result.

RESULT AND DISCUSSION

Experiment 1:

The investigation on the surface of low density paper was done by using the developed tester. In this experiment, there are two types of low density paper was tested which are low quality and high quality paper. The low quality was contains two ply papers and the high quality was contains three ply papers. The average test results after the conversion Analog to Digital Converter (ADC) from signal photo detector of the low quality with low density paper was shown in Table 1. The tests using two ply low quality with low density paper which produces voltage averaging 0.04 V for both the angle of 50° and 130° respectively. The angle of 3° and 177° was showing no voltage output by the photodiodes. The results for one ply low quality with low density paper show that the recorded output voltage is lower compared to the two ply output voltage. Average voltage detected by the photodiode is approximately 0.02 V for both the angle of 50° and 130° respectively. The output voltage difference between two ply and one ply is about 50 %. The standard deviation for low quality with low density paper was shown in Table 2.

Table 1: The Average Experiments Result For Low Quality with Low Density Paper

Total of Ply	Angle			
	3°	50°	130°	177°
1	0.00V	0.02V	0.02V	0.00V
2	0.00V	0.04V	0.04V	0.00V

Table 2: The Standard Deviation For Low Quality with Low Density Paper

Total of Ply	Angle			
	3°	50°	130°	177°
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00

The recorded average results reflectivity test conducted on the high quality with low density paper starting from three ply, two ply and one ply and standard deviation was shown in Table 3 and Table 4 respectively. The average voltage for three ply is 0.07 V for both the angle of 50° and 130° respectively and the standard deviation for the angle 50° is 16.6 % whereas for 130° is 0 %. For two ply high quality paper, the result shows the average voltage detected by the photodiode is approximately 0.05 V for the angle of 50° and 130° respectively. The average voltage 0.01 V for 3° and 0.03 V for 50° and 130° respectively was detected for one ply tissue paper. The output voltage difference between three ply and two ply is about 30 % and 60 % difference between three ply and one ply.

The overall output results for all the different quality and layers of low density paper were shown in Fig. 1. The results average output voltage of high quality paper in one and two ply is higher compared to the low quality paper. The method of surface reflectance can used to distinguish the different quality and layers of low density paper. The layer of paper has played a significant role during the reflectivity test

Table 3: The Average Experiments Result For High Quality Tissue Paper

Total of Ply	Angle			
	3°	50°	130°	177°
1	0.01V	0.03V	0.03V	0.00V
2	0.00V	0.05V	0.05V	0.00V
3	0.00V	0.07V	0.07V	0.00V

Table 4: The Standard Deviation For High Quality Tissue Paper

Total of Ply	Angle			
	3°	50°	130°	177°
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00
3	0.00	0.01	0.00	0.00

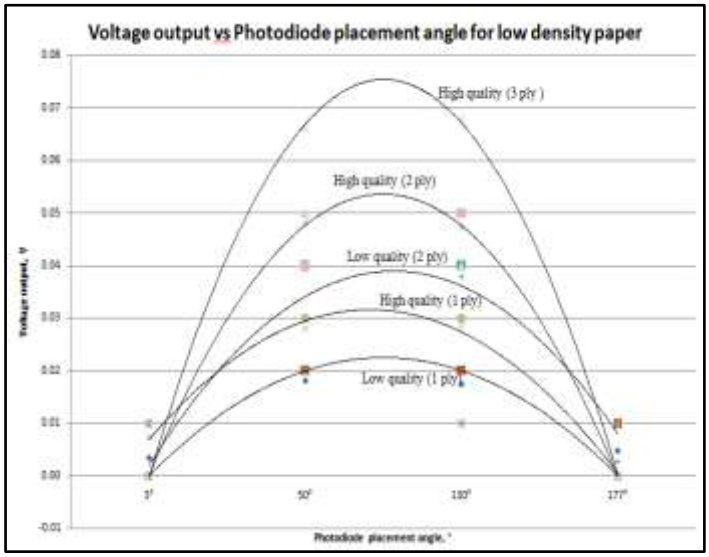


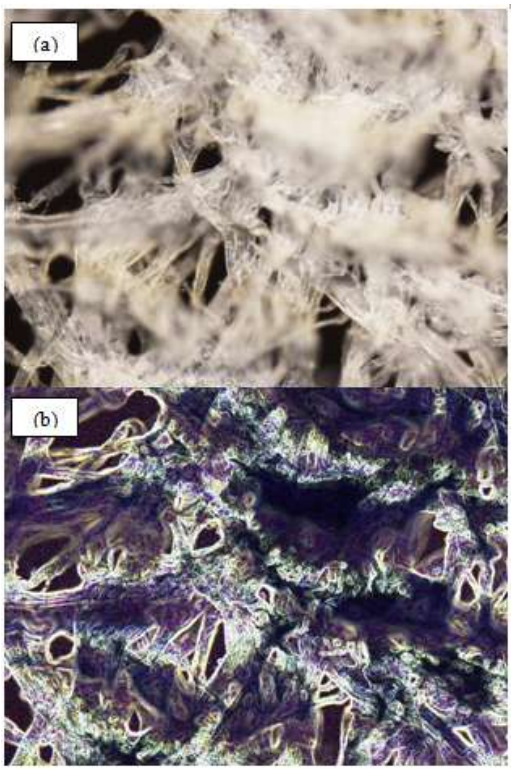
Fig. 1: The plot on voltage output versus photo detector placement angle for low density paper in high and low quality

Experiment 2:

In this section, the investigation on low quality and high quality low density paper as the specimen was done. The high quality paper consists of three ply whereas the low quality paper consists of two ply. The experiment will be investigated on the original total ply and the test will be repeated for progressive ply reduction. The images of

one ply high quality paper before and after image processing was shown in Fig. 2. The images were viewed under high power microscope using 20 times magnification scale. GNU Image Manipulation Program (GIMP) software which comprises edge detection was used to analyze the difference between the specimens. The edge detection using Prewitt Compass algorithm was used in this work. For the two ply and one ply of high quality paper, the images was shown in Fig. 3 and Fig. 4.

From the captured images it can be observed that three ply specimen paper shows higher structure density and minimal porosity characteristic compared to two and one ply. Two ply shows higher porosity and one ply shows even higher porosity which is showed by the dark regions in the figure after image processing.



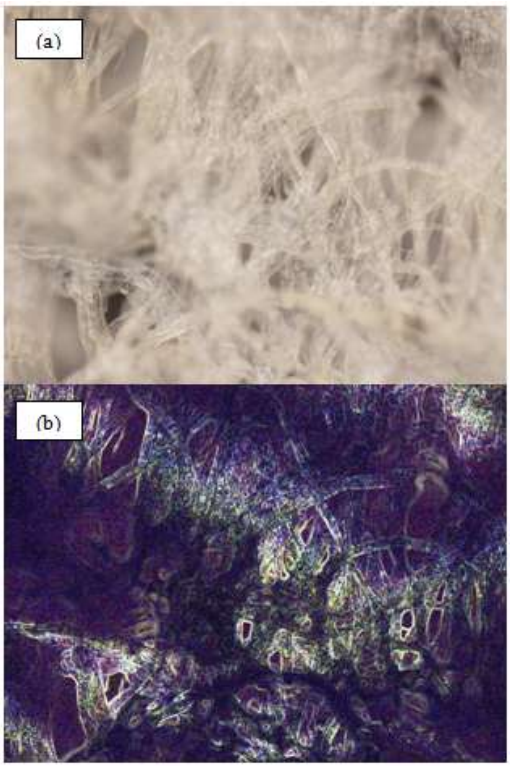


Fig. 2: The images of one ply high quality paper (a) efore and (b) after image processing
Fig. 3: The images of two ply high quality paper (a) before and (b) after image processing

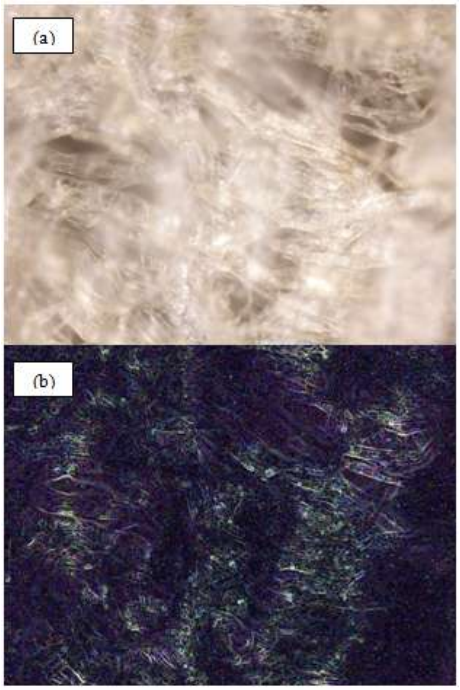


Fig. 4: The images of three ply high quality paper (a) before and (b) after image processing

For the low quality with low density paper, the images of one ply and two ply before and after image processing was shown in Fig. 5 and Fig. 6 respectively. Observation shows that two ply of low quality paper have the higher structure density compared to one ply. In addition, images of one ply from both the low and high quality paper were compared and the image after edge detection shows the fibre arrangement of high quality paper in one ply is denser compared to low quality paper. Besides that, observation shows that high quality with low density paper exhibits transparency and higher brightness compared to low quality paper in the images captured by high power microscope. This can be related to the study done by Foelkel (2007) where the significance of pulp brightness, pulp cleanliness and pulp viscosity were clearly under lined and stressed [17]. In this analysis, optical measurement by high power microscope approach fibre was sufficient to differentiate the quality.

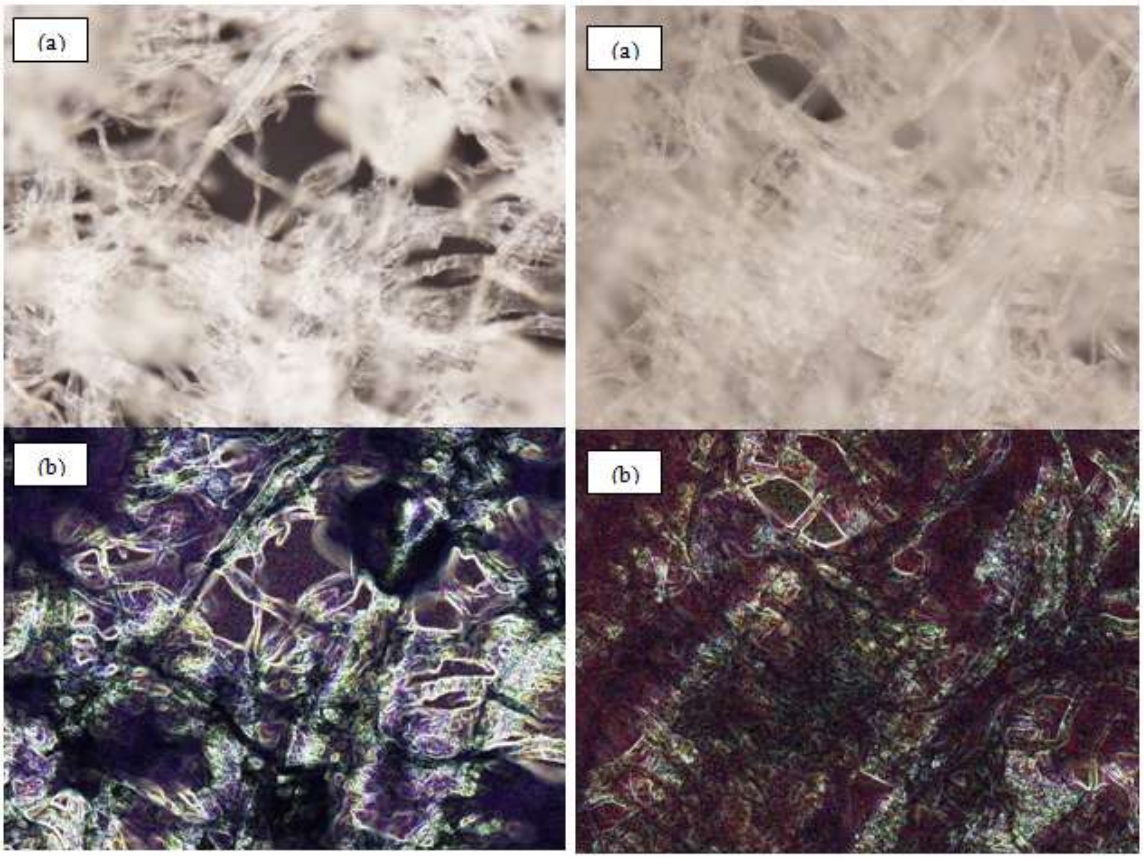


Fig. 5: The images of one ply low quality paper (a) before and (b) after image processing
Fig. 6: The images of two ply low quality tissue paper (a) before and (b) after image processing

Conclusion:

In this work, the investigation on low density paper with low and high quality was done. The single ply tissue paper is less compact, high porosity characteristic and easily viewed through compared to two ply and above for low and high quality paper. From the overall gathered data, it can be deduced that higher quality papers have a higher light reflectivity compared to low quality papers. This can be related with the optical images results which show that higher quality paper have denser fibre structure, lower porosity, pulp cleanliness and brightness.

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