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Effectiveness of interference filter for photoluminescence observations: comparison with absorption filters

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Abstract: Currently, most photoluminescence reagents used in forensic science have short stokes shift, making it difficult to observe strong photoluminescence due to scattering light from forensic light sources when using filters that are not shieldable. However interference filters can be observed near monochromatic light, making them a better alternative to absorption filters. To verify practical applicability of interference filters, interference filters and three other types of previously frequently used absorption filters were observed using a variety of light source products, and transmission light was cross-compared. Interference filters have a lower slope value than absorption filters, and selectively show only the photoluminescence of reagents, regardless of the type of product from the forensic light source. In addition, tilting the angle of the filter surface for observation lowered the $\lambda_{cut\text{-}on}$, which could replace various types of absorption filters with a single interference filter.

Key words: interference filter, absorption filters, photoluminescence, fingerprint, forensic science

1. Introduction

Various photoluminescent reagents are used to detect invisible evidence.[1,2] Evidence visualized in such a manner is then processed through photoluminescence observations using a combination of a barrier filter that blocks the transmittance of certain wavelengths and a suitable forensic light source in consideration of the excitation wavelength (λ_{ex}) and the emission wavelength (λ_{em}) of the photoluminescent reagent.[3]

However, the combined use of a suitable light source and a filter does not necessarily guarantee the observation of the photoluminescence of the highest intensity. For this, a light source with a wavelength close to the maximum λ_{ex} (λ_{ex}^{max}) should be used, which requires the problem of a short stokes shift ($\Delta\lambda = \lambda_{em}^{max} - \lambda_{ex}^{max}$; λ_{em}^{max}: maximum λ_{em}) of the photoluminescent reagents to be solved. Most photoluminescent reagents used in forensic investigations exhibit a short stokes shift. When the stokes shift is short, the use of a light source that approximates to λ_{ex}^{max} leads to an overlap between the λ_{em} of the photoluminescent reagent and the wavelength of the

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light source, thereby preventing the barrier filter from adequately blocking the scattering light of the light source.[4]

Hence, for an observation of the strongest photoluminescence, either the purity of the forensic light source that shows the ratio of certain wavelengths should be increased to reduce the unnecessary scattering light passing through the filter,[4] or the shielding capacity of the barrier filter should be outstanding. However, the purity is not high for most forensic light sources, whereas each light source has a specific emission spectrum despite displaying what appears to be an identical color. Thus, the type of the light source determines the optimum filter (*Table* 1).[5]

The most widely used barrier filter at present is the absorption filter whose slope[6] is higher than that of the interference filter. A slope is a determinant of the shielding capacity of the barrier filters; in addition, the photoluminescent reagents with a shorter stokes shift require the barrier filter to have low slope so as to adequately block the scattering light of the light source and allow a selective observation of photoluminescence. Unless two conditions, i.e., a light source with high purity and a barrier filter with high shielding capacity, are satisfied, it is difficult to observe the photoluminescence with high intensity, which could lead to an unsuccessful detection of evidence.

To verify the potential use of an interference filter that allows the collection of transmitted light that approximates to monochromatic light, this study investigated the practicality of an interference filter through a comparison with three commonly used types of conventional absorption filters.

2. Materials and Methods

2.1. Reagents and equipment

The reagents used in this study were as follows: 1,2-indanedione and Dazzle Orange from Sirchie (USA), dry zinc chloride from Daejung (Korea), 90.0 % petroleum ether from Samchun (Korea), Amos 412 super glue from Amos (Korea), and basic yellow 40 and acid yellow 7 from BVDA (Netherlands). The surfaces used to leave fingerprints were copying paper as a porous surface (Double A, Thailand) and a white tile as a nonporous surface (Sheetline, Korea). For the forensic light source, Angsem1306 green and P20FBG green from Altlight (Korea) and a Polilight PL500 and a Polilight flare plus 2 cyan from Rofin (Australia) were used. For the barrier filter, OG515 and OG550 from Rofin Forensic (Australia) and CUSP and ILPF550 from Altlight (Korea) were used. The chamber applied in the cyanoacrylate (CA) fuming was an HEVA-1410 (Altright, Korea). The tilted angle was measured using a DWL-200 electrogoniometer (Sincon, Korea), and the transmittance and fluorescence spectra were obtained using a Lambda 850 and Lambda LS50B, respectively, from PerkinElmer (USA). The developed fingermarks were photographed using a D5500 (Nikon, Japan) and 60-nm LAOWA macro lens (Venus Optics, China).

2.2. Fingerprinting and methodology

Two male donors deposited fingerprints of their right thumb. The types of the deposited fingerprints were natural and blood fingermarks. For the natural fingermark, the donors washed their hands clean and conducted daily activities, and the fingerprints were

Table 1. Photoluminescence observation conditions of reagent using LED forensic light source suggested by Home Office[5]

Development Technique	Excitation wavelength		Viewing filter (1 % transmission point)	
Acid yellow 7	Blue	430 ~ 470 nm	Yellow	476 nm
DFO[a)]	Green	500 ~ 550 nm	Orange	549 nm
Ninhydrin toned with zinc salts	Blue/Green	460 ~ 510 nm	Orange	529 nm
Superglue dyed with basic yellow 40	Blue	430 ~ 470 nm	Yellow	476 nm
Superglue dyed with basic red 14	Green	500 ~ 550 nm	Orange	549 nm

[a)] 1,8-diazafluoren-9-one

Table 2. Reagent manufacturing and techniques applied

Developing method	Manufacturing method	Applied techniques
Zinc chloride stock solution	Ethyl alcohol 10 mL Zinc chloride dry 0.4 g Ethyl acetate 1 mL Petroleum ether 190 mL	Used to manufacture 1,2-indanedione/zinc[7]
1,2-IND/Zn[a)]	1,2-indanedione 0.8 g Ethyl acetate 90 mL Acetic acid 20 mL Zinc stock 80 mL Petroleum ether 820 mL	Used to develop fingerprints left in copy paper. Immerse the sample in the reagent for 5 sec and heat it with an iron of 160 °C[8,9]
Cyanoacrylate fuming	Complete product	Used to develop fingerprints left in ceramic. Heating cyanoacrylate 2 g to 120 °C in the chamber[5]
Basic yellow 40	Complete product	Apply spray method to fingerprints developed with CA fuming and wash with running water[10]
Blood fixing solution	5-sulfosalicylic acid 2 g Deionized water 100 mL	Wet the tissue with reagents and cover fingermarks in blood for 5 min
Acid yellow 7	Complete product	Apply spray method to fingerprints in blood fixed with blood fixing solution and wash with running water after 5 min[11]
Dazzle orange	Complete product	Applied with a magnetic brush

[a)]1,2-indanedione/zinc

deposited in 1-h intervals. The natural fingermarks, to which a 1,2-indanedione/zinc (1,2-IND/Zn) reagent was applied, were deposited onto the porous copying paper. The natural fingermarks to which basic yellow 40 (BY40) and Dazzle Orange powders were applied, were deposited onto the glass and white tile. The blood fingermarks to which acid yellow 7(AY7) was applied, were deposited onto the white tile after 40-μL of blood was dropped onto the donors' thumb and evenly spread. After deposition, all fingermarks were dried at room temperature for 24 h. *Table* 2 summarizes the methods used to prepare the reagents and apply the techniques.

2.3. Measurements

The slope was calculated as follows: Slp = 10 %-80 % transmittance bandwidth/ $\lambda_{cut\text{-}on} \times 100$ (%) ($\lambda_{cut\text{-}on}$, the wavelength at which the transmittance increases up to 50 % at a long pass filter).

To measure the contrast of fingermarks enhanced by the photoluminescent reagents, the image processing program ImageJ (NIH, USA) was used.[12] The contrast was calculated as *Intensity of developed fingermarks – Intensity of background*. To ensure the consistency, the specimens and camera were maintained at a fixed position, whereas only the types of light source and filter were varied for imaging. The ridge and background analyzed using ImageJ were fixed in specific areas.

3. Results and Discussion

3.1. Transmittance of interference filter

In the photoluminescence observation using a green forensic light source, an orange barrier filter that blocks the light of $\lambda \leq 550$ nm is mainly used. In this study, the transmittance spectrum was compared between the conventional and commonly used orange absorption filters, OG550 and CUSP, and the orange interference filter, ILPF550. The measurement results of the transmittance spectrum using a spectrophotometer (*Fig*. 1) showed that the slope of the interference filter ILPF550 was lower than that of the two previously described absorption filters at ~550 nm, where they could block the light (OG550, 10 %–80 % transmittance bandwidth, 543–565 nm, slp of 4 %; CUSP, 10 %–80 % transmittance bandwidth, 543–565 nm, slp of 4 %; ILPF550, 10 %–80 %

transmittance bandwidth, 548.5–554.5 nm, slp of 1 %).

Here, 1,2-IND/Zn was found to have a relatively short Δλ at 9 nm, with λ_{ex}^{max} 550 nm and λ_{em}^{max} 559 nm.[3] To observe the strong photoluminescence in fingermarks treated with 1,2-IND/Zn, a light source that emits light with λ_{ex}^{max} of ~550 nm should be used. The fingermarks developed using 1,2-IND/Zn were observed by combining the barrier filter with various green forensic light sources (*Fig.* 2). The absorption filters OG550 and CUSP did not produce consistent data in accord with the light source type. Notably, photoluminescence observations were prevented when the light source had a low purity or approximated a wavelength of 530 nm as the light of the light source was transmitted across the filters.

By contrast, comparatively consistent data were obtained for the interference filter regardless of the light source type. The interference filter ILPF550 had a more outstanding shielding capacity than the conventional absorption filters and thus the influence of the purity of the light source was insignificant; in addition, the filter could even block light approximating a wavelength of 530 nm, indicating more complete blocking of the light from the light source in comparison

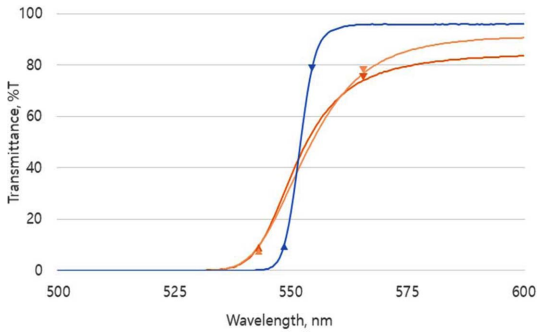

Fig. 1. Transmittance spectrum of absorption filters (OG550, CUSP) and interference filter (ILPF550), (Blue line: ILPF550, Pale orange line: CUSP, Orange line: OG550, ▲: 10 % transmittance coordinates, ▼: 80 % transmittance coordinates).

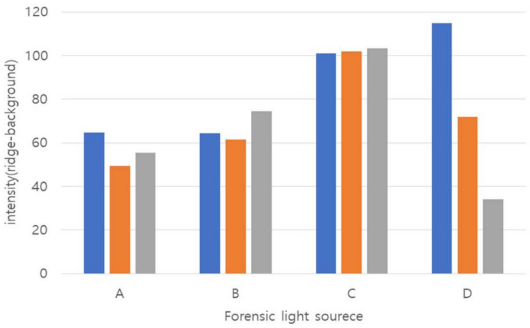

Fig. 3. Calculated contrast (by ImageJ program) of photoluminescence observed with each forensic light source (A~D) and viewing filter in fingerprint developed with 1,2-IND/Zn. based on the *Fig.* 2 (A: Angsem 1306 green, B: P20FBG green, C: Polilight flare plus 2 cyan, D: Polilight PL500 (530 nm); Blue bar: ILPF550, Orange bar: CUSP, Gray bar: OG550).

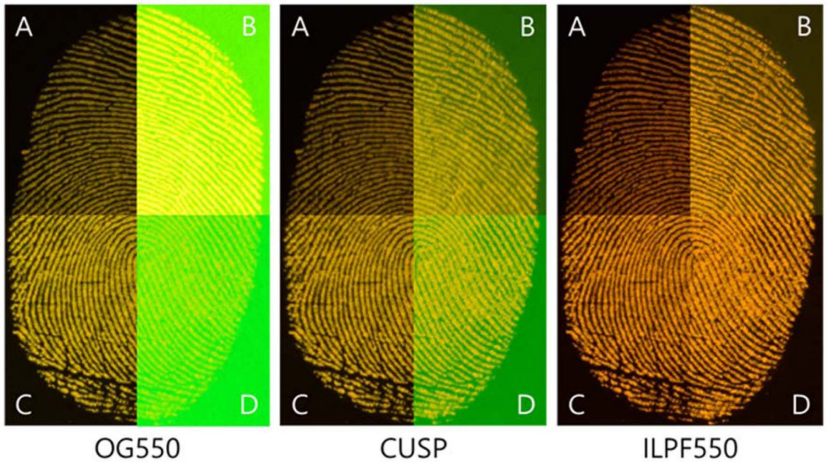

Fig. 2. Fingermarks developed by 1,2-IND/Zn observed by 500 nm wavelength forensic light source (A: Angsem1306 green, B: P20FBG green, C: Polilight PL500 (505 nm), D: Polilight PL500 (530 nm)) with orange color filters (OG550, CUSP, ILPF550).

to the absorption filters. The results of measuring the contrast of the photoluminescence observed through the combination of each filter and four light sources showed that the contrast of the interference filter ILPF550 was greater than or similar to that of the absorption filter OG550 or CUSF (*Fig.* 3).

3.2. Variations of the transmittance angle of the interference filter

The observation of the interference filter with the angle tilted based on 0° showed a decrease in $\lambda_{cut\text{-}on}$ for the long pass filter. The transmittance spectrum of the interference filter ILPF550 was measured with the filter angle tilted at 0°, 22.5°, and 45°. As a result, $\lambda_{cut\text{-}on}$ decreased as the tilted angle increased, whereas the transmittance spectrum of ILPF550 was similar to that of OG515 when the filter plane was tilted at 45° (*Fig.* 4). This property is predicted to allow various conventional absorption filters to be substituted with the interference filter, and the practicality during the photoluminescence observation used in forensic investigations was verified by irradiating the natural fingermarks developed by CA fuming and followed by BY40, as well as by tilting the filter plane for the step-by-step monitoring through the interference filter. As shown in *Fig.* 5, a tilted angle of between 0° and 45° allowed a visual examination of the light transmittance, with the ridge of the highest intensity being observed at 45°.

3.3. Applicability for different photoluminescent reagents

As discussed in 3.2, the results show that the transmittance pattern could be controlled by varying the tilted angle of the interference filter. Based on this, the potential use with other photoluminescent reagents in developing fingermarks was tested. *Fig.* 6 shows the observation through each filter of the fingermarks enhanced using Dazzle Orange and AY7.

For the photoluminescence observation of fingermarks developed using Dazzle Orange, orange filters have mainly been used. Hence, ILPF550 was predicted

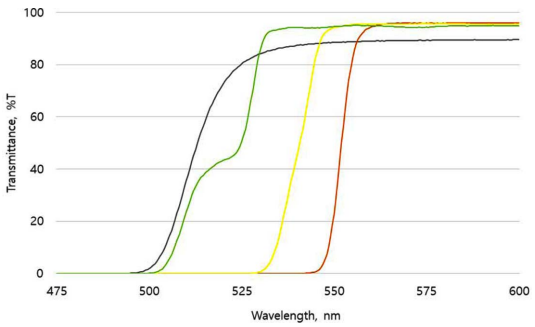

Fig. 4. Comparison of transmittance spectra of ILPF550 filter tilted at various angles and OG515 filter (Orange line: ILPF550 tilted to 0 °, Yellow line: ILPF550 tilted to 22.5 °, Green line: ILPF550 tilted to 45 °, Gray line: OG515).

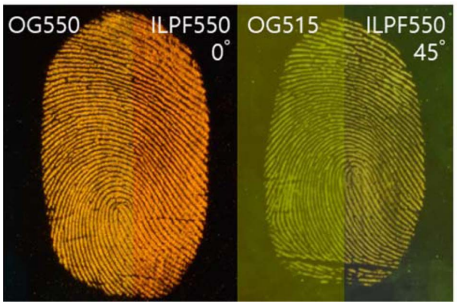

Fig. 6. Nature fingermark developed with dazzle orange powder (left) and fingermark in blood enhanced by AY7 (right) are observed using different filters. Left: Illuminate Polilight PL500 (505 nm), Right: Illuminate Polilight PL500 (450 nm)

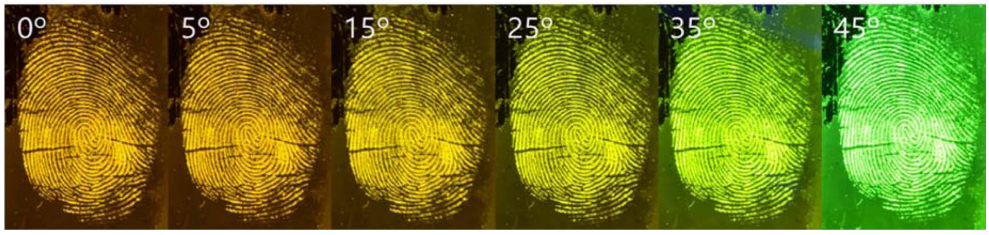

Fig. 5. Nature fingermark enhanced with BY40 after developed by CA fuming is observed using Polilight PL500 (450 nm) with ILPF550. ILPF550 is tilted more in the picture on the right (White letter: The tilted angle of the filter).

to allow an adequate photoluminescence observation in lieu of OG550 for observations of natural fingermarks developed using Dazzle Orange. By contrast, for the photoluminescence observation of fingermarks developed using AY7, yellow filters such as OG515 are required. The observation of blood fingermarks enhanced by AY7 through ILPF550 was shown to be similar to the observation through OG515, when the angle was tilted at 45°. The results indicate that, although the test of all photoluminescent reagents would be unrealistic, the use of two absorption filters might be replaced with the use of a single interference filter, at least for the cases combining a green light source and an orange absorption filter or a blue light source and a yellow absorption filter.

4. Conclusions

Photoluminescence observations with the highest contrast were conducted using an interference filter whose slope was lower than that of absorption filters. Consequently, high-quality photoluminescence may be consistently obtained regardless of the type of light source applied in the observation. In addition, a single interference filter may replace several absorption filters because a change in the angle of the photoluminescence observation through the interference filter can change the observable spectra of the photoluminescence. Based on the findings in this study, further research should more actively investigate the use of interference filters. Furthermore, it is anticipated that the response to various types of evidence may improve in the fields of photoluminescence, including fingermarks.

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