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Thermal Manipulation of Latent Fingerprints using Cyanoacrylate Fuming with Rare Earth Material

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ABSTRACT

Latent fingerprints are used to identify specific individuals during a forensic investigation. Fingerprints provide a clear and concise means of identifying an individual and their history. Traditional techniques for fingerprint analysis include metal powder and magnetic powder dusting; fluorescent dye staining; iodine fuming; vacuum metal deposition and many more. There are several issues with the conventional technologies now in use, including their sensitivity, contrast, background interference, toxicity and complexity. In this study, the cyanoacrylate fuming technique was combined with enhancing agents such as metallic and rare earth minerals to increase the visibility of latent fingerprints in a quick and easy approach. The vapours of ethyl 2-cyanoacrylate react with the fingerprint's natural compounds, increasing the contrast of the impression. Therefore, fingerprints are visible to the human eye after being treated with cyanoacrylate. Rare earth europium oxide was also used to improve the fingerprints. The fingerprints were sprayed with a mixture of europium oxide. Images of the fingerprint samples were taken and they were evaluated. Cyanoacrylate treatment and europium oxide deposition both enhanced the visibility of fingerprints. In contrast to the cyanoacrylate-treated sample, the europium oxide-deposited specimen stood out more clearly. Hence, rare earth elements improved the visibility of hidden fingerprints.

1. Introduction

Crime scene investigations often include fingerprinting as a necessary step. The investigations embrace a series of patterns of fingerprint ridges which include pores, scars, deformations and line shapes [1]. Epidermal ridges are a result of foetal development between the 9th and 24th weeks [2]. These bumps are unique to each person and do not alter over the course of a lifetime. Fingerprints on the palms and soles of one's feet are unique to each individual, even identical twins [1,3,4]. There

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are three different kinds of fingerprint evidence: those that can be seen, those that can be indented, and those that are latent. While latent fingerprints cannot be seen by the naked eye, visible and indented prints may be observed without any development [5]. Visual impressions are often referred to as patent prints. These prints don't need to be developed in order to be seen by the naked eye. Typically, these imprints will be visible in a material such as ink, oil, clay, dirt or blood. Finger ridge patterns are formed when these media come into touch with the finger. There is no need for any kind of optical aid to perceive these patterns [6]. Latent fingerprints are heavily influenced by sweat. When tiny sweat pores under the skin begin to perspire, a latent fingerprint is generated. Latent fingerprints are standard evidence in any criminal inquiry. Nonetheless, due to the complexity of its components, these prints provide the most development challenges [4].

Fingerprints may be made more legible using processes such as powder dusting, digital photography, fluorescent dye staining, vacuum metal deposition or cyanoacrylate/iodine fuming [7,8]. Accordingly, proper development methods are needed to make the hidden fingerprints visible [9]. Fluorescent granules are often used for detection [10]. Normal powders, fluorescent powders, metallic powders and magnetic powders are all used in powder dusting [11,12]. Other methods might use either vapor-phase or non-vapor-phase processes [9,13-15].

There are several problems with conventional approaches like low sensitivity, size inconsistency and strong interference from the backdrop indicating an intricate colour or pattern [7,13,16,17]. Moreover, brushing the powder will ruin the fingerprint details, therefore the process is complicated. Also, examiners' health is put at risk. There is little contrast and there is a lot of autofluorescence interference. There are many disadvantages to using inorganic fluorescent reagents and dyes, including their high cost, hazards, and environmental impacts. Today, fluorescent nanoparticles with high fluorescence intensity, remarkable photochemical stability and good physical and chemical properties are being developed for latent fingerprint (LFP) visualization. Many optical devices and biological applications use rare earth metal lanthanide derivatives with strong luminescence and electron transitions. In liquids and solids, rare earth metals typically exhibit low luminescence because they absorb less light. Hence, to improve the readability of latent fingerprints straightforwardly, this research coupled the cyanoacrylate fuming method with europium oxide.

2. Methodology

2.1 Fuming and Humidity Control in Cyanoacrylate Method

Cyanoacrylate fumes can be deposited over the latent fingerprint in the presence of controlled humidity to form clear and stable prints. In this method, the fumes and the humidity can be controlled by various setups. Here the fumes were controlled by three different methods and fingerprint patterns were monitored. In the first setup, the fumes were developed under direct heat without humidity, whereas the second method followed with the formation of fumes under wet cotton to enhance the humidity and finally, the third method produced the fumes by placing water in a beaker inside the chamber to create the controlled humidity.

2.2 Cyanoacrylate Fuming Method using Ethyl 2-Cyanoacrylate

Acetone was used to clean the grime off micro glass slides. Patterns of fingerprints (the donor was the first author) were captured on tiny glass slides. The ethyl 2-cyanoacrylate glue was stored in a container made from tightly folded and packed aluminium foil [18]. Ten drops of 2-cyanoethyl acrylate were added to the container and it was set on a hot plate [19]. The glue bottle was put on a hot plate and a beaker of water, 100 ml in capacity was placed nearby. Over time, fingerprints lose their moisture content, making it more difficult to create a clear pattern. Higher relative humidity in the chamber was achieved by increasing the proximity of the water reservoir, thus increasing the pattern's moisture content [7]. The chamber was used to house the sample (Figure 1). On the other side of the hot plate, the sample was placed. The sample is arranged in a way that maximizes its exposure to the chamber's gases. The sample was left in the sealed chamber for 30 minutes of exposure to the vapours. The samples were then taken for analysis.

Fig. 1. Fume Chamber with Fingerprint Sample

2.3 Characterization of Europium (III) Oxide

2.3.1 Morphology and crystallinity

X-ray crystallography and scanning electron microscopy were used to examine the europium (III) oxide morphology. The crystalline structure of the material is reflected in this study. Fluorescence spectroscopy was used to study the metal's fluorescence [20-22].

2.3.2 Thermal analysis

The thermal stability of the europium (III) oxide was analyzed at different temperatures and its corresponding UV absorbance value and photoluminescence intensity were measured. Further to know the thermal stabilization of the deposition material europium (III) oxide, thermo gravimetric analysis and differential thermal analysis (TGA and DTA) were performed Phase transition and weight loss percentage were studied at a particular temperature range of 100 – 500°C [23].

2.4 Europium (III) Oxide Deposition

Europium (III) Oxide solution was prepared by dissolving 0.03 grams of europium (III) oxide in 1 millilitre of concentrated nitric acid. The fingerprint template was gathered and placed inside the chamber. The fume cupboard includes a hotplate, a storage space for ethyl-2 cyanoacrylate and a water supply. 30 minutes of ethyl 2-cyanoacrylate treatment is performed on the sample. Once the fingerprint pattern had been removed from the chamber, the europium solution was sprayed on it and left to cure at ambient temperature for 30 minutes [24-26].

2.5 Minutiae Characterization

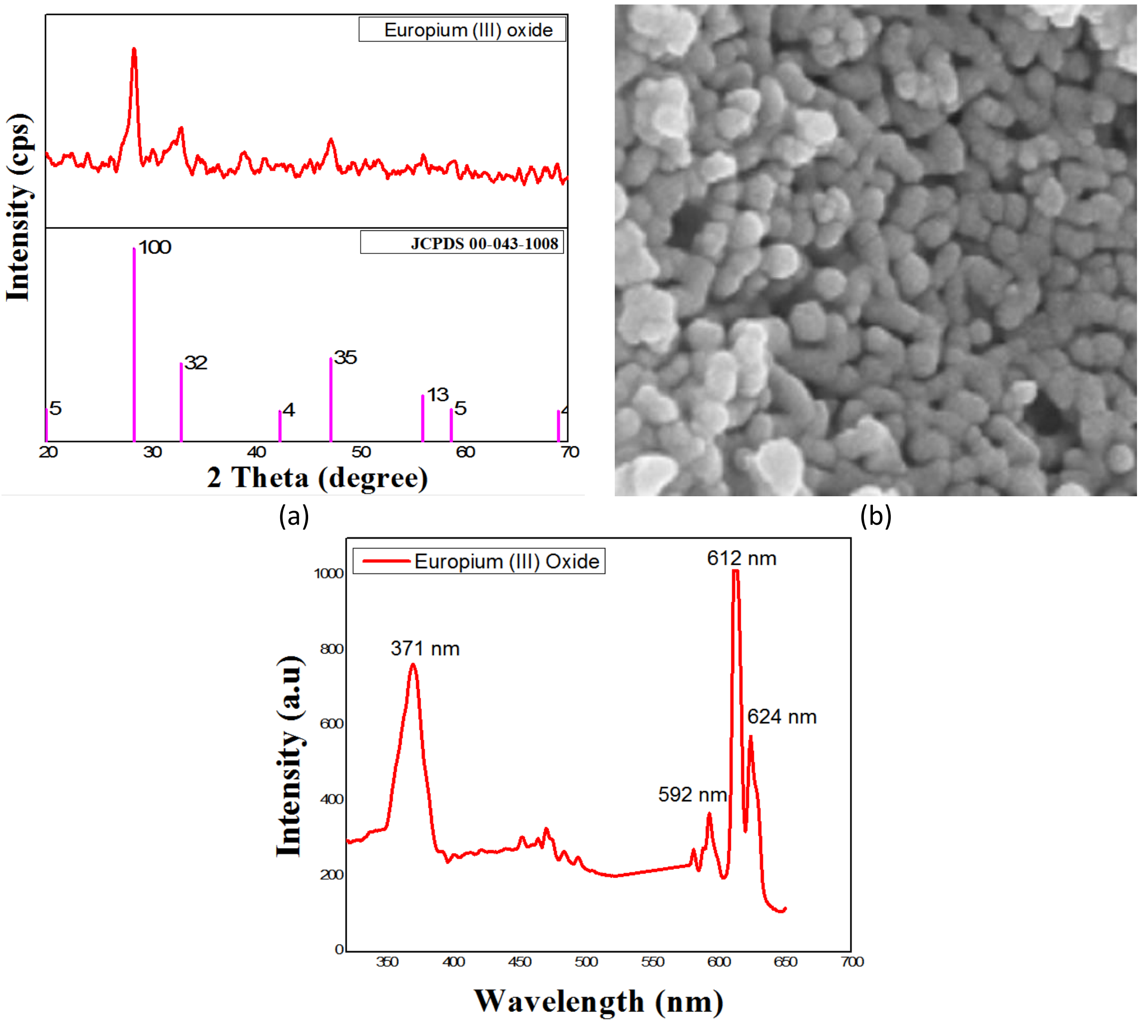
The subtle spots in an individual's latent fingerprint patterns are the minutiae. In forensic contexts, these aspects are utilized to describe and display fingerprints. NIST's Fingerprint Minutiae Viewer (FpMV) was used to examine the fingerprints that were created in this investigation. This allows one to make out the ridge patterns and other features [27].

3. Results

3.1 Characterization of Europium (III) Oxide

3.1.1 Morphology and crystallinity

X-ray diffraction examinations were used to analyze europium (III) oxide and the resulting peaks were compared to those formed by the JCPDS, which had the same 2 Theta values [28]. The SEM study, which was used to characterize the morphology, reveals the distinctly spherical shape of the europium metal oxide [29]. In addition, the red emission of europium oxide is shown by the creation of emission peaks at 371 nm, 592 nm, 612 nm, and 624 nm in fluorescence spectroscopic measurements. Figure 2 showed the morphological and fluorescence spectra of europium (III) oxide.



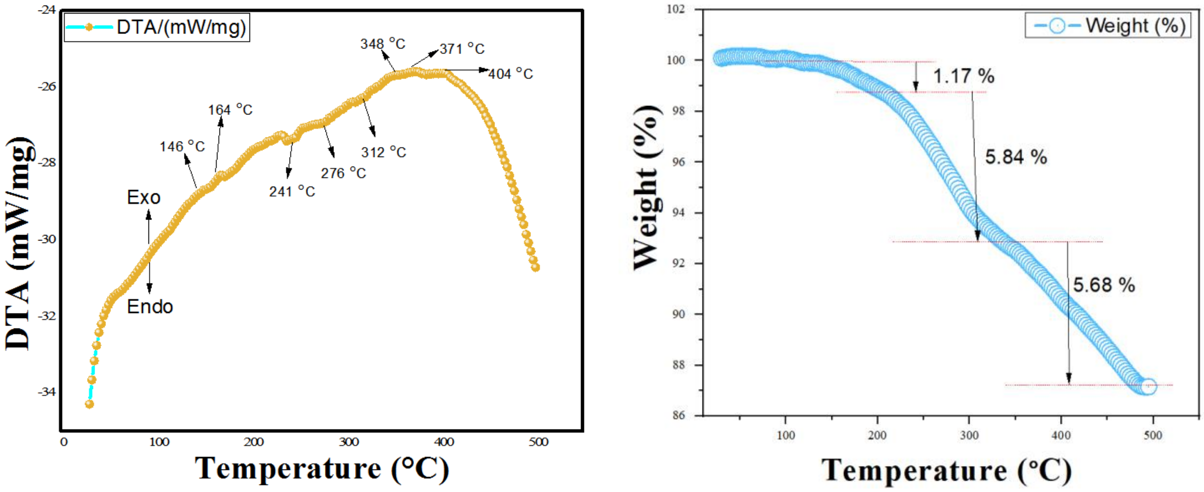
(a) (b)

(c)

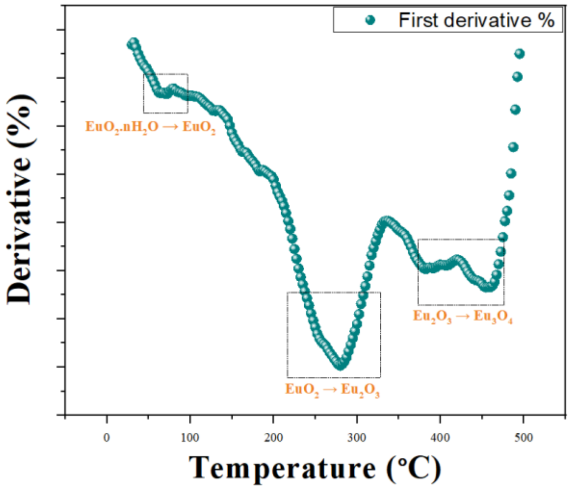
Fig. 2. (a) XRD pattern of europium (III) oxide with reference JCPDS peak, (b) SEM micrograph of europium (III) oxide, (c) Fluorescence spectrum of europium (III) oxide

3.1.2 Thermal analysis

The europium (III) oxide was a thermally stable compound whose thermal stability was analyzed at different temperatures. The thermal stability was recognized by its photoluminescence intensity, UV absorbance and quantum yield. Due to changes in temperature, there was no deterioration of photoluminescence in the compound. Furthermore, the change in temperature increases the quantum yield and photoluminescence characteristics of the europium (III) oxide (Figure 3). From Figure 4, it was clear that the photoluminescence is high with an intensity of 294 (a.u.) at the temperature of 100 °C. Then there was reduced photoluminescence at – 4 °C with an intensity of 167 (a.u.). Table 1 visualizes the photoluminescence effect of europium (III) oxide at different temperatures. From the thermal analysis, the DTA curve showed the endothermic and exothermic phenomena in the temperature range of 100 – 500 ˚C. There was an exothermic reaction at the temperature, 146 °C, 164 °C, 348 °C, 371 °C and 404 °C [30]. Whereas the endothermic reactions occur at the temperature, 241°C, 276°C and 312°C. Correspondingly, the TGA curve represents three weight loss percentages at the temperature, 146 °C, 216 °C, 332 °C and 480 °C. The weight loss is mainly due to the water evaporation, dehydration and phase transitions and energy transitions of the material. This was taken as a first derivative curve and phase transitions at each temperature were studied. The first small peak at the temperature range of 66°C - 200°C was due to dehydration and the formation of europium oxide without any water molecules. The second largest peak corresponding to the weight loss between 277 °C and 332 °C is due to the phase transformation of EuO to Eu_2O_3. Whereas the final peak at 381°C and 458 °C which is nearly equal to the last weight loss region of 332°C and 480°C is due to the phase transformation of Eu_2O_3 to Eu_3O_4.

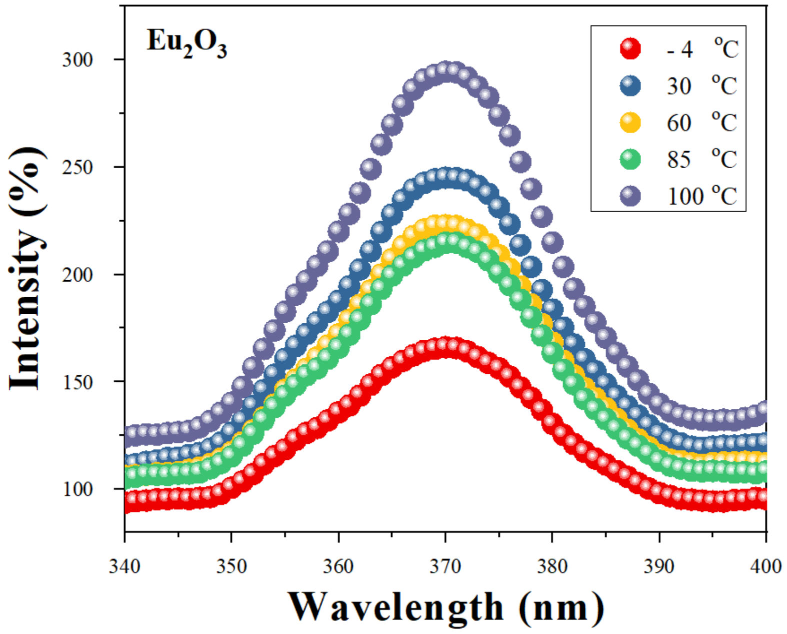


(a) (b)

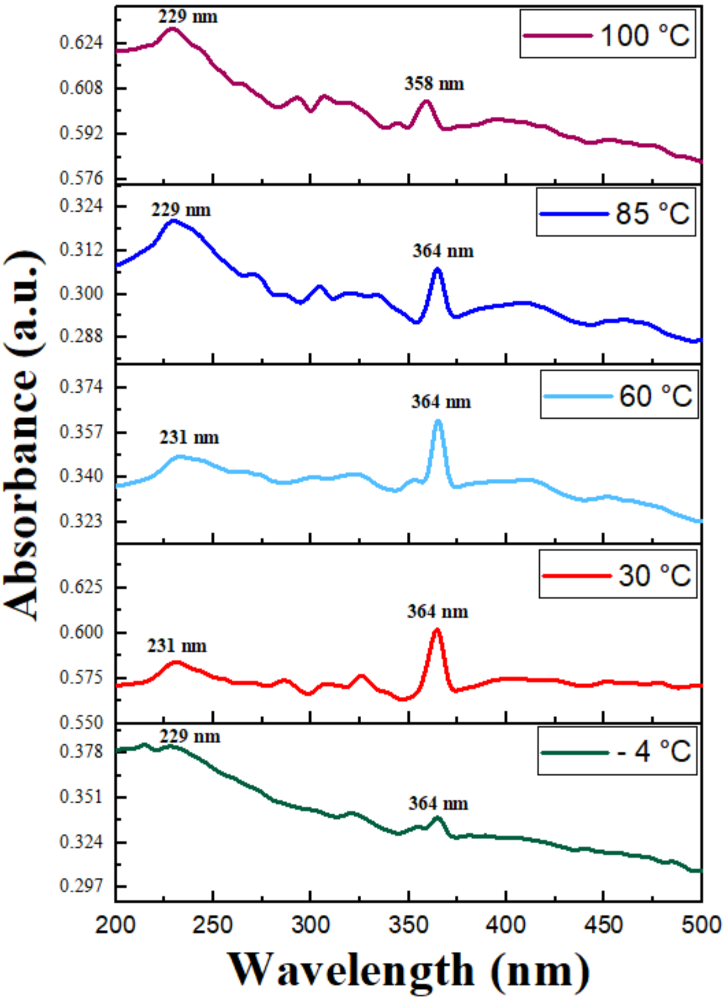


(c)

Fig. 3. TGA and DTA curves of europium (III) oxide at the temperature range of 0 – 500 °C. (a) Exothermic and endothermic reactions of europium (III) oxide in DTA curve, (b) Weight loss percentage of europium (III) oxide by TGA graph, (c) Phase transformation for the corresponding weight loss at different temperatures in TGA curve



(a)



(b)

Fig. 4. Temperature stability study of europium (III) oxide a) Photoluminescence intensity at different temperature storage of europium (III) oxide, b) UV absorbance of stored europium (III) oxide at varying temperatures

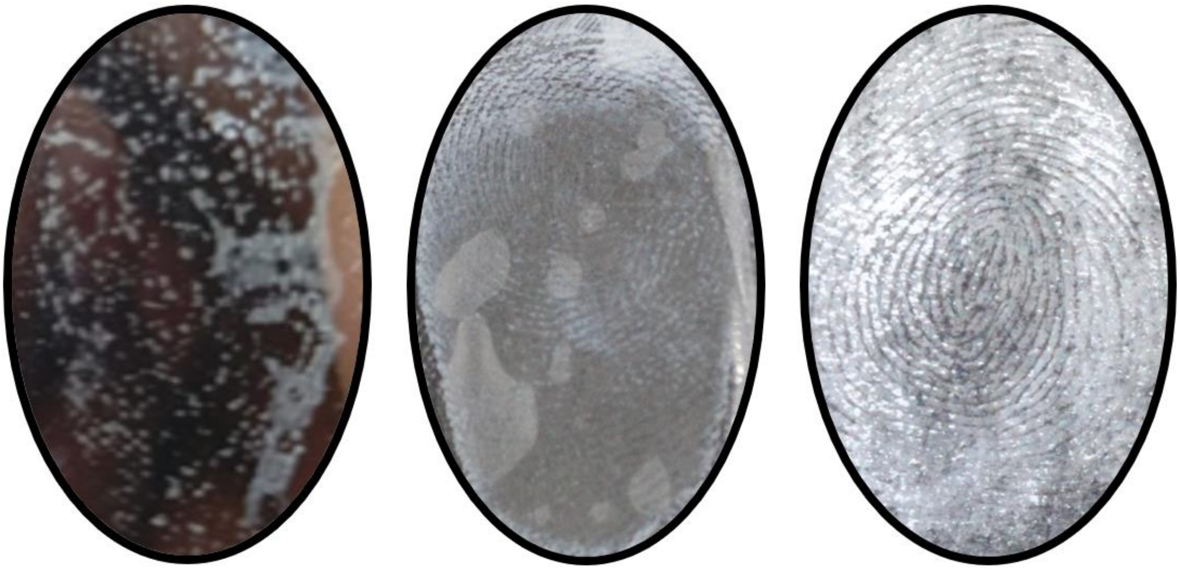
Table 1

Photoluminescence effect and quantum yield of the europium (III) oxide at different temperatures

S.No.	Compound	Temperature (C)	UV Absorbance (a.u.)	PL Intensity (a.u.)	Quantum Yield (%)
1.	Europium (III) oxide	-4	0.338	167	57
2.		30	0.604	245	48
3.		60	0.362	225	76
4.		85	0.307	215	81
5.		100	0.604	294	49

3.2 Enhancing Fingerprint Pattern by Controlled Humidity

Fingerprints were developed by different fuming techniques at controlled humidity. The humidity plays a vital role in forming clear and stable patterns of the latent fingerprints through the cyanoacrylate fuming method. So, three humidity conditions were maintained in the fuming chamber and the fingerprints were developed. Among them, the chamber formed fumes with direct heat without humidity has developed a poor fingerprint pattern, whereas the chamber with a wet cotton plug maintaining moderate humidity without heat triggers very fast fumes for only a few seconds and the fumes were deposited here and there on the fingerprint patterns as the fumes were not controlled. Finally, in the third chamber, the humidity was controlled and maintained throughout the reaction. Fumes were formed in a controlled manner and deposited at a precise position of the fingerprints. Thus, in this study, humidity control is highly necessary to form a clear and stable fingerprint pattern. Figure 5 shows the fingerprint patterns developed at three different humidity [31].



(a) (b) (c)

Fig. 5. Enhanced fingerprint pattern at three different humidity (a) Without humidity, fumes produced at direct heat, (b) Without heat, fumes produced from the wet cotton plug, (c) With humidity, fumes produced in the presence of water

3.3 Improving Fingerprint Patterns with Ethyl 2-Cyanoacrylate:

Fingerprints were treated with ethyl 2-cyanoacrylate for 30 minutes and photographed. Fingerprint samples were studied both before and after being exposed to cyanoacrylate fumes. A maximum of 60 minutes was allotted for fingerprint development. Latent fingerprints before cyanoacrylate treatment and after treatment with cyanoacrylate fumes for 30 minutes and 60 minutes are represented in Figure 6(a), Figure 6(b) and Figure 6(c) respectively. Cyanoacrylate-treated fingerprints showed better visibility when compared to untreated fingerprints. However, not much difference was observed between the 30 minutes and 60 minutes of treated fingerprints. Hence, 30 minutes of exposure to cyanoacrylate fumes was preferred for further analysis.

(a) (b) (c)

Fig. 6. Latent fingerprints (a) before and after cyanoacrylate exposure for (b) 30 minutes and (b) 60 minutes

3.4 Europium (III) Oxide Deposition

After treatment with cyanoacrylate fumes, the latent fingerprints were further enhanced using europium (III) oxide deposition. Europium (III) oxide is observed to exhibit strong luminescence and electron transitions when exposed to UV light of 395 nm. Fingerprints after cyanoacrylate vapor treatment with and without europium (III) oxide deposition were analyzed. Figure 7 displays the comparison of Latent Fingerprints (a) Before and (b) After Ethyl 2-Cyanoacrylate Exposure and (c) After Europium (III) Oxide Enhancement.

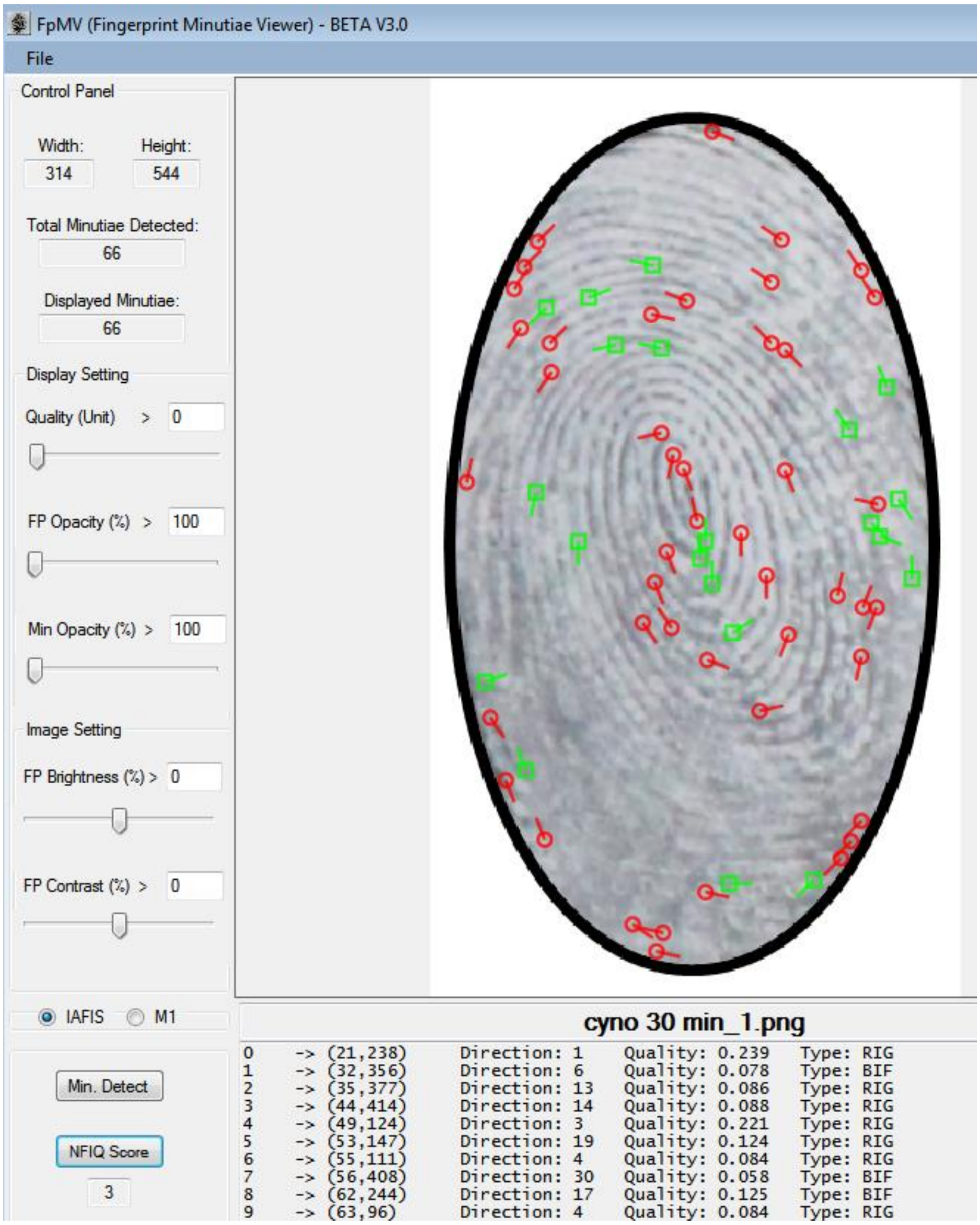
(a) (b) (c)

Fig. 7. Comparison of Enhanced Latent Fingerprint (a) Before and (b) After Ethyl 2-Cyanoacrylate Exposure and (c) After Europium (III) Oxide Enhancement

Compared to fingerprints treated with ethyl 2-cyanoacrylate, fingerprints exposed to europium (III)oxide were more distinct and legible.

3.5 Minutiae Results of the Treated Sample

The finest fingerprints were examined with the help of the fingerprint Minutiae Viewer. Grayscale analysis of europium (III) oxide and cyanoacrylate-enhanced fingerprints allows for the identification of minutiae details. Analysis of the fingerprint treated with ethyl 2-cyanoacrylate revealed 66 discrete features (Figure 8). Figure 9 shows that fingerprints treated with europium (III) oxide showed 104 minutiae points. Europium (III) enhanced and processed fingerprints were used extensively in these investigations. This is because the grayscale of the europium (III) oxide-enhanced image is greater and the background noise is smaller than the grayscale of the other fingerprint types.

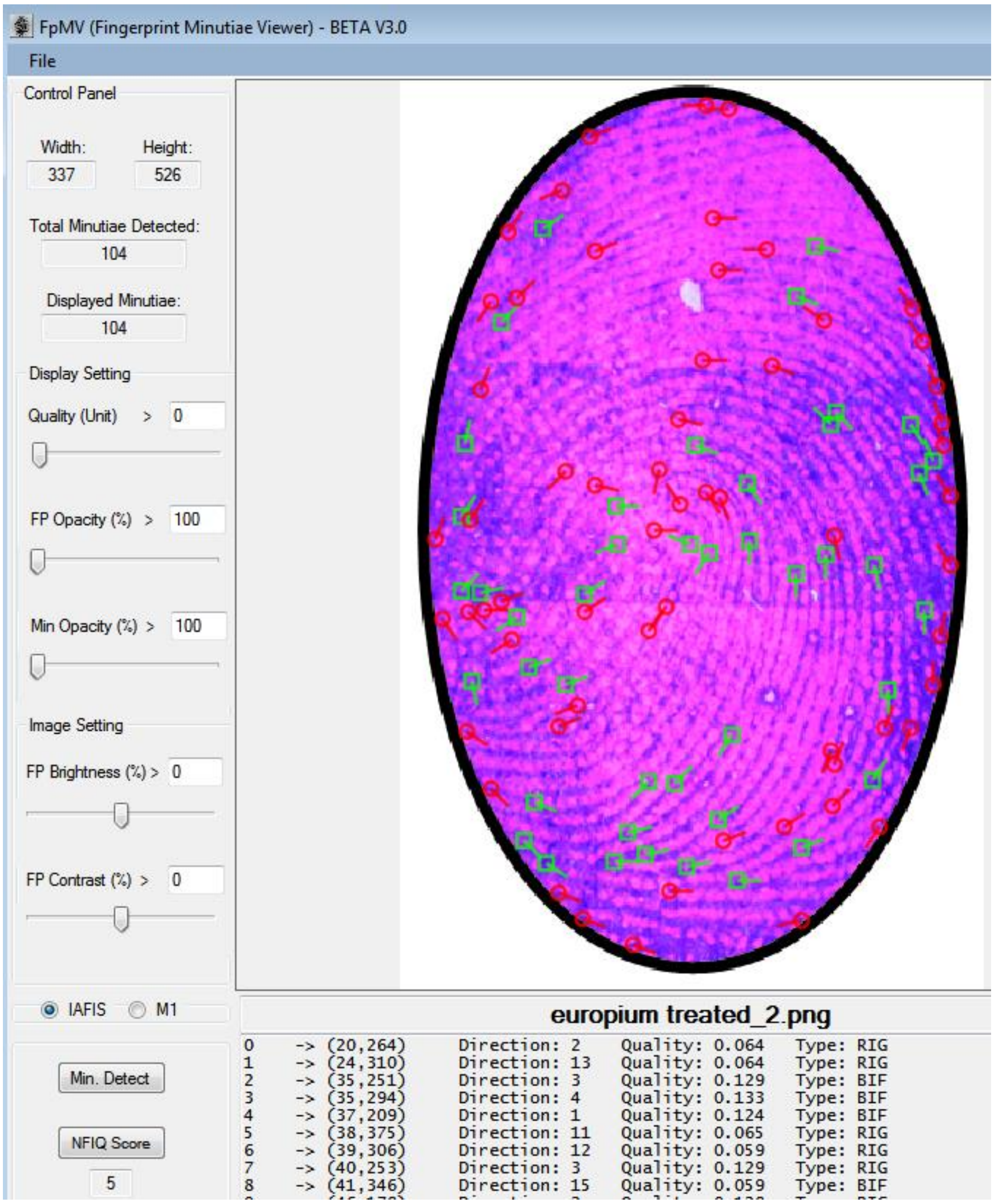


Width: 314
Height: 544
Total Minutiae Detected: 66
Displayed Minutiae: 66
Quality (Unit) > 0
FP Opacity (%) > 100
Min Opacity (%) > 100
FP Brightness (%) > 0
FP Contrast (%) > 0
● IAFIS ○ M1
NFIQ Score: 3

cyno 30 min_1.png

```
0     -> (21,238)     Direction: 1    Quality: 0.239   Type: RIG
1     -> (32,356)     Direction: 6    Quality: 0.078   Type: BIF
2     -> (35,377)     Direction: 13   Quality: 0.086   Type: RIG
3     -> (44,414)     Direction: 14   Quality: 0.088   Type: RIG
4     -> (49,124)     Direction: 3    Quality: 0.221   Type: RIG
5     -> (53,147)     Direction: 19   Quality: 0.124   Type: RIG
6     -> (55,111)     Direction: 4    Quality: 0.084   Type: RIG
7     -> (56,408)     Direction: 30   Quality: 0.058   Type: BIF
8     -> (62,244)     Direction: 17   Quality: 0.125   Type: BIF
9     -> (63,96)      Direction: 4    Quality: 0.084   Type: RIG
```

Fig. 8. Minutiae points found in ethyl 2-cyanoacrylate treated fingerprint through FpMV tool



Width: 337
Height: 526
Total Minutiae Detected: 104
Displayed Minutiae: 104
Quality (Unit) > 0
FP Opacity (%) > 100
Min Opacity (%) > 100
FP Brightness (%) > 0
FP Contrast (%) > 0
● IAFIS ○ M1
NFIQ Score: 5

europium treated_2.png

```
0     -> (20,264)     Direction: 2    Quality: 0.064   Type: RIG
1     -> (24,310)     Direction: 13   Quality: 0.064   Type: RIG
2     -> (35,251)     Direction: 3    Quality: 0.129   Type: BIF
3     -> (35,294)     Direction: 4    Quality: 0.133   Type: BIF
4     -> (37,209)     Direction: 1    Quality: 0.124   Type: BIF
5     -> (38,375)     Direction: 11   Quality: 0.065   Type: RIG
6     -> (39,306)     Direction: 12   Quality: 0.059   Type: RIG
7     -> (40,253)     Direction: 3    Quality: 0.129   Type: RIG
8     -> (41,346)     Direction: 15   Quality: 0.059   Type: BIF
```

Fig. 9. Minutiae points found in Europium (III) oxide enhanced and treated fingerprint through FpMV tool

The natural chemicals of the fingerprint undergo a reaction when exposed to the vapours of ethyl 2-cyanoacrylate, which increases the contrast of the impression. Therefore, fingerprints are discernible to the naked eye after cyanoacrylate treatment has been applied to the surface. In addition, europium oxide which exhibits strong luminescence and electron transitions was used so that the fingerprints could be improved.

4. Conclusions

The simple cyanoacrylate fuming procedure using ethyl 2-cyanoacrylate vapours enhanced the visibility of latent fingerprint imprints. The fingerprint patterns that resulted from applying cyanoacrylate were distinct and easy to see. The compounds in the fingerprints interacted with the vapours of ethyl 2-cyanoacrylate and increased the contrast of the fingerprint. As intended, this approach was both quick and inexpensive. Europium (III) oxide was analyzed for thermal stability under different fuming conditions, which provides evidence for the best material for the stable visualization of latent fingerprints. The fingerprint sample was treated with europium (III) oxide solution after being treated with ethyl 2-cyanoacrylate. The sample treated with europium (III) oxide was transparent and easily observable. The level of noise in the background was highly reduced. Incredibly distinct fingerprints may be obtained from ultra-pure europium nanoparticles.

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References

[1] Arslan, Bilgehan. "Fingerprint Forensics in Crime Scene: A Computer Science Approach." *International Journal of Information Security Science* 8, no. 4 (2019): 88-113.

[2] Ifa, Demian R., Nicholas E. Manicke, Allison L. Dill, and R. Graham Cooks. "Latent fingerprint chemical imaging by mass spectrometry." *Science* 321, no. 5890 (2008): 805-805. https://doi.org/10.1126/science.1157199

[3] Chen, Jie, Ji-Shi Wei, Peng Zhang, Xiao-Qing Niu, Wei Zhao, Ze-Yang Zhu, Hui Ding, and Huan-Ming Xiong. "Red-emissive carbon dots for fingerprints detection by spray method: coffee ring effect and unquenched fluorescence in drying process." *ACS Applied Materials & Interfaces* 9, no. 22 (2017): 18429-18433. https://doi.org/10.1021/acsami.7b03917

[4] Ganapati, M. Tarasase. "Identification of an individual through fingerprints." *Journal of Bio Innovation* 2, no. 2 (2013): 59-72.

[5] Grieve, David L. "Review of: Fingerprints and Other Ridge Skin Impressions." *Journal of Forensic Sciences* 50, no. 1 (2005): JFS2004340. https://doi.org/10.1520/JFS2004340

[6] Hazarika, Pompi, and David A. Russell. "Advances in fingerprint analysis." *Angewandte Chemie International Edition* 51, no. 15 (2012): 3524-3531. https://doi.org/10.1002/anie.201104313

[7] Dadmun, Mark D. "Developing methods to improve the quality and efficiency of latent fingermark development by superglue fuming." *Knoxville (TN): Department of Justice* (2014).

[8] Kellman, Philip J., Jennifer L. Mnookin, Gennady Erlikhman, Patrick Garrigan, Tandra Ghose, Everett Mettler, David Charlton, and Itiel E. Dror. "Forensic comparison and matching of fingerprints: using quantitative image measures for estimating error rates through understanding and predicting difficulty." *PloS One* 9, no. 5 (2014): e94617. https://doi.org/10.1371/journal.pone.0094617

[9] Jia, Xiaobo, Lanlan Li, Jingjing Yu, Xiujun Gao, Xiaojing Yang, Zunming Lu, Xinghua Zhang, and Hui Liu. "Facile synthesis of BCNO quantum dots with applications for ion detection, chemosensor and fingerprint identification." *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 203 (2018): 214-221. https://doi.org/10.1016/j.saa.2018.05.099

[10] Basavaraj, R. B., H. Nagabhushana, G. P. Darshan, S. C. Sharma, and K. N. Venkatachalaiah. "Ultrasound assisted rare earth doped Wollastonite nanopowders: labeling agent for imaging eccrine latent fingerprints and cheiloscopy applications." *Journal of Industrial and Engineering Chemistry* 51 (2017): 90-105. https://doi.org/10.1016/j.jiec.2017.02.019

[11] Li, Kun, Weiwei Qin, Fan Li, Xingchun Zhao, Bowei Jiang, Kun Wang, Suhui Deng, Chunhai Fan, and Di Li. "Nanoplasmonic imaging of latent fingerprints and identification of cocaine." *Angewandte Chemie (International ed. in English)* 52, no. 44 (2013): 11542-11545. https://doi.org/10.1002/anie.201305980

[12] Wang, Meng, Ming Li, Aoyang Yu, Ye Zhu, Mingying Yang, and Chuanbin Mao. "Fluorescent nanomaterials for the development of latent fingerprints in forensic sciences." *Advanced Functional Materials* 27, no. 14 (2017): 1606243. https://doi.org/10.1002/adfm.201606243

[13] Lim, Angelina Yimei, Jan Ma, and Yin Chiang Freddy Boey. "Development of nanomaterials for SALDI-MS analysis in forensics." *Advanced Materials* 24, no. 30 (2012): 4211-4216. https://doi.org/10.1002/adma.201200027

[14] Kim, Young-Jae, Hak-Sung Jung, Joohyun Lim, Seung-Jin Ryu, and Jin-Kyu Lee. "Rapid imaging of latent fingerprints using biocompatible fluorescent silica nanoparticles." *Langmuir* 32, no. 32 (2016): 8077-8083. https://doi.org/10.1021/acs.langmuir.6b01977

[15] Tang, Ho-Wai, Wei Lu, Chi-Ming Che, and Kwan-Ming Ng. "Gold nanoparticles and imaging mass spectrometry: double imaging of latent fingerprints." *Analytical Chemistry* 82, no. 5 (2010): 1589-1593. https://doi.org/10.1021/ac9026077

[16] Sodhi, Gurvinder Singh, and Jasjeet Kaur. "Powder method for detecting latent fingerprints: a review." *Forensic Science International* 120, no. 3 (2001): 172-176. https://doi.org/10.1016/S0379-0738(00)00465-5

[17] Darshan, G. P., H. B. Premkumar, H. Nagabhushana, S. C. Sharma, S. C. Prashanth, and B. Daruka Prasad. "Effective

fingerprint recognition technique using doped yttrium aluminate nano phosphor material." *Journal of Colloid and Interface Science* 464 (2016): 206-218. https://doi.org/10.1016/j.jcis.2015.11.025

[18] Bumbrah, Gurvinder Singh. "Cyanoacrylate fuming method for detection of latent fingermarks: a review." *Egyptian Journal of Forensic Sciences* 7 (2017): 1-8. https://doi.org/10.1186/s41935-017-0009-7

[19] Casault, Paméla, Nicolas Gilbert, and Benoit Daoust. "Comparison of various alkyl cyanoacrylates for fingerprint development." *Canadian Society of Forensic Science Journal* 50, no. 1 (2017): 1-22. https://doi.org/10.1080/00085030.2016.1223438

[20] Prasad, Vandana, Lalit Prasad, Sally Lukose, and Prashant Agarwal. "Latent fingerprint development by using silver nanoparticles and silver nitrate-A comparative study." *Journal of Forensic Sciences* 66, no. 3 (2021): 1065-1074. https://doi.org/10.1111/1556-4029.14664

[21] Choi, Mi Jung, Andrew M. McDonagh, Philip Maynard, and Claude Roux. "Metal-containing nanoparticles and nano-structured particles in fingermark detection." *Forensic Science International* 179, no. 2-3 (2008): 87-97. https://doi.org/10.1016/j.forsciint.2008.04.027

[22] Wang, Meng, Ming Li, Aoyang Yu, Jian Wu, and Chuanbin Mao. "Rare earth fluorescent nanomaterials for enhanced development of latent fingerprints." *ACS Applied Materials & Interfaces* 7, no. 51 (2015): 28110-28115. https://doi.org/10.1021/acsami.5b09320

[23] Wang, DongMei, WenBo Cao, and Jian Fan. "Synthesis and luminescence properties of the europium quaternary complexes nanoparticles." *Science China Chemistry* 57 (2014): 791-796. https://doi.org/10.1007/s11426-013-5039-x

[24] Saif, M., Magdy Shebl, A. I. Nabeel, R. Shokry, H. Hafez, A. Mbarek, K. Damak, R. Maalej, and M. S. A. Abdel-Mottaleb. "Novel non-toxic and red luminescent sensor based on Eu^{3+}: $Y_2Ti_2O_7/SiO_2$ nano-powder for latent fingerprint detection." *Sensors and Actuators B: Chemical* 220 (2015): 162-170. https://doi.org/10.1016/j.snb.2015.05.040

[25] Sametband, Matias, Itzhak Shweky, Uri Banin, Daniel Mandler, and Joseph Almog. "Application of nanoparticles for the enhancement of latent fingerprints." *Chemical Communications* 11 (2007): 1142-1144. https://doi.org/10.1039/b618966k

[26] Wang, Fangyuan, Jian Chen, Huipeng Zhou, Wenying Li, Qingfeng Zhang, and Cong Yu. "Facile detection of latent fingerprints on various substrates based on perylene probe excimer emission." *Analytical Methods* 6, no. 3 (2014): 654-657. https://doi.org/10.1039/C3AY41802B

[27] Salamon, Wayne J., and Kenneth Ko. *Fingerprint Minutiae Viewer (FpMV)*. NIST, 2021.

[28] Xuan, Lee Wei, Mohd Fadhil Majnis, Syahriza Ismail, and Mohd Azam Mohd Adnan. "Synthesis of bi-component ZrO_2/Ag nanotube for heavy metal removal." *Progress in Energy and Environment* 18 (2021): 23-33. https://doi.org/10.37934/progee.18.1.2333

[29] Khoo, Miinyi, Vasanthi Sethu, Anurita Selvarajoo, and Senthil Kumar Arumugasamy. "Performance of fenugreek and okra for the physico-chemical treatment of palm oil mill effluent-modeling using response surface methodology." *Progress in Energy and Environment* 15 (2021): 8-30.

[30] Al-Dailami, Anas, Iwamoto Koji, Imran Ahmad, and Masafumi Goto. "Potential of photobioreactors (PBRs) in cultivation of microalgae." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 27, no. 1 (2022): 32-44. https://doi.org/10.37934/araset.27.1.3244

[31] Jaafar, Nurul Aini, Siti Rohani Mohd Nor, Siti Mariam Norrulashikin, Nur Arina Bazilah Kamisan, and Ahmad Qushairi Mohamad. "Increase Students' Understanding of Mathematics Learning Using the Technology-Based Learning." *International Journal of Advanced Research in Future Ready Learning and Education* 28, no. 1 (2022): 24-29.