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# Nanoscale analysis of the interaction between cyanoacrylate and vacuum metal deposition in the development of latent fingerprints on LDPE

*BJ Jones Ph.D. C.Phys.[1*], R Downham B.Sc.[2], VG Sears B.Sc.[2]*

1. Experimental Techniques Centre, Brunel University, Uxbridge, UB8 3PH, UK
2. Fingerprint and Footwear Forensics Group, HOSDB, Woodcock Hill, Sandridge, St Albans, AL4 9HQ, UK

* Corresponding author email: b.j.jones@physics.org

## Abstract

Vacuum metal deposition (VMD) has been previously demonstrated as an effective development technique for latent fingerprints, and in some cases has been shown to enhance prints developed with cyanoacrylate (superglue) fuming. This work utilises scanning electron microscopy (SEM) to investigate the interactions of the two development techniques when applied to latent fingerprints on low density polyethylene (LDPE). Cyanoacrylate (CA) is shown to act principally on the eccrine deposits around sweat pores, where polymerisation results in long polymer fibrils a few hundred nanometres in width. Subsequent VMD processing results in additional areas of development, for example between pores. However, the primary mode of deposition of zinc is by interaction with the polymerised CA, the fibrils of which become decorated with zinc nanoparticles. Areas with limited CA deposition and no significant polymerisation are also enhanced with the VMD process, resulting in increased print development.

## Introduction

Vacuum metal deposition (VMD) is an established technique for fingerprint development. Conventionally, a thin, discontinuous layer of gold is deposited, and nanoclusters of gold subsequently act as nucleation sites for zinc deposition [1,2]. This has shown to be a particularly effective technique for development of latent prints on various papers [2-5] and polymers [1,2,5-9]. Research has shown that VMD may be the optimal technique for some surfaces, including papers exposed to moisture [3], plastics submerged in water or exposed to body fluids [5], and semi-porous polymer banknotes, such as those first introduced in Australia in 1988 [6]. Studies have shown that VMD is particularly useful in the development of older prints, showing effectiveness on latent prints over 24 months old in laboratory trials [10] casework prints approximately six years old,

subsequently leading to an identification [5] and enabling development of prints described as at least sixteen years old [5].

It has been shown that the effectiveness of VMD and other development techniques are strongly influenced by the type of polymer substrate [1,8,11]. Research studies and casework have highlighted a number of problems with vacuum metal deposition, some of which are substrate dependent. These include reverse development [1,10], excess gold deposition which inhibits zinc nucleation and hence latent print development [8] and empty prints, where the VMD processing deposits zinc around the latent print on the general background, but no metal is deposited on or between the fingerprint ridges [7,10].

A number of groups have proposed improvements to the VMD process to enable increased development efficacy, including additional treatment with increased gold deposition [8] and a single-metal silver deposition process, after or as an alternative to the existing gold-zinc deposition [12]. Other works have shown that cyanoacrylate fuming (CA) can act as an effective pretreatment for VMD development [5-7,10,13]; VMD following CA can lead to improved ridge detail, making identification possible [7,10,13] or alternatively can lead to the development of additional marks [5]. Previous works [11,14,15] have demonstrated the importance of nanoscale analysis of both developed fingerprints and surfaces, in order to improve the understanding of development technique processes and interactions. Electron microscopy techniques have been previously used to study variation between commercial development agents for prints on adhesives [14], polymer surfaces developed with powder suspension [11] and for elucidating interaction of multiple techniques for development of bloodied prints [15]. This work utilises scanning electron microscopy to examine the interaction between the cyanoacrylate and vacuum metal deposition processes, to better understand the mechanisms of development enhancement.

**Experimental**

Latent fingerprints on low density polyethylene (LDPE) substrates were collected at the Home Office Scientific Development Branch (HOSDB) from seven donors. Depletion series of ten natural prints were collected from each donor. Utilising a similar process to an earlier study [11], no grooming procedure for loading with sebaceous or eccrine material was applied, although donors were asked not to have washed their hands for at least 30mins before donation. Variability was minimized by lightly rubbing fingertips together prior to deposition.

Once donated, the fingerprints were aged for 24 hours. The first mark in each depletion series was removed and stored as a control. Cyanoacrylate (superglue) fuming was then carried out, utilising

an MVC 5000 fuming cabinet with 'Cyanobloom' glue. Again example fingerprints were removed and retained as controls. The remaining marks were dyed with basic yellow (BY40) approximately one hour after the cabinet fuming cycle had been completed. Once more example marks were removed for comparison. Finally, VMD processing (gold-zinc method) was carried out 3 days after superglue treatment on the remaining marks.

Sections were taken from representative samples and mounted on aluminium stubs, utilising carbon loaded adhesive and conductive silver paint. To enable accurate comparison, this paper shows images from a single donor; one sample with CA fuming, a second with CA followed by BY40 dye, and a third sample with CA fuming, dye and VMD in sequence. Mounted samples were examined within a Zeiss Supra 35VP Scanning electron microscope (SEM), with secondary electron and backscattered electron analysis. Study of electrically insulating samples by this method usually requires additional coating to ensure conductivity, and a thin layer of carbon, gold or platinum is often applied. In this instance, however, as we aim to study the interaction of VMD deposited metal with the treated fingerprint, it was essential to allow examination of samples without any additional metal coating. This is achieved through utilising variable pressure (VP) mode, here with nitrogen at pressures of 15 Pa to 60 Pa and accelerating voltages of 5 kV to 20 kV. Though not always allowing highest quality images, this technique allows the study of non-conducting samples. Elemental evaluation was conducted by utilising backscatter electron images, and with an Oxford Instruments INCA energy dispersive x-ray analysis (EDX) system operating with this microscope.

**Results and discussion**

Figure 1 shows SEM images of the latent fingerprint on LDPE developed with cyanoacrylate fuming (CA) only. The low magnification images, figure 1a and 1b, show the macro features of fingerprint, and indicate that the deposition of the developing agent appears to be primarily associated with eccrine secretion from sweat pores. Figure 1c shows a section of one such pore at a higher magnification, showing the boundary of developed and undeveloped areas and micro-structure of cyanoacrylate polymer, with characteristic fibrils from the development of the fingerprint. Figure 1d, shows the fine structure of this deposited development agent. The sample here is strongly affected by the electron beam, which affects the contrast in the higher magnification images.

Scanning electron microscope images of the latent fingerprint sample developed with CA followed by basic yellow dye, are shown in figure 2. The macro features of the developed fingerprint, shown in figure 2a, show strong similarity to the sample without the dye process (figure 1a), and no additional areas of development are visible. Higher magnification images figures 2b, 2c, show no additional development mechanisms and characteristic cyanoacrylate fibrils retain the structure seen in the CA development. The highest magnification (figure 2d) clearly shows the fibril structure

in this area, without the beam-induced distortion previously (figure 1d). These images are consistent with the dyeing process that is used to increase contrast and visualisation, rather than extend the developed area [2,16].

Figure 3 shows scanning electron microscope images of the latent print on LDPE developed with a sequence of techniques: a cyanoacrylate fuming process and BY40 dye, followed by vacuum metal deposition of gold and zinc. Figure 3a is an SEM image at low magnification, showing the macro structure of developed fingerprint, by comparison with development shown in figures 1a, 1b, and 2a, additional developed areas away from the cyanoacrylate deposition are readily identifiable. Figure 3b shows the characteristic polymer fibrils from the CA process, partially covering the developed fingerprint ridge.

Figure 3c shows an area with significant development from superglue fuming, showing cyanoacrylate fibrils which after the VMD process are now coated with a particulate decoration. At the same magnification, figure 3d shows an area of developed fingerprint ridge with no significant superglue deposit. The nodular nature of development process is apparent. This may be related to the initial stages of cyanoacrylate polymerisation, though does not assist with contrast development with the CA process and would not interact with dyeing agents in the same manner as the polymer chains. This nodularization stage is only present in areas developed by VMD, but is not detected in all such areas.

A scanning electron microscopy backscatter electron image of the sample developed with CA and VMD process is shown in figure 4a. This elemental contrast technique shows atomic number distinction between cyanoacrylate fibrils and the decorating particulates observed in figure 3c. Small area elemental analysis by energy dispersive X-ray analysis (EDX) was conducted over areas of the developed print, representative spectra are shown in figure 4b. High levels of zinc are associated with the areas of cyanoacrylate polymerisation, consistent with the zinc particulate decoration of the cyanoacrylate fibrils observed in figures 3c and 4a. There are also lower levels of zinc content in areas of the fingerprint ridge which are developed with the VMD process but which do not contain significant areas of cyanoacrylate polymerisation. Figure 4b also shows there is no detectable zinc content in areas of the fingerprint between ridges. These analyses indicate zinc nanoparticle decoration of cyanoacrylate fibrils, as well as zinc deposition associated with areas of fingerprint ridges away from effective CA development.

**Conclusions**

Latent fingerprints on low density polyethylene were developed by cyanoacrylate fuming, and by a sequence of cyanoacrylate fuming followed by vacuum metal deposition of gold and zinc. The developed prints were studied by variable pressure scanning electron microscopy. Initial examination shows cyanoacrylate fuming produces polymer chains mainly focussed around pores in the latent fingerprint. The application of gold and zinc through a vacuum metal deposition technique to a sample previously treated with cyanoacrylate causes the development of additional areas not coated with cyanoacrylate, which relates to the improved definition of the print seen in other works [2,5,11]. However, the primary interaction of the zinc deposition appears to be with the cyanoacrylate, decorating the polymer chains with nano-scale particulates. Other areas of the fingerprint ridges are also developed and contain zinc at lower levels. It is possible that the nodularisation of areas without extensive cyanoacrylate polymer chains, related to initial polymerisation without extended polymer growth, may enhance metal deposition and therefore promote visualisation following the VMD process.

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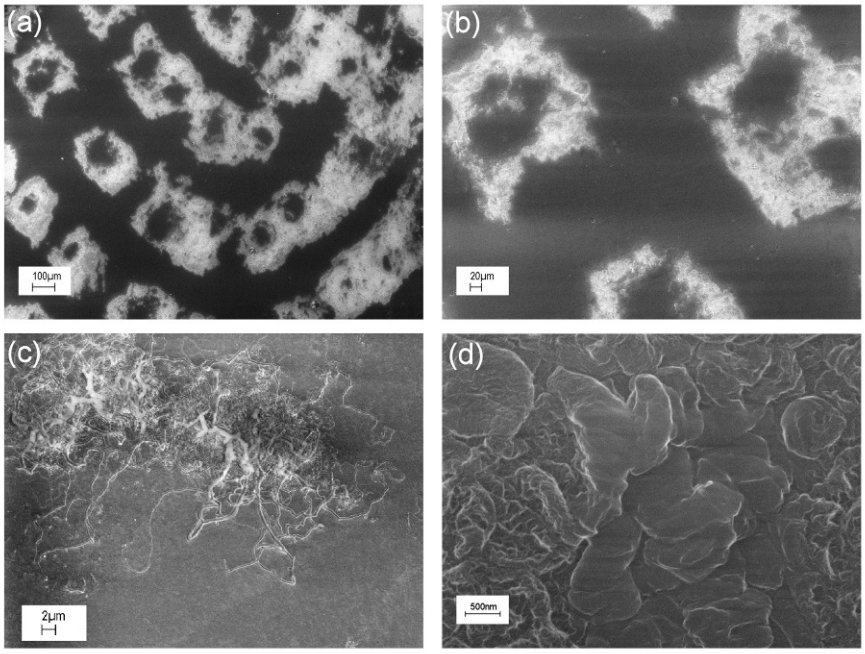


Figure 1. Scanning electron microscope images of fingerprint developed with CA fuming

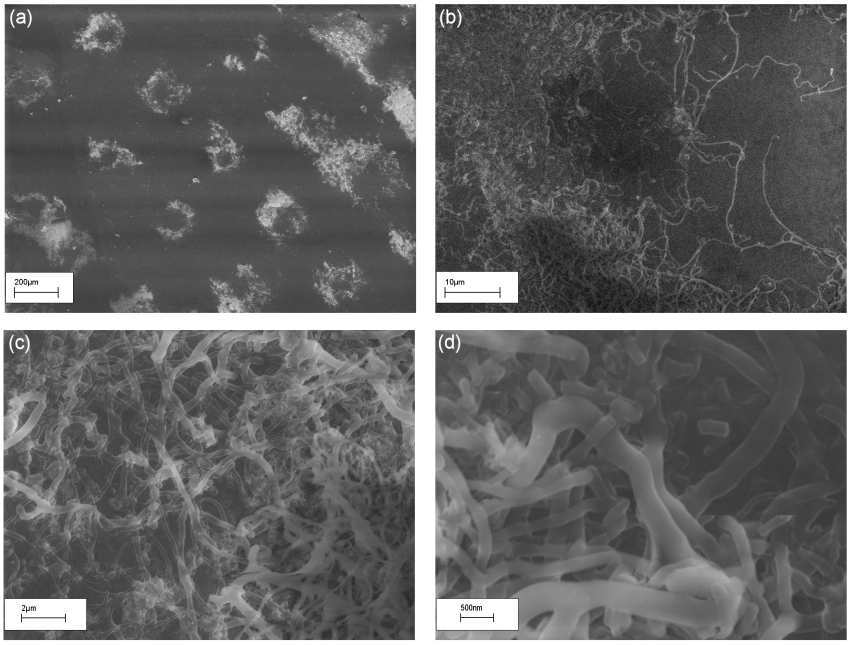


Figure 2. Scanning electron microscope images of fingerprint developed with CA fuming followed by BY40

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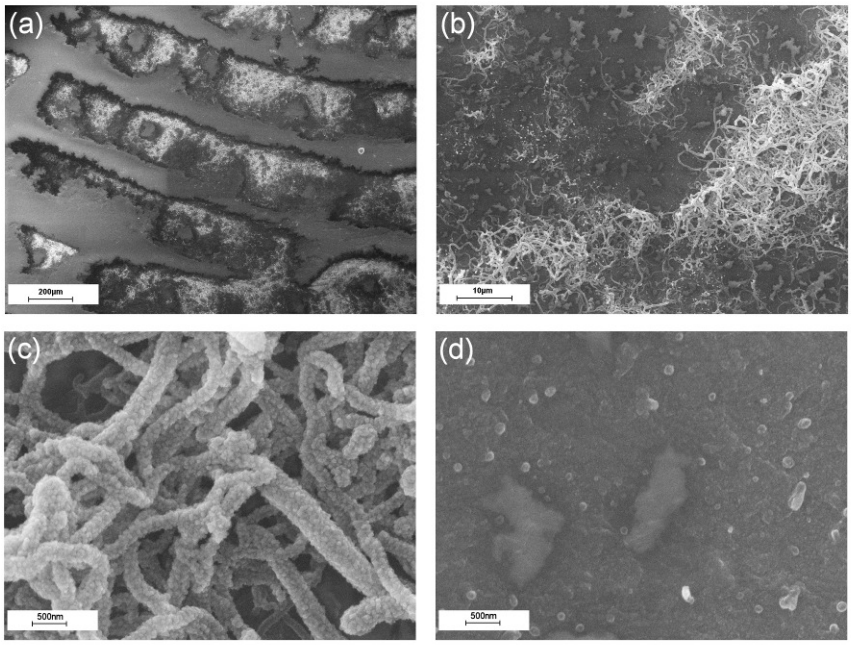


Figure 3. Scanning electron microscope images of fingerprint developed with VMD following CA fuming and BY40.

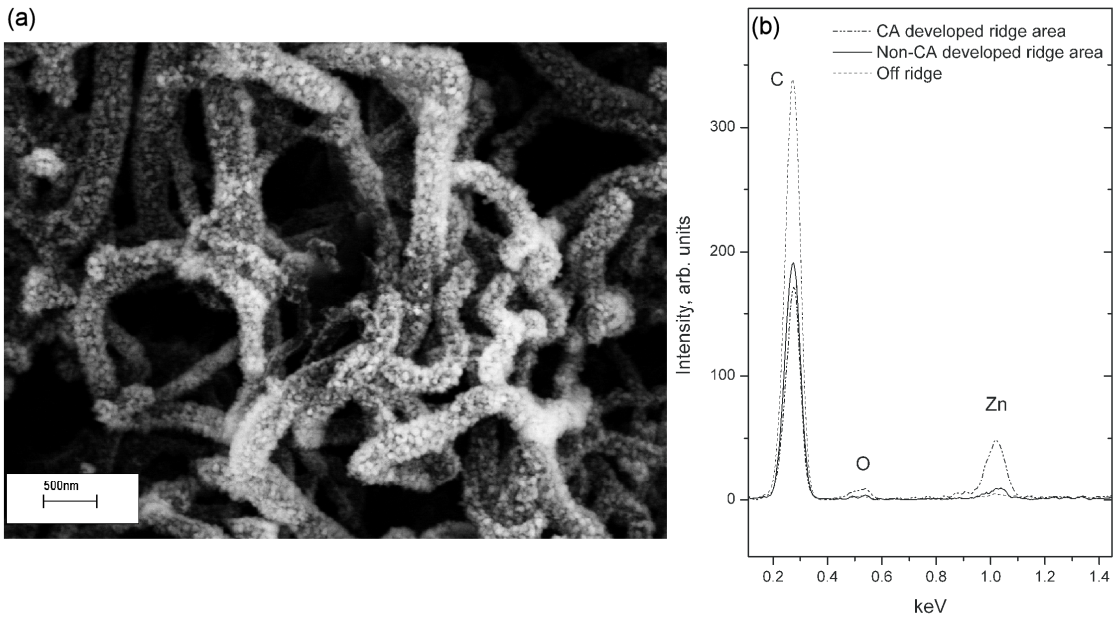


Figure 4, Compositional analysis of fingerprint developed with CA and VMD. (a) Backscatter electron image of cyanoacrylate fibrils with zinc nanoparticle decoration and (b) Energy dispersive X-ray (EDX) analysis of an area off fingerprint ridge and areas of ridge with cyanoacrylate polymerisation, without extensive polymerisation.