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Detection of Gunshot Residue by Use of the Scanning Electron Microscope

Current methods used to determine whether or not an individual has fired a handgun are based on analyses of samples taken from various regions of the hand for total content of antimony, barium, and often lead. High amounts of these elements are considered to be characteristic of gunshot residue [1–11]. However, the ability to identify residue conclusively has been severely restricted by the environmental occurrence of these same elements. Results of the studies described in this paper indicate that, by combining information about the morphology of gunshot residue particles with elemental analysis of individual particles [obtained by using an X-ray analyzer with the scanning electron microscope (SEM)], it is possible to reach a conclusion of increased significance concerning the presence of residue as distinguished from environmental contamination. The results of extensive studies of residue particles and analyses of numerous hand samples are presented here. It has become apparent that the new technique is a major improvement and that it is moderately rapid when performed by a trained microscopist.

In addition to a need for improved analysis procedures, successful detection of gunshot residue requires a simple and reliable method for residue collection and specimen preparation. Ideally, the sample collection will preserve information about the spatial distribution of residue, which can be of additonal aid to the investigation [6,12]. In past work, the collection techniques were developed primarily for the bulk elemental analysis methods, which only measure the total amount present. The paraffin casts, plastic film casts, and cotton swabs that have been used extensively for neutron activation and atomic absorption analyses are not readily adaptable to the SEM, which requires that the particulate matter be prepared on the surface of a specimen stage without destroying morphological or chemical characteristics. A procedure for gunshot residue collection in which adhesive layers are used has been successfully used in this work. The method provides retention of spatial information, requires no special specimen treatment, and is easily executed in the field. A similar method was recently used with atomic absorption analysis [13].

The basic physical and chemical forms of gunshot residue particles have not been well characterized. Most handguns produce residue that contains visible particles

ranging in size from 0.01 to 0.1 cm, plus smoke deposits, and there is unanimous agreement that variations occur in the properties of residue produced by different firings of a single gun under uniform conditions [1,12,14]. In earlier investigations, considerable attention was given to the detection of nitrates and nitrites in the large particles found on the hand after discharge of a gun [15]. Not all guns deposit these particles on the firing hand. Attention was directed later to the inorganic elements, and in reports of the Gulf General Atomic group [12] and the Aldermaston group [14] it was concluded that most of the antimony and barium in residue on the hand is contained in a few large particles [12]. Some attention has been given to elemental characterization of individual residue particles by autoradiography [14,16,17] and by chemical color tests [18]. These studies have shown that individual visible particles do indeed contain characteristic heavy metals.

Experimental

The analyses were carried out with a JSM U-3 SEM equipped with a Nuclear Diodes lithium-doped silicon X-ray analyzer crystal of 160 eV (full width at half maximum intensity) resolution and an EDAX International data processing system. The specimens reported here were coated with a conducting layer of carbon by an evaporation process that was controlled to give a layer of about 20-nm thickness. The coating operation requires 15 min and can be accomplished for several specimens simultaneously. The particle micrographs were obtained by using secondary electron imaging, and the X-ray analyses were obtained at 25 kV by using a beam current of about 10^{-10} A with the specimen stage offset 6 deg from normal electron beam incidence toward the X-ray detector. Elemental analyses are reported in terms of X-ray counts per second for the emission lines, without background subtraction. The X-ray analyses were performed over a time interval sufficient to provide a signal to noise ratio of about 10:1 in the X-ray spectrum. This requires about 10 to 100 s if the particle consists mainly of heavy metal. The SEM beam was rastered during measurement; thus, the X-ray analyses reported are averaged over the analyzed surface. Unfortunately, the amount of X-ray signal was insufficient to permit high-resolution X-ray imaging. Therefore, it was not possible to locate residue particles directly by merely making an X-ray micrograph of the entire sample specimen at high resolution. If the particle under study was believed to be nitrocellulose, care was taken to minimize the electron beam current to avoid particle damage.

Gunshot residue was also analyzed by using an Applied Research Laboratories ion microprobe mass analyzer (IMMA) with a 20-kV, 3×10^{-9} A, negatively charged oxygen (0^-) beam. The gunshot residue samples collected for analysis by IMMA were coated with a conducting layer of gold. Gunshot residue was also analyzed by using an Applied Research Laboratories electron microprobe at 17 kV and 5×10^{-8} A. The electron microprobe elemental spectra were obtained by using wavelength dispersive X-ray analyzers with lithium fluoride and ammonium dihydrogen phosphate crystals.

Test firings were conducted at indoor and outdoor ranges with the following guns: .22 caliber Colt revolver, .22 caliber Ruger pistol, .32 caliber Llama semiautomatic pistol, .380 caliber Browning semiautomatic pistol, 9-mm Browning high-power semiautomatic pistol, .38 Special Smith and Wesson revolver, and .45 caliber 1911 Colt semiautomatic pistol. Of the guns used, the Browning .380 semiautomatic and Colt .22 revolver had considerable wear, and the Browning .380 provided copious quantities of large black particles that were easily visible on the hand after ejection of the cartridge case. The .38 Special revolver, the 9-mm semiautomatic, and the .22 caliber Ruger pistol were essentially new guns that ejected no visible residue particles onto the firing hand. In firing tests, care was taken to avoid contamination of the firing hand by loading operations. The commerical brands of ammunition used in the test

firings were as follows: for .22 caliber, Federal, Western Super X, and Remington; for .32 caliber, Federal; for .380 automatic, Remington; for 9-mm Luger, Federal; for .38 Special, Western, Super Vel, Norma, and Remington; and for .45 automatic, Western, Super Vel, Norma, and Remington.

The "pure residue" specimens, including muzzle discharge particles, were collected in polyethylene bags that surrounded the gun during firing. Particles were then removed from the inside surfaces of the bags. The pure residue that reaches the hand was collected by covering the firing hand with a latex glove or by covering the surface of the hand with an adhesive layer before firing. Unless otherwise stated, the samples called "handsamples" were collected from the hand, immediately after firing, on adhesive layers (Scotch No. 465 adhesive) attached to 2.5-cm diameter aluminum disks that also served as SEM sample supports. A strip of adhesive with paper backing was attached to the flat surface of each disk. For sampling purposes, the protective paper backing was removed, and the exposed adhesive layer on the flat surface of the disk was repeatedly pressed against the surface of the hand until the entire web area and back of the hand had been sampled. The 22 separate specimens from hands that had not fired a gun (termed "handblanks" here) were obtained from 10 laboratory workers, 3 automechanics, 3 subjects who had placed their hands in the flow of automobile exhaust, 2 machinists, 1 carpenter, 1 painter, 1 plumber, and 1 subject who had rubbed his hands in soil prior to sampling.

In tests of identification capability, efforts were made to provide dirty and clean handblanks and to have ordinary amounts and types of contaminants on the hand before firing to simulate natural circumstances.

Results

Partially Burned Smokeless Powder Particles

The guns studied produced substantial residue deposits when the muzzle discharge was included in the residue. The most prominent features of these deposits were black specks as large as 0.1 cm. Their shapes were irregular, as if the particles were the fragmented and partially burned remnants of smokeless powder.

These larger particles were the most prominent features of the pure residue in the SEM photomicrographs. They ranged from 10^{-3} to 10^{-1} cm; typical examples are shown in Fig. 1. At low SEM magnification ($\times$ 100), smoothly contoured surfaces and edges, and craters of round cross sections penetrating into or through the surfaces, were observed. At higher magnification, which was required for examination of the smaller particles, the surfaces were rough and often had a sponge-like or cratered appearance. The X-ray signals of lead, antimony, and barium, averaged over the surface of these particles by scanning, were consistent with a low concentration of these elements. A barium mapping of one of these characteristic particles by SEM is shown in Fig. 2. There is striking evidence that the barium is concentrated in the round spots on the particle surface. X-ray analyses confined to regions of the large particles that did not have the round particles present indicated absence of heavy metals. The comparative abundance of bremsstrahlung radiation in the latter regions can be interpreted as arising from light elements such as those contained in organic materials. Typical properties of a large number of these particles are summarized in Table 1. Boehm [19] previously observed similar particles on cloth using the SEM, and Diederichs et al [20] have observed them using the SEM to analyze cotton swabs taken from the firing hand

The technique of IMMA was used for further analysis of these large particles because it responds to organic compounds. Since the technique is about 10^6 times more sensitive than SEM X-ray analysis, lead, antimony, and barium could be detected in the surface of the large particles, even for regions that did not have spherical particles.
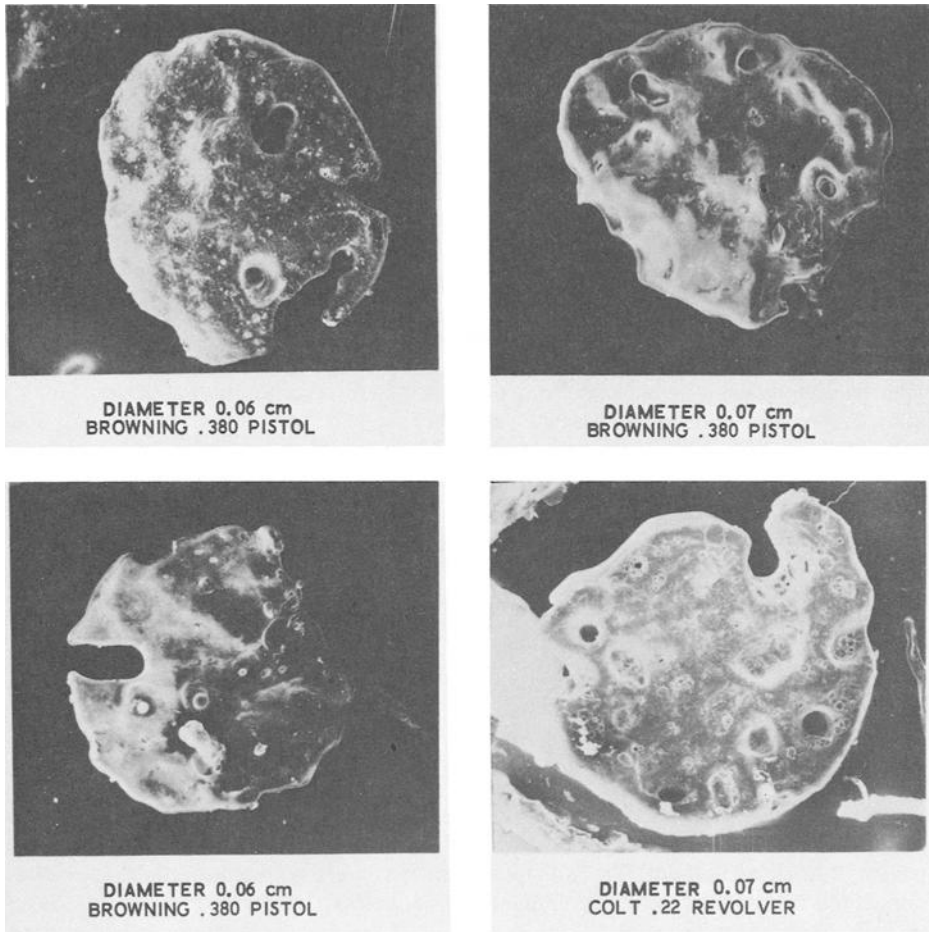
FIG. 1—*Secondary electron micrographs of typical partially burned smokeless powder particles by SEM.*

However, during the process of analysis, as the ion beam bored into the particle surfaces, the signals from these elements vanished, which indicated that a thin layer containing these elements had been present on the surface. The surface areas of the large particles that were not covered by round spots were composed of compounds that fragmented into light elements and molecular ions, which are also observed for the precursor smokeless powder. The large particles were analyzed in bulk by computerized gas chromatography-mass spectrometry and positively shown to contain gunpowder.

The large particles either structurally decomposed or dislodged from instrument specimen supports when examined with high electron-beam currents.[2] [High currents were associated with continuous display cathode ray tube (CRT) mode of the SEM and with normal analysis by electron microprobe and IMMA.] This is consistent with the

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[2] The electron beam-induced structural decomposition of smokeless powder might be valuable for residue characterization because the particle surface cracks due to heating, if high-beam currents are used, and then material from the interior of the particle appears to flow into the vacuum. (Some other organic materials have been observed to behave in this manner.)
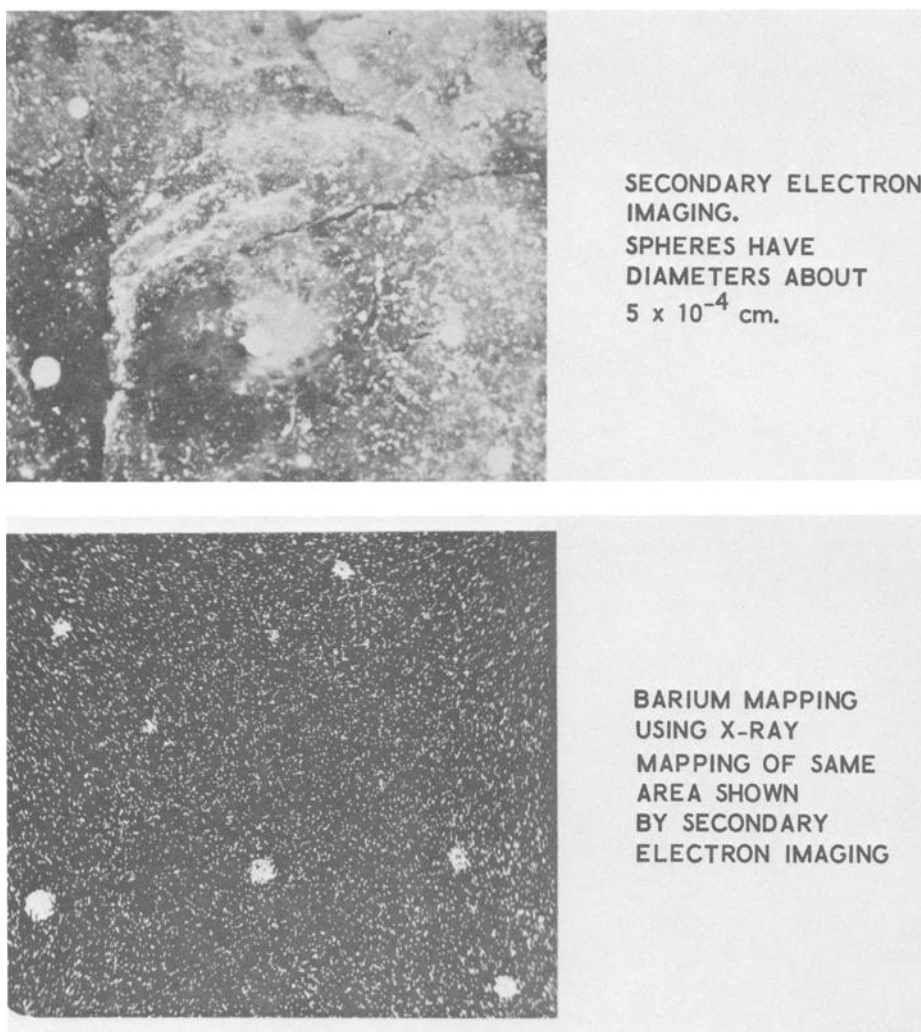
SECONDARY ELECTRON IMAGING. SPHERES HAVE DIAMETERS ABOUT 5×10^{-4} cm.

BARIUM MAPPING USING X-RAY MAPPING OF SAME AREA SHOWN BY SECONDARY ELECTRON IMAGING

FIG. 2—*Surface of a partially burned smokeless powder particle by SEM at high magnification.*

low thermal stability of smokeless powder. The particles with high concentrations of heavy metals were stable at high beam currents (provided they were rigidly attached to the instrument specimen support).

The round spots on the surface of the large organic particles were studied in detail because of their potential value as identifying features of residue. These spots appeared to be spherical or spheroidal at high magnification with secondary electron imaging (Fig. 3). X-ray analysis confined to individual spheres invariably revealed strong lead, antimony, or barium signals that were consistent with the particles being largely composed of these elements. Lead is most frequently encountered, even for ammunitions that have primers rich in antimony and barium. Other elements are also often associated with these residue particles, but not regularly or in any fixed ratios. Typical analytical results for the various classes of particles are summarized in Table 1, and the

TABLE 1—Characteristics of particles analyzed from various residue specimens by SEM.

	Partially Burned Smokeless Powder Fragments		Spherical Particles from Hand Specimens		Nondescript Particles from Hand Specimens	
	Median	Range	Median	Range	Median	Range
Colt .22 Revolver; Western,[a] Remington,[b] and Federal[c] Ammunition[d]						
Diameter, cm	0.05	0.003– 0.07	0.0007	0.0003– 0.004	0.0015	0.0005– 0.01
Number embedded spheres	60	16– 60	...		...	
Lead[c,f]	250	100–350	400	40–1400	250	0–1900
Barium	0	0– 20	150	...	30	0– 500
Antimony[f,g]	0	0– 30	0	0– 43	0	0– 140
Additional elements	0	0	0	0– 2	1	1– 4
Browning .380 Semiautomatic Pistol; Remington[h] Ammunition[i]						
Diameter, cm	0.05	0.01 – 0.07	0.001	0.0006– 0.006	0.02	0.001 – 0.02
Number of spheres	50	3–160	...		...	
Lead[c,f]	50	0–200	300	0– 500	90	30– 400
Barium	80	0–600	180	0– 700	60	0– 700
Antimony[f,g]	0	0–400	40	0– 500	0	0– 80
Additional elements	3	0– 6	0	0–	0	0
Smith and Wesson .38 Special Revolver; Western[h] and Remington[h] Ammunition[j]						
Diameter, cm	0.05	...	0.003	0.0007[k]– 0.005	0.003	0.0005– 0.05
Number of spheres	7	...	...		...	
Lead[c,f]	130	...	300	0–2200	200	0–1100
Barium	11	...	100	0–1200	20	0– 800
Antimony[f,g]	0	...	0	0– 100	0	0– 10
Additional elements	2	...	2	0– 5	3	0– 7

[a] Of particles examined from this ammunition, 28% contained two or more of the elements lead, antimony, and barium; the pure primer contained lead and barium but no antimony.
[b] Of particles examined from this ammunition, 8% contained two or more of the elements lead, antimony, and barium; the pure primer contained only lead.

[f] The measurements are in terms of counts/s at peak intensity, 50 eV per channel.
[g] Based on the antimony L lines, which are frequently overlapped by the calcium K_α line.
[h] The pure primer contained lead, barium, and antimony.
[i] Eight partially burned smokeless powder particles, 10 spherical parti-

cles, and 12 nondescript particles were examined.

[j] Two partially burned smokeless powder particles, 21 spherical particles, and 22 nondescript particles were examined.

[k] Recent investigations using round nose lead ammunition indicate that spherical particles of diameter less than 7 μm with predominately lead composition are most frequently found in this residue.

[c] Of particles examined from this ammunition, 59% contained two or more of the elements lead, antimony, and barium; the pure primer contained lead, barium, and antimony.

[d] Five partially burned smokeless powder particles, 10 spherical and 26 nondescript particles were examined. It is possible that the smaller "smokeless powder" particles, 0.003 to 0.01 cm, are inorganic and have spherical inclusions on the surface.

[e] Based on lead M line, which is frequently overlapped by the sulfur K lines.

X-ray spectrum from a typical spherical particle (Fig. 3, *top right*) is shown in Fig. 4, *bottom left*.

The spherical features were 3×10^{-4} to 3×10^{-3} cm in diameter and were invariably found on the surface of the large particles, but they also occurred in abundance as separate, isolated particles of the residue. These comprised the only
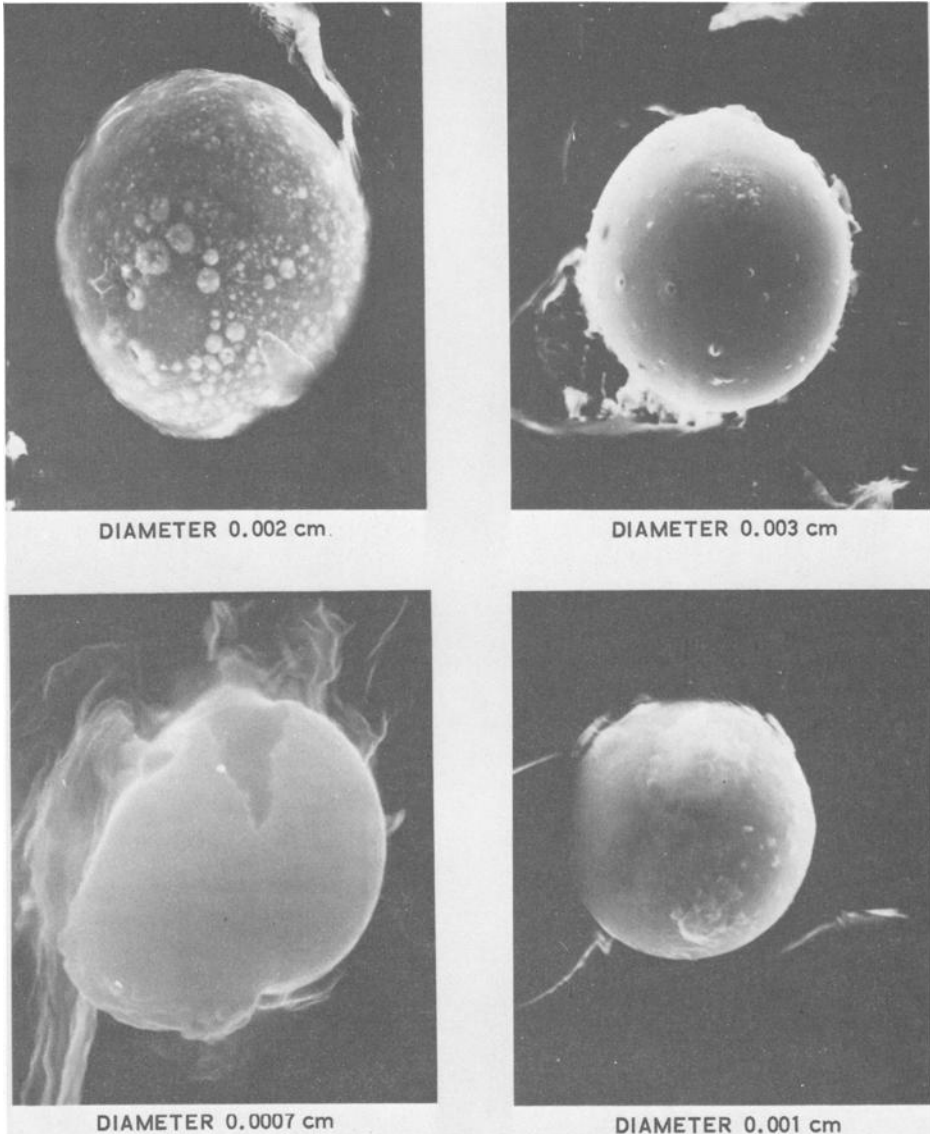

FIG. 3—*Typical spherical particles from specimens collected after firing obtained by secondary electron imaging:* (top left) *lead, 75 counts/s; antimony, 160 counts/s; and barium, 260 counts/s;* (top right) *lead, 3 counts/s; antimony, 0; barium, 370 counts/s; calcium, 160 counts/s; and silicon, 60 counts/s;* (bottom left) *lead, 85 counts/s; antimony and barium, 0;* (bottom right) *lead, 180 counts/s; antimony, 0; and barium, 80 counts/s.*
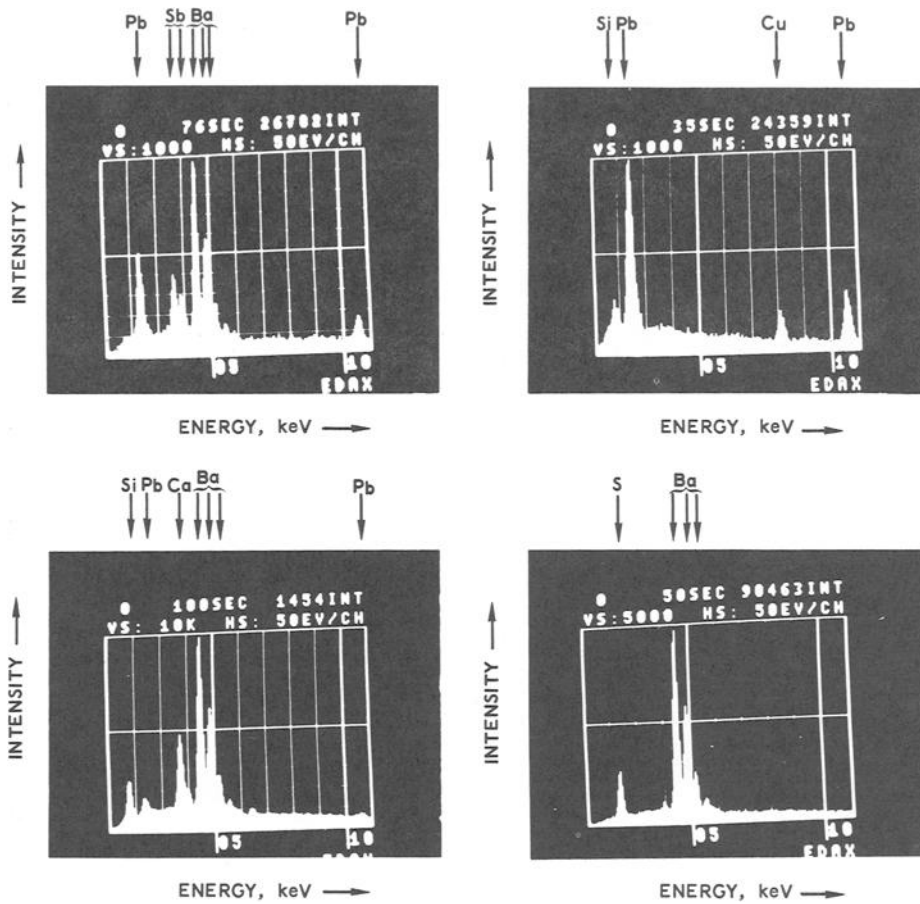
FIG. 4—*Energy dispersive X-ray spectra of particles by SEM;* (top left) *analysis of the nondescript gunshot residue particle shown in Fig. 5 at the top left;* (top right) *analysis of the nondescript gunshot residue particle shown in Fig. 5 at the top right;* (bottom left) *analysis of the spherical gunshot residue particle shown in Fig. 3 at the top right; and* (bottom right) *analysis of the environmental particle shown in Fig. 7 at the bottom right.*

regions with high concentrations of heavy metals on the surface of the partially burned smokeless powder particles.

Particles of nondescript morphology, 1×10^{-4} to 5×10^{-2} cm in diameter, were less common than the spheroids but were still abundant in most residue handsamples and pure residue. Several of these particles are shown in Fig. 5. Some appear to be metal fragments, others clumps of composite materials that might be produced during the combustion process. No common features that could be used to distinguish between residues produced by various guns and ammunition were recognized for the nondescript particles, but analysis efforts were cursory. For the guns studied, these and the spherical particles comprise the largest fraction of the residue that deposits on the hand. Lead and barium were usually the elements of highest concentration. Although antimony is present in many primer compositions (all but some .22 caliber ammunition), it was frequently observed to be of relatively low concentration in residue particles.

A wide variation in particle compositions was observed in terms of the ratios of X-ray intensities of lead to antimony and barium for particles from a single discharge.

DIMENSIONS 0.002 x 0.001 cm

DIAMETER 0.0003 cm

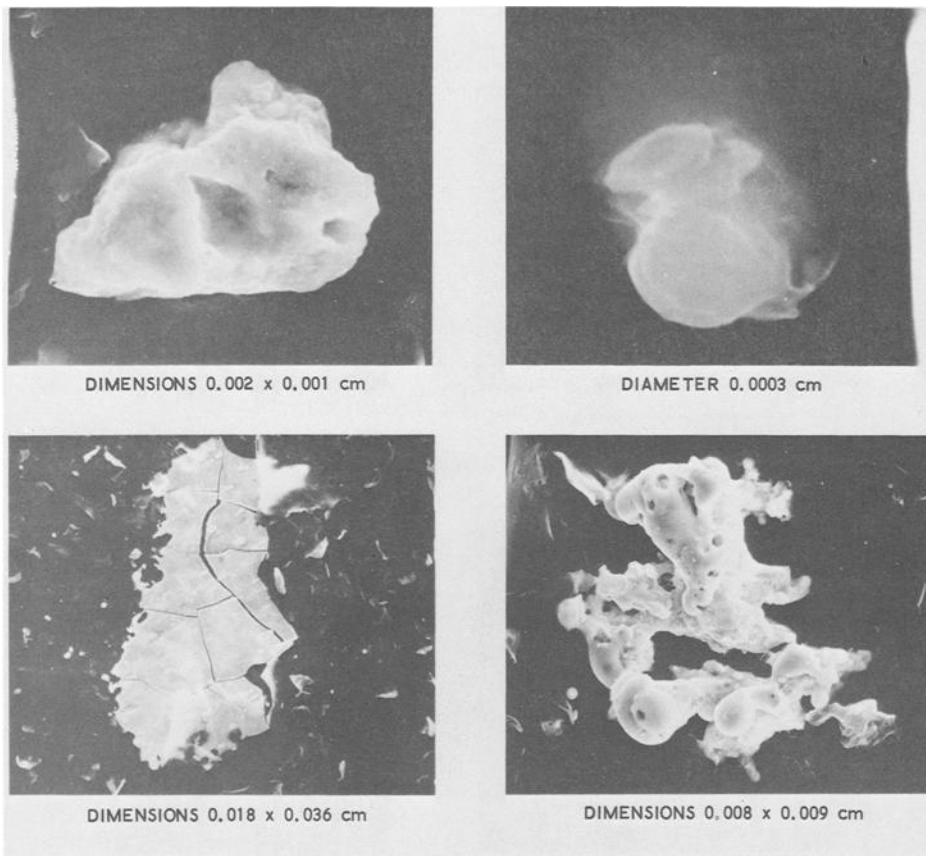DIMENSIONS 0.018 x 0.036 cm

DIMENSIONS 0.008 x 0.009 cm

FIG. 5—Secondary electron micrographs and X-ray fluorescence of typical nondescript gunshot residue particles; (top left) Ruger .22 revolver; lead, 6 counts/s; antimony, 15 counts/s; and barium, 42 counts/s; (top right) Smith & Wesson .38 Special revolver; lead, 40 counts/s; antimony and barium, 0; silicon, 10 counts/s; and copper, 15 counts/s; (bottom left) Llama .32 pistol; lead, 35 counts/s; antimony, 180 counts/s; and barium, 400 counts/s; (bottom right) Smith & Wesson .38 Special revolver: lead, 5 counts/s; antimony, 0; barium, 340 counts/s; silicon, 30 counts/s; and calcium, 140 counts/s.

Additionally, copper, silicon, iron, sulfur, and calcium were occasionally present in high concentrations. (They were less abundant in spheroidal than in nondescript particles.) No attempt was made to analyze data for dependence on type of gun or ammunition. However, it was observed that residue particles from the brands of .22 caliber ammunition with primers that lack barium and antimony tend not to contain these elements. The identification value of this information is limited because a few residue particles from ammunition with primers that lacked barium and antimony have been observed to contain some antimony or barium. The source has not been ascertained in this work. Conversely, residue particles from primers that contain lead, barium, and antimony often produce only lead X-ray fluorescence. Therefore it is unlikely that specific makers of guns and ammunition can be readily identified by current SEM analysis, but it is possible that future refinements might modify this conclusion.

The principal X-ray line of calcium is the K_α at 3.69 keV, which overlaps the antimony L doublet when energy dispersive detection is used. Therefore, the analyst

must be alerted to the necessity to judge the presence of antimony on the basis of the occurrence of the partially resolved L doublet at 3.60 keV, with the intensity ratio 1:0.8. Sulfur is detected by its K lines at 2.31 and 2.46 keV, which are not resolved and also overlap the lead M line at 2.38 keV. These lead and sulfur lines are shown in Fig. 4, *top right and bottom right,* respectively. Therefore, the lead L line at 10.5 keV must be used in order to confirm the presence of lead.

The electron microprobe with wavelength dispersive X-ray analysis easily resolved lead from sulfur and antimony from calcium; the results indicated that these elements often occur together in particles. (This is expected because many primers contain sulfur in the form of antimony sulfide and calcium in the form of calcium silicide.) Shown in Fig. 6 are the higher-resolution elemental analysis spectra obtained by using the electron microprobe with the two crystals that are required to cover the same range that energy dispersive analysis covers with a single detector crystal.

Representative handblanks were examined in the SEM to establish a basis for differentiation of handblank particles from gunshot residue. Secondary electron micrographs and X-ray analyses of representative particles most easily confused with gunshot residue are shown in Fig. 7. The most frequently detected elements were silicon, iron, calcium, sulfur, chlorine, potassium, titanium, zinc, copper, and aluminum. Organic particles from the hand were abundant. Fortunately, their morphology is easily recognized, and their X-ray fluorescence is weak; it consists mainly of bremsstrahlung from light elements. In an average handblank, there are also many mineral particles that contain silicon, calcium, or titanium. They have smooth surfaces with a crystalline appearance. Fibers are common; they contain primarily light elements and occasionally sulfur or chlorine. Particles from more than 20 handblanks were examined and none would be confused with gunshot residue. Automobile exhaust from leaded gasoline produces the particles that most resemble gunshot residue, particularly with respect to lead content and size. However, bromine was a prominent constituent of most of these contaminant particles, as shown in Fig. 7 *top left,* whereas it is not detected in gunshot residue particles [21]. All lead exhaust particles encountered had nondescript morphologies.

Overall, 140 samples from hands that had fired were examined. Only one displayed no evidence of residue. To test the success of identifying gunshot residue in a mixed group of residue specimens and handblanks, a blind test was carried out. Of 35 specimens, 17 were specimens collected immediately after firing and 18 were handblanks. All were identified correctly by the electron microscopist, who was not aware of specimen identity. Less than 1 h[3] was required for the analysis of each specimen. The residue specimens were produced by single firings of .22 (10 of 17 firings), .38, .380, .45, and 9-mm caliber guns. Both revolvers and semiautomatics were used to obtain representative results. With the larger caliber semiautomatic and worn revolvers, particulate deposit was rich, and positive analyses required only brief searches for suitable particles. For sparse residue specimens produced by clean guns, such as the new .22 Ruger pistol, it was difficult to locate particles of interest, and a large number of environmental particles were subjected to X-ray analysis before a gunshot residue particle was identified.

A limited study was made of the ability to detect residue collected from the hand 1, 2, and 3 h after firing. Subjects fired one round from a .22 caliber Colt revolver and then engaged in unrestricted activity, except that hand-washing and contact with sources of additional residue were avoided. Gunshot residue particles were found on all but one of the 20 specimens. The negative specimen had been collected 2 h after firing,

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[3] Characteristic particles are sometimes found almost immediately, but 1 h may be required to establish their absence with confidence.
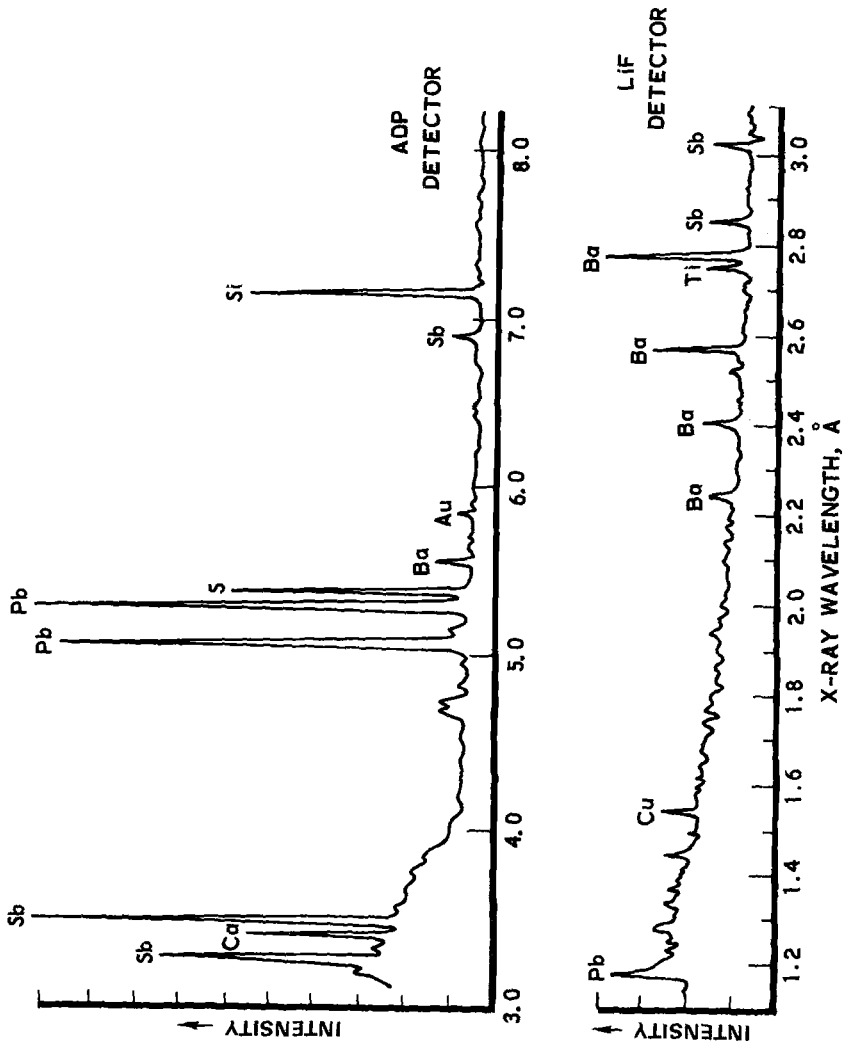
FIG. 6—*Electron microprobe analysis of gunshot residue primer specimen coated with a gold conductive layer.*
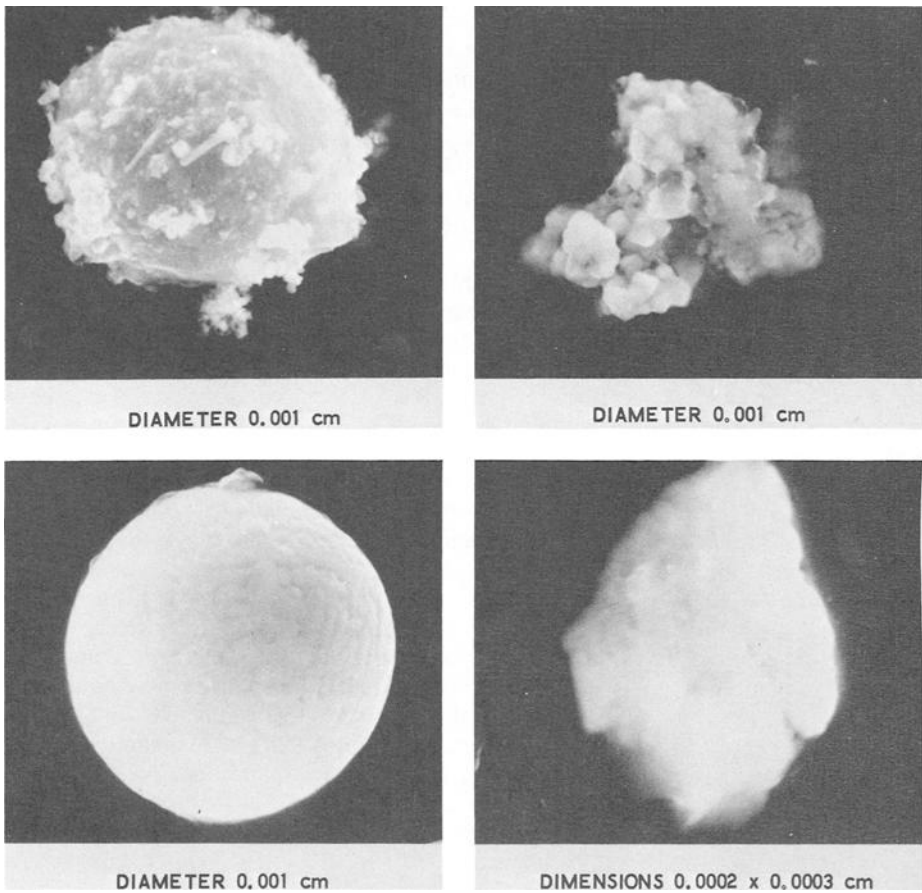
FIG. 7—*Secondary electron micrographs and X-ray fluorescence analysis of handblank particles;* (top left) *autombile exhaust particle: lead, 25 counts/s and bromine, 17 counts/s;* (top right) *automobile exhaust particles: lead, 55 counts/s;* (bottom left) *environmental particle; iron, 255 counts/s;* (bottom right) *environmental particle; barium 340 counts/s and sulfur, 80 counts/s.*

and the subject had engaged in vigorous activity. It was evident that a noticeable decrease in number of residue particles occurred for the 2 and 3 h samples.

Discussion

The three particle categories that have proven useful for analysis of residue characteristics can provide the means for identification of unknown specimens. The large particles of partially burned smokeless powder are most easily located and identified. The spheres are also quite characteristic of residue but can be more difficult to locate because their small size necessitates scanning over large areas of the specimen at high magnification. The large nondescript particles are the most difficult to distinguish from contaminant particles, but they are more likely to be found than partially burned smokeless powder.

In the limited examination of handblanks reported here, there was no difficulty in distinguishing handblank particles from gunshot residue. Although contaminants were found in the same size range as gunshot residue particles, most contaminant particles had characteristic features quite distinct from gunshot residue. For example, few had

heavy metals, except particles produced by various metal working processes, and these had shapes and combinations of elements that were distinctive of the particular process. Judd and co-workers [22] surveyed contaminant particles found on the clothes of industrial workers and found a direct correlation between the elemental content of the particles and the occupation of the subjects. The topography and shape of contamination particles were further identifiable with job classification. Another source of data on environmental particles is the Particle Atlas [23] in which particle properties that are useful for identification of unknowns are listed, and optical and SEM micrographs are given of an extensive range of particulate matter covering the substances that are representative of environmental contamination. All the materials included in the Atlas can be distinguished and identified by their microscopic properties. Most have characteristic structure, such as smooth crystal planes, that permit unique identification.

The SEM micrographs of many environmental particles resemble those of the nondescript gunshot residue particles and a few of them contain lead. Automobile exhaust is probably the most ubiquitous source of lead particulate contamination. Although most exhaust examined has contained bromine, some particles do not reveal it with SEM X-ray analysis. Therefore lead by itself is not an ideal basis for identification of residue. Several common lead pigments resemble nondescript gunshot residue: chrome yellow has lead, chromium, and iron; lead white has lead and iron; and naples yellow contains lead, antimony, iron, aluminum, and silicon [23]. At high SEM magnification ($\times$ 10 000), the latter was observed to be crystalline, but this is the only feature that distinguishes it from some types of residue. Some glass beads contain barium, iron, calcium, and silicon in spherical particulate form, and red lead and some electrical insulation materials contain lead and iron. Spherical particles that range from 10^{-4} to 3×10^{-3} cm are rather common. Many spray processes form them; for example, sprays of molten metals or molten salts usually solidify into such spheres. Plastics, aerosol sprays, oil soot, coal fly ash, and pollen particles often assume this shape. Therefore, elemental analysis is essential if these particles are to be distinguished from gunshot residue. It is apparent that the simultaneous presence of lead, antimony, and barium as major constituents of particles from 10^{-4} to 10^{-1} cm is highly uncommon for environmental particles but is frequently observed in gunshot residue.

It is much more difficult to justify a conclusion that a handblank specimen contains no gunshot residue particles at all than to establish the presence of at least one or more gunshot residue particles in a specimen that contains many residue particles. If every residue particle on a specimen must be counted for quantitative purposes, then much effort must be expended in covering the total area of the specimen.

Results of the blind test of the analysis procedure with randomly mixed handblanks and firing samples indicated that the method has excellent potential for successful application. That 35 randomly mixed firing and handblank specimens were identified correctly can be compared with the results obtained in the Gulf General Atomic work [1], which relied on detection by neutron activation analysis. In order to make the comparison, we established a 1% level of confidence criterion for the antimony/barium threshold; the threshold was fixed such that no more than 1% false positives were obtained for handblanks using their Group A with low occupational exposure. (The results would be less favorable for the other groups.) Then, the corresponding thresholds are 0.7 μg barium and 0.2 μg antimony. For their .38 revolver data, 68% of the analyses of samples collected after firing would be false negatives, and for .22 caliber guns, 84%.

The method clearly provides the potential for significant improvement of gunshot residue detection; however, a number of aspects of the method need to be investigated before its full capabilities can be determined. The persistence of particulate residue has not been established, and any successful method must detect residue a reasonable time·

after a firing event because most suspects in shooting cases are not apprehended until some time after the firing event. It is expected that the micron-sized particles should be retained well by the skin because of the large surface to mass ratio, but this hypothesis must be tested. Only a limited number of handblanks have been examined; therefore, thorough examination and classification of common contaminant particles that might be confused with residue need to be undertaken.

Summary

Particle analysis techniques provide much more information useful for identification of gunshot residue than the conventional analytical techniques that measure only the concentration of elements averaged over the entire specimen. By combining the morphological information by microscopy with elemental analysis by X-ray fluorescence, the SEM provides definitive identification of residue particles. Therefore, the particle analysis technique should be more revealing in situations where conventional methods fail as the quantity of residue approaches the background level.

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