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RESEARCH PAPER

Spectroscopic detection of exogenous materials in latent fingerprints treated with powders and lifted off with adhesive tapes

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Abstract Fingerprint evidence offers great value to criminal investigations since it is an internationally recognized and established means of human identification. With recent advances in modern technology, scientists have started analyzing not only the ridge patterns of fingerprints but also substances which can be found within them. The aim of this work was to determine whether Fourier transform infrared (FTIR) spectromicroscopy could be used to detect contamination in a fingerprint which was dusted with powder (a technique already recognized as an effective and reliable method for developing latent fingerprints) and subsequently lifted off with adhesive tape. Explosive materials (pentaerythritol tetranitrate, C-4, TNT) and noncontrolled substances (sugar, aspirin) were used to prepare contaminated fingerprints on various substrates. Freshly deposited fingermarks with powders which were lifted off with adhesive tapes (provided by Singapore Police Force) were analyzed using a Bruker Hyperion 2000 microscope at the ISMI beamline (Singapore Synchrotron Light Source) with an attenuated total reflection objective. FTIR spectroscopy is a nondestructive technique which requires almost no sample preparation. Further, the fingerprint under analysis remains in pristine condition, allowing subsequent analysis if necessary. All analyzed substances were successfully distinguished using their FTIR spectra in powdered and lifted fingerprints. This method has the potential to significantly impact forensic science by greatly enhancing the information that can be obtained from the study of fingerprints.

Keywords IR spectroscopy / Raman spectroscopy · Forensics / Toxicology · Chemometrics / Statistics

Introduction

A fingerprint is an impression left by the friction ridges of a human finger. It has long been regarded as a unique and typical feature for each person, and it remains unchanged during an individual's lifetime. That is why identification of fingerprints is one of the commonest procedures done by forensic experts at a crime scene [1]. The process of identification is based on finding a pattern of ridges matching that of a specific person in the database. The commonest type of fingerprints found during investigations is the barely visible latent fingerprint, which needs special chemical or physical treatment to enhance its visual detection [2, 3].

A plethora of methods are used nowadays for visualizing latent fingermarks, including powdering, use of amino acid sensitive reagents such as ninhydrin, and cyanoacrylate (superglue) fuming [2–4]. Selecting the right method depends on the surface which has to be analyzed. For more than 100 years, treating an article or object which has a hard, nonabsorbent surface with a powder to reveal the pattern details of any latent fingermark that may be present has been the most effective method to differentiate it from the substrate material. The range of powders available for this purpose is extensive, with the most commonly used powders consisting of various grades of graphite [3]. Fingerprint technicians usually have a small number of specific powders that they prefer to use. The powder of choice is the one that shows the

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best contrast with the surface being examined. With fresh fingermarks, the powder particles adhere to the moisture and greasy materials in the latent fingerprint deposit, whereas with older fingerprints, the powders adhere principally to the fatty deposits and other contaminants. Since the powders are colored, the ridge patterns become visible, and the latent fingerprint is said to have developed. Powders are applied using a fiberglass or camel-hair brush specially constructed to minimize potential damage to the detail of the latent fingerprint; contact of the brush with the fingerprint could have a destructive effect, so the powdering must be done very carefully [3, 5].

Very often, fingerprints found at crime scenes are deposited at hard-to-reach places, and without their being transferred, their further analysis seems to be impossible. There are a wide range of different types of foils/tapes designed for lifting fingerprints from a range of surfaces.

The principle of the lifting process is essentially the same regardless of the foils involved. First, the foil is pressed down onto the fingerprint, then it is slowly removed and transferred to a box of evidence. This procedure must be done with great care so that the fingerprints are not destroyed irrevocably. Typical lifted fingerprints fade and ultimately disappear in time. Fading can be noticeable after days or weeks, depending on the storage temperature—the lower the better.

As mentioned above, analysis of fingerprints is conducted mainly to identify the person involved in a crime. However, each fingerprint has its own history—not only sebaceous and eccrine residues can be found within fingerprints, but everything that was touched or handled by a person can speak as additional forensic evidence.

The development of vibrational spectroscopy techniques for nondestructive detection of latent fingerprint contaminations has increased in recent years. With advances in modern technology, scientists have started analyzing not only the ridge patterns of fingerprints but also substances which can be found within them to broaden the amount of evidence which can be found at a crime scene [6–14].

Fourier transform IR (FTIR) spectroscopy has been a workhorse technique for the analysis of various types of samples in laboratories all over the world. A FTIR spectrum represents a signature of a sample with absorbance or transmittance peaks which correspond to the frequencies of vibrations between the bonds of the atoms making up the material. Because each different material is a unique combination of atoms, no two compounds produce the exact same FTIR spectrum. Therefore, FTIR spectroscopy can result in a positive identification (qualitative analysis) of every kind of material. The size of the peaks in the spectrum is a direct indication of the amount of material present. With modern software algorithms, FTIR spectroscopy is an excellent tool for quantitative analysis. FTIR spectroscopy is also known as a nondestructive technique, and very often requires almost no sample preparation; hence, a fingerprint which has undergone FTIR analysis remains in a pristine condition for further analysis, including the identification of an individual who was involved in a crime. Analysis of contaminations within latent fingerprints must be performed under an IR microscope to allow control of which part is analyzed. Depending on the substrate, experiments can be done in transmission mode or reflection mode. However, in the case of fingerprints deposited on a substrate that is nonreflective and nontransparent for IR light, the only option to analyze any exogenous substances within them is the use of an attenuated total reflectance (ATR) objective. This measures changes that occur in a totally internally reflected IR beam when the beam comes into intimate contact with a sample. The IR beam is directed onto an optically dense crystal with a high refractive index. Internal reflectance creates an evanescent wave that extends beyond the surface of the crystal into the sample held in contact with the crystal [15, 16].

The quality of FTIR spectra collected for particles that are very small can be improved by using synchrotron radiation, which is hundreds of times brighter (in terms of brilliance) than conventional thermal IR sources. IR light can be focused down to a 3–10-μm spot size, giving superior signal-to-noise ratio capability and better diffraction characteristics than using a Globar source. Use of synchrotron radiation makes possible the analysis of very small particles which can not be measured with a laboratory source [17].

In previous work [18] we focused on direct FTIR spectromicroscopy analysis of solid microscopic particles existing in latent fingerprints deposited on various substrates commonly found in everyday life, without any further sample preparation. This work extends our research to include FTIR spectroscopic detection of exogenous substances in fingerprints which have been enhanced by powder dusting (a technique already recognized as an effective and reliable method for developing latent fingerprints) and subsequently lifted off with adhesive tapes.

Experimental

Explosive materials [pentaerythritol tetranitrate (PETN), C-4, TNT] and noncontrolled substances (sugar, aspirin) were used to prepare contaminated fingerprints on various substrates. Explosive materials were provided by Singapore Police Force (SPF).

Prior to analysis of contaminated fingerprints, reference FTIR spectra were collected for comparison purposes for all exogenous substances used in this work. To prepare samples for analysis, a small amount of less than 1 mg of explosive material or noncontrolled substances was mixed with less than 100 mg of KBr. The mixtures were ground to a fine powder until all visible crystallites disappeared and the mixture became “pasty” and stuck to the mortar. Next, the powder was put into a standard evacuable pellet press assembly, placed in a hydraulic press, and compressed with a clamping force of 80 kN to produce a thin, transparent pellet with a diameter of 13 mm and a thickness of less than 1 mm.

Before fingerprint sample preparation, hands were washed with water and ordinary liquid soap and dried with a towel. A volunteer’s index finger was lightly touched with ground exogenous substances prepared earlier to contaminate the fingertip. Excess loose powder was brushed away with another hand, so that no powder was noticeable on the skin. Afterwards, a fingerprint was deposited on various substrates, including polyethylene foil, an aluminum slide, a mirror, and a silicone slide. It is important to stress that no macroscopic traces of the chemicals used were visible on substrate surfaces. The location of all prepared fingerprints was known before the samples underwent FTIR analysis.

Latent fingerprints were subsequently treated with the powders provided by SPF. Three types of powders were examined: Hi-Fi Silk Gray, catalog no. 102 LD (gray powder), composed basically of aluminum dust, typically used on dark-colored surfaces and on mirrors and metal-polished surfaces; Hi-Fi Silk Black, catalog. no. 101 LD (black powder), composed of black carbon or charcoal, applied to white or light-colored surfaces; and Hi-Fi Indestructible White, catalog no. 103 LD (white powder), composed mainly of titanium oxide and used for dark-colored objects. These powders were applied lightly to a nonabsorbent surface with a fiberglass brush, and stuck to perspiration residues and/or deposits of body oils left on the surface. The excess powder was removed by dusting the surface with a gentle, smooth motion until the best fingerprint image had been developed.

As mentioned already, the use of special foils/tapes for lifting off fingerprints broadens the scope of their analysis—fingerprints deposited on various substrates at hard-to-reach places can be transferred to the laboratory for further examination. In our work, fingerprints contaminated with exogenous substances and enhanced with powders were lifted off using three adhesive tapes provided by SPF (namely, Sirchie hinge lifter, Spex C-lifts, and BVDA black Gellifter) and underwent FTIR analysis to determine the ability of the adhesive tapes to transfer exogenous substances together with fingerprint marks.

Typical particles which ranged in size from 5 to 20 μm in diameter easily observed under a microscope in the contaminated fingerprint were analyzed during our studies. This initial localization of particles was done using 15× IR Schwarzschild objective working in visual mode. For all experiments, the appropriate size of the slits were set to define the area for FTIR spectrum collection.

During the experiments, the following FTIR spectra were collected:

(a) FTIR spectra of pure explosive and noncontrolled substances to serve as reference spectra in further analysis; samples were prepared in the form of KBr pellets and measured in transmission mode under the IR microscope.
(b) FTIR spectra of contaminated fingerprints deposited on various substrates and enhanced additionally with three powders analyzed in transmission mode or reflection mode under the IR microscope.
(c) FTIR spectra of pure adhesive tapes to check their transparency in IR light.
(d) FTIR spectra of lifted-off (with adhesive tapes) contaminated fingerprints dusted with powders measured by means of the ATR objective.

All FTIR spectra were collected within the spectral range of 600–4,000 cm^{-1} by averaging 600 scans per point at 4-cm^{-1} spectral resolution using a Bruker Hyperion 2000 IR microscope equipped with a liquid-nitrogen-cooled mercury cadmium telluride detector. The scanner velocity was set to 20 kHz. Experiments were performed in either transmission mode or reflection mode, depending on the substrates; a 20× ATR germanium objective was used to analyze fingerprints lifted off by adhesive tapes. To identify the particle of interest, the ATR objective was used in visual mode, followed by switching to IR mode. During analysis, the particle was contacted by the tip of the germanium crystal (100 μm in diameter). With this approach, IR spectral information was gathered only from the surface layer of the sample to a depth of approximately 0.5 μm. As intimate contact between the sample and the crystal is necessary when working with an ATR objective, the same pressure was applied to the germanium crystal during background and sample analysis.

The spectra were divided by the relevant background spectra to give a ratio of the transmittance (T) output. All spectra were presented in absorbance units (A=-log T) (for transmission or reflection experiments) or in ATR units (for ATR experiments) as a function of wavenumber (the number of waves per centimeter). For ATR mode, a single-channel spectrum of the germanium crystal was taken as a background; for transmission or reflection mode, backgrounds were collected from an area of the substrate which was free of contamination.

Results and discussion

FTIR spectra collected for exogenous substances used as contamination in latent fingerprints contain their own sets of various peaks as a function of wavenumber [cm^{-1}] which can be used to distinguish one substance from another. The relative peak height and the spectral position provide a unique characterization for any molecule that is IR-active. Reference spectra for all pure exogenous materials used in this work are presented in Fig. 1. They are in agreement with spectra

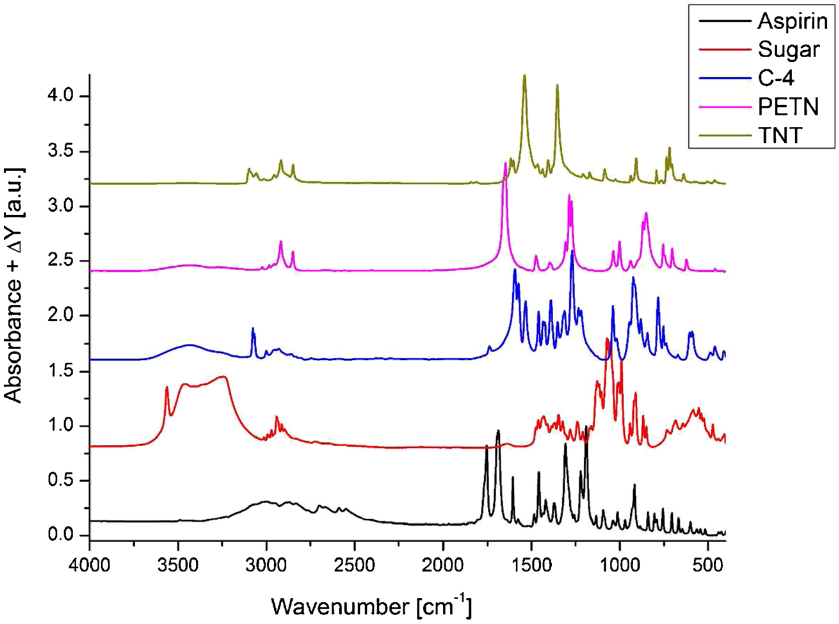

Fig. 1 Fourier transform IR (FTIR) spectra collected for pure exogenous substances. Subsequent spectra were shifted on the vertical axis by ΔY for improved readability. *PETN* pentaerythritol tetranitrate

available in the database [19], and hence they were used as our own reference library for further analysis.

This study is mainly focused on the 600–1,800-cm^{-1} spectral region, where the signature region is included and characteristic groups absorb, thus allowing unambiguous detection and identification of exogenous substances within fingermarks in further analysis.

In the powdered fingerprints it was quite difficult to visually differentiate between the particles of contamination and the powder, because the powder layer made the exogenous material indistinct. However, the particles were easily distinguishable by their FTIR spectra. FTIR spectra collected for exogenous substances within a latent fingerprint deposited on various substrates and developed with gray, black, or white powder available in this work are marked by high similarity to the respective reference spectrum. There were no significant differences among them, except for the peak intensities; as in fingerprints the amount of contaminated material is very small, so the intensities of the characteristic lines of the contaminants (exogenous substances) are lower than those in the reference spectra. Figure 2 shows a representative example of a FTIR spectrum obtained for aspirin in a powdered (gray powder) fingerprint which was deposited on a mirror; for comparison, FTIR spectra for aspirin collected from nonpowdered fingerprints and pure aspirin for reference purposes are also shown.

After the experiments, FTIR spectra were analyzed using OPUS 6.0 [20] supplied by the manufacturer of the spectrometer. This analysis included a baseline correction, normalization procedures, and peak-picking analysis (qualitative analysis) as well as preliminary statistical interpretation.

All spectra collected from enhanced contaminated fingerprints were searched against our own library (containing reference spectra) by using the IDENT method available in OPUS. The aim of IDENT analysis was to determine the differences between a test spectrum and the reference spectra from the library. The smaller the spectral distance, the better the two spectra match. The results are presented as a hit quality (HQ) value (proportional to spectral distances) within the range from 0, denoting perfect match, to 2, denoting no match. A low value of HQ (around 0) for the FTIR spectra in Fig. 2 reveals a high similarity of these spectra to the FTIR spectrum for pure aspirin. For all FTIR spectra collected for contaminated latent fingerprints dusted with powders, HQ values were found within the region from 0.1 to 0.3. This

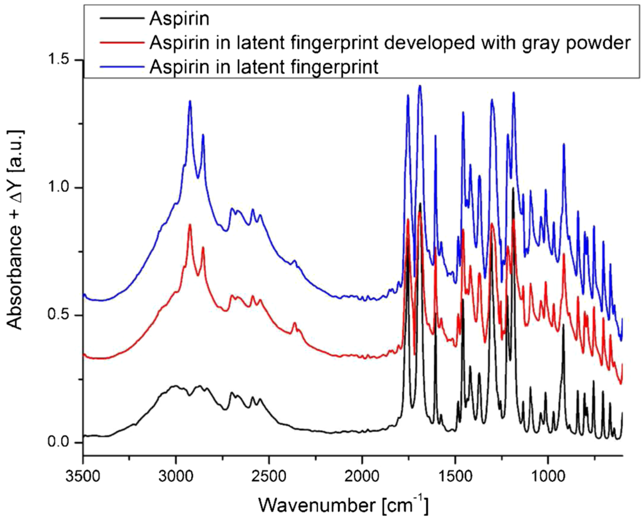

Fig. 2 FTIR spectra collected for an aspirin-contaminated fingerprint deposited on a mirror and additionally enhanced by the gray powder. The FTIR spectrum for pure aspirin is presented as a reference. Spectra were shifted on the vertical axis by ΔY for improved readability

shows the identification of exogenous substances in all spectra with a high degree of certainty.

At a real crime scene, the most challenging fingerprints to analyze are those deposited on substrates at hard-to-reach places; the only option to examine them is by their transfer using special lifters. To check the lifter "transparency" in IR light and compatibility with FTIR spectroscopy, experiments in transmission mode were performed. As can be seen in Fig. 3, BVDA black Gellifter is totally nontransparent in the mid-IR region. For Sirchie hinge lifter, IR light is mainly blocked in the region of interest (600–1,800 cm^{-1}). Spex C-lifts seems to be transparent in the region from 1,750 to 4,000 cm^{-1}; however, this foil has also some limitations—a large number of its own lines can cover those spectral peaks which are characteristic of contaminants in latent fingerprints. A useful alternative for analysis of powdered fingerprints lifted off by adhesive tapes was the ATR objective. As this part of the experiment was crucial in our work - precise analysis of 24 samples was done, three different tapes were used for lifting off latent fingerprints contaminated by three explosive materials and enhanced by three different powders. For Spex C-lifts and Sirchie hinge lifter, nine samples were prepared (e.g., Spex C-lifts "collected" samples contaminated by C-4 or PETN or TNT fingerprint dusted with gray, black, or white powder). For BVDA black Gellifter, six samples were prepared (this tape was not used to lift off contaminated latent fingerprints dusted with black powder). As the analysis for each lifter was done in an analogous way, for clarity, our further discussion is focused on the results obtained with one of the tapes—Spex C-lifts.

Although FTIR spectroscopy is a powerful technique for analysis of various substances, a significant amount of processing is required to extract useful information from a large number of raw spectra. Chemometric methods have the ability to analyze the vast spectral distribution and thoroughly discriminate among spectra of different samples that show very small changes. Multivariate statistical methods are based on the idea that many nonselective variables must be taken into consideration instead of only one variable, and then ultimately combined in a multivariate model [21] which helps in analysis, especially in cases where large amounts of data are generated. The most frequently used chemometric methods in research are hierarchical cluster analysis (HCA) and principal component analysis (PCA) [22].

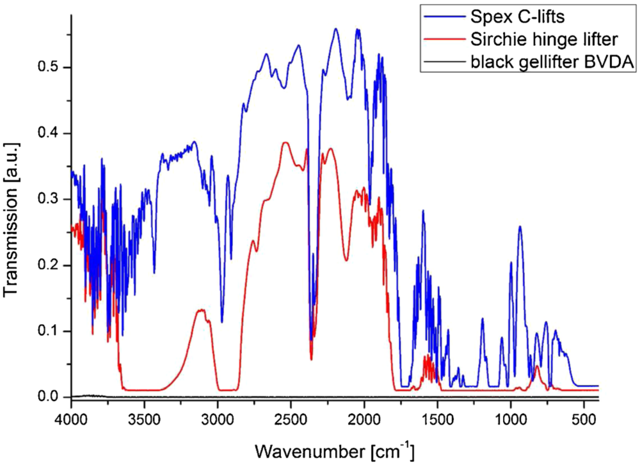

Fig. 3 FTIR spectra collected in transmission mode for lifting foils typically used at a crime scene

The R platform for statistical computing and graphics [23] was used in the calculations of the statistical methods presented here. Additionally, Chemospec [24] and Lattice [25] libraries were loaded in order to perform analysis and visualize the results. Figure 4 presents the means of FTIR spectra and their standard deviations for fingerprints contaminated by C-4, PETN, or TNT, enhanced by gray, white, or black powder and lifted off by Spex C-lifts. Reference spectra collected for C-4, PETN, and TNT are presented in the right panel for visual comparison.

The first attempt in our data evaluation was performed using HCA. As all experiments were conducted in a controlled way, we knew which explosive material had been used for fingerprint contamination. Therefore, all FTIR spectra were preliminarily divided into three groups denoted as C-4, PETN, and TNT, and additionally into three subgroups depending on the type of powder used, e.g., C-4_white, C-4_gray, and C-4_black.

For HCA, each spectrum is treated as a point in *n*-dimensional measurement space. HCA assesses the similarity between spectra by measuring the distances between the points in the measurement space. Spectra within the same group are more similar to each other than spectra from different groups. As can be seen in Fig. 5, the number of calculated clusters strongly depends on the value of similarity (heterogeneity—vertical axis). For a similarity equal to 2.5, six clusters can be recognized. The first and second clusters contain spectra collected for latent fingerprints contaminated by C-4, and additionally enhanced with gray powder (first cluster) or black or white powder (second cluster). The fourth cluster contains almost all spectra taken for latent fingerprints contaminated with TNT and dusted with three different powders (gray, black, or white). Only one spectrum (where TNT was used as a contaminant; enhancement was done with black powder) belongs to the third cluster. The fifth and sixth clusters are formed by FTIR spectra measured for samples contaminated by PETN, and additionally enhanced with black powder (the fifth cluster) or gray or white powder (the sixth cluster).

A lower value of similarity provides a higher number of clusters, leading to a rather unclear classification. As in our case three explosives were used for sample preparation, three distinctive clusters were expected as a final result of HCA. To find a more reliable technique to detect clusters in multivariate data sets, PCA was used for further evaluation.

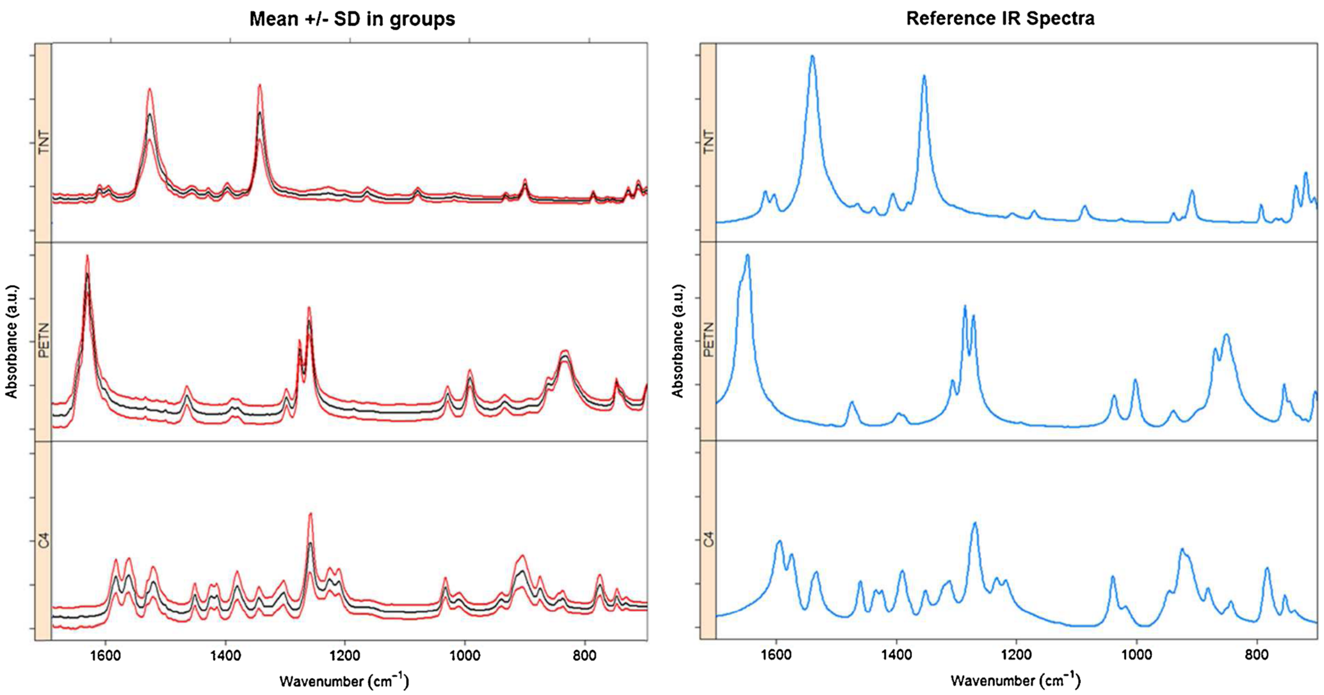

Fig. 4 Means of FTIR spectra and their standard deviations (*SD*) for fingerprints contaminated by C-4, PETN, or TNT, enhanced by gray, white, or black powder and lifted by Spex C-lifts. Reference spectra collected for C-4, PETN, and TNT are presented in the *right panel* for visual comparison

PCA transforms the original measurement variables into a small number of new variables called principal components (PCs) that maximize the explained variance in the retained components.

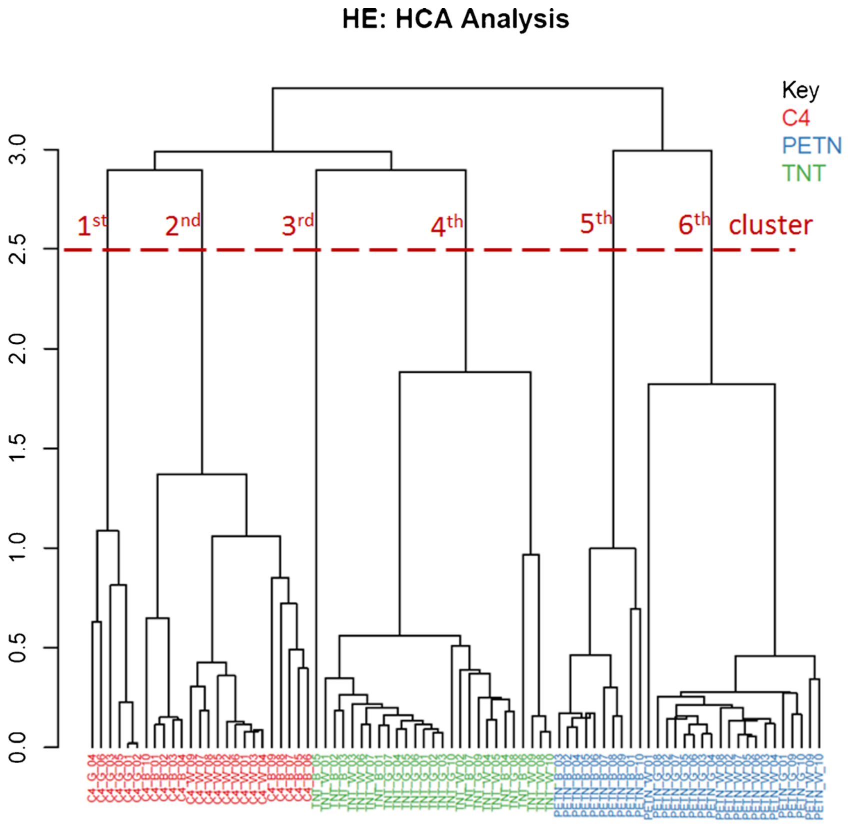

Fig. 5 Hierarchical cluster analysis (HCA) of FTIR spectra of fingerprints contaminated by C-4, PETN, or TNT, dusted with gray, black, or white powder and additionally lifted off by Spex C-lifts. The *vertical axis* represents the value of similarity between FTIR spectra used in the analysis. The spectra are colour-coded according to key includes as an *inset*

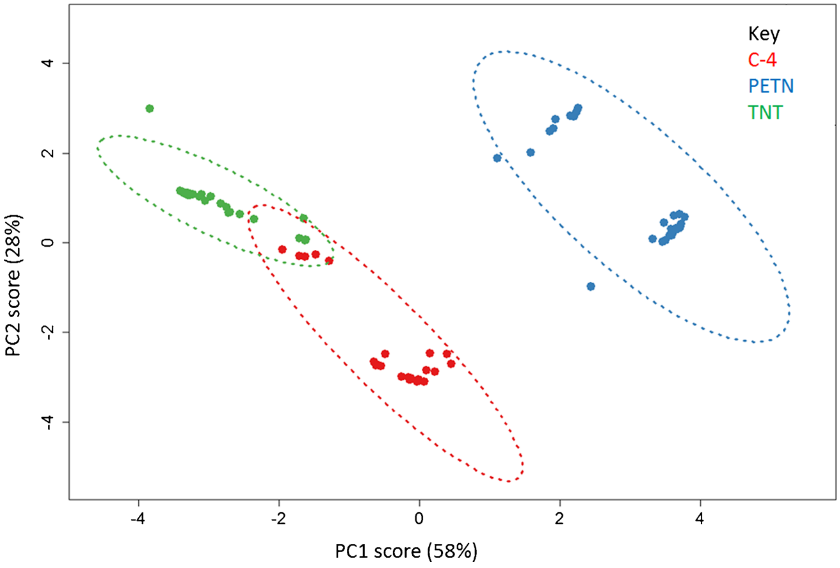

Fig. 6 Principal component (*PC*) analysis (PCA) of FTIR spectra of fingerprints contaminated by C-4, PETN, or TNT, dusted with gray, black, or white powder and additionally lifted off by Spex C-lifts

With the data plotted in a coordinate system defined usually only by the two or three largest PCs, it is possible to find similarities and differences among spectra. Score plots reveal patterns in the data, including clusters, trends, and outliers. In such plots, each point represents one spectrum (sample); points closely located denote similar spectra, i.e., samples with similar characteristics, whereas distant points suggest different spectra.

Figure 6 depicts the resulting score scatter plots using the first and second PCs for FTIR spectra collected for latent fingerprints contaminated by C-4, TNT, or PETN, enhanced by gray, white, or black powder and lifted off by one of the tapes—Spex C-lifts. With the use of the first two factors, 86 % of the total variance is described. Three ellipses corresponding to a 95 % confidence interval range attempt to group points for C-4, PETN, and TNT. However, in Fig. 6, the ellipses for C-4 and TNT partially overlap. Additionally, existing groups are divided into subgroups—two for PETN, TNT, and C-4—which correspond to the conclusion from HCA where more clusters were present than expected.

To obtain more consistent and conclusive results, we decided to perform statistical analysis separately for each powder. In our opinion, the results obtained from HCA provide better results for white and gray powder, the spectra are linked into three clusters—C-4, TNT, and PETN—at a lower similarity value than when all spectra collected for contaminated and dusted fingerprints underwent HCA together, which can be seen in Fig. 7. This may result from the fact that use of the particular powder has a significant influence on the measured FTIR spectra. Analysis of the results performed on spectra divided into groups where the type of powder was a main separator reveals that differences among FTIR spectra collected for various explosives are more evident in the case of gray or white powder. Black powder seems to be a rather worse separator, which can be understood by taking into account that this powder contains mainly black carbon or charcoal, and

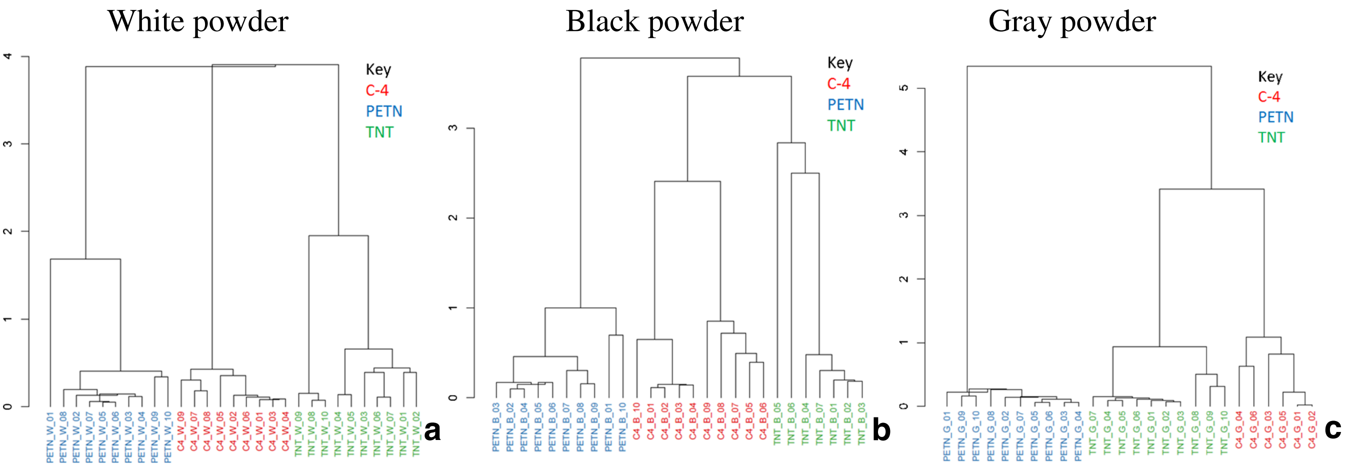

Fig. 7 HCA of FTIR spectra of fingerprints contaminated by C-4, PETN, or TNT, dusted with white (**a**), black (**b**), or gray (**c**) powder and lifted by Spex C-lifts

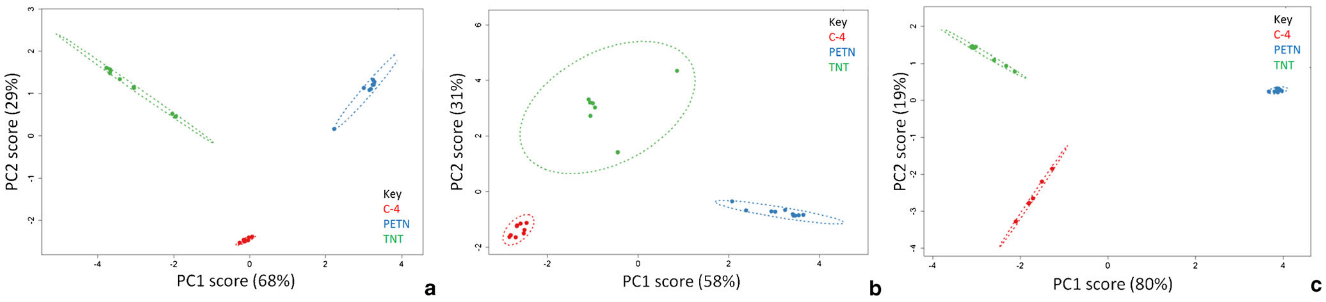

Fig. 8 PCA of FTIR spectra of fingerprints contaminated by C-4, PETN, or TNT, dusted with white (**a**), black (**b**), or gray (**c**) powder and lifted by Spex C-lifts

hence its own lines can contribute to the final FTIR spectra of exogenous substances.

PCA performed for each powder individually produces very well separated groups for C-4, PETN, and TNT. Figure 8 depicts the resulting score scatter plots using the first and second PCs. For the first two factors, when white powder is used, 97 % of the total variance is described, for black powder 89 % of the total variance is described, and for gray powder 99 % of the total variance is described.

As mentioned earlier, analogous analyses were performed for measurements using two different tapes: BVDA black Gellifter and Sirchie hinge lifter. Despite the fact that these tapes are either totally nontransparent in the mid-IR region (BVDA black Gellifter) or IR light is mainly blocked in the region of interest (600–1,800 cm^{-1}) (Sirchie hinge lifter), the application of an ATR objective in these studies made possible collection of satisfactory FTIR spectra. PCA performed for FTIR spectra divided prior to analysis into three sets, depending on the type of powder used, revealed the existence of three groups (PETN, TNT, and C-4); for the group of gray or white powders, almost 100 % of the total variance was described using only two PCs for both BVDA black Gellifter and Sirchie hinge lifter. For the black-powder group, nearly 90 % of the variance was described for FTIR spectra of fingerprints lifted off by Sirchie hinge lifter.

To sum up, we can say that the distinction of FTIR spectra obtained for contaminated fingerprint samples developed with three powders and lifted off by various tapes is very good, especially where PCA was performed separately for various powders.

The only prerequisite from the perspective of FTIR analysis is the use of the ATR objective, which allows the collection of spectra even in the case of nontransparent or partially transparent materials.

Conclusions

Typical analysis of fingerprints is based on the identification of a suspected person by finding the exact match between analyzed patterns of ridges collected at the crime scene and those stored in the database. However, a fingermark itself can serve as a mine of information as it always contains a plethora of substances which can add valuable clues to a criminal investigation. FTIR spectroscopy is a powerful technique being used in many applications, including the analysis of contamination in latent fingerprints. In this work, we have focused on the analysis of exogenous substances deposited within the latent fingerprint developed with commercially available powders and lifted off by foils provided by SPF.

The FTIR spectra obtained for the substances in powdered fingerprints were of comparable quality to spectra obtained for the substances deposited in nonenhanced fingerprints.

As shown, the application of powders did not prevent the collection of satisfactory FTIR spectra for the residue particles. However, the time taken to locate the exogenous material within fingerprints was increased owing to the physical presence of other substances.

In previous work [18], we proved that a Mylar foil can be used as a lifting medium, and this allowed analysis of contaminated fingerprints deposited earlier on various nonporous and porous substrates (cardboard, door, table) which are difficult to access. In this work, we used lifters custom-designed and widely used by SPF to transfer latent fingerprints from objects which can not be analyzed directly.

Use of these special lifters for relocation of the contaminated latent fingerprints enhanced with powder showed again that successful identification of exogenous materials was still possible on the basis of their unique FTIR spectra. We proved that BVDA black Gellifter, Sirchie hinge lifter, and Spex C-lifts are good lifting media and can be used in FTIR analysis when an ATR objective is used. Nowadays, ATR is the most widely used FTIR sampling tool, allowing analysis with no sample preparation, which greatly speeds up analysis. However, it is necessary to remember that using an ATR objective has some drawbacks: in experiments, direct intimate contact between the particle and the ATR crystal is necessary, during analysis the particle can stick to the crystal and the sample can be partially destroyed, and the crystal must be cleaned after every spectrum is taken. Despite such drawbacks, we have to stress that in many cases analysis of samples with this objective is irreplaceable. In our work—as we showed earlier—the choice of lifting tape could have potential implications for the unambiguous identification of exogenous material within a latent fingerprint. On the basis of FTIR spectra collected in transmission mode for available lifters, we can conclude that positive identification could be potentially made only with the use of Spex C-lifts. Use of an ATR objective removes the problems connected with the use of a proper substrate and opens the way to analysis of unlimited sample types.

FTIR spectroscopy is an extremely reliable and well-recognized fingerprinting method—many substances can be characterized, identified, and also quantified. FTIR spectromicroscopy can be used to detect exogenous substances deposited within latent fingerprint, providing evidence of what was handled or touched by the person whose fingerprints were found at the crime scene.

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