

Infra-red Spectroscopic Imaging of Latent Fingerprints and Associated Forensic Evidence

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Abstract: Fingerprints can reflect a specific chemical history, such as that of exposure to certain explosives. These are clearly distinguished from overlapping and interfering latent fingerprints, using infra-red spectroscopic imaging techniques and multivariate analysis.

Keywords: Infra-red Spectroscopic Imaging, specific chemical history, associated Forensic Evidence.

I. INTRODUCTION

Fingerprint identification is the most common method used by forensic experts at a crime scene. Each individual has a unique pattern of ridges, which form upon the tips of the human fingers. Differentiation of latent fingerprints is difficult using current forensic methods due to the eccrine gland secretion of a variety of contaminants. However, there have been developments of a new technique for the visualization of fingerprints based upon chemical markers. The production of fluorescence images of fingerprint, is done with the use of nanoparticles. This enables the production of chemical information regarding the use of drugs. A tool which has been reported to distinguish individual prints with definitive chemical exposure histories, is the application of a desorption electrospray ionization mass spectrometer, which reconstruct an image of a fingerprint based upon the exogenous residues. The DESI-MS technique, detects specific compounds such as cocaine and explosives by their distinctive mass/charge fragments, which are then used to reconstruct their fingerprints. Forensic investigators use reconstruction of fingerprints (which are based upon exogenous compounds) to distinguish between prints, based upon the material that has been handled, the filtering out overlapping eccrine and sebaceous prints that may have rendered a print unusable.

Another technique used for reconstructing latent fingerprints is by vibrational spectroscopic imaging. This technique generates latent fingerprints by their chemical contrast, using spectroscopic signatures which are identified in deposits left by fingerprints. Latent fingerprints have been detected upon surfaces of various materials using infra-red spectroscopic approaches, as previously successful studies have shown. These reconstructed fingerprint images is based upon residues of eccrine and sebaceous, other than exogenous compounds, which could be used as part of the forensic evidence. In this study, infra-red spectroscopic imaging is applied, along with principle component analysis, so that overlapping fingerprints can be distinguished, through the reconstruction of images based upon exogenous compounds.

II. EXPERIMENTAL

2.1 Latent Fingerprint Preparation

A blank fingerprint is blotted on aluminium coated slides, 10 μ l of 500 μ g ml⁻¹ of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) explosive solution is deposited using a micropipette, upon the second fingerprint of a volunteer. Prior to the blotting of the RDX contaminated fingerprint upon the blank print which contained only secretions, the RDX solution was spread and allowed to dry.

2.2 Method

Infra-red spectroscopic images of the fingerprints were obtained, in an infra-red reflection from a sample of 6mm x 9mm. The images that were collected, were within the 400-700 cm⁻¹ spectral range and had 16 scans per pixel at 4

cm^{-1} spectral resolution and $25\mu\text{m}$ spatial resolution when the Perkin-Elmer spectrum spotlight 300 imaging system, which was equipped with a liquid nitrogen-cooled MCT linear array detector. Visualization of an infra-red fingerprint image depends upon the identification and the separation of spectral features which reflect the chemical properties of fingerprint deposits. To obtain the spectral features of interest, differentiation between the background signals and the spectral noise is achieved by a combination of multivariate techniques, such as principle component analysis (PCA), and band-target entropy minimization (BTEM).

2.3 Results and Discussion

A convenient way of generating infra-red chemical images which represent a fingerprint are the strong C-H stretching vibrations, which are found in the fatty acids and triglycerides, which are richly found within the sebaceous residues. Figure 1b shows that a fingerprint image can be obtained from the infra-red absorption of the C-H stretching mode region, but overlapping prints are not distinguishable. Solid phase RDX has an infra-red spectrum consisting of strong NO_2 deformations and ring stretching modes with weak CH_2 stretching modes. Figure 1e and 1f, illustrate the infra-red spectra of pure RDX crystallites. Pure RDX crystallites have peaks within the $1300\text{-}700\text{cm}^{-1}$ and $3125\text{-}2750\text{cm}^{-1}$ of the spectral region. Figures 1c and 1d, illustrates an infra-red spectra showing NO_2 stretching and CH_2 stretching bands which demonstrate, that the RDX compound has been mixed with natural secretions. Figure 1d illustrates the vibrational modes which attribute to RDX being observed at 776 , 900 and 1262cm^{-1} . All these modes can be clearly seen above the background vibrational signal, (which is very large) which is inherent to the sebaceous eccrine secretions.

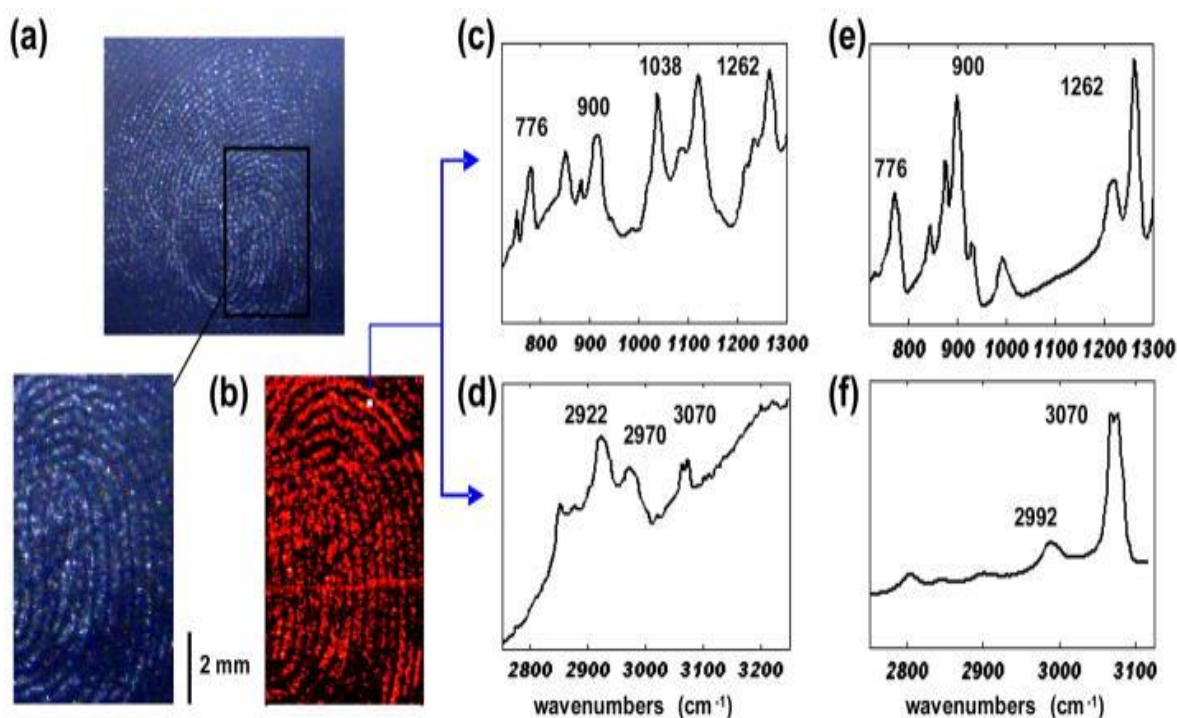


Figure 1: (a) A white light photograph of the two overlapping latent fingerprints. The rectangle outlines the sample area imaged by infrared spectroscopy. (b) Fingerprint image obtained based on the infrared absorption of the CH stretching mode region. (c, d) Infrared spectra of fingerprint deposits from a pixel, highlighted in figure 1b, containing mixture of RDX compound and eccrine/sebaceous residues. (e, f) Infrared spectra of pure RDX crystallites.

With cases of overlapping prints, it is difficult to determine which print belongs to the RDX chemicals, as traces of the RDX can be seen in some of the pixels of the infra-red fingerprint image. It is essential to spatially resolve the RDX chemicals from the eccrine and sebaceous secretions using multivariate analysis. This is essential so that further association of the detected RDX chemicals in the infra-red fingerprint can be made. This is shown in Figure 1b. Singular value decomposition (SVD) was used upon the infra-red spectral image data sets so that the basis vectors which account for the majority of the variance within the data could be obtained. The major chemical compounds within the spectra

image were then obtained from the minimum number of significant basis vectors using BTEM and/or principle component rotation. Figures 2a and 2b clearly show the pure component spectra for the RDX and the natural eccrine/sebaceous residues which were retrieved using multivariate analyses. The relative contributions of each component is calculated and presented as a score image by projecting each of the spectral components upon the original set. From the image shown in figure 2d, it is clear that the ridges of the blank fingerprint on the upper left corner become more prominent as the amount of eccrine/sebaceous residue increases. This is compared to the loop-shaped fingerprint which contains RDX. Figure 2c show the score image of the RDX spectral component revealing the connection of RDX deposits to one of the two overlapping fingerprints.

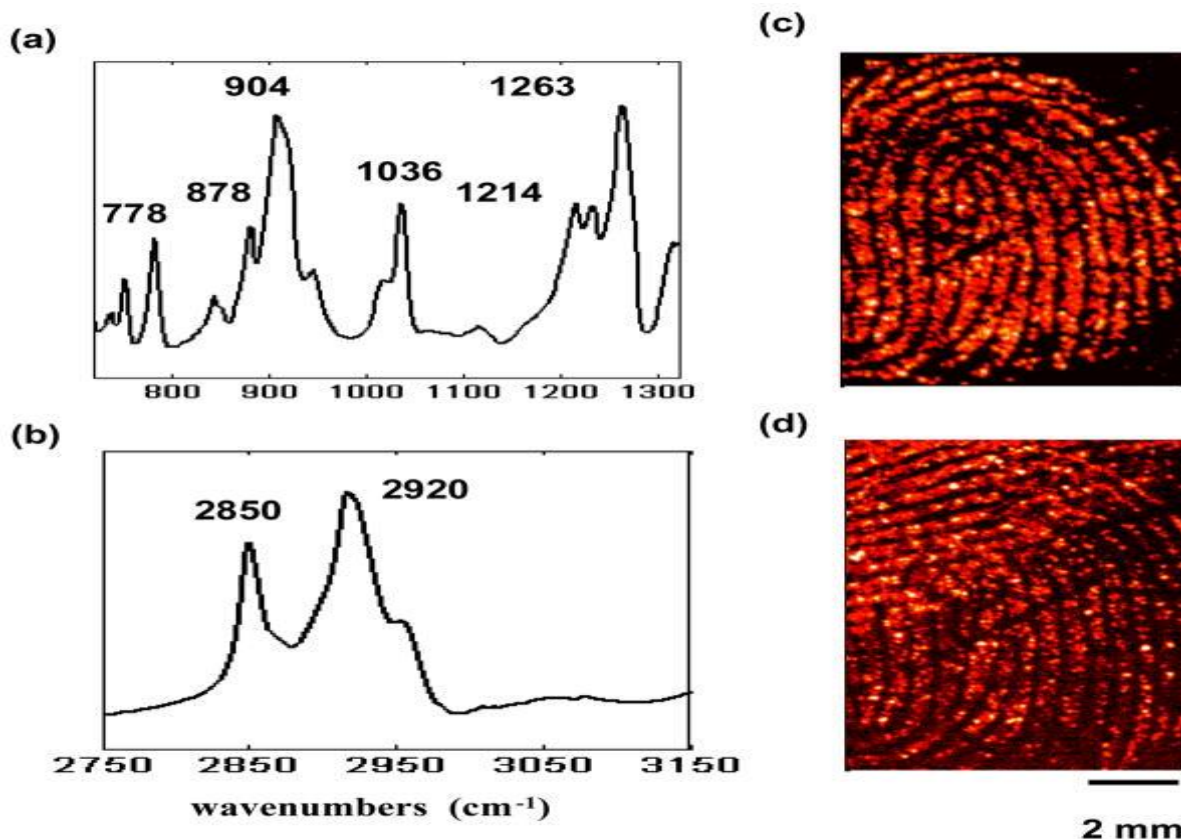


Figure 2: (a) Pure component spectra of RDX retrieved using multivariate analyses in the 1300–700 cm⁻¹ region. (b) Pure component spectra of eccrine/sebaceous residues retrieved in the 3150–2750 cm⁻¹ region. (c) A score image displaying the distribution of the retrieved RDX component. (d) A score image displaying the distribution of the retrieved eccrine/sebaceous component

FTIR is sensitive for these exogenous compounds and was established by spotting a known amount of RDX onto a slide and then imaging that specific region. A known concentration of RDX is normalized to the geometric area from which the compound has been detected, the detection limit was found to be 0.1ng pixel⁻¹. A spectroscopic image of the fingerprint shows that even after the individual has washed their hands, trace amounts of the RDX is still detected. As the spatial resolution of FTIR imaging increases, relative to the DESI-MS imaging, the trace chemical residues which are trapped between the fingerprint ridges which are clearly detected and spatially resolved while clearly delineating associated forensic evidence from the normal eccrine and sebaceous secretions inherent in the fingerprint.

III. CONCLUSION

It has been demonstrated that infra-red imaging spectroscopy can be used to identify latent fingerprints and reveal their chemical history. Sample preparation and derivatization or addition of the fluorescent antibodies is not required, as the infra-red chemical imaging technique is straightforward. They are potentially capable of generating a database which can search for fingerprints which are directly related to forensic evidence with a basic print.

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