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Technical note

Fingermark visualisation on metal surfaces: An initial investigation of the influence of surface condition on process effectiveness

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ABSTRACT

Fingermark recovery from metal surfaces is an area of operational interest, both from the association of metals with weapons used in violent crime and from the increasing incidence in metal theft. This paper reports a feasibility study into the effectiveness of a range of fingermark visualisation processes in developing fingermarks on clean metals (brass, bronze and stainless steel), and on the same metals after prolonged exposure to an outdoor environment. Scanning electron microscopy (SEM) was used to investigate how the surface type and condition could influence the development of fingermarks for each of the processes used. It was found that the behaviour observed varied between each of the processes (cyanoacrylate fuming, Lumicyano™, gun blueing and carbon-based powder suspension). In some cases the chemical composition of the surface affected the development of the mark more than the surface condition, and in other cases the reverse was true. The best performing processes differed according to the surface type and condition, with cyanoacrylate fuming processes working best on brass and bronze, and powder suspensions being better on stainless steel. These preliminary results reinforce the need to take into account both surface type and condition before selection of the most effective fingermark visualisation process and demonstrate the value of techniques such as SEM in developing a fundamental understanding of the interactions between fingermarks and surfaces.

1. Introduction

Metals play a significant part in everyday life. They are used in pure form or as alloys to produce a variety of objects, including tools, machinery, weapons, jewellery and decorative art objects, and because of their value, metals are commonly encountered in theft.

Rises in metal prices on the world's commodity market has contributed to a significant increase in the number of offences over the last few years, causing damage to critical national infrastructure including power, transport, telecommunications and water supply [1,2]. According to the UK Home Office, there are over 7000 police reported metal thefts a month that cost UK economy at least £220 million each year, although the estimated total cost could be up to £777 million according to The Association of Chief Police Officers [1].

The metals commonly stolen are copper, brass, bronze, steel, aluminium, lead and cast iron due to their scrap value. Targets for metal theft include copper wire and cable from transport and utility networks causing disruption to connected networks, theft of lead from churches and other heritage buildings, bronze memorial plaques, thefts of catalytic converters and theft of street furniture such as aluminium road signs and cast iron drain covers.

The consequences of these thefts are much higher than the metal value, such as destroying valuable statues and war memorials, disrupting railway traffic or causing long power interruptions:

- In December 2011, the theft of copper cable cut the power to a Llandough hospital in Wales resulting in 80 operations being cancelled [1,2].
- In December 2005 a bronze statue worth £3 million made by Henry Moore was stolen from his Foundation in Much Hadham, Hertfordshire is believed to have been melted down for its scrap value of no more than £1500 [3].
- A copper pipe worth just £15 on a black market stolen from a high school in Droitwich Spa caused damage worth £250,000 [4].

Despite the high profile of such incidents and the resultant focus on metal theft, the recovery rates for fingerprints on such surfaces are reportedly poor. This is partly due to the fact that many of these metals are exposed to outdoor environmental conditions, and become weathered over time. Deterioration of metals induced by outdoor

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environmental factors is due to a complex interaction of climate and local meteorological characteristics, pollutants and natural constituents from the surrounding environment. It is a result of different chemical and physical factors including [5]:

I. Contaminants and pollutants

Several such substances may accelerate metal corrosion, including sulphur-containing gases (polluted air), cleaning chemicals (especially aerosols), soot, dust, and dirt, and degrading plastics.

II. Humidity & temperature

Humidity plays the most important role in outdoor metal corrosion due to a prolonged time that the surface remains wet and a higher rate of deposition of pollutants. When a critical humidity of 60–80% (10–14 g H_2O/m^3 at 20 °C) is exceeded it leads to a formation of a thick electrolyte film essential for the corrosion reactions. In a polluted environment, an increase in ambient temperature can accelerate metal damage due to an increased rate of chemical reactions on the surface.

III. Water

Corrodes metals and comes from rain, melting ice, floods, condensation. Water aggressiveness (and pH) is influenced by several substances it may contain e.g. carbon dioxide, sulphur dioxide, ammonium, chlorides, the amount of dissolved salts, presence of organic substances and microorganisms, and content of solid particles.

IV. Handling and other physical forces

Corrosion from salts and acids on bare hands, damage by application of stress or foreign objects by mechanisms including abrasion, wear and fatigue.

It can therefore be seen that a weathered metal surface may differ significantly in character to one that has not been subjected to such conditions. The effect of metal surface condition on fingermark recovery has been explored through a collaborative exercise conducted across several countries with membership of the European Network of Forensic Science Institutes (ENFSI). In this exercise samples of weathered metal bearing fingermarks were sent to participants for processing using whichever processes and processing sequences they thought appropriate, and low recovery rates were observed. This prompted further work to explore processes that had potential to improve these recovery rates including the development of Natural Yellow 3, a lipid specific reagent, that was capable of staining the water insoluble constituents of fingermarks and was also fluorescent to provide contrast with the weathered metal surfaces [6].

A majority of non-porous surfaces received into fingerprint laboratories are effectively chemically inert, which is not the case for many untreated metal surfaces. In the case of metals and alloys, chemical reactions may occur between constituents of the fingermark (e.g. salts) and the metal surface, the extent of this being dependent on the composition of the metal/alloy and the fingermark. In extreme circumstances this can result in a permanent record of the fingermark being etched into the metal surface. The interactions that occur are also dependent on the previous environmental exposure of the metal/alloy, which will influence formation of surface oxide films. To date, the principal focus of research into techniques specifically designed for visualising fingermarks on metal surfaces has been driven by requirement to recover fingermarks from brass cartridge casings. A range of techniques have explored for such surfaces, which include gun blueing [7,8], cold patination fluid [9], palladium deposition [10], cyanoacrylate fuming [11], scanning Kelvin probe [12], electrostatic powdering [13] and thermal development [14]. Techniques that have been proposed for other classes of metal include electrodeposition, which is more specific to stainless steel surfaces [15]. However, the exhibits that may be associated with metal theft are often significantly larger than the small scale of cartridge casings, and many of the processes above may not be suitable for such large items.

The objective of this study was twofold: firstly, to evaluate, at an initial feasibility level, the effectiveness of a range of processes with different methods of development in terms of their ability to visualise fingermarks on a range of metal surfaces in both "clean" and "weathered" conditions. Secondly, to conduct a microscopic study into the modes of development on the clean and weathered parts of the metal sample to see if any differences observed in development effectiveness could be related to surface condition and its associated microstructure.

2. Materials and methods

2.1. Materials

Three metals representative of those commonly encountered in indoor and outdoor crime scenes (e.g. points of entry, tools, stolen metallic goods) were chosen as target surfaces:

- Bronze (approx. 88% copper and 12% tin)
- Brass (approx. 70% copper and 30% zinc)
- Stainless steel (grade 304 – iron, with carbon 0.08% max, chromium 18–20%, nickel 8–12%, traces of manganese, phosphorus, sulphur, silicon, nitrogen)

All metals for this study were purchased from Alloy Sales Ltd. (Hatfield, Hertfordshire, UK).

The samples used in the study were 75 × 25 mm in size. One set were cut from sheets of metals that had been newly received and stored indoors, and a further set from equivalent sheets of metal that had been naturally weathered by leaving them outdoors for 2 years and exposed to UK weather conditions. The samples left outdoors were placed in racks holding the samples between 20 and 30° to vertical, allowing rain water to run down the uppermost face. The panels were not placed in direct contact with the ground.

2.2. Sample preparation

Four sets of metals were prepared, one for each of the visualisation processes under evaluation. Each set contained 3 samples of each of the "new" metals (bronze, brass, stainless steel) and 3 samples of each of the weathered metals (bronze, brass, stainless steel), a total of 18 metal samples. Each of the metal samples contained half of a natural, half of a sebaceous and half of an eccrine fingermark after deposition. A total of 27 latent fingermarks were deposited per set of samples, as illustrated in Fig. 1. The weathered samples were always placed at the top of the set of two samples during deposition.

2.3. Fingermark deposition

Because this was an initial feasibility study, and the primary aim was to explore the role of the surface in development, only one "good" donor was used in this study. The use of further donors to build data would be desirable but this had not been passed by the relevant ethics committee at the time of the study. A single male donor deposited fingermarks across the boundary of the two metal samples – weathered metal (top sample) and new metal (bottom sample). Marks were deposited by gently holding a finger in contact with the surface for about 2 s. Natural, sebaceous and eccrine-rich fingerprints were deposited as illustrated in Fig. 1 and described below.

Natural fingermarks: the donor washed their hands with soap and water and dried them with a paper towel. They were asked to carry out normal activities but not handle any potential contaminants such as foodstuffs for 1 h. After that time the donor rubbed their fingers