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TECHNICAL NOTE

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The Application of Infrared Chemical Imaging to the Detection and Enhancement of Latent Fingerprints: Method Optimization and Further Findings

ABSTRACT: Fourier transform infrared (FTIR) chemical imaging allows the collection of fingerprint images from backgrounds that have traditionally posed problems for conventional fingerprint detection methods. In this work, the suitability of this technique for the imaging of fingerprints on a wider range of difficult surfaces (including polymer banknotes, various types of paper, and aluminum drink cans) has been tested. For each new surface, a systematic methodology was employed to optimize settings such as spectral resolution, number of scans, and pixel aggregation in order to reduce collection time and file-size without compromising spatial resolution and the quality of the final fingerprint image. The imaging of cyanoacrylate-fumed fingerprints on polymer banknotes has been improved, with shorter collection times for larger image areas. One-month-old fingerprints on polymer banknotes have been successfully fumed and imaged. It was also found that FTIR chemical imaging gives high quality images of cyanoacrylate-fumed fingerprints on aluminum drink cans, regardless of the printed background. Although visible and UV light sources do not yield fingerprint images of the same quality on difficult, nonporous backgrounds, in many cases they can be used to locate a fingerprint prior to higher quality imaging by the FTIR technique. Attempts to acquire FTIR images of fingerprints on paper-based porous surfaces that had been treated with established reagents such as ninhydrin were all unsuccessful due to the swamping effect of the cellulose constituents of the paper.

KEYWORDS: forensic science, chemical imaging, fingerprints, fingermarks, infrared, FTIR, hyperspectral imaging, cyanoacrylate, ninhydrin

While the technique of Fourier transform infrared (FTIR) chemical imaging is almost a decade old, its value to forensic science is only now being realized. Its application to the detection and enhancement of latent fingerprints was reported in early 2005 (1). Work has also focused on the application of FTIR chemical imaging to the analysis of other forensic trace evidence such as paint chips (2), fibers (3), and hair (4).

Infrared chemical imaging has the potential to solve many of the background interference problems encountered in the visualization of fingerprints on difficult surfaces using conventional methods. "Difficult" surfaces can contain pictures or text that obscure the ridge details of a latent or pretreated fingerprint. On such surfaces, infrared imaging can provide significantly improved results because the contrast is not based on the response of the surface or print to lighting conditions but rather is based on spectrochemical differences. This chemical contrast allows the imaging of fingerprints on surfaces where conventional fingerprint detection and enhancement methods prove difficult or impossible. Preliminary work in this area demonstrated that FTIR chemical imaging can produce superior results with fingerprints deposited on polymer banknotes (1). During the current study, this work has been extended to test the applicability of FTIR chemical imaging to other difficult nonporous surfaces such as aluminum drink cans, as well as porous surfaces such as copy paper, thermal paper, and masking tapes.

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Fourier transform infrared chemical imaging typically employs a focal plane array (FPA) detector that collects images which consist of thousands of pixels, with an infrared spectrum at each pixel. Typical FTIR chemical images are a fraction of a millimeter in size with a real spatial resolution of 10–20 μm [dependent on wavelength; better resolution can be achieved using micro attenuated total reflectance (ATR) FTIR imaging (4)]. We have described strategies for the imaging of larger samples such as whole fingerprints (1). These strategies are instrument-dependent but often involve the combination or *mosaicking* of a number of single images, known as *tiles* (e.g., in the Digilab/Varian or Bruker systems). When combined with expanded field of view optics, this allows the collection of images of up to several centimeters in size. As an example, the Digilab Stingray system is capable of producing mosaics of up to 4096 (64 × 64) tiles, representing an image area of 4.48 × 4.48 cm. Note that the Digilab Stingray system employed in this study produces square mosaics of particular sizes, whereas other systems, such as the PerkinElmer Spotlight 300 system or the Bruker Hyperion imaging system can generate images of any size and aspect ratio (5,6).

Collating an image larger than a few millimeters introduces a number of challenges in terms of image collection time and file size. It is often necessary to reduce the spectral resolution and number of scans to achieve a practical image collection time. Likewise, spectral resolution and spectral range often need to be minimized in order to yield a manageable data file which can be processed with relative ease. Another strategy to reduce the file size involves the aggregation or averaging of neighboring pixels. This reduces the total number of spectra (and hence the file size) at the expense of spatial resolution.

For the infrared imaging of fingerprints, it is necessary to optimize spectral resolution, number of scans, spectral range, and pixel aggregation for every new surface and/or fingerprint pretreatment tested. A technique for the systematic optimization of these parameters is presented in this article. Latent fingerprints on aluminum drink cans which have been treated with cyanoacrylate (superglue) fumes have been selected as a test surface to demonstrate this optimization process. While fingerprints treated in this manner are often visible to the naked eye and may be photographed using conventional techniques, some sections of aluminum drink cans are difficult to image under white light. In such cases, FTIR chemical imaging can yield superior results.

Materials and Methods

Fingerprints were prepared and deposited on a range of surfaces by thoroughly washing, rinsing, and drying hands before swiping a cleaned finger across an oily region of the face (forehead, nose, or neck) and finally placing the mark on the desired surface. The surfaces used during this study include clean, dry glass microscope slides, infrared reflective (metal oxide-coated) microscope slides (Kevley Technologies, Chesterland, OH) freshly cleaned and dried circulated Australian polymer $5 banknotes, a range of white A4-sized copy paper and various masking tapes, thermal paper, and aluminum drink cans.

Freshly deposited latent fingerprints were developed using a purpose-designed forensic cyanoacrylate fuming cabinet (Carter-Scott Design, Melbourne, Australia). Approximately 1 mL of ethyl cyanoacrylate (Selleys® Supa Glue, Sydney, Australia) was used for each treatment. Glass slides and aluminum drink cans were fumed until ridge development was obvious (an average of 10 min). Samples where ridge development was not obvious were fumed simultaneously with a glass slide containing a freshly deposited print and fuming was stopped when ridge development on the glass slide was obvious but not overdeveloped (*c.* 10–30 min). Polymer banknotes were fumed for an average of 60 min. Although ridge development on the banknotes was not visible to the naked eye at this point, a reference fingerprint on a glass slide began to show signs of over-development at fuming times in excess of 60 min. Samples on porous or semi-porous substrates were treated with ninhydrin, DFO (1,8-diazafluorenone) or 1,2-indanedione according to accepted methods (7).

Infrared chemical imaging of fingerprints was carried out using a Digilab Stingray system (Randolph, MA), which comprised an FTS 7000 FTIR spectrometer coupled with a UMA 600 infrared microscope and a Lancer 64×64 FPA detector. Images and spectra were collected and processed with Digilab Win IR Pro software. All samples were imaged in reflection mode using the expanded field of view (EFOV) setting, in which each individual image tile is approximately 700×700 μm in size. Other parameters such as spectral resolution, number of co-added scans, number of image tiles (image size), pixel aggregation factor, and raw data processing methods were varied and optimized during this study. A full description of this optimization procedure is provided in the Results and Discussion section below.

Results and Discussion

Optimization of Parameters

The optimization of large sample images, such as entire fingerprint images, involves a balance between various spectral and image collection parameters. The main parameters which need to be considered include:

TABLE 1—*Effect of various parameters on image collection time, file size, and image quality.*

	Image collection time	File size	Spatial resolution and image quality
Spectral resolution	*	*	†
Number of co-added scans	*	‡	†
Spectral range	‡	*	‡
Pixel aggregation	‡	*	*
Number of image tiles (image size)	*	*	‡
Image formation parameters	‡	‡	*

*Does have an effect.
†May have an effect.
‡Does not have an effect.

- Instrumental parameters (spectral resolution, number of averaged scans, spectral range, pixel aggregation, number of image tiles in a mosaic); these parameters will affect collection time, file size, spatial resolution, and image quality.
- Image formation parameters (processing of the data to give the best contrast between the fingerprint and its background).

Instrumental Parameters

Table 1 summarizes the effects of each parameter on image collection time, file size, and image quality. The selection and optimization of the various parameters is discussed below.

In FTIR spectroscopic analyses, there is a trade-off in that higher resolution enables the separation of more closely spaced peaks, but at the expense of longer collection times (scans are longer and more are required) for the same signal-to-noise quality. Higher resolution (more points per wavenumber) also increases spectral file size, a negligible issue with single spectra, but a potential problem for image data that contains thousands of spectra and may involve file sizes exceeding one gigabyte. Strategies for reducing file size include:

- Spectral truncation to a narrow region of interest (e.g., the C=O stretching region of cyanoacrylate for fumed fingerprints); this reduces the image file size, although it may have no effect on raw image data files that the imaging software may additionally produce.
- Collection of data with lower (e.g., 16 cm^{-1} rather than 8 cm^{-1}) spectral resolution.
- Pixel aggregation: this is the averaging of spectra at adjacent pixels to form larger pixels. This has the advantage of reducing the file size (fewer spectra) of the images produced, at the expense of spatial resolution. It is an effective strategy if the spatial resolution sacrificed is unnecessary for the satisfactory imaging of the sample. For the imaging of fingerprints, our results indicate that a spatial resolution of 44 μm can still produce images with sufficient clarity for the resolution of detail down to the third level (resolution of pore structure).

Spectral image collection times can be reduced in the following ways:

- Collect data with lower spectral resolution, as mentioned earlier.
- Decrease the number of co-added scans.
- Decrease the image size if possible (minimize the number of tiles in a mosaic image if appropriate).

Table 2 shows the approximate time taken by the Digilab Stingray system for the collection of a 1024 tile FTIR image with various resolutions and scan numbers. This will produce an image the size of a typical fingerprint (up to 2.24×2.24 cm).

TABLE 2—*Typical image collection times for various combinations of spectral resolution and number of co-added scans.*

	Spectral resolution	
Co-added scans	16 cm^{-1}	32 cm^{-1}
4	3 h	2 h 30 min
16	5 h 30 min	4 h 15 min
64	18 h	11 h 15 min

In general we have found that for the efficient FTIR imaging of entire fingerprints, the operator is limited to a spectral resolution of 16 or 32 cm^{-1}. It should be noted that it is possible to obtain images of smaller sections of fingerprints (e.g., 1.12 × 1.12 cm) with higher spectral resolution settings (e.g., 8 cm^{-1}) where necessary. Future advances in computer processing ability may resolve the problem of handling larger images with these settings. A similar limitation has been found for the number of co-added scans, in that more than 64 scans per image tile leads to impractical collection times (but does not affect the image file size).

Thus, when optimizing an image collection method for a new reagent/surface combination, a resolution of 16 cm^{-1} and 64 co-added scans is a good starting point. If exploitable fingerprint images are generated using these settings, then the same sample can be used to test 32 cm^{-1} resolution with 64 scans. If the results are still satisfactory then the number of scans can be reduced. Optimal settings are reached when exploitable fingerprint images are produced in the shortest timeframe (i.e., the lowest number of scans and the lowest resolution while maintaining ridge detail).

Table 3 summarizes the approximate image size options for the Digilab Stingray system used during this study. An image consisting of 16 image tiles (4 × 4) allows the sampling of a few ridges of a latent fingerprint. This size is reasonable for method optimization of new surface/reagent combinations since it allows an assessment of the contrast achieved between the ridges and the background in the shortest space of time. Since method optimization often involves the collection of a number of images with a range of settings, using a 16 tile image (compared to 256 or larger) also minimizes the file size of the data collected. Once other parameters such as spectral resolution and number of co-added scans have been optimized, an image consisting of 1024 tiles (2.24 × 2.24 cm) is usually appropriate for the imaging of an entire fingerprint.

Image Formation Parameters

The parameters discussed here represent the most important choices when it comes to maximizing the spectrochemical contrast between fingerprint ridges and their background. At a minimum, most chemical/hyperspectral imaging software allows the user to form images based on (i) simple spectral intensity at a single frequency (wavelength), (ii) the integrated intensity (area) under a spectral peak, usually baseline corrected, or (iii) ratios of intensities at two different frequencies. A monochrome or colored image can be created based on these intensities, using either a brightness (black to white) or a false color scale (e.g., blue, through green and yellow, to red). As with many samples, fingerprints on an ideal, featureless background can be imaged simply using method (i), or, with better results method (ii). For example, it is trivial to form an image of a latent fingerprint on glass or metal using the C–H stretching or bending peaks in the spectrum of the oily sebaceous material in a fingerprint. Method (ii) is usually superior because of the baseline correction involved and because it is less susceptible to noise, spikes and band overlap. Method (iii) is problematic in many cases because intensity ratios often take on extreme values at random pixels dues to noise or baseline effects. These extremes cause a flattening of the contrast in the rest of the image.

TABLE 3—*Typical image sizes using expanded field of view (EFOV) optics on the Stingray FTIR imaging system.*

Number of tiles	Sample area (in EFOV mode)
1 (1 × 1)	700 × 700 μm
4 (2 × 2)	1.4 × 1.4 mm
16 (4 × 4)	2.8 × 2.8 mm
256 (16 × 16)	1.12 × 1.12 cm
1024 (32 × 32)	2.24 × 2.24 cm
4096 (64 × 64)	4.48 × 4.48 cm

However, there are many situations where the fingerprint background has infrared absorption peaks that are similar in frequency to those of the latent fingerprint, and overlap occurs. This spectral overlap can reduce or destroy image contrast, and so the methods listed above can struggle or fail. The overlap between the C=O stretching vibration in cyanoacrylate-fumed fingerprints and that in the intaglio printing on Australian polymer banknotes is an example of this (1). In some cases, experimentation with baseline and/or integration bandwidth within method (ii) can yield satisfactory results, particularly where spectral overlap is not complete and the peak desired for imaging is sufficiently resolved as a shoulder, for example. However, the best results in this situation are obtained through the use of second and fourth order derivative spectra when forming the images.

A disadvantage of derivative spectra is that they are noisier than the original spectra. Taking odd-order (e.g., first or third) derivatives of a spectrum splits each absorbance peak into positive and negative components, with zero intensity at the original peak maximum. For this reason, odd-order derivative spectra are usually not useful for imaging purposes, but even-order derivatives have some important advantages: (i) overlapping peaks can be more easily resolved from each other, since they are much narrower than the original peaks; and (ii) they are generally devoid of many of the baseline and offset artifacts that may afflict the original spectra. Thus, images based on second (or higher even-order) derivative spectra generally provide the best contrast possible between a fingerprint and its background.

The frequencies that yield the best images can be found easily by "playing" through the derivative spectrum and observing the images that are formed at each consecutive frequency. This can be done with images formed using single frequency spectral intensities (method [i] above), because method (ii) offers little advantage with the "baseline-corrected" second derivative spectra. Playing through all of the available frequencies is recommended as good fingerprint contrast can be achieved at unexpected frequencies, thanks to the resolution of small shoulder bands in the second derivative spectra. Since second derivative spectra have negative peaks where there were positive peaks in the original spectra, the images formed may be negatives, but can be "flipped" using image editing software or by negating the derivative spectra. Note that in certain cases (if the original spectra were collected with sufficient density of points), taking the second derivative of the second derivative spectrum (i.e., the fourth derivative) can resolve more peaks and provide better image contrast.

The abundance of information contained in hyperspectral images often lends itself to chemometric (multivariate statistical) analysis

or interpretation. An example of this is the application of principal component imaging or hierarchical cluster analysis (and other clustering techniques) to group pixels according to spectral similarity. For fingerprints, the obvious aim would be to group spectra into ridge and background classes (clusters) based on the comparison of entire spectra, rather than discrete frequencies or peaks. While we have attempted this type of analysis of hyperspectral fingerprint images with some success, in our experience there is generally no advantage to these techniques over the methods described above. To paraphrase this, we have found that if appropriate fingerprint contrast cannot be achieved using second derivative spectral imaging, then chemometric techniques will probably not yield a better result because the information required to differentiate the fingerprint from its background probably does not exist. This is only an empirical observation, but it can be explained at least partly (in the case of cyanoacrylate-fumed prints) by (i) the fact that during fuming, a small amount of cyanoacrylate is deposited between ridges as well as on them, and (ii) the high variability of the fingerprint background, which prevents all of the background spectra from being classified into one cluster.

Example of Optimization of Parameters—FTIR Chemical Imaging of Fingerprints on Aluminum Drink Cans

The method optimization procedure discussed above will be outlined by way of an example. The same procedure can be applied to any new surface and reagent combination. The example used is that of cyanoacrylate-fumed fingerprints on aluminum drink cans.

Text and images printed on aluminum drink cans can make the imaging of fingerprints using conventional methods difficult, even after cyanoacrylate development and subsequent fluorescent staining. Reflected ultraviolet imaging techniques can yield good results on some, but not all, drink can backgrounds. However, the high infrared reflectivity of metal surfaces means that it is very easy to rapidly obtain high signal-to-noise infrared spectra of thin coatings on the metal, and thus produce excellent image contrast in almost all cases.

Since the infrared imaging process involves placing the sample on a motorized microscope stage, it is important that the sample is flat and relatively smooth. For this reason, aluminum cans used in this study were 'flattened' by cutting the top and bottom off the can and cutting a vertical slit along the length of can. The can was then unrolled and held flat in a specially designed clamp. This clamp consisted of two sheets of Perspex hinged on one side and held flat against one another (with the aluminum can in-between) with the aid of fold back paperclips. The upper side of the clamp had a viewing hole through which the target fingerprint could be analyzed and a microscope slide was fixed to the underside of the clamp so that it could be mounted directly onto the motorized microscope stage. This clamp was also useful for flattening and holding polymer banknotes and document samples for imaging.

For the optimization process an image size consisting of 16 tiles (2.8 × 2.8 mm) was selected as this allowed the imaging of a few ridges of the treated print while minimizing the collection time and data file size. The first step in the optimization process was to find a suitable combination of spectral resolution and number of co-added scans which produced exploitable fingerprint images in the shortest timeframe. As mentioned above, a good starting point for a new reagent/surface combination is a resolution of 16 cm^{-1} and 64 co-added scans. Figure 1*a* shows an image of a small section of a cyanoacrylate-fumed fingerprint on an aluminum Coke can which was produced using these settings. It is clear that the second and third level fingerprint ridge detail is of sufficient quality for subsequent comparison. Next the resolution was set to 32 cm^{-1} while the number of scans was maintained at 64 (see Fig. 1*d*). Since the results with these settings were also satisfactory, further images were collected whereby the number of scans was reduced (Figs. 1*b*, 1*c*, 1*e*, and 1*f*).

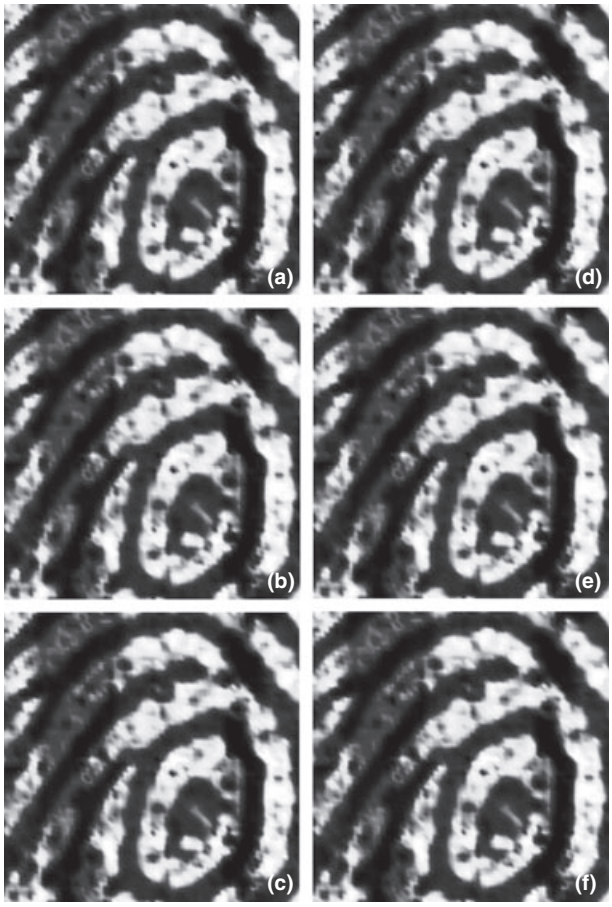

FIG. 1—*FTIR chemical images of ethyl cyanoacrylate fumed fingerprint on aluminum drink can collected using various settings for spectral resolution and number of co-added scans: (a) Resolution 16 cm^{-1}, 64 co-added scans (b) Resolution 16 cm^{-1}, 16 co-added scans (c) Resolution 16 cm^{-1}, 4 co-added scans (d) Resolution 32 cm^{-1}, 64 co-added scans (e) Resolution 32 cm^{-1}, 16 co-added scans (f) Resolution 32 cm^{-1}, 4 co-added scans.*

The optimal settings were chosen based on the settings which produced an image of an exploitable fingerprint in the shortest timeframe (i.e., the lowest number of scans and the lowest resolution while maintaining ridge detail). From the images in Figs. 1*a–f* it is clear that the quality of fingerprint image produced is not diminished when the resolution and number of scans are reduced. For this reason, the settings which gave the shortest image collection time and smallest image file size (resolution 32 cm^{-1}, 4 co-added scans—Fig. 1*f*) were selected for future infrared chemical imaging of cyanoacrylate fumed fingerprints on aluminum drink cans.

As discussed above, we have found that a pixel aggregation value of 16 (which gives a spatial resolution of about 44 μm) produces good quality fingerprint images. This is demonstrated by the quality of the images shown in Fig. 1 which were all formed using a pixel aggregation of 16. Figure 2 shows a comparison of images formed using a pixel aggregation of 16 (~44 μm pixel size—Fig. 2*a*) and 64 (~88 μm pixel size—Fig. 2*b*). It is clear from these results that useful fingerprint detail is lost with a pixel size of 88 μm (or higher). For the imaging of entire fingerprints, a pixel size of <44 μm may result in files which are too large to process.

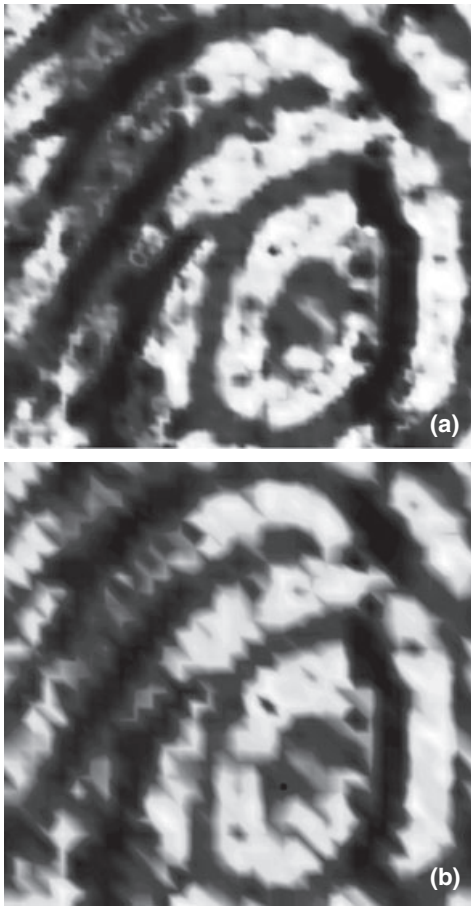

FIG. 2—*FTIR chemical images of ethyl cyanoacrylate fumed fingerprint on aluminum drink can collected using a pixel aggregation value of (a) 16 (pixel size ~44 μm) and (b) 64 (pixel size ~88 μm).*

The final stage in the optimization process is to explore the possibility of narrowing the spectral range in order to reduce the total file size of fingerprint images. This step was performed in combination with the optimization of image formation parameters. Initially the entire spectrum was collected during the optimization of spectral resolution and number of co-added scans. Using this data, it became clear that the best contrast between the fumed print and the background was achieved at certain frequencies in the region between 1750–1800 cm^{-1} (C=O stretching frequency). Certain frequencies below this region also produced images of the print but the region above 1900 cm^{-1} failed to produce images of any practical value. For this reason the spectral range was truncated between 1900–900 cm^{-1} for the imaging of further samples which minimized the overall file size of the image data. The best images were formed using a frequency slice within the region of 1750–1800 cm^{-1} from the second or fourth derivative data. Table 4 shows a summary of the optimized method for the infrared chemical imaging of cyanoacrylate-fumed fingerprints on aluminum drink cans.

TABLE 4—*Optimized settings for the infrared chemical imaging of cyanoacrylate-fumed fingerprints on aluminum drink cans.*

Parameter	Optimized settings
Spectral resolution	32 cm^{-1}
Number of co-added scans	4
Spectral range	1900–900 cm^{-1}
Pixel aggregation	16
Number of image tiles (image size)	1024 (2.24 × 2.24 cm)
Image formation parameters	Frequency slice within the range 1750–1800 cm^{-1} from the second or fourth derivative data

FTIR Chemical Imaging of Fingerprints on Porous Surfaces

The success of FTIR imaging of fingerprints on nonporous and semi-porous surfaces, such as glass, polymer banknotes, and drink cans, led us to investigate the possibility of using this technique to image fingerprints on porous surfaces that had been developed using established reagents such as ninhydrin and DFO.

The problem usually encountered in reflectance infrared spectroscopy of paper-based surfaces is the high absorbance of cellulose components of the paper over much of the spectrum. Attempts to collect infrared reflectance spectra of inks (for example) on paper backgrounds usually fail because the ink spectrum is swamped by the paper. ATR measurements are more successful in detecting some inks on paper (8), but ATR imaging of an area as large as a fingerprint is not technically feasible at the time of writing. The question addressed in this work was whether the products formed by the reaction of fingerprint reagents and amino acids in fingerprints could be detected by ordinary reflectance infrared imaging on the following surfaces, some of which are less porous than ordinary paper: masking tape, thermal paper, and white copier paper.

Unfortunately the answer to this question for all combinations of reagents and surfaces was in the negative. This is probably not surprising when the difficulty of paper backgrounds is considered along with the low concentrations of amino acids in fingerprints, which have been reported to be between 0.3 and 2.59 mg/L in sweat. This corresponds to an average amino acid content of 250 ng per print (9). The amount (in molecular terms) of product formed in fingerprints developed using ninhydrin or DFO must be less than or equal to the original number of amino acid molecules, whereas cyanoacrylate development of fingerprints has the advantage of amplification; i.e., many cyanoacrylate monomer units are deposited for each initiating species present in a fingerprint. Therefore, any reagent that might be proposed for the development of fingerprints for subsequent infrared chemical imaging should either produce an amplification effect, or have an infrared absorbance that is strong and isolated enough (in the spectrum, relative to paper) for it to be detected at very low levels.

Infrared Chemical Imaging of Large Sample Areas

Untreated Fingerprints—We have previously published FTIR chemical images of untreated latent fingerprints on IR reflective slides (1). These images were the results of preliminary findings and show only a small section of the untreated fingerprint. An FTIR chemical image of an entire fingerprint is shown in Fig. 3. This image was generated using the C–H stretching frequency at about 2921 cm^{-1}. The ability to generate FTIR chemical images of fingerprints using this region of the spectrum is limited to backgrounds which do not absorb in this region. The imaging of untreated fingerprints via this technique is therefore most successful on surfaces such as metals and ceramics.

One area of interest is the detection of trace materials within untreated fingerprint deposits. Work is currently underway to determine the potential of FTIR chemical imaging for the determination of trace materials within untreated fingerprints. The feasibility of this technique has already been demonstrated (10,11). Related research

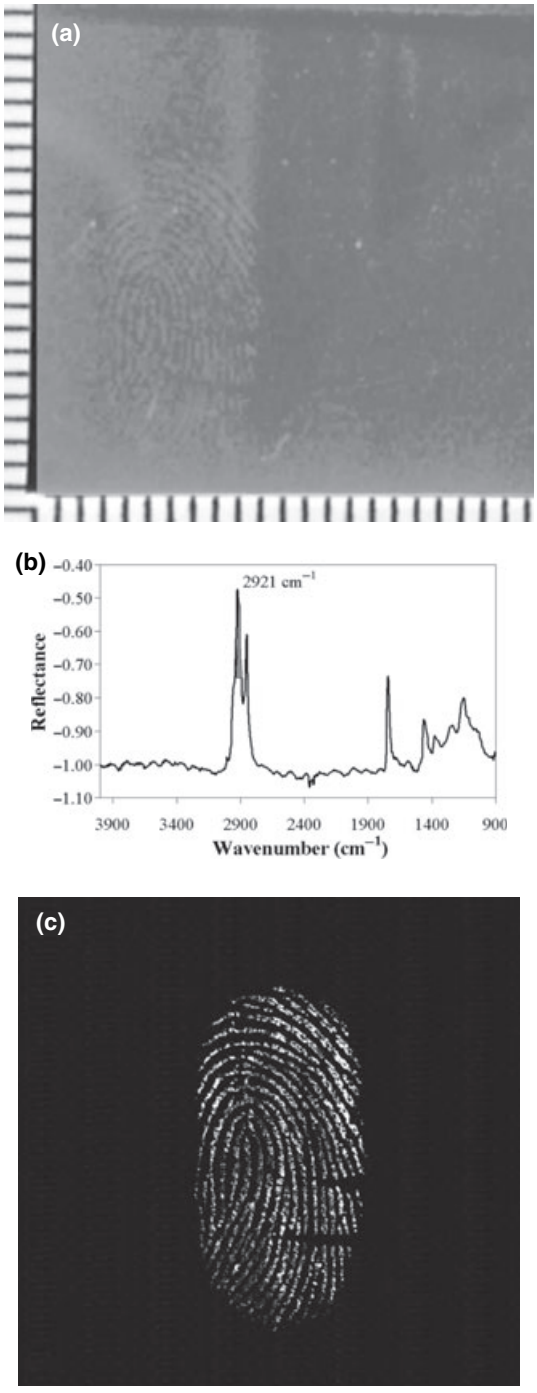

FIG. 3—*Untreated fingerprint on infrared reflective slide: (a) White light photograph. (b) Monochrome representation of FTIR chemical image.*

has shown that Raman spectroscopy may be used for the detection of drugs of abuse in latent fingerprints (12,13). Although the technique was successful in obtaining spectral identification of several drugs of abuse in fingerprints, the authors note that there were difficulties involved in visually locating these substances in the latent prints. This is a problem which may be overcome using hyperspectral imaging techniques. Fingerprints contaminated with explosives have also been analyzed using a Raman spectrometer (14).

Cyanoacrylate Fumed Fingerprints on Polymer Banknotes—By the end of 2004, 22 countries from all major regions of the world were using polymer notes in their national currencies (15). Our

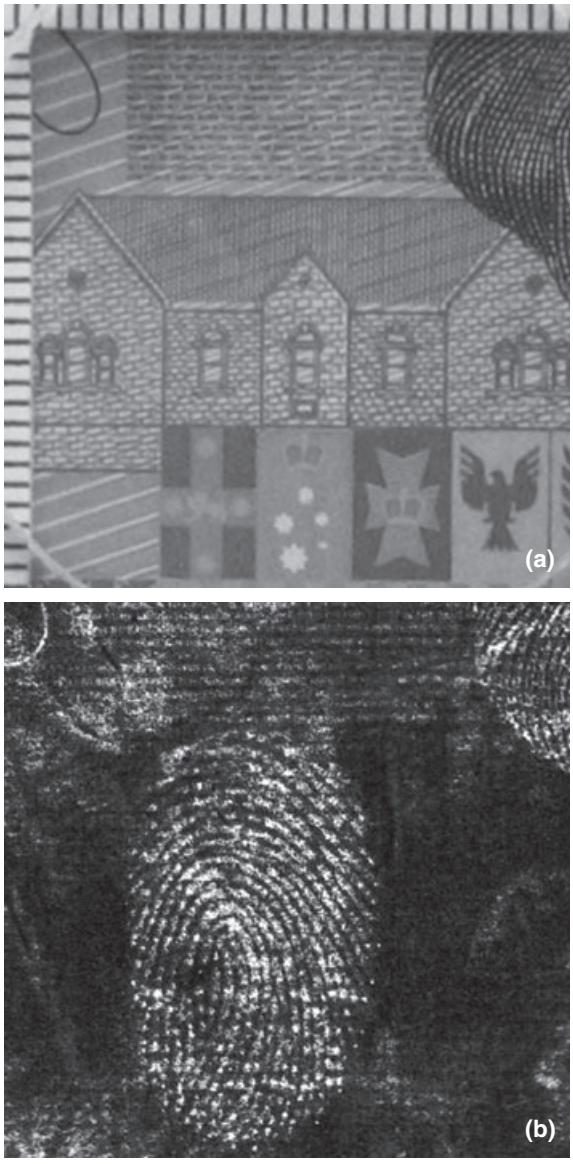

FIG. 4—*Ethyl cyanoacrylate fumed fingerprint on $5 note (aged 1 month prior to fuming): (a) White light photograph, (b) Monochrome representation of FTIR chemical image.*

original work on the FTIR chemical imaging of fingerprints focused on Australian polymer banknotes because of the difficulties which had been encountered in visualizing latent fingerprints on these notes using conventional methods. Since this initial work, we have been able to improve the image collection process so that larger fingerprint images can be obtained in a shorter period of time. This was achieved by reducing the spectral resolution from 16 to 32 cm^{-1} and reducing the number of scans from 64 to 16. The images obtained with these settings (32 cm^{-1} resolution and 16 scans co-added) are comparable to those using the previously published settings (16 cm^{-1} resolution and 64 scans co-added). Using the new settings, an image measuring 2.24 × 2.24 cm can be collected in just over 4 h. This compares with an image collection time of about 18 h using the previous un-optimized settings. The new image collection method is best demonstrated by the successful imaging of aged fingerprints. Figure 4 shows an image of a one-month-old fingerprint on an Australian $5 note which has been fumed with ethyl cyanoacrylate. The FTIR chemical image of this print (Fig. 4*b*) has been

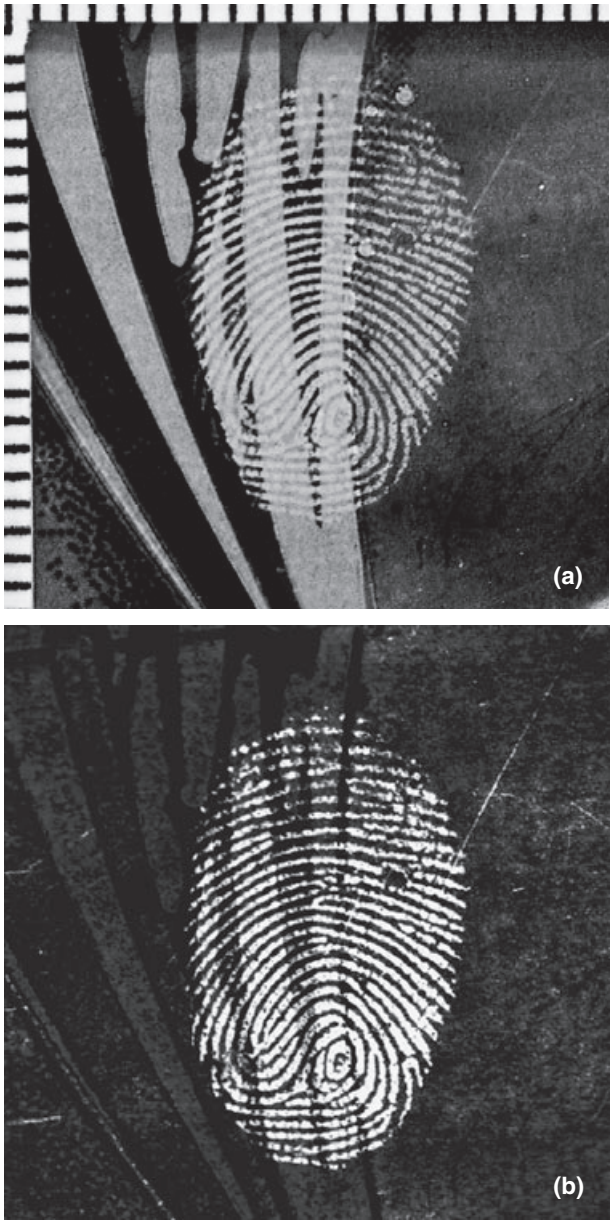

FIG. 5—*Ethyl cyanoacrylate fumed fingerprint on Coke aluminum drink can: (a) White light photograph, (b) Monochrome representation of FTIR chemical image.*

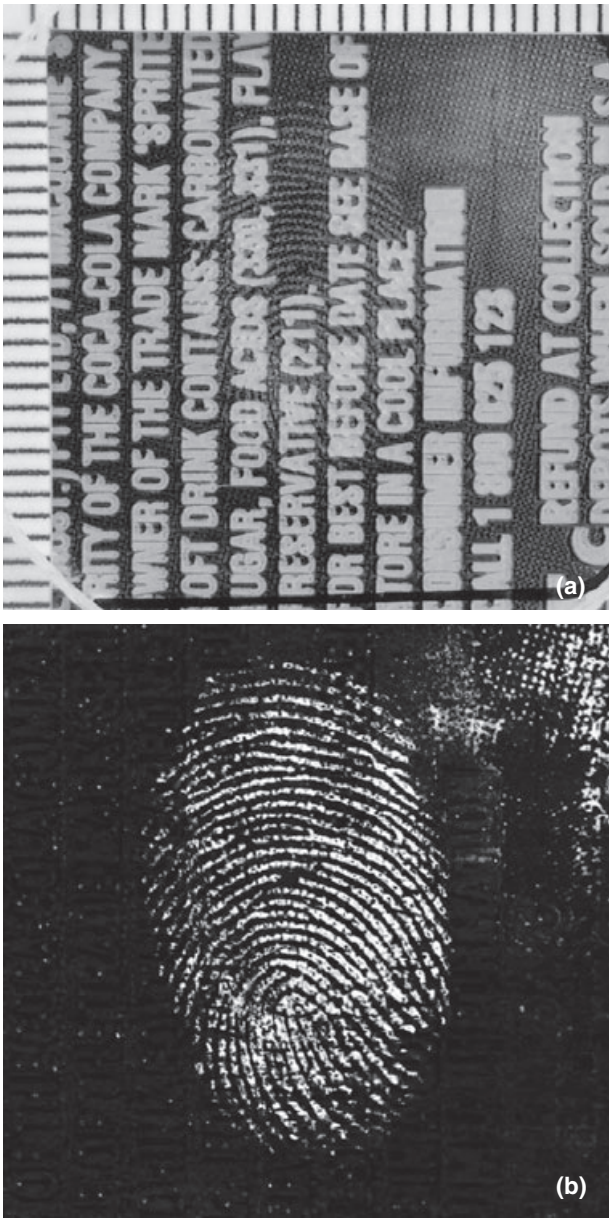

FIG. 6—*Ethyl cyanoacrylate fumed fingerprint on Sprite aluminum drink can: (a) White light photograph, (b) Monochrome representation of FTIR chemical image.*

formed using a frequency slice at 1735 cm^{-1} (C=O stretch) from the fourth derivative spectrum. The fingerprint ridge detail is exceptional for a 30-day-old print on such a difficult background. Further work is continuing on the FTIR imaging of older prints; it is expected that its success will mirror that of other approaches based on prior cyanoacrylate development of fingerprints.

Cyanoacrylate Fumed Fingerprints on Aluminum Drink Cans—The procedure used for optimizing the image collection method for cyanoacrylate fumed fingerprints on aluminum drink cans is discussed above. Figures 5–7 show a number of FTIR chemical images of cyanoacrylate fumed fingerprints on various aluminum cans collected using this optimized method. The most noteworthy results were on sections of the aluminum can where ridge detail may be obscured by colored patterns or text under white light. In these cases, FTIR chemical imaging was able to produce superior fingerprint images where the background pattern or text was completely eliminated and the ridge details of the fingerprint were pronounced. As can be seen in Figs. 6*a* and 7*a*, the cyanoacrylate-fumed fingerprints were often difficult or impossible to image using traditional white light photography. Attempts to visualize the fingerprints using reflected UV light (254 nm) met with varied success, depending upon the background, but in all cases there was an indication of the presence of the fingerprint; this means that UV illumination can be considered as a method for the initial location of fumed fingerprints, prior to FTIR imaging, on certain backgrounds such as drink cans.

Practical Considerations and Limitations of the Method

This research was carried out using a Digilab Stingray system equipped with a Lancer 64 × 64 FPA detector. Although FTIR

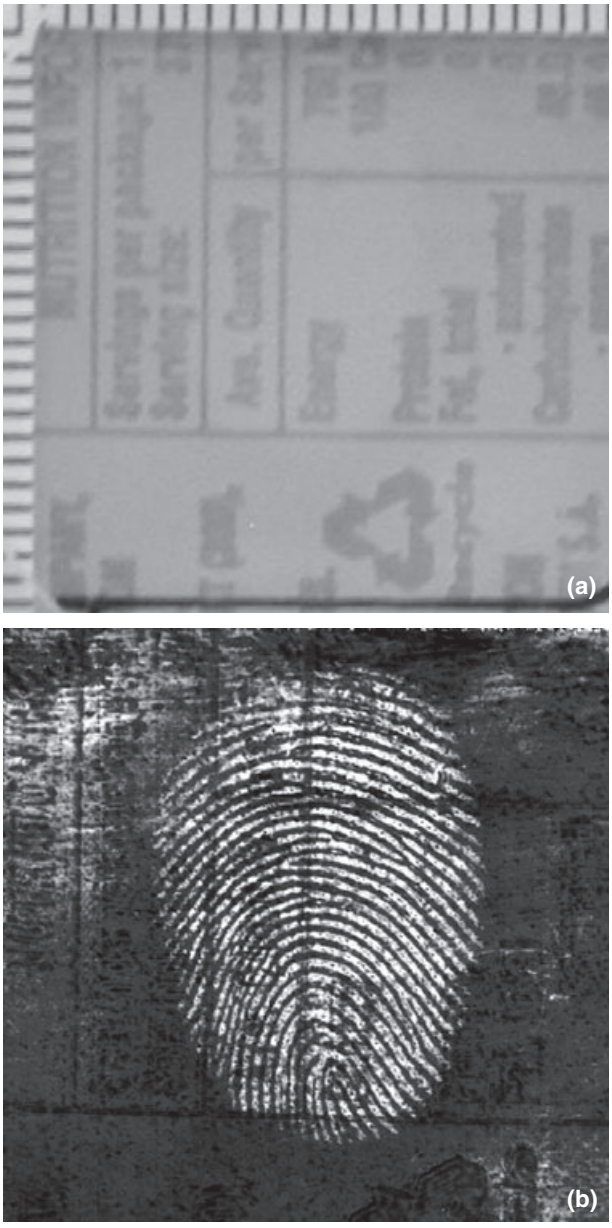

FIG. 7—*Ethyl cyanoacrylate fumed fingerprint on Lift aluminum drink can: (a) White light photograph, (b) Monochrome representation of FTIR chemical image.*

imaging instruments vary between manufacturers (e.g., Digilab/Varian vs. Perkin-Elmer), the process of optimization discussed has wide applicability. Provided "pixel aggregation" can be related to a pixel size (as we have done), and provided that the different sensitivity of different detectors is taken into account, the optimization process is general to most instruments because spatial and spectral resolution are standard parameters.

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