DETECTION OF VISIBLE AND LATENT FINGERPRINTS BY MICRO-X-RAY FLUORESCENCE

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ABSTRACT

Numerous methods are available to forensic scientists for detecting fingerprints in which the prints are treated with various agents to enhance the visual contrast between the print and the surface. In the present work, the spatial elemental imaging capabilities of micro-X-ray fluorescence (MXRF) were used to visualize fingerprint patterns based on inorganic elements present in the prints. A major advantage of using MXRF is that the prints are left unaltered for other analyses such as DNA extraction or for archiving. Most of the fingerprints which were examined were imaged from the potassium and chlorine present in the print residue. Among the various prints studied, lower count rates were also observed in the elemental maps of Ca, Al, Na, Mg, Si, P, S, and the X-ray source scatter. A sebaceous oily fingerprint left by one subject was successfully imaged by MXRF, but sebaceous prints left by a different person were undetectable, indicating print elemental composition may be person and/or diet dependent. Prints containing substances that might be found in real world cases were also visualized including sweat, lotion, saliva, and sunscreen.

INTRODUCTION

Using traditional visual contrast enhancement methods, fingerprints present on certain surfaces can sometimes be difficult to detect including some fibrous papers, textiles, woods, leather, plastic, adhesives, and human skin[1,2]. Prepubescent children’s fingerprints are particularly difficult to detect over time[3] because they do not contain sebum and consist of relatively volatile free fatty acids[4], and prints on dark or multicolored backgrounds can be problematic due to inadequate contrast with the surface color[5,6]. Thus, imaging fingerprints based on elemental composition by MXRF could prove beneficial to detecting these problematic types of prints.

In MXRF a specimen is irradiated with a microfocused X-ray beam, and fluorescence X-rays emitted from the irradiated spot are detected as a function of location on the specimen. By moving the specimen surface relative to a stationary X-ray beam, a two dimensional elemental distribution image is collected by monitoring variations in elemental X-ray intensity versus position. These intensity differences correspond to relative differences in concentration of a given element dispersed across the specimen[7].

Fingerprints contain inorganic elements as well as organic compounds[1]. Therefore, they can potentially be imaged by MXRF based on inorganic elements present along the print pattern (friction ridges). To the best of the authors’ knowledge, only one XRF study of human
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fingerprints has been published[8]. In that work the authors used grazing angle XRF to examine the elemental composition of various forensic samples including fingerprints. In the current work, MXRF was used both to collect elemental spectra and to image visible and latent fingerprint friction ridges. Some examples where MXRF may prove uniquely valuable include young children’s prints, fingerprints on dark, multicolored, or porous surfaces, and prints containing certain residues such as saliva, gunpowder, or sunscreen.

EXPERIMENTAL

Instrumentation. Two commercial MXRF instruments were used in this work. Most of the specimens were examined with a Kevex Omicron using a 100 W molybdenum X-ray anode and a liquid nitrogen cooled Si(Li) detector. To greatly increase elemental count rates and decrease image collection times, the instrument was retrofitted with a monolithic polycapillary optic designed by X-ray Optical Systems, Inc. In this instrument the optic produced an analysis spot ~190 μm in diameter measured at the tungsten M5-N6,7 (Mα) peak energy. (The IUPAC nomenclature for labeling XRF elemental lines is used here[9].) To improve light element detection limits, data were collected while flushing the analysis chamber with helium. All spectra and images were acquired using a source current resulting in a maximum dead time of 50% (exact power settings specified for each specimen below). Spectra were collected from several spots on each specimen, and relative intensity images were acquired of any elements detected in the spectra as well as of other elements that could potentially be detected in fingerprints. For all but a sunscreen print specimen, elemental intensity images were collected using the K-L2,3 (Kα) peaks for Na, Mg, Al, Si, P, Cl, K, Ca, and Fe. The source Mo scatter L3-M4,5 (Lα) peak was also used for imaging. The resolution of the images discussed here was 256 x 256 pixels.

An EDAX Eagle II XPL MXRF instrument with a 40 W rhodium anode and a liquid nitrogen cooled Si(Li) detector was used to examine one of the specimens discussed here. This system contained a monolithic polycapillary optic capable of producing a focal spot ~40 μm FWHM at the molybdenum K-L2,3 peak energy. The specimen was examined under vacuum. All elemental images were collected using a source power setting of 20 kV and 1000 μA resulting in a net count rate of ~10,000 cps. The same elemental mapping process used with the Kevex system was also used with the EDAX instrument.

Specimen preparation. Two subjects supplied the fingerprints examined in this work. All prints made on polypropylene were prepared using Chemplex 4 μm polypropylene (Prolene®).

Sebaceous print. Subject #1 left a fingerprint on polypropylene after touching the forehead. The subject’s hands were not washed prior to making the print. The specimen was imaged with the EDAX instrument. Elemental intensity images were collected using the K-L2,3 peaks for Na, Mg, Si, S, Cl, K, Ca, Ti, Mn, Fe, and Cu. The source Rh scatter L3-M4,5 peak was also used for imaging. Each elemental image consisted of 512 x 400 pixels corresponding to an area from the middle of the fingerprint. The intensity collection time per pixel was 200 msec.

Perspiration. Subject #2 wore a latex glove for ~2 hrs to induce perspiration and made a fingerprint on polypropylene. The subject’s hands were not washed prior to perspiring and making the print. The specimen was imaged using the Kevex instrument operated at 21 kV and
3 mA. The elemental images were acquired from a 17.4 mm x 17.4 mm region of the specimen. The elemental intensity collection time per pixel was 1.06 sec.

**Lotion.** Subject #2 applied Eucerin lotion to washed and dried hands and rubbed into the skin until no lotion was visible. A fingerprint was then left on polypropylene. The specimen was imaged with the Kevex instrument using 15 kV and 3 mA. Each elemental image corresponded to a 22 mm x 24.7 mm region of the specimen. The elemental intensity collection time per pixel was 1.22 sec.

**Saliva.** Subject #2 left a fingerprint on polypropylene after licking a finger. The subject’s hands were washed prior to licking the finger. The specimen was imaged with the Kevex instrument using source power settings of 15 kV and 3 mA. Each elemental image corresponded to a 24.6 mm x 24.6 mm region of the specimen. The elemental intensity collection time per pixel was 906 msec.

**Sunscreen.** After washing the hands with soap and tap water, subject #2 applied sunscreen (Neutrogena sensitive skin SPF 30 containing 9.1 % TiO$_2$) and rubbed it into the hands until no sunscreen was visible. A fingerprint was made on a piece of black paper cut from a two pocket-type presentation folder. A spectral analysis of this paper indicated that it contained low levels of Al, Si, Ca, and K. The specimen was imaged with the Kevex instrument in air at 21 kV and 3.1 mA, and the Ti K-L$_{2,3}$ and Mo L$_{3-M_{4,5}}$ scatter peak relative intensity images were collected. Each elemental image corresponded to a 17.6 mm x 17.6 mm region of the specimen. The elemental intensity collection time per pixel was 805 msec.

**RESULTS AND DISCUSSION**

There are numerous advantages to detecting fingerprints by MXRF. It is a nondestructive technique, and minimal specimen preparation is required since elements present in the fingerprints are detected. The surface color is irrelevant, so prints could potentially be detected on dark or multicolored surfaces that can be troublesome for traditional contrast enhancement methods. MXRF is also capable of both imaging print friction ridges and simultaneously providing chemical information that should be beneficial to a forensic analyst.

There are also limitations to detecting fingerprints by this method. Some prints will not be detected due to the presence of inorganic elements at trace levels below the typical MXRF ppm detection limits. One would need to know the approximate location of a print on a surface to examine it in an MXRF instrument. However, if a partial print could be located by conventional powder or chemical developers, a complete print might be detectable with MXRF based on its elemental constituents. Also, the surface of commonly handled items such as a firearm handle or a book of matches would be logical first choices for examination. A large area could even be imaged quickly at low lateral resolution, and a slower, high resolution image could be collected from any region that exhibited relatively higher count rates of a given element. Large objects unable to fit in the spectrometer would also be a problem, but a commercial instrument currently available (the EDAX Eagle XXL) can accommodate specimens up to ~0.5 m$^2$ in area, and there is no physical limitation preventing building systems to hold even larger specimens. A print could even be lifted with tape and examined on the tape. A surface containing a high concentration of an element detected in a print would also be a problem, but confocal MXRF[10,11] should be able to circumvent this issue by analyzing mainly the print residue on the surface and eliminating a majority of the substrate signal.
Sebaceous and perspiration prints. Print friction ridges were evident in the chlorine image collected from an oily sebaceous print left by subject #1 after wiping the forehead. A less pronounced friction ridge pattern was also present in the potassium and sulfur images. (The sulfur possibly originated from amino acids or sulfur-containing soap or shampoo residue present on the skin.) Multiple prints made by subject #2, however, were undetectable. Thus, the elemental composition in fingerprints may be person and/or diet dependent, but more subjects need to be studied to confirm this.

Sebaceous fingerprints consisting mainly of oils, amino acids, and other organic compounds are generally the most difficult to detect with MXRF due to sub-microgram quantities of inorganic constituents typically present[1]. However, sebaceous prints were easily detected after treatment with inorganic agents including iron citrate powder and RuO$_4$ vapor and imaging the Fe K-L$_{2,3}$ and Ru L$_{3}$-M$_{4,5}$ peaks respectively. Salts such as NaCl and KCl excreted in sweat and inorganic residue present on the hands after touching surfaces can also aid in detecting sebaceous prints. Friction ridges could be seen in the chlorine (figure 1) and potassium images acquired from a print left by subject #2 after perspiring heavily. The outlying spots were due to chlorine present in a marker used to outline the location of the print. Subtle ridges were also found in the silicon, sodium, and molybdenum scatter images. Presumably the sodium image was less prominent than the potassium image due to the Si(Li) detector’s poor sensitivity for sodium, and the specimen could not be run under vacuum when using the capillary in the Kevex instrument.

![Figure 1. Chlorine K-L$_{2,3}$ image from a print made on polypropylene after perspiring.](image)

Lotion. Prominent friction ridges were present in both the chlorine (figure 2) and potassium maps. The bright line on the edges of the image was due to chlorine present in a marker used to outline the location of the print. Weaker ridge detail was also observed in the sodium, magnesium, aluminum, calcium, and molybdenum scatter maps. Interestingly, only low levels
of magnesium and aluminum were detected in a point spectrum collected from a film of dried lotion on polypropylene. Thus, the substantial amounts of potassium and chlorine found in the fingerprint did not originate from the lotion itself. This would seem to indicate that the lotion served as a carrier for transferring any potassium and chlorine present on the hands or in the outer skin layers to the surface.

Figure 2. Chlorine K-L\textsubscript{2,3} image from a lotion-containing print made on polypropylene.

**Saliva.** Because the organic components of young children’s fingerprints volatilize over time, identifying fingerprint patterns from saliva residue would be valuable in missing child cases. About half of the friction ridges were observed in subject #2’s fingerprint in the potassium, chlorine, and phosphorous MXRF maps due to saliva residue present on the finger. The entire print pattern was not observed due to excess saliva transferred to the surface in some spots. Multiple specimens were not studied in this preliminary work to try to achieve a better print, but in a real world case, a child touching a surface multiple times would likely leave some prints that had a fairly even distribution of detectable material.

**Sunscreen.** Prints containing sunscreen would be expected to be found in some real world forensic cases. Sunscreen residue consisting of only organic agents is not detectable by MXRF, but identifying sunscreen prints containing titanium or zinc oxide is straightforward. The latent print studied in this work was left on black paper and invisible, but the print friction ridges were very evident in the titanium image.

**Print longevity.** Since nonvolatile elements such as potassium are detectable by MXRF, a fingerprint should in theory be detectable indefinitely if left undisturbed. With contrast enhancement methods, however, some of the organic compounds present in a print (which are used for color treating a print) can volatilize or bleed into porous surfaces as a print ages. A print containing lotion was analyzed 7.5 months after first being imaged, and the friction ridges could still be detected easily in the chlorine and potassium maps.
Future directions. An area deserving further study is determining if certain people consistently generate prints that are detectable or undetectable by MXRF. Also, any correlations between diet and the ability to detect fingerprints will be examined. Efforts are underway to study prints treated with various XRF-detectable inorganic developers. The authors also intend to greatly improve the elemental signal to background using confocal MXRF which should minimize the substrate signal and background scatter. Use of a monochromatic X-ray source will also be examined to reduce the background.

CONCLUSION

The potential to detect fingerprints by MXRF was demonstrated. Although this method currently requires a priori knowledge of the general location of a print in order to examine it, there are a number of areas where MXRF could complement or supplement traditional contrast enhancement methods. Such areas include prints in missing child cases, prints on dark, multicolored, or porous surfaces, and prints containing special residues such as sunscreen or gunpowder. MXRF provides valuable chemical information in addition to a print pattern. It is also nondestructive. Thus, an examined print would remain intact for other analyses. In conclusion, MXRF is a valuable tool that complements the current list of methods available to forensic investigators.

REFERENCES