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A comparison between atmospheric/humidity and vacuum cyanoacrylate fuming of latent fingermarks

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ABSTRACT

A number of pseudo-operational trials were set up to compare the atmospheric/humidity and vacuum cyanoacrylate fuming processes on plastic carrier bags. The fuming processes were compared using two-step cyanoacrylate fuming with basic yellow 40 (BY40) staining and a one-step fluorescent cyanoacrylate fuming, Lumicyano 4%. Preliminary work using planted fingermarks and split depletions were performed to identify the optimum vacuum fuming conditions. The first pseudo-operational trial compared the different fuming conditions (atmospheric/humidity vs. vacuum) for the two-step process where an additional 50% more marks were detected with the atmospheric/humidity process. None of the marks by the vacuum process could be observed visually; however, a significant number of marks were detected by fluorescence after BY40 staining. The second trial repeated the same work in trial 1 using the one-step cyanoacrylate process, Lumicyano at a concentration of 4%. Trial 2 provided comparable results to trial 1 and all the items were then re-treated with Lumicyano 4% at atmospheric/humidity conditions before dyeing with BY40 to provide the sequences of process A (Lumicyano 4% atmospheric–Lumicyano 4% atmospheric–BY40) and process B (Lumicyano 4% vacuum–Lumicyano 4% atmospheric–BY40). The number of marks (visual and fluorescent) was counted after each treatment with a substantial increase in the number of detected marks in the second and third treatments of the process. The increased detection rate after the double Lumicyano process was unexpected and may have important implications. Trial 3 was performed to investigate whether the amount of cyanoacrylate and/or fuming time had an impact on the results observed in trial 2 whereas trial 4 assessed if the double process using conventional cyanoacrylate, rather than Lumicyano 4%, provided an increased detection rate. Trials 3 and 4 confirmed that doubling the amount of Lumicyano 4% cyanoacrylate and fuming time produced a lower detection rate than the double process with Lumicyano 4%. Furthermore, the double process with conventional cyanoacrylate did not provide any benefit. Scanning electron microscopy was also performed to investigate the morphology of the cyanoacrylate polymer under different conditions.

The atmospheric/humidity process appears to be superior to the vacuum process for both the two-step and one-step cyanoacrylate fuming, although the two-step process performed better in comparison to the one-step process under vacuum conditions. Nonetheless, the use of vacuum cyanoacrylate fuming may have certain operational advantages and its use does not adversely affect subsequent cyanoacrylate fuming with atmospheric/humidity conditions.

1. Introduction

Cyanoacrylate fuming is a routine enhancement technique for the development of latent fingermarks. When fingermark residue comes into contact with the cyanoacrylate monomer vapour, polymerisation occurs along the ridges of the fingermark to produce a white deposit [1]. Cyanoacrylate polymerisation occurs due to the reactivity of the polarised carbon to carbon double bond, which includes two electron withdrawing groups (the cyano group and the ester group). These two electron withdrawing groups make the double bond vulnerable to nucleophilic attack, therefore making the resulting anion very stable due to the negative charge being pulled across the entire molecule [2].

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One mechanism for the polymerisation of cyanoacrylates suggests the formation of zwitterions with the anionic part being the active propagating species [2]. Cyanoacrylate polymerisation is base initiated and weak bases, such as water, will initiate polymer growth. The polymerisation reaction may also be accelerated by other bases such as sodium carbonate [3] and sodium hydroxide [4]. It is thought that increasing the relative humidity (RH) to 80% causes sodium chloride (NaCl) crystals in the latent fingermark to take up water. Latent residues contain other bases and some of these may also initiate polymerisation [5]. Short chains, oligomers, of cyanoacrylates may be formed due to atmospheric humidity, which could take part in further polymerisation on the fingermark [6]. Sebaceous fingermarks treated with cyanoacrylate fuming exhibit a large amount of circular polymer on the ridges as well as clumps of 'noodle-like' polymer. It is suggested that this morphology is a result of emulsion polymerisation, with fatty acids acting as emulsifiers of aqueous and oily phases. Due to the presence of the 'noodle-like' polymer in sebaceous marks, it is suggested that whatever initiates the growth of polymer in eccrine fingermarks is also present in unevenly distributed, smaller amounts in sebaceous fingermarks [6]. Lewis et al. reported that the moisture contained within a fingermark was more important than the moisture in the air during the fuming process [7]. Eccrine fingermarks showed reduced quality of developed marks with time due to the loss of moisture from the mark. Sebaceous marks demonstrated less age dependence and it has been suggested that such marks could retain moisture in the residues over time but that the constituents of the sebaceous mark did not contribute to the polymerisation reaction [7].

1.1. Two-step process

Following cyanoacrylate fuming, a second treatment is generally required to improve the contrast of the white cyanoacrylate polymer against the background. Currently, fluorescent dyes and powders are routinely used in these two-step cyanoacrylate processes. A methanol solution of Rhodamine 6G was proposed as a suitable fluorescent dye for cyanoacrylate polymer in the early 1980s [8,9] and is still in use in certain countries. Other countries (including the UK) consider the use of Rhodamine 6G in methanol inadvisable because of the suspected health risks posed by both dye and solvent. In 1985, the UK Home Office Centre for Applied Science and Technology (CAST, then called Police Scientific Development Branch PSDB), identified basic yellow 40 (BY40) in ethanol as a safe, effective alternative dye system to Rhodamine 6G [6]. BY40 absorbs in the violet-blue region of the light spectrum and cyanoacrylate marks treated with BY40 will emit in the green-yellow region. The use of BY40 in sequence with cyanoacrylate fuming has been shown to produce twice as many identifiable prints in comparison to cyanoacrylate treatment alone [6]. CAST trialled many other dyes, such as safranine O, ardrox and nile red, and currently recommends the use of BY40. For surfaces not compatible with ethanol or in areas with poor ventilation, a water-based formulation may be used; however, a water-based solution of basic red 14 is recommend in such instances as it produces fluorescence of higher intensity than water-based BY40 [6].

1.2. One-step process

A one-step fluorescent cyanoacrylate process combines the cyanoacrylate fuming and dyeing procedure into a single step process. This offers the possibility of saving time, space and effort as well as avoiding the use of flammable solvents. In the early 1990s, Weaver and Clary [10] reported a one-step fluorescent process using a solid cyanoacrylate polymer and 3 M styryl dyes. More recently, research has investigated other one-step processes available such as Polycyano (Cyano UV, Foster and Freeman, U.K.) [11,12], fuming orange and CN yellow (Aneval, Inc., Illinois, US) [13] and Lumicyano (Crime Scene Technology, France) [14]. Most of these products require heating temperatures of $\geq$230 °C with the exception of Lumicyano where a traditional hot plate temperature of 120 °C is required. These one-step processes appear to provide enhancement comparable to the conventional two-step process but subsequent treatment with a fluorescent dye may result in an improved detection rate as reported elsewhere [12,15,16]. The Lumicyano polymer appears to have a "slightly better developed polymeric nanofiber morphology in comparison with the traditional method" [17]. Furthermore, the successful tagging of cyanoacrylates with fluorescent species such as p-DMAB, p-DMAC and dansyl chloride has also been reported [17].

1.3. Atmospheric cyanoacrylate process

The atmospheric/humidity process involves heating the cyanoacrylate up to a temperature of 120 °C in a chamber at 80% RH. This results in the deposit of a white polymer along fingermark ridges where the morphology of the polymer is a long, fibrous structure which extends upwards and outwards when observed under scanning electron microscopy [6]. This 'noodle-like' polycyanoacrylate morphology allows for efficient light scattering and easier visual perception. The RH in the atmospheric process has a large influence on the development of latent fingermarks. Humidity levels that are below 75% produce underdeveloped marks and those above 80% RH tend to increase background development, therefore resulting in a reduced definition of the developed mark. The optimum RH range was reported as 85–90%; however, a lower value of 80% is recommended to account for the discrepancy between the fuming cabinet display and the actual relative humidity value [18]. Furthermore, it does not get too close to 100% which may result in excessive background development. Development at 60% RH yields a 'tortellini-like' polymer structure and a two-dimensional film, possibly due to the initiation by a hard anion which then leads to a very fast initiation and many active centres of polymer growth [19]. At 80% RH, the initiation of polymerisation is slower resulting in fewer active centres of polymer growth and thus leading to growth in one direction and a 'noodle-like' morphology [20]. The morphology of the cyanoacrylate at 80% RH allows for suitable visualisation due to the light scattering and because it traps fluorescent dyes molecules for successful staining and observation of fluorescence.

The atmospheric process heats up the cyanoacrylate to 120 °C to accelerate the fuming of marks in the cabinet; however, this may result in uneven coverage and overdevelopment where both the ridges and furrows of the latent fingermark are filled with cyanoacrylate polymer [21]. The use of high temperatures for some of the latest atmospheric one-step fluorescent cyanoacrylate processes may also result in the production of toxic hydrogen cyanide gas [22].

1.4. Vacuum cyanoacrylate process

In the vacuum process, the articles to be treated are sealed in a vacuum chamber together with the cyanoacrylate. The use of the vacuum cyanoacrylate process initiated with the development of custom build chambers; however, due to high costs many other researchers utilised simpler set ups such as benchtop desiccators [23]. More recently, although not specifically designed for vacuum cyanoacrylate fuming, other low pressure chambers have been commercially developed [24,25]. Treatment pressures range from 0.1 Torr to 50 Torr (1atmosphere = 760 Torr = 101,325 Pa = 1.013 - bar) [21,23,26–28] where at reduced pressure, the cyanoacrylate will vapourise at a reduced temperature and in most cases the use