CONTRAST ENHANCEMENT OF LATENT FINGERPRINT IMAGE BASED ON POLARIZED SPECULAR REFLECTION

Sutassana Orsathit, Mayuree Hansupanusorn*
Department of Physics, Faculty of Science, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand
e-mail: mayuree.kit@kmutt.ac.th

Abstract: The non-contact optical method to captured fingerprint images using polarized specular reflection for increasing the contrast of latent fingerprint was presented. The experimental setup was constructed with conventional white light bulb directed with different incident angles onto the smooth surface. Latent fingerprint was deposited on non-absorbing and non-porous photo paper. Image of the fingerprint was collected by digital camera with circular polarizing (CPL) filter in front of lens. Conventional digital fingerprint images were recorded by digital camera, analyzed, and transformed to the gray scale images by MATLAB program. Results from the digitized intensity profile across vertical lines on the gray scale image showed that the contrast of fingerprint image collected with CPL filter was 100-350% higher than that without CPL filter. The best contrast was obtained when using CPL filter and the incident/reflection angle of about 45 degree.

Introduction: In forensic science, finger marks or fingerprints are widely used for identifying person. The ridges of the skin tend to leave a dielectric residue on a surface touched by a finger (shown in Fig.1). The residue area and non-residue area come from ridges and furrows respectively. There are two types of fingerprints distinguishable by their formation process. The first is an exemplar fingerprint which is obtained by human finger directly. The other is latent fingerprints which is obtained from crime scene very difficult to see under ordinary viewing conditions and has lower quality than the exemplar ones. Most of the techniques used to discover the latent fingerprint will destroy the sample surface. Such techniques bring the examined object into contact with applying powder or cyanoacrylate fuming. Therefore, the non-invasive optical method to imaging the latent fingerprint has been developed. The optical method can collect and store digital images from the crime scene without the need of applying powder and controlled darkroom operation. Demos and Alfano [1] found that the use of linear polarized-light illumination in the optical scanner was able to give the scanned fingerprint images with higher quality and contrast and the enhanced contrast can be clearly observed through the intensity profile. Lin, et al [2] showed that images of the latent fingerprint at a crime scene can be obtained digitally using camera equipped with linearly polarized light in a specular reflection configuration. In this work, we presented the latent fingerprint image collecting system using circular polarizing (CPL) light source and the specular reflection condition, and coupled with the image transformation into the gray scale type prior to contrast analyzing. The effect of having CPL filter and changing specular reflection angle on the quality and contrast of the fingerprint image was studied.

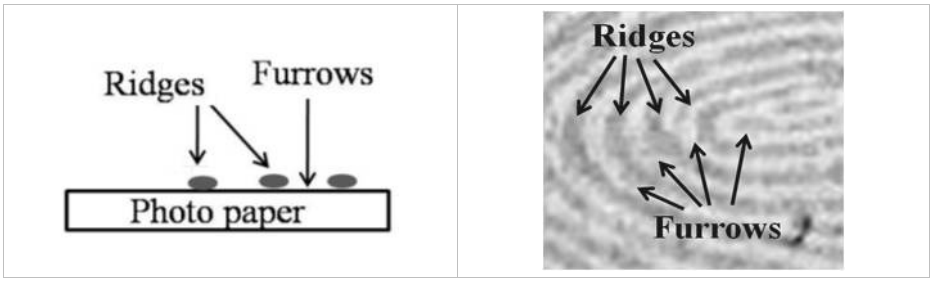

Figure 1. Diagram and photo of the fingerprint deposit.

Methodology: The experiment setup for latent fingerprint image collecting system was arranged as shown in Fig.2. The experiment was setup under regular room light. A white light source (compact fluorescent bulb) equipped with a diffuser plate was illuminated onto a photo paper containing latent fingerprint pattern. The incident angle of light source was oriented at 30, 45 and 75 degree, equals to the viewing (reflection) angle of the camera. A CPL filter was mounted in front of the camera for taking a completely polarized light. The obtained conventional digital image files (as shown in Fig.3a) were transformed into the gray scale image files (as shown in Fig.3b) using the MATLAB program. The "Gelquest" program (free software used for analysis of the contrast of DNA fingerprints) was used to create the intensity profile along a selected vertical line (as shown in Fig.3c) on the gray scale image. The contrast (C) values were calculated from the values of consecutive maximum (I_{max}) and minimum (I_{min}) values along the intensity profile [1] using the relation:

$$C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \qquad (1)$$

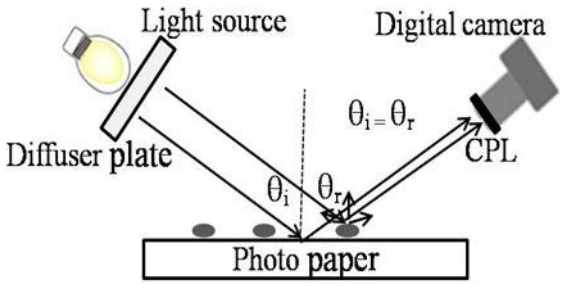

Figure 2. Schematic diagram of the experimental setup.

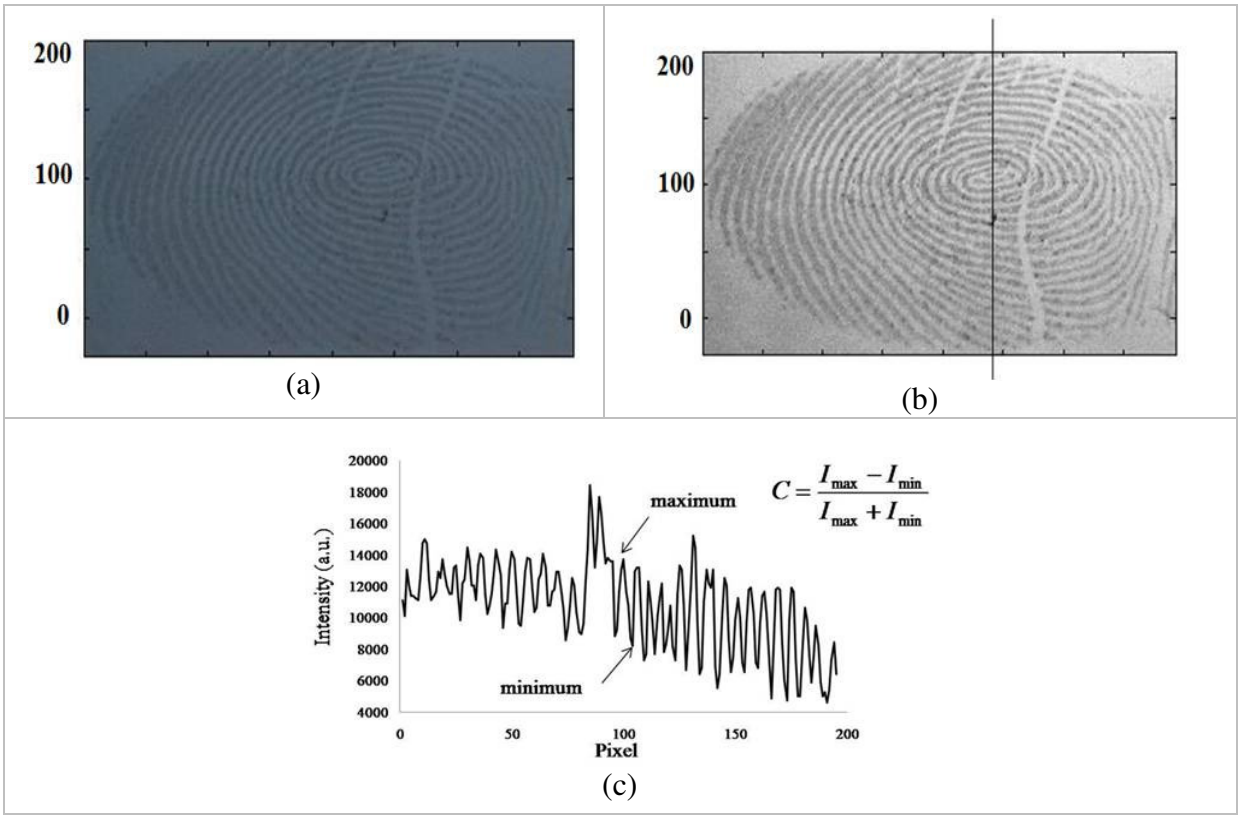

Figure 3. (a) Original fingerprint image, (b) gray scale image, and (c) the intensity profile along the vertical line shown in (b).

Results, Discussion and Conclusion:

Transformation of the original image into the gray scale image

The original image of latent fingerprint deposited on the photo paper (Fig.3a) was not clear. It was difficult to distinguish the non-residue area (furrows) and residue area (ridges) by naked eyes. After transforming the digital original image into the gray scale image, the overall reflected intensity was lower but the peak height between the minimum and maximum was widening (as shown in Fig.4). This indicated that the gray scale image of latent fingerprint had lower brightness but significantly improved contrast.

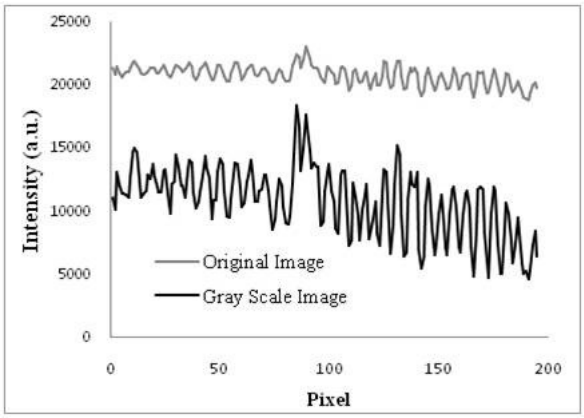

Figure 4. Intensity profiles of the original image and gray scale image.

Effect of the incident angles

The image of latent fingerprint on photo paper was captured at three different incident angles (30, 45 and 75 degree) without using CPL filter. The results of the images and their corresponding intensity profiles are shown in Fig.5. It was found that clear and complete images were obtained at 30 and 45 degree. The image obtained at 75 degree (Fig.5c) was blurred and the part of fingerprint pattern was lost. This was probably due to low surface reflection as the incident beam is near grazing angle which yields low surface details, and also some contribution of non-reflected light source that may directly enter the detector which causes high brightness and the blurred image. Considering at the center area of the image, the contrast of the image at incident angle of 30 and 45 degree was 0.191 and 0.214, respectively, while that at 75 degree was only about 0.06-0.10.

Effect of the circular polarizing filter

The effect of adding circular polarized light on the image contrast was shown in Fig.6. The intensity profiles for both at 45 and 30 degree incident light clearly indicated that the images obtained with CPL filter gave less reflected signal (less brightness) but higher contrast (larger difference between the maximum and minimum for consecutive peak in the profile). The calculated contrast values at the center position of the image (at about 100^{th} pixel) at incident angle of 45 degree with CPL filter, $C_{45,CPL} = 0.252$ vs. that without CPL filter, $C_{45} = 0.214$, and the contrast at 30 degree with CPL filter, $C_{30,CPL} = 0.248$ vs. that without CPL filter, $C_{30} = 0.191$.

To quantify the degree of contrast enhancement, the contrast ratios for incident angle of 45 and 30 degree ($C_{30,CPL}/C_{30}$ and $C_{45,CPL}/C_{45}$) at various pixels along the vertical line were plot (as shown in Fig.7). The results showed that CPL filter can enhances the image contrast (having the contrast ratio > 1) in any position along the vertical line. Enhancement of 150-300% and 150-200 % was obtained at the incident angle of 30 and 45 degree, respectively.

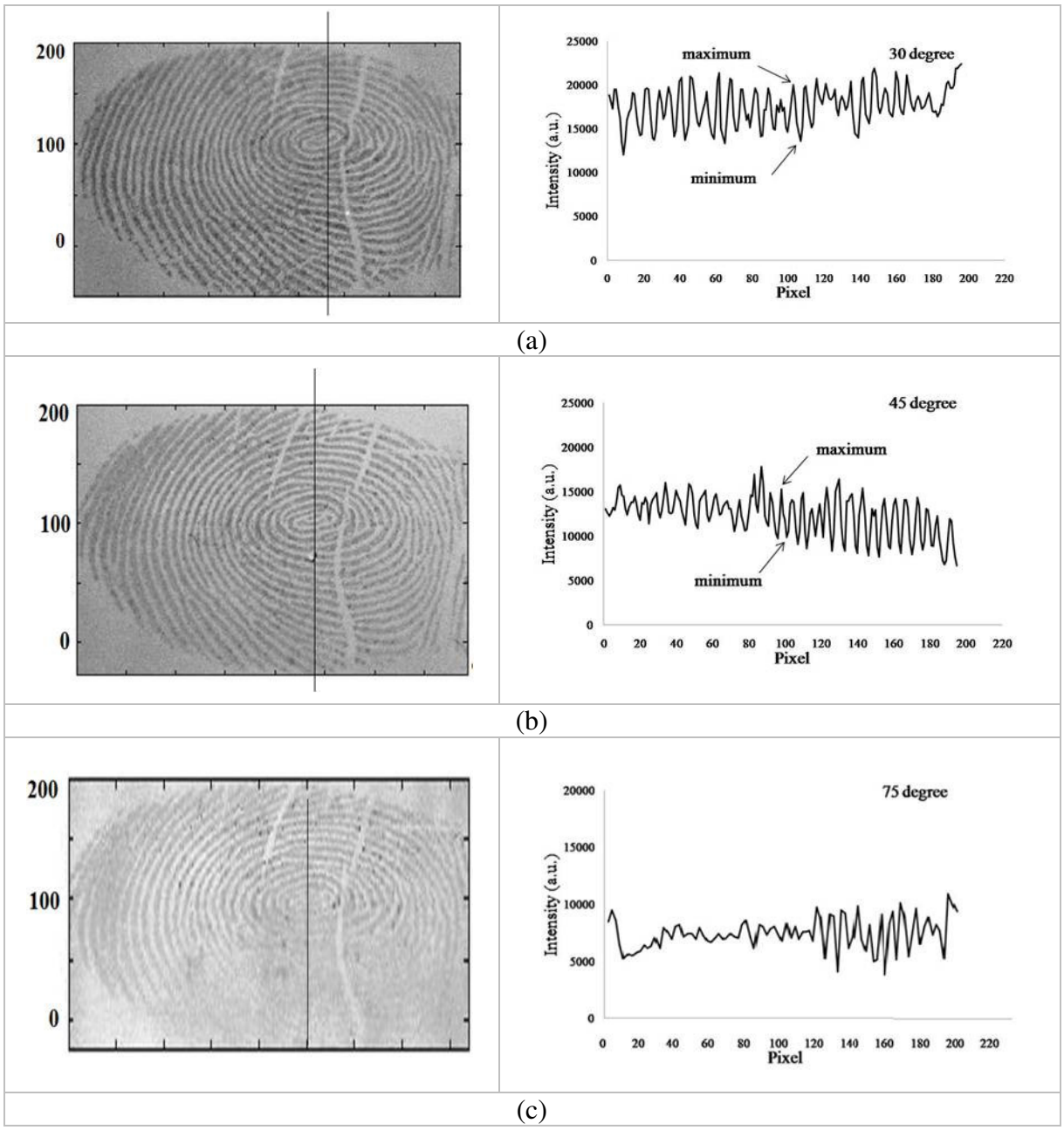

Figure 5. Gray scale fingerprint images and their corresponding intensity profiles without CPL at different incident angle: (a) 30, (b) 45 and (c) 75 degree.

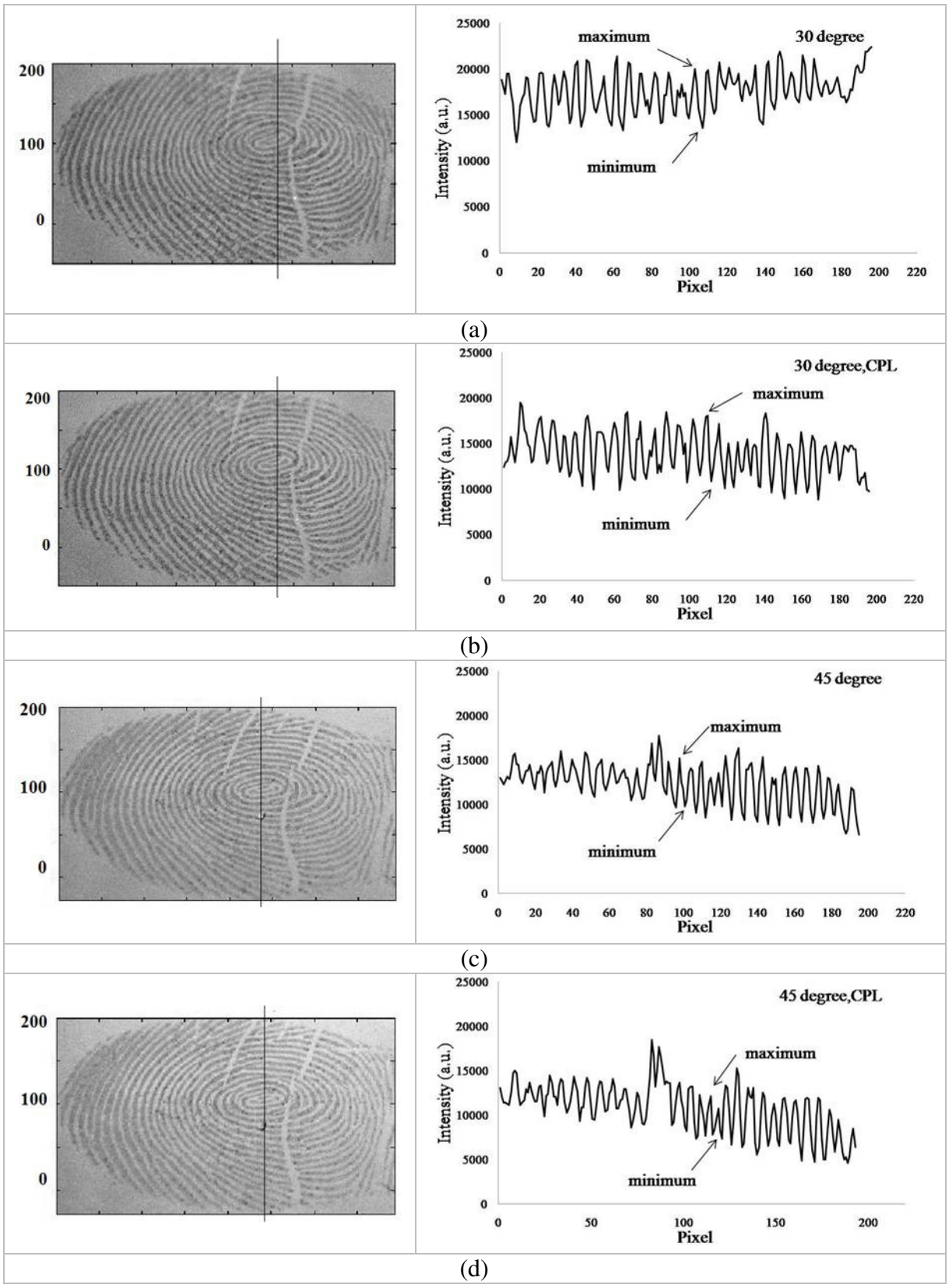

Figure 6. Gray scale images and their corresponding intensity profiles at incident angles of 30 and 45 degree: (a, c) without CPL filter and (b, d) with CPL filter.

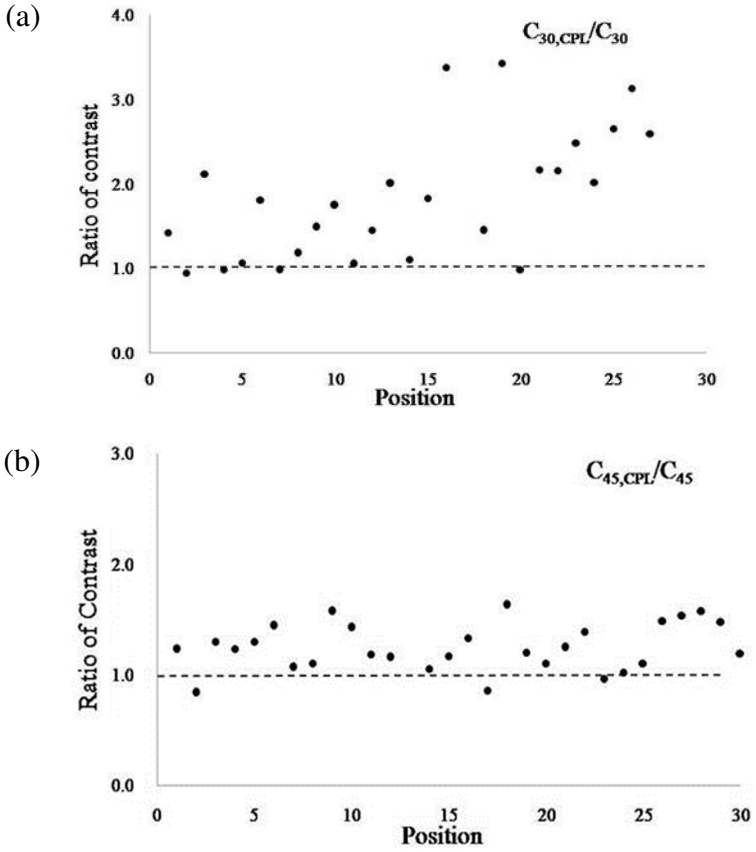

Figure 7. Ratio of contrast $C_{30,CPL}/C_{30}$ and $C_{45,CPL}/C_{45}$ obtained from the image with incident angles of (a) 30 degree and (b) 45 degree.

Summary

The latent fingerprint images were digitally collected using circular polarizing light in the specular reflection condition. It was found that clear and complete fingerprint images were obtained at incident angle of 30 and 45 degree while image obtained at 75 degree was blurred and the part of fingerprint pattern was lost. Adding CPL filer yields image with higher contrast (100-350% enhancement) and the best contrast was obtained when using CPL filter and the incident/reflection angle of about 45 degree.

References:

1. Demos SG, Alfano R. Electronics Letters: 1997; 33: 582-584.
2. Lin S, Yemelyanov K, Pugh E, Engheta N. Journal of the Optical Society of America A: 2006; 23: 2137-2153.

Acknowledgement:

This work was partially supported by the Graduate Financial Support from the faculty of Science, KMUTT.

Keywords:

Latent fingerprint, polarized light, specular reflection, gray scale image.