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Visualization of Sebaceous Fingerprints on Fired Cartridge Cases: A Laboratory Study

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ABSTRACT: The visualization and endurance of fingerprints on cartridge cases after the firing process have been examined. Cartridges of M16, AK-47 (Kalashnikov) and Parabellum have been tested. Despite difficulties in visualizing these fingerprints, it was found that in some cartridge cases under laboratory conditions—for instance, on M16 brass cartridges—substantial parts of the fingerprints remain intact after shooting. The careful use of illumination after metal vapor deposition enabled visualization. Different possible mechanisms responsible for the partial destruction of the fingerprints are discussed.

KEYWORDS: forensic science, latent fingerprints, fired cartridge cases

Latent fingerprints visualized on fired cartridge cases, which are imprinted before the firing process, serve as excellent forensic evidence in criminal and terrorism cases. However, visualization of such fingerprints is still not always successful using current techniques. Moreover, the endurance of such fingerprints has been questioned for many years.

Several methods of visualizing latent fingerprints on pristine brass cartridge cases have been developed. Metal exchange reactions (by immersion plating), copper-selenide (CuSe) deposition, black powdering, and cyanoacrylate polymerization produce good images of latent fingerprints on unfired cartridge cases (1–7). However, the results obtained by these methods upon treating fired cartridge cases are often not clear and reproducible. Research in the Israeli Police laboratories and other forensic laboratories showed that an ammoniacal solution of silver nitrate and ''gunblue'' solution visualized latent fingerprints on unfired cartridge cases, but gave poor results on fired cartridge cases (4,5). Plasma etching revealed good images of unfired fingerprints, but gave only very partial images of fingerprints on expended cartridges (8). A combined procedure of polymerization with superglue (9,10) followed by plasma etching also failed to develop good images on fired cartridge cases (11). Sampson reported that superglue developed latent fingerprints on fired nickel cartridge cases, but not on fired brass cartridge cases (12). Saunders and Cantu (5) confirmed that fingerprints on fired cartridge cases gave poor results when developed by superglue vaporization with or without electroless multimetal deposition (gold deposition followed by silver). However, they argued that diluted ''gunblue'' solutions gave good results on both fresh and old fingerprints on brass, nickel and washed copper-fired cartridge cases. Donche reported that superglue developed fingerprints on fired plastic and cardboard cartridge cases but worked poorly with fingerprints on fired metal (brass, nickeled brass, and lacquered steel) cartridge cases (13). Similarly, electroless multimetal deposition of gold followed by silver gave positive results with smooth plastic cartridge cases and negative results with metal cartridge cases (13). On the other hand. Given (14) claimed that black powder and vapors of HNO_3 developed good images of the fingerprints on both brass and nickeled brass cases, even 21 days after printing and firing. Very recently Brown and his co-workers (15) claimed that vacuum cyanoacrylate (with fluorescent staining) and selenous acid treatments were the most suitable method for visualizing fingerprints on spent cartridge cases; however, only certain revolvers and the SLR rifle yielded identifiable ridge details. In brief, all these reports allude to the difficulty in visualizing fingerprints on fired cartridge cases.

In this report we demonstrate that in many cases, substantial parts of fingerprints on M16 brass cartridge cases survive firing, under laboratory conditions, and stay partially intact. They are optically visible and can be better visualized after vapor-deposited coating with reflecting metals which improve their visibility. An explanation of the changes that the fingerprints undergo upon firing is suggested based on these results.

Experimental

Chemicals Used

Palladium dichloride and dipotassium hexachloropalladate were purchased from Aldrich. Black (1-001 Black) and magnetic powders were received from Lightning Powder Co. (Salem, OR) whereas ''gunblue'' solutions (Kettner Waffen Brünierung Nr. 40099) were purchased from Kettner (Germany). The brass 5.56 mm caliber unfired cartridges for the M16 were produced by the Israel Military Industries (IMI).

Visualizing Instruments

Preliminary routine observations of the latent fingerprints and the developed images were made with a magnifying glass (×5)

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equipped with a fluorescent bulb. Stronger side illumination was obtained by a 120 W Osram diffusive lamp that was placed on one side and a white screen placed opposite to it. Two stereo-microscopes were used for obtaining better images: an Olympus SZ-STU1 stereo-microscope and a Leitz-Wetzlar comparison microscope (bench stand) equipped with CCD camera (Panasonic WV-CD20) and a monitor. The latter was used also for documentation. Scanning electron microscope (SEM) images were acquired using a Jeol JSM-6400 scanning microscope.

Samples Tested

All cartridge cases were cleaned by immersing in an acetone bath for 20 to 30 s and then wiping with tissue paper. This cleaning procedure was repeated until the tissue paper remained clean (4 to 5 times). A few experiments were conducted in which M16 cartridges were not cleaned before shooting. The clean cartridge cases were impressed with either eccrinic or sebaceous fingerprints. The eccrinic fingerprints were applied as follows: a washed (with soap and water) and dried hand was wrapped in a plastic bag until it became wet with sweat. Then a fingerprint was impressed on a clean cartridge case. Sebaceous fingerprints were gently pressed and rolled on the surface of the cartridge case after a finger was rubbed on the face near the nose. The location of the print was marked by a notch on the cartridge before the prints were applied.

Three groups of 15 unfired cartridges each of Parabellum brass 9 mm, M16 brass 5.56 mm, and AK-47 copper-washed unfired cartridges were treated. One-third of each group was impressed with eccrinic fingerprints while the other two-thirds were impressed with sebaceous fingerprints. All the impressed unfired cartridges were fired from their respective weapons. A long-barrel M16 rifle was used for the brass 5.56 mm cartridges. The imprinted unfired cartridges were loaded carefully into each magazine. The ejected cartridge cases were collected during firing into clean paper bags attached to the ejector port of the rifle. Several groups of unfired cartridges were shot in the semiautomatic mode, while others were shot automatically.

Visualizing Procedures

Four procedures for visualizing latent fingerprints on cartridge cases were used:

1. Application of soot: an impressed cartridge case was covered with a heavy black smoke that was produced by burning a small piece of camphor.
2. Palladium deposition (3): a solution of 0.1 M disodium tetrachloropalladate in 0.9 M aqueous sodium chloride was prepared in the following way: 0.88 g palladium chloride was added into a solution of 2.925 g of sodium chloride in 50 mL triply distilled water (TDW). The mixture was shaken until all the $PdCl_2$ dissolved. To visualize the latent fingerprint, the printed cartridge case was immersed in the reagent solution for 40 s and then briefly washed in a TDW bath.
3. Selenation: a stock solution of 0.4545 M selenous acid (H_2SeO_3) in 2 M nitric acid (HNO_3) was prepared by dissolving 0.645 g solid H_2SeO_3 in a mixture of 2 mL HNO_3 (69%) and 9 mL of TDW. The solution was diluted to 110 mL. Visualization of a fingerprint with the selenous developer was carried out by immersion of the printed case in the reagent solution followed by a brief wash with TDW.
4. Silver deposition: an ammoniacal silver solution was prepared (7) by dissolving: 4.5 g $AgNO_3$, 100 g $(NH_4)_2SO_4$, and 7 g of NH_4OH in 1 L of TDW. Visualization was accomplished by immersing the printed case in the reagent solution followed by a brief wash with TDW.

SEM Examination

Eight impressed M16 brass cartridge cases were prepared for SEM examinations: two sebaceous *fingerprints* on *fired* cartridge cases, two sebaceous *spots* on *fired* cartridge cases, two sebaceous *fingerprints* on unfired *cartridge cases,* and two sebaceous *spots* on *unfired* cartridge cases. We used the samples with the spots to remove the ambiguity in the identification of the ridges and the valleys, *vide-infra.* The brighter bands in the fingerprint micrographs were identified as ridges, since the sebaceous spots were brighter than the surface around them. The sebaceous *spots* were made by contaminating a latex-gloved finger with sebaceous material and then impressing it on a cartridge case. This procedure resulted in a sebaceous spot that was fingerprint-detail free. Half of the prints were gold coated by sputtering, the other half by carbon. The coated samples were observed by SEM at very low electron energies (5 keV with the gold and 1 keV with the carbon coated cartridges).

Results and Discussion

The cartridge cases were initially inspected by a naked eye and a microscope after they were fired. Signs of firing could be seen on the cartridge cases. In general, the cartridge cases lost their shine (the AK-47 cartridge cases were not bright before the firing as well) and they were covered with a thin dark layer of powder and black spots.

Our attempts to develop fingerprints on fired brass cartridge cases confirmed the previous reports: no proper images were obtained consistently. Employing powders as a means of visualizing fired *eccrinic* latent fingerprints, failed. On the other hand, aqueous reagents, e.g., palladate, could not be used because they dissolve the eccrinic fingerprint. The results which summarize the attempts to develop sebaceous latent fingerprints on fired cartridge cases are presented in Table 1. The findings confirm the difficulties in obtaining properly developed latent sebaceous fingerprints on fired cartridge cases. Nonetheless, several important conclusions can be drawn from the experiments:

(*i*) Most of the immersion-plating experiments with the different cartridge cases resulted in the reproducible formation of an area without ridge detail, in which the fingerprint was impressed, that was not covered by a precipitate. Such a non-developed area was especially distinct upon treating M16 cartridgecases. This clearly suggests that some of the sebaceous material remains, and at the same time, that the *gunpowder residue* which covers the brass surface does not prevent the immersion-plating process since it takes place outside the area of the fingerprint.

(*ii*) The powders used are totally inadequate for developing latent fingerprints on fired cartridge cases. This suggests that the ridges and valleys are indistinguishable with regard to the mechanism that is responsible for powder attachment. This can also be concluded from the immersion-plating experiments. In other words, the firing process causes the areas that were covered by ridges and those that were not covered, i.e., valleys, to be unsusceptible to the physical or chemical treatments applied.

(*iii*) Due to the fact that several experiments yielded partial detailed images, it is possible that part of the detail of the fingerprints survives the firing.

TABLE 1—*Summary of observations of different treatments of cartridge cases upon which a sebaceous fingerprint was imprinted before the firing process.*

Development Reagent	M16 Cases	AK-47 Cases	Parabellum Cases
Palladate	Area of fingerprint was not covered by precipitate; a few experiments gave partial detailed image	Area of fingerprint was not covered by precipitate	Whole area was covered by a precipitate
''Gunblue''	Area of fingerprint was not covered by precipitate	Whole area was covered by a nonhomogeneous precipitate	Area of fingerprint was not covered by precipitate
Ammoniacal silver	Partial detailed image in fingerprint location	Area of fingerprint was not covered by precipitate	Area of fingerprint was not covered by precipitate
Black powder	Black coating with no details	Black coating with no details	Black coating with no details
Magnetic powder	Weak black coating with no details	Black coating with no details	Black coating with no details

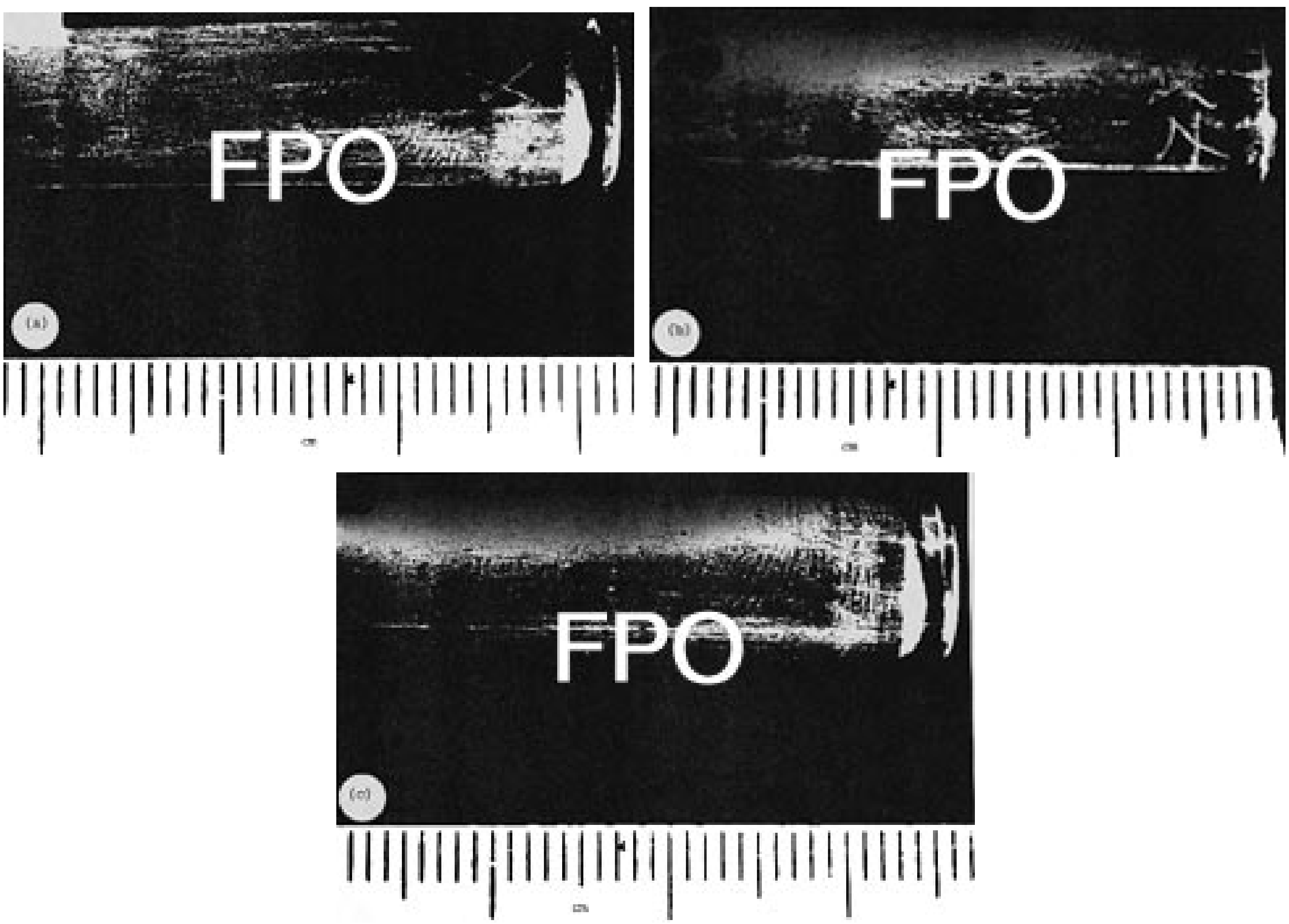

FIG. 1 *a–c—Photographs of three fingerprints on fired M16 cartridges without any treatment. The fingerprints were impressed before firing.*

Firing Renders Prints Visible on M16 Cartridge Cases

Since the M16 5.56 mm brass cartridge cases with impressed sebaceous fingerprints gave the best results, further investigation was carried out with this ammunition. Observations through a magnifying glass confirmed that at least partial patterns of the prints survived the firing. For example, in one experiment, 28 sebaceous impressed M16 cartridge cases out of 30 showed some sort of marks after firing. Some cartridge cases exhibit small parts of the prints, most of them exhibit large parts, and in five cartridge cases out of thirty an almost complete ridge mark was detected (without minute detail) after firing. Figures 1*a–c* show images of fingerprints on three fired cartridges that were photographed without any treatment. It is important to realize that although palladium development of such complete fired fingerprints produced visible marks, nevertheless, fingerprint detail was inadequate for fingerprint comparison purposes.

Enhancement of Developed Prints on M16 Cartridge Cases Using Metal Vapor Deposition Methods

Reflection poses a problem in observing fingerprints on metallic surfaces and in particular on cartridge cases. For example, the details of a visible fingerprint on flat brass can hardly be seen by a metallurgic microscope (in which the incident light is normal to the surface). Therefore, the angle of observation as well as of the incident light must be carefully controlled and optimized. The reflectivity contrast between ridges and valleys can be enhanced

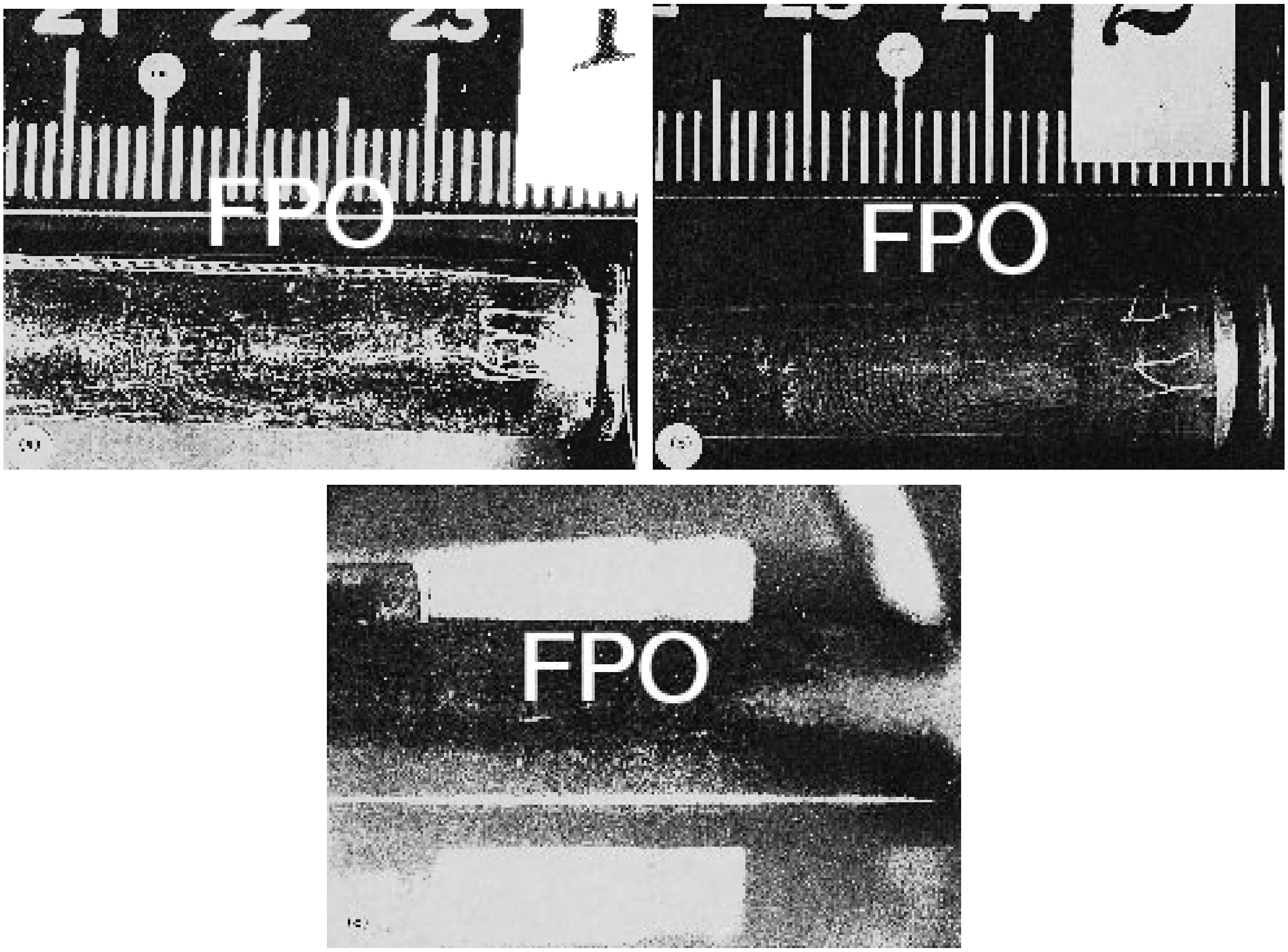

FIG. 2—*Photographs of fingerprints on fired M16 cartridges after coating with a thin metallic film: a—platinum; b—aluminum; c—silver.*

by metal vapor deposition. Figures 2*a–c* show images of fingerprints on fired cartridge cases after coating with thin metal films of platinum (Fig. 2*a*), aluminum (Fig. 2*b*), and silver (Fig. 2*c*). Our preliminary results show that best results on brass cartridge cases are obtained by sputtering or vapor depositing metals with high reflectivity such as gold, aluminum, and silver. It is difficult to draw definite conclusions, primarily because the images are heavily dependent on the fingerprint donor. Although fingerprints are usually divided into two, eccrinic and sebaceous, in most cartridge cases a combination of the two, the so-called ''simple'' fingerprint, is found. The latter is the result of a ''not washed on purpose but not dirty'' hand and it consists of less lipid material than the sebaceous fingerprint. We found that while ''simple'' fingerprints on fired cartridge cases of one donor are entirely invisible, other donors provide clear visible fingerprints.

Structural Changes of Latent Prints Due to the Firing Process—a Model

So far we have shown that it is possible to visualize sometimes fingerprints on fired brass cartridge cases, though not by the methods used with unfired cartridges, i.e., aqueous metal deposition. These findings raise the question about the changes that the fingerprint undergoes upon firing. A partial explanation to this puzzle can be found by a careful observation of a palladate treated fired case on which a clear almost complete fingerprint can be seen (Fig. 3). Interestingly, comparing the image obtained on a fired case with that of an unfired cartridge reveals that the valleys in the former are distinctively narrower. Note that partially visible sebaceous fingerprints on fired cartridge cases give, indeed, poor images; however, it is sometimes possible to improve the developed images by treating the partial visible fingerprints with sulfuric

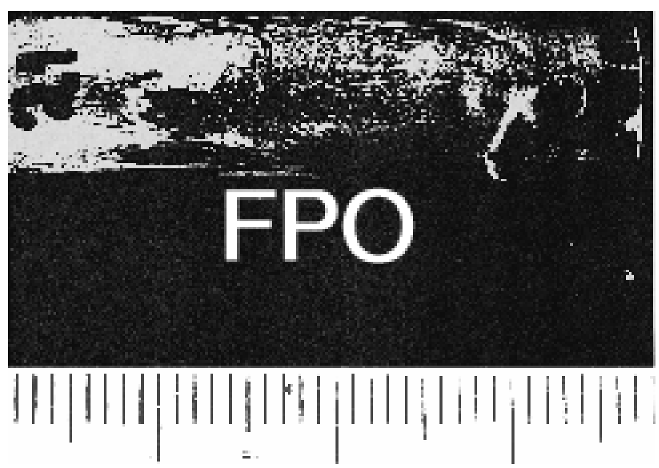

FIG. 3—*Photograph of a fingerprint on fired M16 cartridge after treatment with palladate.*

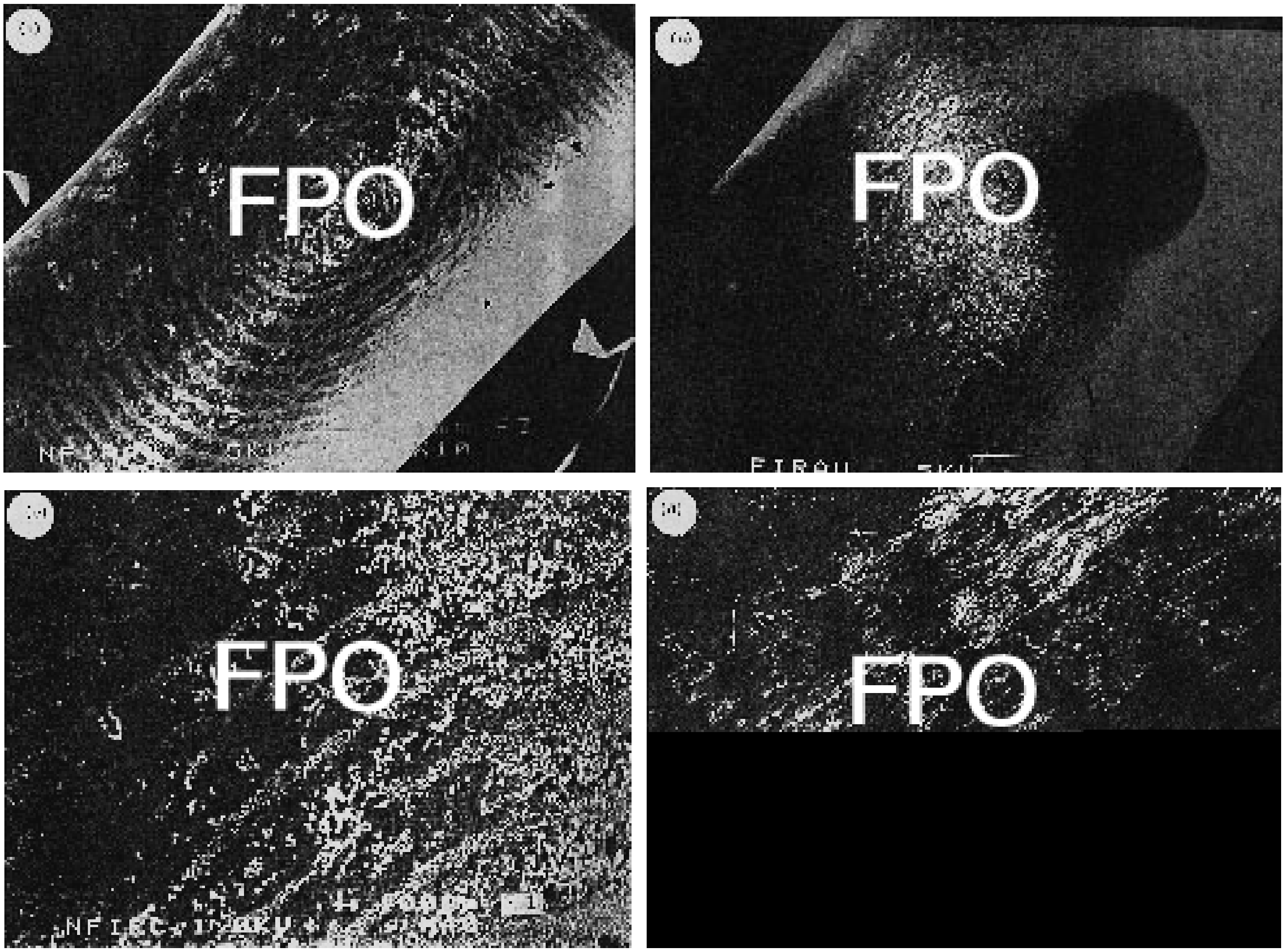

FIG. 4—*SEM images of fingerprints on M16 cartridges: a—unfired cartridge coated with gold; b—fired cartridge coated with gold; c—unfired cartridge coated with carbon; d—fired cartridge coated with carbon.*

acid or disodium dipersulfate solution and then developing with the palladium developer. These substances presumably cause the partial oxidation of the organic material and therefore enhance the contrast between areas heavily covered with carbon material (the ridges) and those covered by only the firing products (valleys). All these results suggest that the valleys become partially coated as a result of the firing, and that the coating is to some extent removable.

The firing process forms a thin layer of the gunpowder residue. This layer covers the shiny cartridge case surface and makes it dull and dotted by tiny dark spots. The powdered layer is easily removed from the metal surface by gentle rubbing with tissue paper. It seems that this layer alone does not considerably inhibit the development with the aqueous palladate since the surface of the fired cartridge cases outside the fingerprint locations is not homogeneously palladized. On the other hand, fresh sebaceous fingerprints impressed on *expended* cartridge cases covered with a residue of gunpowder are visualized with the palladate developer, indicating that indeed the gunpowder residue does not block the brass surface from reacting with palladium. Additional evidence for our hypothesis about the changes that the ridges and valleys of the fingerprint undergo upon firing is provided by scanning electron microscopy. Careful inspection of SEM Figs. 4*a–d* clearly shows that the valleys of the fired fingerprints become substantially narrower while the ridges are expanded upon shooting. It can be seen (Fig. 4*a*) that while the organic material (brighter lines) in a gold coated unfired cartridge is narrower than the valleys (dark lines), this is changed after the firing process (Fig. 4*b*). These results are not dependent on the nature of the thin conducting coating (which is necessary to enhance the contrast in the SEM) as is confirmed from carbon coated unfired (Fig. 4*c*) and fired (Fig. 4*d*) cartridges. Thus, it is conceivable that the sebaceous material of the ridges expands into the valleys upon the firing event and thus interferes with the developing and resolving process.

It should be emphasized that we cannot determine at this stage what causes the expansion of the sebaceous material that is accompanied also by the flattening or smearing of the fingerprint. At least two factors might be responsible for this: the sudden temperature jump or, what seems more reasonable, the friction of the expanded case against the barrel while ejected from the weapon. A recent report by the Israel National Police-DIFS (4) as well as our experiments indicate that the latent print is not destroyed by temperatures of up to a few hundred degrees C. Clear visual fingerprints were obtained on unfired cartridges, which were heated followed by palladium treatment. On the other hand, Wiesner and Springer showed that the loading and unloading of unfired cartridge cases also did not appreciably damage the fingerprint. Therefore, we believe it is the combination of temperature from the expansion of the case and, in particular, the enhanced friction against the barrel after expansion that is responsible for transferring substantial parts of the organic material of the ridges into the valleys. Further efforts should therefore concentrate on developing procedures for removing the organic material selectively from the valleys and restoring the original fingerprint.

Conclusions

In essence, this study has only minor operational implications due to the fact that the fingerprints were examined under laboratory conditions, that are significantly different than those found at the crime scene. Nevertheless, understanding the structural changes that the fingerprints undergo upon firing, together with improving our observation and developing approaches to latent fingerprints on fired cartridge cases, has the potential to eventually resolve this forensic challenge.

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