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Latent fingermark visualisation using a scanning Kelvin probe

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Abstract

The current state of the art in fingermark visualisation on metallic surfaces by a scanning Kelvin probe (SKP) technique is described. Latent eccrine fingermarks deposited on a range of polished and roughened metallic surfaces can be effectively imaged. Results are presented which show that the SKP technique is able to visualise fingermarks obscured beneath optically opaque soot films and retrieve ridge detail in instances where fingermarks have been physically removed (e.g. by rubbing with a tissue) from a metal surface. SKP Volta potential mapping of small, severely non-planar metal objects such as fired brass cartridge cases is demonstrated.

Keywords: Fingermark; Scanning Kelvin probe; Visualisation; Latent; Metal surface

1. Introduction

Over a century after fingerprint evidence was first used to obtain a criminal conviction, the detection and identification of fingerprints remains at the forefront of modern crime investigation [1,2]. When a fingertip is brought into contact with a surface, pores on the papillary ridges deposit a residue of perspiration, consisting of 99% water with the remainder made up of inorganic salts such as NaCl and organic substances such as urea. In addition, fingertip contact with the face or scalp leads to the presence of sebaceous materials, such as fatty acids, within the fingermark residue. The complex patterns formed by the ridge contours are unique to a given individual, a premise which underpins the use of fingermarks as a means of identification admissible in a court of law. Invisible or latent fingermarks are detected by the use of a ''developer'' which produces a high degree of visual contrast between ridge deposit patterns and the surface on which the fingermark is deposited.

In cases where fingermarks are deposited on metallic surfaces, development techniques range from powder dusting [3], to various chemical treatments such as cyanoacrylate fuming [4] or exposure to ruthenium tetroxide [5] and detect either the moisture present within the fingermark residue and/or one or more of the organic components associated with the deposit. Other water-based development techniques, such as selenous acid [6], ammoniacal silver nitrate [7], palladium salts [8] and gun-blueing mixtures [7,9] rely on electrochemical interactions with exposed metal between fingermark ridge deposits to enhance contrast. Such reagents generally work best when the fingermarks are substantially sebaceous in nature and are ineffective in visualising water-soluble eccrine deposits. In a recent paper we showed how fingermarks deposited on metallic surfaces could be visualised directly, without development or any other form of perturbation, by Volta potential mapping using a scanning Kelvin probe (SKP) [10]. Uniquely, since the technique is based on purely potentiometric measurements, fingermark patterns could be detected beneath intact, substantially insulating films such as clear and pigmented lacquers. Furthermore, because the Volta potential is primarily influenced by non-volatile inorganic salts, fingermarks could also be visualised even after the metal surface had been heated to temperatures sufficient to volatilise the organic components of the deposit. In the work presented here, further developments in the SKP technique as a potential forensic tool for fingermark visualisation are described. Improvements in instrument performance by modifying probe tip design and scan parameters are outlined along with modifications to the existing design to enable height profiling of highly non-planar objects such as coins or fired cartridge cases.

We have also sought to identify circumstances where SKP analysis may be more effective than established methods at visualising fingermarks on metal surfaces. The ability of SKP to effectively visualise latent eccrine fingermark patterns is

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demonstrated on both iron and brass, for both polished and heavily gritted (roughened) surfaces. In addition it will also be shown that discernible ridge detail can be retrieved by scanning a fingermarked metal surface after the fingermark deposit had been removed by rubbing with a tissue. The effect of smoke contamination on fingermark visualisation by SKP is also presented showing that although eccrine print detail becomes indistinct, sebaceous patterns remain clear even when covered with thick soot layers. Finally, examples of SKP visualisation of latent eccrine fingermarks, deposited post-firing on brass cartridge cases will be given. Although not exploiting the previously observed ability of SKP to detect fingermarks after exposure to high temperatures [10], such examples serve to demonstrate the capability of the technique to deal with ''real'', highly non-planar surfaces.

2. Experimental details

2.1. Materials

Samples of 1 mm thick iron, copper, nickel, titanium and aluminium (99.9% purity) were obtained from Goodfellow metals Ltd. 1 mm thick brass foil, 37% zinc 63% copper, was obtained from Advent Research Materials Ltd. Spent brass cartridge cases of 0.45 in. calibre were provided by the UK Forensic Science Service. Prior to fingerprint deposition, all metal samples were abrasively cleaned and polished using aqueous slurries of 5 μm polishing alumina. Cleaned samples were rinsed with distilled water, followed by acetone, and allowed to dry in air. ''Natural'' fingermarks from a single donor were deposited using constant pressure from the left forefinger after freshly washing the hands with soap and water. Sebum-rich fingermarks were deposited as above but after rubbing the side of the nose with the fingertip. Eccrine deposits (i.e. inorganic-salt-rich) were produced by rinsing the left forefinger with ethanol followed by 30 min enclosure in an airtight plastic bag. Unless otherwise specified, SKP mapping of fingermarked samples was typically carried out within 6 h of fingermark deposition. The effect of smoke contamination on SKP fingermark visualisation was studied by passing an inverted, fingermarked region of an iron substrate through the centre of a candle flame. By repeating this procedure several times, different thicknesses of soot layers could be built up. Quantification of smoke layer thickness was achieved by placing a glass slide in a position adjacent to the fingermark and using an UV–vis spectrophotometer (Unicam model 5625) to measure the transmittance of the soot film at a wavelength of 500 nm.

2.2. Methods

The scanning Kelvin probe apparatus used in this work is described in detail elsewhere [10,11]. The vibrating reference probe assembly was mounted in a fixed position above a moving test sample. The reference probe itself consisted of a gold wire, which was vibrated along the vertical axis using a moving coil electromechanical actuator. Scan parameter optimisation was carried out using a 50 μm diameter wire, while subsequent, high-definition scans of fingerprinted metal surfaces were performed using a more robust 100 μm diameter wire, mechanically profiled to a 20 μm tip. The probe vibration frequency was 280 Hz and the vibration amplitude was 40 μm peak-to-peak. Reference probe vibration amplitudes were checked using stroboscopic observation in conjunction with a travelling microscope. The experimental arrangement was such that the tip of the vibrating reference probe was held at earth potential and positioned inside a stainless steel environment chamber, which was also at earth potential. The electromechanical actuator and vibrator drive electronics were positioned outside the environment chamber in order to ensure effective electrostatic and magnetic shielding of both the reference probe and sample. Vibration was conducted to the probe tip via a 80 mm long glass push rod.

Positioning and scanning of the test sample was carried out using a micromanipulation stage consisting of three orthogonally arranged (x, y, z), stepper motor driven, linear bearings (Time and Precision Ltd.). The probe was held at a constant height above the sample surface and scanned in a raster of parallel lines to generate a regular array of values which could be mapped using commercially available cartography software (Surfer^{TM}, Golden software). For the majority of the work presented here, data points were acquired at 0.05 mm intervals and at a mean probe-to-sample height of 50 μm. To perform each measurement the ac current, $i(t)$, generated in the external circuit connecting the sample and vibrating probe, was amplified and converted into an ac voltage signal, $V(t)$, using a dc biased transconductance amplifier circuit. The $V(t)$ signal was detected using a lock-in amplifier (EG&G model 7265). The dc output of the lock-in amplifier, V_{dc}, was transmitted to a feedback system based on an integrator circuit which controlled the dc bias, E, applied to the sample via the transconductance amplifier so as to automatically null $i(t)$. The magnitude of the dc bias (equivalent to the Kelvin potential ($-E_{kp}$) or the Volta potential difference between the probe and sample) applied via the integrator, was digitised and logged. Probe scanning and data logging were all carried out automatically under computer control. Unless specified, all scans were performed in ambient air (nominal temperature 22 °C, RH 50%). A photographic image showing the major components of the SKP instrument used in this work is given in Fig. 1.

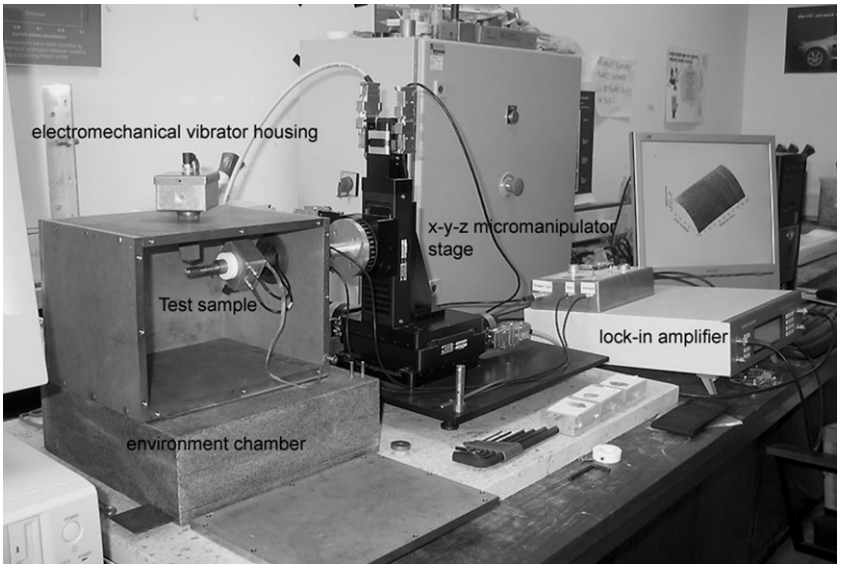

Fig. 1. Photographic image of the SKP instrument.