J Forensic Sci, Mar. 2005, Vol. 50, No. 2
Paper ID JFS2004263
Available online at: www.astm.org

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The Effect of Electron Beam Irradiation on Forensic Evidence. 1. Latent Print Recovery on Porous and Non-Porous Surfaces*

ABSTRACT: The recent use of the postal system as a means of delivering anthrax spores via several contaminated envelopes has led to the selective irradiation of mail. These as yet unsolved attacks and the U.S. Postal Service's decision to irradiate certain types of mail has led to some unexpected complications. The high doses of radiation required to destroy biological agents like anthrax are sufficient to induce damage to other materials present in the envelope. There have been reports of damage to many different items that have been subjected to irradiation, including paper, precious gems, plastic, computer discs, and electronics. However, few studies have examined the effect of such treatments on items of forensic interest. In this paper, the authors focused on the impact of the irradiation process on the ability to visualize latent prints. This experiment involved using several donors, substrates (both porous and non-porous), and visualization reagents. The results indicate that the irradiation process can have a detrimental effect on the success of certain visualization reagents.

KEYWORDS: forensic science, latent prints, fingerprints, latent print chemistry, mail irradiation, electron beam irradiation, biological agents

The as yet unsolved anthrax attacks in late 2001 brought about a radical change in the way mail destined for certain government offices in the Washington, DC metro area was to be handled. For the first time, Americans faced the possibility of their own mail becoming a delivery device for biological agents. In response to these terrorist acts, during which five people lost their lives and hundreds were exposed, the U.S. Postal Service (USPS) began to examine the possibility of exposing certain types of mail to various decontamination methods. Because of its widespread use and acceptance in the food decontamination industry, electron beam irradiation was ultimately selected for sanitizing the mail.

While obviously not a high priority in the immediate aftermath of the anthrax attacks, the prospect of unintended collateral damage to items subjected to the electron beam irradiation process was soon realized. The heat and radiation generated by the process induced changes in paper and with the plastic windows present in business envelopes. Some of these newly formed compounds were quite volatile, leading to complaints about disagreeable odors emanating from processed mail. In some cases, dramatic color changes were observed with certain papers and plastics. Documents produced with toner based printers and copiers were especially susceptible to the new processing technique. The heat generated during the processing caused the toner to soften and then fuse to the sheet above or envelope, causing the pages to become stuck together. Even the integrity of data on magnetic floppy discs and CD-ROM discs became subject to damage.

Anecdotal references to damage caused by the irradiation process have become more common since 2002. One report cited damage to two banknotes that had been shipped in plastic sleeves (1). The article reported that one of the notes had become discolored, and the plastic holders had been damaged to the point of becoming discolored, brittle, and even melted in some areas. Similar damage was also reported to have occurred to coins shipped through the USPS priority/insured mail (2). In this case, the encapsulated coins became severely discolored, and the plastic holder was warped and partially melted.

Although changes to paper and plastic items can be a nuisance, a more important problem lies in possible changes to materials of forensic interest. Would heat levels, estimated to be in excess of 150°C (~300°F) in certain cases (personal communication with J. Millhouse, 1 August 2003) be sufficient to alter items like fingerprints, writing inks, or other trace evidence? There have been only a few limited studies conducted to examine the impact of electron beam irradiation on trace forensic evidence. To date, most of the studies have focused on the impact of such treatments on certain writing inks (3,4). An additional study examined the effect of electron beam irradiation on archival museum materials (5). However, there appear to be no data available on the effect of such treatments on recovering latent prints.

Latent prints are a complex mixture of inorganic and organic compounds (6). Recent studies have detected as many as 346 compounds (of which 303 were positively identified) from sweat (7,8). It is likely that some of these compounds certainly would be modified under conditions that produce temperatures as high as 150°C. The question is whether or not these changes would have any effect on the visualization of latent prints. Since different latent print visualization reagents target distinctly different components of sweat residue, it is not possible to make any general predictions. To address this issue, an experiment was designed to evaluate the irradiation effect on latent print recovery using several different donors, substrates, and visualization processes.

Methods and Materials

A total of 320 prints were tested and evaluated during this study. The prints were taken from five donors (four male and one female).

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* All references pertaining to specific manufacturers or their products do not imply endorsement by either the authors or the United States Secret Service.
Received 27 June 2004; and in revised form 18 Sept. 2004; accepted 19 Sept. 2004; published 2 Feb. 2005.

Four prints were taken from each donor for each visualization technique. Seven techniques were used on the porous samples, and nine techniques were used on the non-porous items. The deposited prints were allowed to age for at least one week prior to irradiation exposure. The prints were cut down the center, and one half was designated either as a control or as an irradiated sample. The random nature of this assignment limited the possible impact of left or right pressure bias when the prints were deposited.

The electron beam irradiation process was performed at a facility in Swedesboro, NJ. The exact radiation dose and conditions will not be specified for operational security reasons. As a point of comparison, typical irradiation dosages for food can vary from 1 kGy for fruit, 3 kGy for poultry, and up to 30 kGy for spices and seasonings (9). The unit of measurement for absorbed radiation dosages is the Gray, which is abbreviated Gy and is equivalent to 100 rads (10). The U.S. Environmental Protection Agency estimates that mail irradiation dosages are equivalent to approximately two million times that of a chest x-ray, which they claim is more than sufficient to kill any biological agent (11). It is important to note that it is nearly impossible to expose all of the samples to a specified dosage of radiation; rather, the USPS guarantees that all specimens will receive a minimum radiation dosage.

The samples in this study were shipped directly to the USPS facility in New Jersey and then shipped directly back to our laboratory. The normal timeframe for items sent through the mail that require irradiation is about eight days (12). The estimate includes at least two days for the mail to reach Washington, DC; one day to ship to the irradiation facility; one day to irradiate; one day to return to Washington, DC; and 2–3 days to unpack, air out, and spray the treated items to remove/suppress any odor. Additional time may be required for a particular agency to process and deliver the mail internally.

Two types of porous substrates were used: Xerox Premium Multipurpose 4024 Paper (216 mm × 279 mm, 75 g/m^2 or 8.5 in. × 11 in., 20 lb, 88 brightness) and white, blue lined paper (216 mm × 279 mm, 60 g/m^2 or 8.5 in. × 11 in., 16 lb, 50% recycled content, purchased from GSA, NSN 7530-01-124-5660). Three different types of non-porous substrates were used, including a clear polyvinyl chloride (PVC) based plastic, clear plastic Ziplock®-type bag, and a black colored polyethylene based garbage bag material.

The reagent formulas provided below are taken from standard operating procedures contained in the U.S. Secret Service Guide to Chemical, Optical, and Physical Methods for the Visualization of Latent Prints. The following reagents and techniques were used on the porous samples.

Ninhydrin (0.6% w/v)

The ninhydrin solution was prepared by mixing 120 g of ninhydrin with 1 L of absolute ethanol (200 proof). After the ninhydrin crystals had dissolved completely, this solution was added to 19 L of petroleum ether and mixed thoroughly. The samples were processed by dipping them into the ninhydrin solution and allowing the items to air dry. The samples were then placed into a humidity chamber (70°C, 60% RH) for approximately 30 min to accelerate the development process.

Diazafluoren-9-one (0.05% w/v)

The diazafluoren-9-one (DFO) solution was prepared by mixing 0.5 g of DFO with 100 mL of methanol. Once the DFO completely dissolved, 100 mL of ethyl acetate and 20 mL of glacial acetic acid were added to this solution. After the DFO had thoroughly dissolved in this solution, 780 mL of petroleum ether was added slowly. The resulting solution was then mixed thoroughly. The samples were processed by dipping them into the DFO solution and allowing the items to air dry. The samples were then placed into a dry oven set at 100°C for 20 min to accelerate the development process. Print fluorescence was evaluated using a Spex Crimescope CS-16. The excitation wavelength was set at 515 nm, and an orange Luma-Lite filter (with an approximate cut on wavelength of 535 nm) was used to view the fluorescence emission.

Physical Developer

The physical developer solution was prepared by mixing 900 mL of a redox solution, 50 mL of a 20% silver nitrate solution, and 40 mL of a detergent solution. The redox solution was prepared by mixing 30 g of ferric nitrate nonahydrate, 80 g of ferrous ammonium sulfate hexahydrate, and 20 g of citric acid monohydrate into 1 L of reverse osmosis/deionized (RO/DI) water. The detergent solution was prepared by mixing 4 g of n-dodecylamine acetate and 4 g of Synperonic N into 1 L of RO/DI water. The silver nitrate solution was prepared by mixing 20 g of silver nitrate into 100 mL of RO/DI water. The samples were processed by first placing them into a malic acid neutralization bath (prepared by dissolving 25 g of malic acid into 1 L of RO/DI water) for approximately 15 min. The samples were then placed into the working PD solution. The samples remained in the solution until ridge detail with good contrast was developed. The samples were dried by placing them between blotter sheets and then passing them through an Arkay Stat-Dri Professional Model ST-22 photographic drum style drier.

Iodine

Iodine fuming was done by grinding up iodine crystals to a fine powder and placing a small amount into the bottom of a sealed Ziplock® bag containing the samples. External heat from a hot air drier was used to accelerate the conversion of iodine powder to iodine vapor. The prints were allowed to stay in the bags for approximately 20 min. The liquid iodine technique was tried on a few of the samples but was ultimately not used because of intense background development, resulting from the presence of starch sizing in the two papers.

Black Powder (non-magnetic)

Non-magnetic black powder (Lightning Powder Company, Inc.) was used with a fiberglass fiber Zephyr® brush (Lightning Powder Company, Inc.) to develop prints on both paper substrates.

Black Powder (magnetic)

Magnetic black powder (Lightning Powder Company, Inc.) was used in conjunction with the magnetic wand applicator to develop prints on both paper substrates.

Silver Nitrate

The silver nitrate solution was prepared by dissolving 30 g of silver nitrate into 100 mL of RO/DI water and 900 mL of ethanol. The samples were dipped into the solution and then allowed to air dry. The samples were then exposed to short wave ultraviolet radiation (254 nm) to speed the development.

The following reagents and techniques were used on the non-porous samples.

Cyanoacrylate Ester (CAE) Fuming

The non-porous samples were processed with Instabond™S-100 brand ethyl cyanoacrylate liquid adhesive (NSN 8040-00-142-9193). After completing a purge cycle, the samples were placed into the Sandridge fuming chamber (manufactured by Mason Vactron). A dime-sized amount of the cyanoacrylate liquid was placed into an aluminum dish, which was then placed onto a heating plate within the chamber. The chamber door was then secured and the development process initiated. The chamber's relative humidity was set at approximately 100%, and the hot plate temperature was set at 140°C. The samples were fumed for approximately 20 min.

CAE Fuming/RAM

The samples were initially processed in the fuming chamber as described above. After fuming, the samples were dipped into a solution of the combination dye stain RAM (composed of rhodamine 6G, ardrox, and MBD). The RAM dye stain was prepared by mixing 3 mL of a rhodamine 6G stock solution (100 mg rhodamine 6G dissolved in 100 mL of methanol), 2 mL of Ardrox liquid dye, and 7 mL of a MBD stock solution (100 mg 7-(p-methoxybenzylamino)-4-nitro-2,1,3-benzoxadiazole (MBD) dissolved in 100 mL of acetone) and then adding 20 mL of methanol, 10 mL of isopropanol, 8 mL of acetonitrile, and 950 mL of petroleum ether. Print fluorescence was evaluated using a Spex Crimescope CS-16. The excitation wavelength was set at 495 nm, and an orange Luma-Lite filter (with an approximate cut on wavelength of 535 nm) was used to view the fluorescence emission.

CAE Fuming/BY 40

The samples were initially processed in the fuming chamber as described above. After fuming, the samples were dipped into a solution of the dye stain basic yellow 40 (BY 40). The BY 40 dye was prepared by mixing 2 g of basic yellow 40 into 1 L of ethanol. Print fluorescence was evaluated using a Spex Crimescope CS-16. The excitation wavelength was set at 455 nm, and an orange Luma-Lite filter (with an approximate cut on wavelength of 535 nm) was used to view the fluorescence emission.

Multi-Metal Deposition

The samples were processed by immersing them into the colloidal gold solution followed by a rinse with RO/DI water and then further amplified using a modified physical developer solution. The colloidal gold solution was prepared by combining 1 mL of gold trichloride solution (prepared by mixing 1 g of gold trichloride into 10 mL of RO/DI water) with 1000 mL of RO/DI water. Once the solution reached a gentle boil, 15 mL of a sodium citrate solution (prepared by mixing 1 g of sodium citrate into 100 mL RO/DI water) was added. The port wine colored solution was allowed to boil for an additional 10 min before adding 5 mL of Tween 80. The solution was mixed thoroughly and then allowed to cool to room temperature. Once the solution had reached room temperature, the pH was adjusted to 2.8 using aliquots of the citric acid solution (prepared by mixing 4.8 g of citric acid into 50 mL of RO/DI water). The modified physical developer solution was prepared by mixing 990 mL of a modified redox solution (prepared by dissolving 16 g of ferric nitrate nonahydrate, 44 g of ferrous ammonium sulfate hexahydrate, and 11 g of citric acid into 1000 mL of RO/DI water) with 10 mL of a 20% w/v silver nitrate solution. The samples were placed into the colloidal gold solution and agitated for approximately 30 min. After rinsing the samples with RO/DI water, the samples were placed into the modified PD solution for approximately 10 min. The samples were then rinsed again and allowed to air dry.

Vacuum Metal Deposition

Samples were placed into a vacuum metal deposition chamber (manufactured by Vacuum Metal Deposition, Costa Mesa, CA). The chamber was then pumped down to a pressure on the order of 10^{-3} torr. At that point, approximately 1–2 mg of gold (0.999 pure) was evaporated and condensed on the surface of the samples. Next, approximately 200 mg of zinc metal (0.999 pure) was evaporated and condensed on the surface of the samples. The chamber was then vented to atmospheric pressure, and the samples were removed for inspection.

Gentian Violet

The gentian violet solution was prepared by mixing 1 g of gentian violet into 1 L of RO/DI water and stirring the solution for approximately 20 min. The samples were processed by dipping them into the gentian violet solution and then allowing them to air dry.

Sudan Black

The Sudan black solution was prepared by mixing 15 g of Sudan black powder with 500 mL of RO/DI water and 1 L of ethanol. This mixture was stirred for approximately 10 min. The samples were processed by dipping them into the Sudan black solution and then allowing them to air dry.

Black Powder (non-magnetic)

Non-magnetic black powder (Lightning Powder Company, Inc.) was used with a fiberglass fiber Zephyr® brush (Lightning Powder Company, Inc.) to develop prints on all three non-porous substrates.

Black Powder (magnetic)

Magnetic black powder (Lightning Powder Company, Inc.) was used in conjunction with the magnetic wand applicator to develop prints on all three non-porous substrates.

Results

Porous Samples

The paper samples that had been subjected to irradiation were noticeably discolored. When compared side to side with the control samples, the irradiated samples had a faint yellow tint. Given the high temperatures caused by the treatment process, it is likely that decomposition of organic compounds in both the paper and latent print residue occurred. An extreme example of this is noted in Fig. 1, where the prints from one particular donor were partially charred during the irradiation process and were visible to the unaided eye without processing.

The irradiated samples processed with DFO showed a noticeable decrease in both the initial color and fluorescence intensity. In contrast to the control samples, many of the irradiated samples appeared to have no initial color development. These trends were generally true with the prints deposited from all five donors on

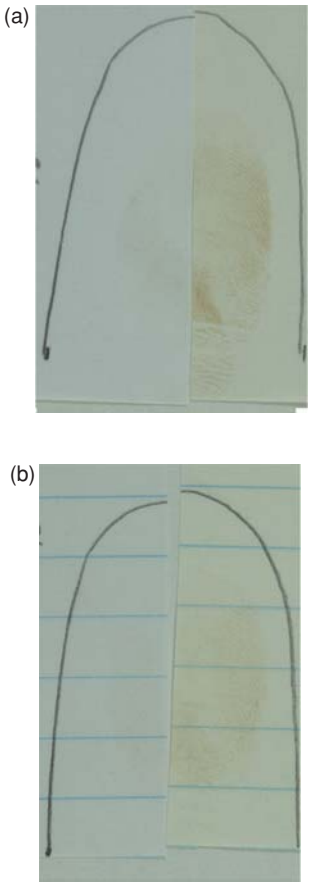

FIG. 1—*Two examples of latent prints that became visible after the irradiation process; in both cases the irradiated samples are on the right side.*

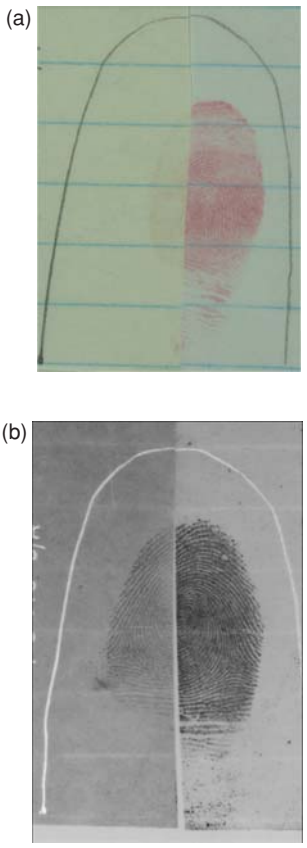

FIG. 2—*The difference in initial DFO color development between the irradiated samples (left) and the control sample (right) (a) and an example of the difference in DFO fluorescence intensity between the irradiated (left) and control (right) samples (b).*

both paper types. Figure 2 shows a comparison of both initial color and fluorescence intensity differences between the irradiated and control samples.

A similar trend was observed with the samples treated with ninhydrin. There was a noticeable decrease in the intensity of the Ruhemann's purple development observed with the irradiated samples. There were also differences noticed with different donors. The color intensity of the irradiated prints developed from donors 1 and 5 on both papers were consistently and significantly diminished compared to the control samples. In contrast, the irradiated samples developed from donors 2, 3, and 4 were only slightly less intense overall. In some instances the development was of comparable intensity, but the quality of the ridge detail was not as well defined. Figure 3 shows examples of these differences.

The samples processed with physical developer exhibited a different trend. Nearly all of the irradiated samples appeared to have better development than the control samples (regardless of donor and paper type). This trend is shown in Fig. 4. The slight yellow discoloration of the irradiated samples was noticeably diminished after processing with PD. It has been suggested that the compounds responsible for this discoloration are water soluble (5). The results obtained with PD were somewhat surprising since it is generally accepted that this reagent reacts with non-water soluble lipid compounds (13). If indeed that is what PD reacts with, it is somewhat surprising that the lipids present in the print residue survived the high temperatures generated during the irradiation process.

Once dipped into the silver nitrate solution, both papers tended to darken almost immediately. Because of this discoloration, further exposure to ultraviolet radiation was not done. As a result, the ridge detail that did develop appeared as an off-white color (due to the formation of silver chloride) against the darkened background. Further exposure would have darkened the background further and also converted the off-white colored ridge detail to a gray black color, diminishing the contrast even further. Of interest, the background discoloration of the irradiated samples was noticeably less intense than that of the control samples. Overall, irradiated samples that were treated with silver nitrate generally did not produce any ridge detail (see Fig. 5). In some cases an amorphous shaped print with no detail developed on the irradiated samples. The intensity and clarity of the ridge detail developed on the control samples varied by donor. Control prints from donor 5 produced the most consistent results. The development of other control samples ranged from fair to poor.

The ability of certain magnetic powders to develop relatively fresh prints on paper has been reported (14). Even though the prints were about a week and a half old by the time they were processed, an attempt to use powders was made. As expected, the use of both black non-magnetic and magnetic powder to visualize prints on the two paper surfaces generally did not produce good results. The magnetic black powder did produce some ridge detail on control prints from donor 5. Although some detail was developed on the irradiated samples, it was generally less intense and less well defined (see Fig. 6).

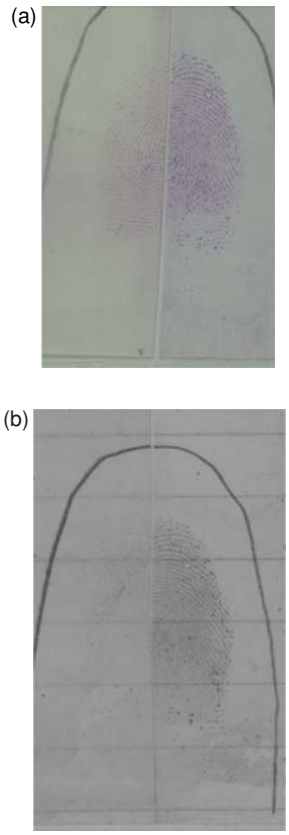

FIG. 3—*The difference in both intensity and color of the initial ninhydrin color development between the irradiated (left) and control (right) samples (a) and a similar example in which there is a noticeable difference between the irradiated (left) and control (right) samples (b).*

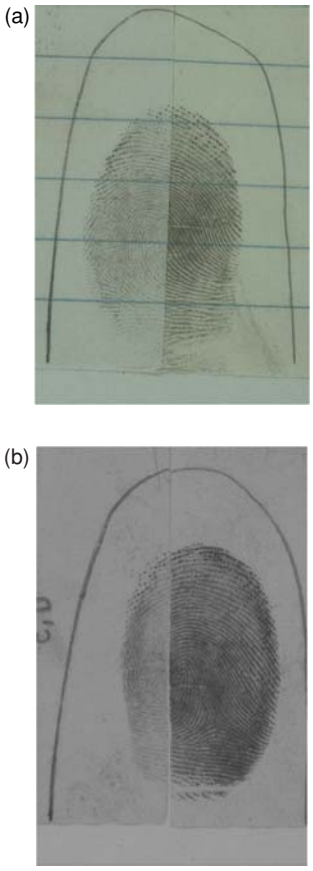

FIG. 4—*The difference between the intensity of PD development between the irradiated (right) and control (left) samples (a) and a similar example in which there is also a noticeable difference between the irradiated (right) and control (left) samples (b).*

Although not in common use as a reagent for detecting prints on paper today, iodine has been used since the 19th century for developing prints on porous surfaces. Overall, the iodine fuming results were not very good. The most consistent results were obtained from prints deposited by donor 3 on the Xerox photocopy paper. Figure 7 shows that development was comparable, but slightly less intense. In some cases a minor color change was observed.

Non-Porous Samples

The irradiation process appeared to have a more dramatic effect on the non-porous substrates (see Fig. 8). Whereas the porous samples had only a slight discoloration, the non-porous ones had damage ranging from severely discolored (PVC) to wrinkled (polyethylene trash bags). Overall, as with the porous samples, the ability of the various visualization reagents to develop latent prints on non-porous surfaces that had been irradiated was reduced significantly.

The non-porous samples processed only with cyanoacrylate ester fuming exhibited significant differences in intensity. Figure 9 shows two examples of prints from donor 5 that clearly illustrate this difference.

Since processing seldom ends at the CAE fuming stage, two laser dye stains were used to enhance two sets of CAE fumed prints. The first stain, RAM, is actually a combination of three different dyes. The other dye stain used was BY 40. Overall, the results were consistent with what was observed with the prints fumed only with CAE. In most cases, the intensity and quality of the ridge detail was significantly greater for the control samples than with the irradiated

FIG. 5—*The difference between the intensity of silver nitrate development between the irradiated (right) and control (left) samples.*

ones. Figure 10 shows examples of CAE fumed prints treated with both RAM and BY 40.

Most of the samples treated with gentian violet did not develop ridge detail. The PVC samples failed to produce ridge detail for the control or irradiated specimens. However, in the samples that did develop detail, the intensity and clarity of the development was comparable between the control and irradiated samples. Figure 11 illustrates some of the better examples of development on the polyethylene Ziploc® material.

FIG. 6—*An example of the minor differences between irradiated (right) and control (left) samples that have been treated with black magnetic powder.*

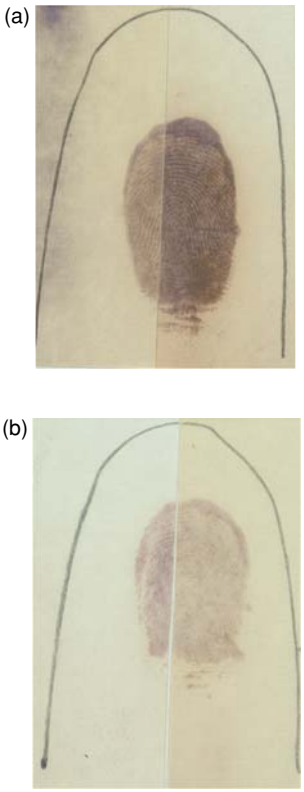

FIG. 7—*A difference between the intensity and color of iodine development between the irradiated (left) and control (right) samples (a) and a similar example in which a difference in color and intensity can be seen between the irradiated (right) and control (left) samples (b).*

Neither the control nor the irradiated samples that were treated with Sudan black produced any ridge detail. Background staining was quite extensive on the Ziploc® bag samples, and virtually no reaction was observed with the PVC material. These results were somewhat surprising considering that Sudan black has been recommended for non-porous surfaces like plastics (15).

As was the case with the samples treated with physical developer, the irradiated samples treated with multi-metal deposition appeared to have comparable to slightly better ridge development than the control samples (see Fig. 12). Interestingly, there were noticeable differences in intensity between the control and irradiated samples after the colloidal gold step. However, there must have been sufficient gold present in the irradiated samples to be

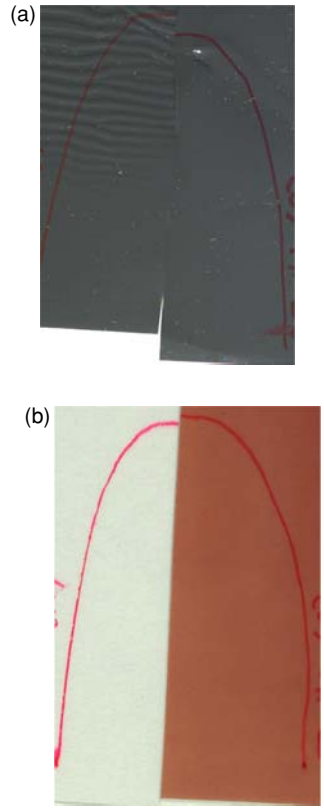

FIG. 8—*Side effects of the irradiation process: a wrinkling effect present in the irradiated trash bag sample (left) (a) and the discoloration that occurred with the PVC samples (right) (b).*

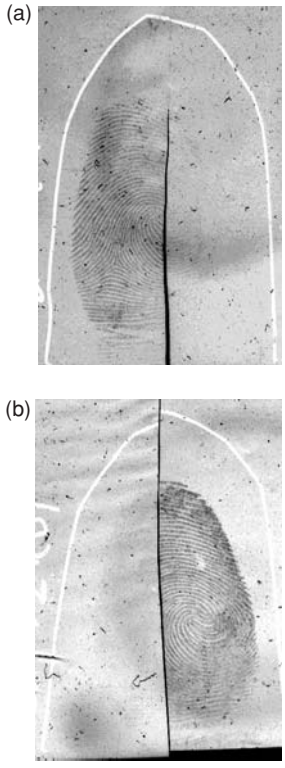

FIG. 9—*The difference in intensity of cyanoacrylate fumed development between the irradiated (right) and control (left) samples (a) and a similar example in which there is a difference between the irradiated (left) and control (right) samples (b); in both cases the images have been color reversed.*

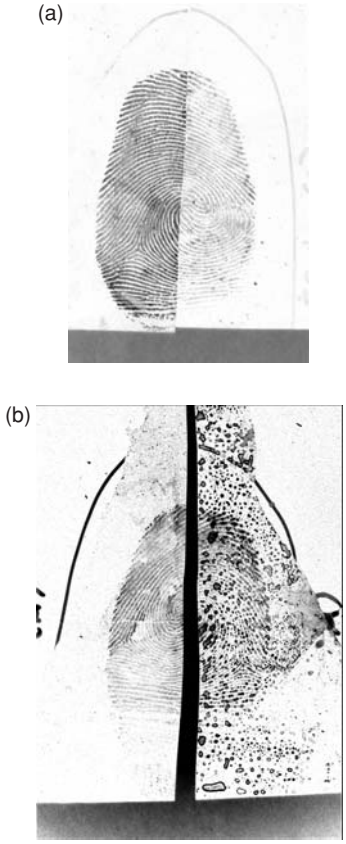

FIG. 10—*The difference in intensity of irradiated (right) and control (left) samples treated with cyanoacrylate fuming and RAM (a) and a similar example that shows the difference in intensity of irradiated (right) and control (right) samples treated with cyanoacrylate fuming and BY 40 (b); note the significant increase in background staining with the irradiated sample.*

FIG. 11—*An example of the minor differences between irradiated (right) and control (left) samples that have been treated with Gentian violet.*

amplified by the modified PD solution to the same extent as the control samples.

The samples processed with both magnetic and non-magnetic powders showed generally poor results overall (especially on the PVC). Samples processed with magnetic powder were generally better than those processed with regular black powder, with the exception of the PVC samples. However, there were clear differences noted between samples that had been irradiated and ones that were controls. Figure 13 shows two samples processed with regular powder.

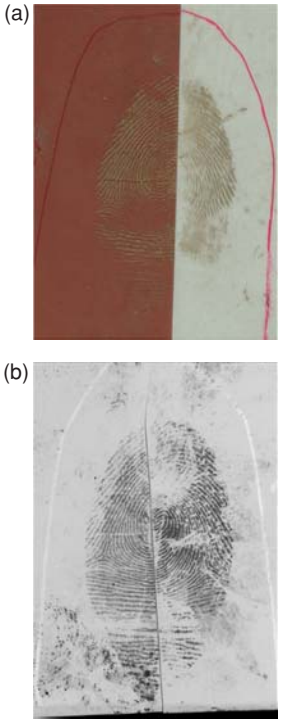

FIG. 12—*The minor difference in intensity between irradiated (left) and control (right) samples that have been treated with the multi-metal deposition reagent (a) and a similar example that shows the difference between irradiated (left) and control (right) samples (b).*

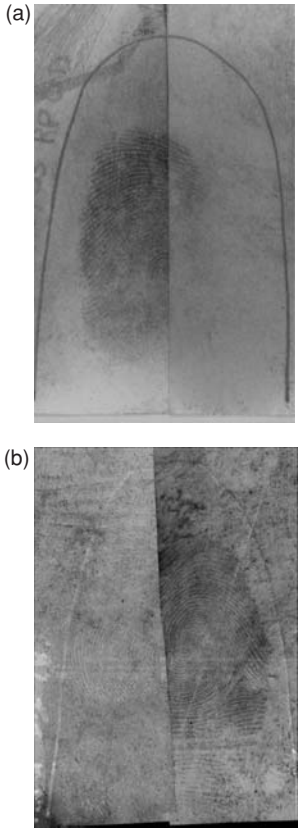

FIG. 13—*The difference in intensity between irradiated (right) and control (left) samples on Ziploc bag material that have been treated with standard black powder (a) and a similar example that shows the difference between irradiated (left) and control (right) samples on trash bag material (b).*

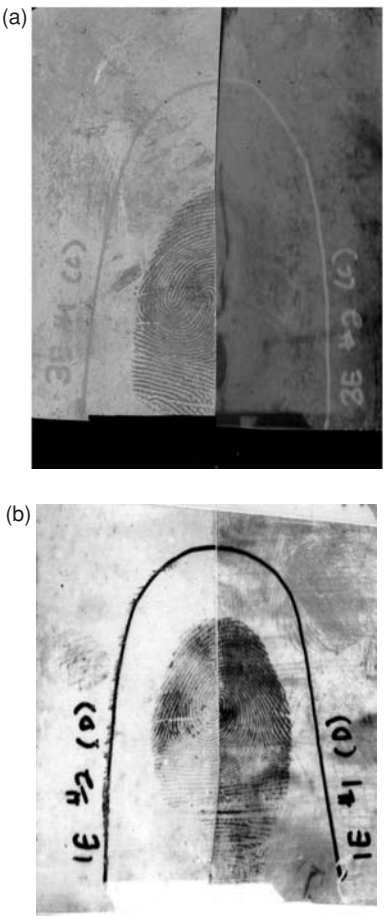

FIG. 14—*The difference between irradiated (right) and control (left) samples on polyethylene that have been processed with the vacuum metal deposition technique (a) and the difference in intensity between the irradiated (left) and control (right) samples on PVC (b).*

Irradiated samples processed using the vacuum metal deposition machine were generally less developed than control samples. The irradiated PVC samples tended to show no ridge detail at all, while some detail was observed after development with the control samples. A few of the control and irradiated polyethylene plastic bag samples showed relatively similar development. Figure 14 shows two examples of VMD processed prints.

The results obtained from this study illustrate some dramatic changes in the ability to recover latent prints after electron beam irradiation. Apparently there are a number of changes occurring not only to the latent print chemistry, but also the chemical and physical properties of the substrate as well. Shortly after the anthrax incidents in 2001, the Smithsonian Institution's Center for Materials Research and Education (SCMRE) published information that described the effects of electron beam irradiation on research and museum collection items (16). They reported that the large amounts of energy absorbed by the substrate (and thus the latent print residue) could lead to a complex series of chemical reactions, including the formation of ions, activated atoms and molecules, and free radicals. SCMRE also found that irradiation conducted in a regular atmospheric environment could produce reactive species like ozone as well as oxygen and hydroxyl radicals.

In addition to reactive species, processes like de-polymerization, chain scission, and reactions involving removal of functional groups (e.g., deamination, decarboxylation) also were reported to occur. Such reactions could ultimately remove reactive sites contained on and within the latent print residue. For example, significant deamination could lead to reduced reactivity of the latent print residue to amino acid reagents like ninhydrin and DFO. This may help to explain the somewhat poor results obtained with those reagents on the irradiated samples.

Paper, or more specifically cellulose, was reported to be particularly sensitive to irradiation methods. Chain scission, cross linkage, and oxidation processes could lead to embrittlement of paper, acidification, and discoloration. SCMRE reported that dosages as low as 7 kGy could lead to significant oxidation and depolymerization. Although generally less susceptible, synthetic polymers also could experience similar degradation effects upon exposure to electron beam irradiation. Some of these effects are clearly demonstrated on the substrates shown in Fig. 8. Such dramatic changes in the chemical and mechanical properties of substrates also could significantly affect the latent print residue. This was especially evident with the irradiated samples on the PVC substrates, which generally yielded relatively poor friction ridge development.

The prognosis for ameliorating the effects of electron beam irradiation (or for that matter, other similar processes like gamma irradiation) is somewhat bleak. Fortunately, the amount of mail that currently receives irradiation treatment is only a small portion of the total volume of mail delivered in the United States. However, that percentage may change if further biological incidents occur in the future.

Conclusions

The irradiation process appears to have a significant impact on the ability to visualize latent prints from treated surfaces. There were only a few exceptions to this trend. The two colloidal techniques, physical developer and multi-metal deposition, both produced results that were at least comparable (but in some cases superior) to the results obtained from the control samples. Overall, there were significant differences in results observed with different donors and surface types. It is likely that some types of surfaces endure the irradiation process better than others. There also may be an unequal distribution of temperature and radiation between different pieces of mail during the irradiation process. This could result in parts of an item receiving significantly different doses than other nearby items (i.e., if the item were in the middle of a stack versus the outer edge). However, the results of this study indicate that despite all of these variables, the general trend is that some level of damage will occur to both the substrate and the latent print. The diminished quantity and quality of ridge detail visualized on irradiated surfaces will adversely affect latent print identifications.

Acknowledgments

The authors would like to thank John Twomey, Forensic Photographer, Forensic Services Division, United States Secret Service, for his assistance with the photographs used in this paper, Ms. Janice Millhouse, United States Postal Service, for her assistance with irradiating the latent print samples, and Dr. Tony Cantu, Chief Forensic Research Scientist, United States Secret Service for his input and editorial review of this manuscript.

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