

Aqueous electrolytes: retrieving latent fingermarks from crumpled aluminum foil

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Abstract: Development of latent fingermarks on the flat surface of aluminum foil is an easy task. Fingermark powders, powder suspension, and cyanoacrylate fuming are applied routinely and work well. Development of latent fingermark on crumpled foil is a bit of a challenge. Depending upon the depth and nature of the folds, the presently used techniques may not help to develop fingermarks in their full form. In the present study, an attempt has been made to resolve this issue by using aqueous electrolytes. The results obtained by using the proposed technique were compared with powder, powder suspension, and cyanoacrylate fuming techniques. The proposed technique was found to be better than that of other techniques in the case of crumpled aluminum foil.

Keywords: crime scene, latent fingermarks, nonporous surfaces, crumpled aluminum foil, aqueous electrolytes

Introduction

Criminals often leave their signed confessions, in the form of latent fingermarks, on different surfaces at the crime scene.¹ Over the years, numerous techniques have been suggested to develop latent fingermarks on different types of surfaces, generally classified as porous, semiporous, and nonporous.² Aluminum foil has gained popularity in the wrapping and food packaging industries, and it may be found at the crime scene as a flat surface, folded piece or in a crumpled mass. Fingermark powders, powder suspension, cyanoacrylate fuming,³ scanning Kelvin probe (SKP),⁴ electropolymerization,⁵ electrodeposition of metal nanoparticles,^{3,6} columnar thin film deposition,⁷ thermal visualization,⁸ luminescent carbon dot,⁹ silica gel G,¹⁰ and aqueous electrolytes^{11,12} have been reported to develop latent fingermarks on nonporous surfaces.

Among these techniques, the use of aqueous electrolytes to develop latent fingermarks is a comparatively newer technique and has been proven to be useful in developing latent fingermarks on different types of surfaces.^{11,12} Aqueous electrolyte is any substance that when dissolved in water forms charged ions.¹³

In the present study, aqueous electrolytes have been used to develop latent fingermarks on crumpled aluminum foil. The results have been compared with those produced with three commonly used techniques: fingermark powder, powder suspension, and atmospheric cyanoacrylate fuming.

Materials and methods

Aluminum foil

Two rolls of aluminum foil (thickness: 11 microns and 18 microns) were purchased from local stores and used in the current study.

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Acquisition of latent fingermarks

Natural fingermarks were deposited on crumpled aluminum foil (total 100; 25 samples per technique) in the current study as per the International Fingerprint Research Group (IFRG) guidelines.¹⁴ The volunteers were informed verbally about the noninvasive nature of the experiment and requested to pull out foil from the rolls and make crumpled masses with bare hands (Figure 1). The crumpled masses (100 samples) were carefully removed by KS with gloved hands, and the deposited fingermarks left unprocessed for 1 day. The wooden handle of a knife and an ice pick were wrapped with foil by the volunteers. The wrapped, crumpled foil was then carefully removed from the wooden handle by KS. Five volunteers, including three males and two females, were asked (from the department students and staff), irrespective of their donor capabilities, for the deposition of natural fingermarks. The age of the volunteers ranged from 25 to 48 years. The volunteers were asked to wash their hands properly with soap and allowed to do natural activities for 4 hours before the deposition of fingermarks on the foil.

Chemicals

Fused calcium chloride (CaCl_2 ; 95% extra pure), potassium permanganate (KMnO_4 ; analytical reagent [AR] grade), and liquid detergent (neutral) were procured from Loba Chemie (Mumbai, India). Activated charcoal powder was procured from SDFCL, Ltd. (Mumbai, India), and used in the study.

Preparation of electrolytes

Separate solutions of fused CaCl_2 and KMnO_4 were prepared in distilled water (CaCl_2 8% w/v and KMnO_4 4% w/v), as suggested by Jasuja et al,¹² and mixed. It has been shown that 6%–8% w/v CaCl_2 was the optimized concentration to develop latent fingermarks on aluminum. Hence, KMnO_4 was experimented with CaCl_2 (8%), and different concentrations

of KMnO_4 ranging from 1% to 5% (with an interval of 1.0%) were tried to get optimized concentration.

Fingermarks development procedure

The following four techniques were used individually to develop the latent fingermarks on the crumpled foils (and the fingermarks of the same person were treated by all the techniques to avoid donor intervariability):

1. Immersion in aqueous electrolytes for 30 minutes (Figure 2A).
2. Brushing with activated charcoal powder (used as a dry fingermark powder).
3. Spraying with charcoal powder-based powder suspension.¹⁵ 15 g of activated charcoal powder and 1–2 mL of liquid detergent were added to 100 mL of water and stirred until thoroughly mixed. Excess powder was detached by water sprayed gently above the developed fingermarks.
4. Cyanoacrylate fumed in an atmospheric cabinet.³ 3 g of cyanoacrylate (Foster + Freeman Ltd., Evesham, UK) was placed in a fuming cabinet at 80% ($\pm 2\%$) of relative humidity and at 120°C for ~ 15–30 minutes.

The developed fingermarks were photographed with a Nikon® Coolpix L120 (Tokyo, Japan), Semi SLR digital camera. The third-level details of a fingermark were examined under a stereomicroscope at 40× by KS.

Assessment of developed fingermarks

The IFRG grading scheme¹⁴ was followed for the assessment of the developed fingermarks (Table 1), and the developed fingermarks were graded by KS (both with the naked eye and using a stereomicroscope) in order to maintain a standard objectivity and uniformity and avoid interobserver variations.

Results

For aqueous electrolytes, the optimized concentration of CaCl_2 (8%) was tested with 1%–5% of KMnO_4 in a 1:1 ratio. Accordingly, the grade of developed fingermarks was assigned a value by KS, as per the IFRG guidelines.¹⁴ For example, a solution of 8% CaCl_2 and 2% KMnO_4 in a 1:1 ratio gave grade 2 of the developed latent fingermarks (Table 2, Figure 2B). Of note, the split latent fingermarks were developed with 1%–5% of KMnO_4 and 8% CaCl_2 in a 1:1 ratio to get the optimized concentration of KMnO_4 (Table 2, Figure 2C).

A mixture of 8% solution of CaCl_2 and 4% solution of KMnO_4 (ratio 1:1) was found to be most effective to develop



Figure 1 The mode of natural fingermarks collection on different foil forms.

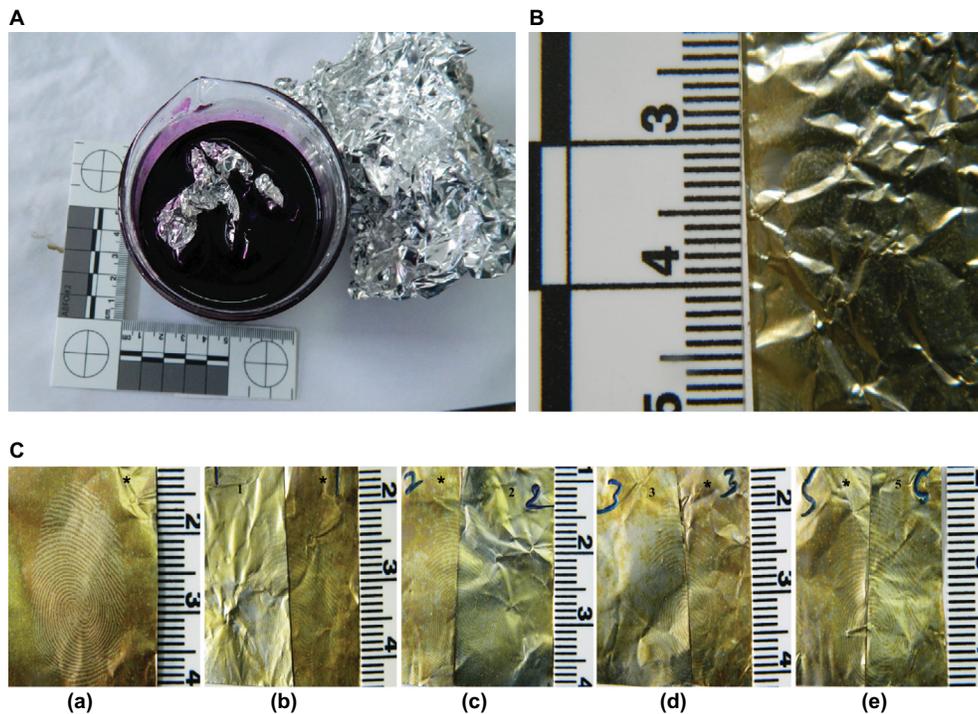


Figure 2 (A) The crumpled foil immersed in aqueous electrolyte solution. (B) The developed latent fingerprint of grade 2 on crumpled aluminum foil with the solution of 2% KMnO_4 and 8% CaCl_2 (with 1:1 ratio). (C) The developed latent (split) fingerprints on aluminum foil with the solutions of 1%–5% KMnO_4 and 8% CaCl_2 (with 1:1 ratio). *Represents the development of latent fingerprints with the concentration of: 4% KMnO_4 and 8% CaCl_2 : (a) 4% KMnO_4 and 8% CaCl_2 (b) (1) 1% KMnO_4 and 8% CaCl_2 (c) (2) 2% KMnO_4 and 8% CaCl_2 (d) (3) 3% KMnO_4 and 8% CaCl_2 (e) (5) 5% KMnO_4 and 8% CaCl_2 . (1)–(5) in (b)–(e) are the respective serial numbers.

Table 1 The IFRG guidelines

Grade	Details observed
0	No development
1	Signs of contact but less than 1/3 of mark with continuous ridges
2	1/3–2/3 of mark with continuous ridges
3	More than 2/3 of mark with continuous ridges, but not quite a perfect mark
4	Full development – whole mark clear with continuous ridges

Note: Data from a previous study.¹⁴

Abbreviation: IFRG, International Fingerprint Research Group.

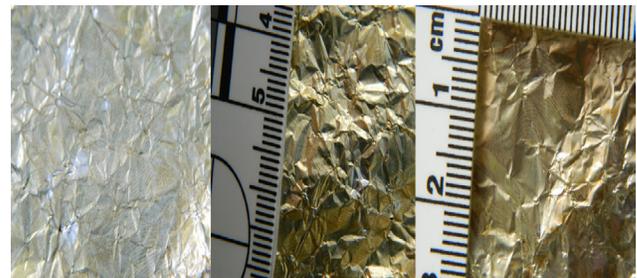


Figure 3 The developed latent fingerprint of grade 4 on crumpled aluminum foil with the solution of 4% KMnO_4 and 8% CaCl_2 (with 1:1 ratio).

Table 2 The range of different concentrations of KMnO_4 tested with CaCl_2 and accordingly assigned grade of developed fingerprint

Serial no	Calcium chloride (w/v) (optimized concentration)	Potassium permanganate (w/v)	Solution CaCl_2 : KMnO_4	Grade of developed fingerprint
1	8%	1%	1:1	2
2	8%	2%	1:1	2
3	8%	3%	1:1	3
4	8%	4%	1:1	4
5	8%	5%	1:1	3

latent prints of very high quality (grade 4) at room temperature (20°C–24°C; Figures 3 and 4).

The powdering technique could develop only partial prints of grade 2 (Figure 5).

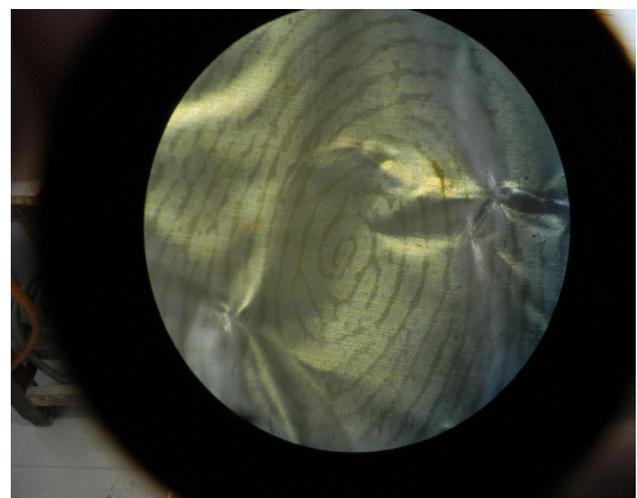


Figure 4 The developed latent fingerprint of grade 4 by aqueous electrolytes on crumpled aluminum foil under stereomicroscope at 40 \times .

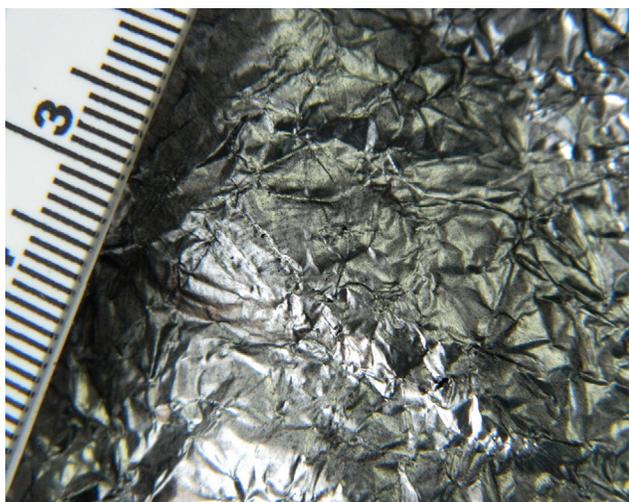


Figure 5 The developed latent fingerprint of grade 2 on uncrumpled aluminum foil with the powder method.

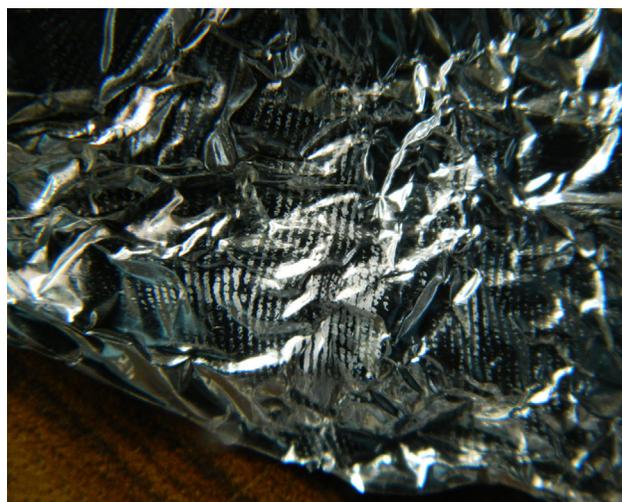


Figure 8 The developed latent fingerprint of grade 3 on crumpled aluminum foil (outer side) with the cyanoacrylate fuming.

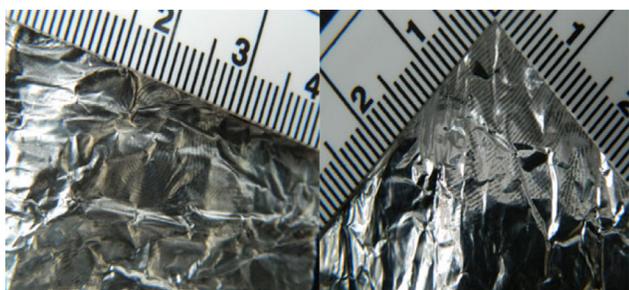


Figure 6 The developed latent fingerprint of grade 3 on uncrumpled aluminum foil with the powder suspension.



Figure 9 The completely developed latent fingerprint of grade 4 on uncrumpled aluminum foil with the cyanoacrylate fuming.

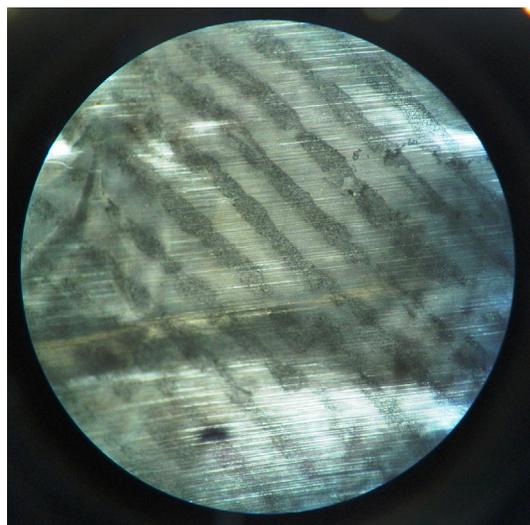


Figure 7 The developed latent fingerprint of grade 3 with the powder suspension on uncrumpled aluminum foil under stereomicroscope at 40x.

The powder suspension technique provided better results than the powdering technique (Figures 6 and 7).

Results produced by the atmospheric cyanoacrylate fuming technique were better than those by the powdering and

powder suspension technique. As can be seen in Figure 8, the exposed portions of the foil have clearly developed prints, whereas the unexposed portions (insides of creases and folds) remained undeveloped. The uncrumpling of foil and further exposure to the fumes have provided further details (Figures 9 and 10).

From this comparative study (Table 3), it was found that aqueous electrolytes had developed the latent fingerprints on 21 out of 25 samples of crumpled aluminum foil; cyanoacrylate fuming had developed 17 out of 25; powder suspension had developed 12 out of 25; and powdering had developed 7 out of 25 samples (Figure 11). Therefore, based on the comparative study, the effectiveness of techniques was found in the following order:

Aqueous Electrolytes > Atmospheric Cyanoacrylate Fuming > Powder suspension > Powder technique.

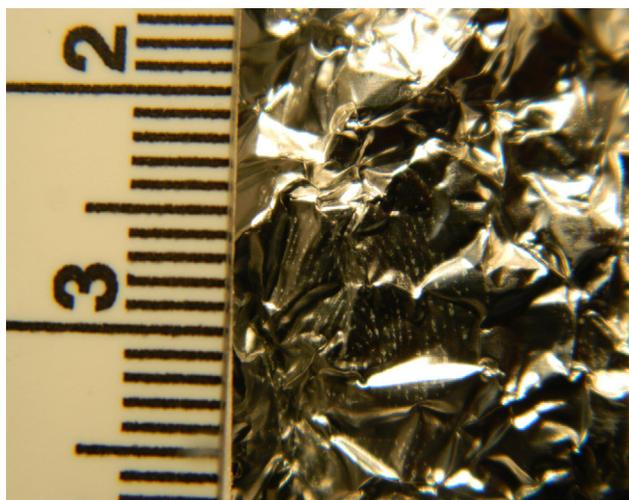


Figure 10 The partially developed latent fingerprint of grade 3 on uncrumpled aluminum foil with the cyanoacrylate fuming.

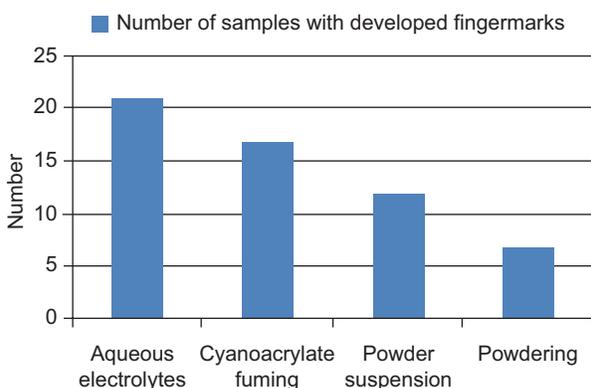


Figure 11 Depicting the results of the comparative study among mentioned techniques.

Table 3 The most common grades of developed fingerprints with four different techniques

Serial no	Technique	Foil state	Most common grade of developed fingerprints
1	Aqueous electrolyte	Crumpled	4
		Uncrumpled	4
2	Charcoal powder	Crumpled	0
		Uncrumpled	2
3	Powder suspension	Crumpled	0
		Uncrumpled	3
4	Cyanoacrylate fuming	Crumpled (outer layer of the foil)	3
		Uncrumpled	4

Discussion

Various authors have proposed different techniques for the visualization of latent fingerprints on metal surfaces.³ Vacuum metal deposition prior to SKP proved to be faithful by enhancing the low SKP potential contrast between ridges

and furrows.⁴ An electropolymerization process (of pyrrole and porphyrins) has been suggested for the development of latent fingerprints on the unfired weapons. The polymerization process occurred between furrows, leaving the residual part intact, giving a negative impression of the fingerprint. Similarly, deposition of gold or silver nanoparticles on conductive surfaces by electrochemical workstation developed the latent fingerprints.⁶ The different metal surfaces were treated thermally for the visualization of the latent fingerprints. The temperature was varied from 200°C to 750°C in the furnace, depending on the metal. The differential oxidation of the metal and residue results in the contrast between ridges and furrows.⁸ Aqueous electrolytes have recently been introduced for the development of latent fingerprints on metal surfaces. Very dilute solutions of acids and bases were first used for the development of latent fingerprints on metal surfaces.¹¹ Later on, inorganic salts were used as aqueous electrolytes for the development of latent fingerprints on different metal surfaces.¹² In the current work, the application of aqueous electrolytes has been tested for the development of latent fingerprints on the crumpled foil. When the crumpled foil is immersed in the aqueous electrolytes solution, the liquid seeps into the folds and wrinkles of the foil deeply, making latent fingerprints visible. The atmospheric cyanoacrylate fuming technique is also very useful for developing fingerprints on nonporous surfaces; however, the results with aqueous electrolytes have been found to be better than those with the atmospheric cyanoacrylate fuming technique while analyzing crumpled foil.

Photographing the developed fingerprints on crumpled foil was a challenging process. The low depth-of-field in close-up photos may need extra care. If circumstances permit, the foil could be carefully uncrumpled to get more details of the developed fingerprints. However, uncrumpling is possible only in the case of aqueous electrolyte-developed fingerprints (because of the permanency of the developed fingerprints), but was detrimental to the developed fingerprints in the powder, powder suspension, and atmospheric cyanoacrylate techniques. However, cyanoacrylate-developed fingerprints have shown better stability than the powder and powder suspension techniques.

As has been suggested, the development of latent fingerprints by aqueous electrolytes may occur because of the formation of film by depassivation of the aluminum surface by CaCl_2 . KMnO_4 , being a strong oxidizing agent, acts simultaneously on the film formed by CaCl_2 . Therefore, it alters the film by oxidizing it and colors the surface, thereby enhancing the latent fingerprints.¹²

Conclusion

The use of aqueous electrolytes to develop latent fingermarks on crumpled aluminum foil has been found to be better than the commonly used fingermark powdering, powder suspension, and atmospheric cyanoacrylate fuming techniques. The added advantage is permanency of the developed fingermarks.

Acknowledgments

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Disclosure

The authors report no conflicts of interest in this work.

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