FORENSIC SCIENCE COMMUNICATIONS

Table of Contents
Back Issues
Search

Editors
About FSC
Instructions for Authors
Meetings and Conferences

FBI Publications
FBI Laboratory

Current Issue

*Forensic Science Communications* July 2006 – Volume 8 – Number 3
Research and Technology

# Summary of the FBI Laboratory's Gunshot Residue Symposium, May 31–June 3, 2005

**Diana M. Wright**
Forensic Examiner
Chemistry Unit
FBI Laboratory
Quantico, Virginia

**Michael A. Trimpe**
Forensic Scientist
Hamilton County Coroner's Office
Cincinnati, Ohio



## Abstract

In response to the need for formalized gunshot residue (GSR) discussions, the FBI Laboratory hosted a four-day symposium in the spring of 2005 to address a wide range of issues. Attendees included GSR examiners and researchers from international, federal, state, and local government agencies as well as private laboratories. The topics that were discussed and the general guidelines that were approved by the group are presented in detail. Some issues were too broad for the time allotted or will require more study before consensus can be reached. Several participants made plans to pursue some of these areas in greater detail, with studies designed around suggestions initiated at the symposium. There was agreement that the GSR community is in need of a document that can provide general guidelines with respect to the policy for accepting cases, the criteria necessary for reporting a positive GSR result, and the importance of both elemental composition and morphology in defining the presence of GSR.

## Introduction

In early 2005 approximately 40 scientists representing local, state, federal, international, and private laboratories were invited to attend an FBI-sponsored symposium dedicated to topics relevant to the detection and significance of GSR analyses. This event was held in Quantico, Virginia, from May 31 through June 3, 2005. The mission of the symposium was to attempt to establish guidelines for the acceptance, practices, and interpretation of GSR examinations conducted primarily by scanning electron microscopy with energy dispersive X-ray spectrometry detection (SEM/EDS). Although the goals were ambitious, they were not unrealistic, given that the attendees were selected based primarily on their experience level and firsthand knowledge of key analytical aspects of the discipline. Many of the symposium participants had previously conducted research in selected areas that proved to be quite beneficial to the group. These scientists shared their published and unpublished research with the group in order to facilitate discussions.

From the early planning stages, the format of the symposium was modeled after a scientific working group (SWG), in which experts in the relevant area of discussion could present work that would form the basis for discussion and eventual guidelines in that discipline. In order to provide a starting platform for these discussions, several topics of primary interest were sent to the attendees for review. These topics were determined from discussions on a listserv dedicated to forensic applications of SEM, as well as from discussions within the general GSR/SEM community. Participants were encouraged to rank the listed topics by importance and to add subjects that might be more specific to the individuals or their agencies. This list formed the basis for the order of the topics and the time allotted to each. Participants were also surveyed regarding their level of expertise; instrumentation; sample reports for positive, inconclusive, and negative findings; and information pertaining to any legal challenges they may have encountered in this discipline.

In order to encourage participation among the attendees, a consensus-building format was established. Based on the ranked listings received during the planning of the symposium, the moderator would open a topic for discussion with a general statement such as, "A conclusion regarding a positive GSR result should be based on both morphology and elemental composition." If the statement required clarification, some discussion might ensue at that time. Once the statement was in a form that was acceptable to most participants, a vote was taken. The choices offered for a question such as described were usually "Agree," "Disagree," or "Need to discuss further." The vote was conducted using a keypad system in which all votes were recorded electronically and anonymously. The tally was then projected onto a screen so that all attendees could quickly determine if consensus had been reached. If a majority was reached, the minority voters were allowed to comment further on their vote or let the vote stand as it was decided. If the vote was split, further discussion could be held to determine if the discrepancy resulted from a poorly worded statement or a lack of agreement as to the concept itself. Topics that were too broad or deemed in need of additional study were set aside to allow for maximization of the time allotted.

As a result of cumulative discussions, participants agreed upon some general concepts, which will be shared in this paper. The discussions that took place will provide a basis for more uniform agreement as to how GSR evidence is accepted, analyzed, and interpreted. The symposium participants agreed that more work is needed to establish criteria in several key areas. However, progress was achieved in some areas, and those discussions will be described here.

## GSR Defined

The first two topics were considered to be of primary importance because they relate to the fundamentals of the examination. Participants were asked if they could reach consensus as to the source of the residue studied and the nomenclature used to describe it. There was agreement that GSR originates in part from the firearm, the cartridge case, and the bullet, with most of the inorganic residue resulting from the primer. Most experts agreed that despite the combination of potential sources that could contribute to the formation of detectable residues, the best term to describe these particles is *gunshot residue*, or *GSR*, as opposed to such terms as *primer residue* or *cartridge discharge residue*.

When asked about terminology to describe the significance of GSR particles, most experts said they prefer to describe the classic three-component PbBaSb spheroid particle only as being *characteristic of* gunshot residue rather than *unique to* GSR. Only 4 out of 39 voting participants would choose to retain the use of the word *unique* for such particles. (The majority who chose to abstain from the *unique* classification cited work by Torre et al. from 2002 that reported a rounded, molten non-GSR particle that contained PbBaSb.) However, most attendees agreed that when a population of particles is taken into consideration, this type of three-component particle can be described as having come from a discharged firearm. Particles containing only two of the three components are currently described as *commonly associated with GSR*, *characteristic of GSR*, *consistent with GSR*, and/or *indicative of GSR*.

Additionally, the majority of attending experts stated that when two-component particles are identified in the absence of three-component particles, they would indicate the presence of these particles in some form in their laboratory reports. Most of the experts also agreed that BaSb particles no longer can be given the same weight as PbBaSb particles because of the former's reported presence in some types of used brake pads. However, a majority of respondents also indicated that it is possible to differentiate between brake pad particles and gunshot residue particles. All agreed with this statement when taking into consideration the entire population, morphology, and elemental distribution in the particles. Studies also have been conducted that find that similar conclusions can be reached regarding fireworks (Mosher et al. 1998; Trimpe 2001).

### Composition and Morphology

Almost all participants indicated that particle morphology, elemental composition, and, if necessary, a comparison of any known residue (from ammunition involved in the case) should be considered when categorizing particles as GSR. All participants indicated that a noncrystalline (nonsymmetrical) particle containing PbBaSb might be characterized as a GSR particle. In conjunction with the elemental profile, a majority indicated that the physical form of a GSR particle should show evidence of rapid solidification in the form of a spheroid or other shapes variously described as *noncrystalline*, *condensed*, *rounded*, *fused together*, or *irregular*. Sizes also would be expected to vary. There was no definitive consensus reached as to what term would most likely be used to describe the morphology of particles in residue from a discharged firearm. However, the terms *spheroid*, *condensed*, and *rounded* to describe particle shape were the most popular from a list that also included *noncrystalline*, *irregular*, *molten*, and *none of the above*.

To illustrate the importance of both morphology and elemental composition in consideration of potential GSR particles, case studies of brake pads were provided. Karl Lueftl and colleagues in Germany tested brake pads from BMW vehicles and observed a small number of GSR-like particles (with molten-looking shape), which lacked barium (Lueftl and Gebhart 2004). A. J. "Skip" Schwoeble provided data from 20 Volkswagen brake discs, from which he observed that all potential GSR particles also contained Mg-Si-Fe constituents, thereby disallowing a conclusion of positive firearm-related residues (Schwoeble 2005). John Giacalone's study of brake pads supported this work in concluding that GSR-like particles could be produced from brake pads, but the exclusion based on nonallowed elements and the morphology specifically associated with GSR make it possible to distinguish between brake dust and firearm GSR (Giacalone 2000).

In a limited study conducted by the Texas Department of Public Safety, 11 brake pads from automobiles in the laboratory's parking lot were sampled. A total of four SbBa particles were found on the 11 sampling stubs. Of those four particles, one was composed primarily of zirconium, one had a crystalline morphology, and the remaining two were noncrystalline, nonspheroidal entities (White 2005). In another study to determine how often a three-component GSR-like particle is found in brake dust, the Virginia Department of Forensic Science completed a preliminary evaluation in 2004. Brake dust samples were collected from 66 vehicles, including 8 Volkswagens and 2 Audis. More than 134,000 brake dust particles were analyzed; 851 were classified as two-component particles during the automated SEM/EDS analysis. The majority of those particles were potentially barium sulfate. An occasional two-component BaSb particle with high levels of iron was also detected. However, no three-component (PbBaSb) particles were detected (DeGaetano, Maye, and Harrison 2005).

A paper titled "Further Studies to Discriminate Primer Discharge Residues from Particles of Environmental Origin" presented at the 2005 SCANNING conference was also mentioned in the discussion (Garafano et al. 2005). In this work, X-ray mapping revealed that the PbBaSb distribution did not indicate a fusion of the elements, but rather showed them to be only in proximity as nonhomogeneous aggregates that appeared in dense fields of particles (i.e., not separated far enough to prevent fluorescent excitation of elements in nearby particles). Samples were obtained from 15 cars (11 models of Volkswagen, Audi, Opel, and BMW manufacture) and 3 motorcycles manufactured by Ducati. More than 100 particles were examined with compositions similar to GSR (i.e., PbBaSb, BaSb, PbSb, or PbBa). Results revealed that each of these particles was found with Pb > Sb or Ba as reported by Torre et al. in 2002 and Cardinetti in 2004. Fe, Cu, Zn, and Si, all "allowable" elements in GSR residues, were also present in the spectra. The authors also noted that particles of fused PbSb, which cannot be distinguished from GSR species, were observed.

### Hand Sampling and Contamination

All participants agreed that GSR sampling should be done at the scene, where permissible, and as expeditiously as possible. With respect to sampling and transfer concerns, it was unanimously agreed that it would be best to sample a subject's hands before bagging the hands or placing the subject in a police vehicle. It was also agreed that armed law enforcement officers can transfer GSR particles to a subject through contact. Almost all participants agreed that if the subject's hands cannot be sampled before placing the subject in a police vehicle, the subject's hands should be bagged in order to prevent possible contamination. Another recommendation was that, to the extent possible, all used cartridge cases and/or firearms be kept away from the GSR sampling kits, the area where sampling will take place, and the area of the laboratory where GSR analyses are performed.

The majority further agreed that it is possible for a handcuffed person's hands to be contaminated by the prior presence of GSR in the backseat of a police vehicle. However, if asked in court how likely it is for a handcuffed person's hands to be contaminated in the backseat of a police vehicle, most GSR experts would answer, "I don't know." Faye Springer offered data from a study of the backseats of law enforcement patrol vehicles in which 40 GSR samples were collected from 20 Sacramento Police Department patrol units as the vehicles were returning from the officers' shifts. None of the sampled backseats contained PbBaSb or PbBa particles. However, 6 vehicles tested positive for lead particles, and 2 contained one PbSb particle each (Springer 2005).

The Colorado Bureau of Investigation's study of the backseats of 26 law enforcement patrol vehicles indicated that at least 1 three-component particle was found in 14 of the vehicles. Five of the remaining 12 vehicles had at least 1 two-component particle detected. Only 7 vehicles had no PbBaSb particles detected (Rugh and Crowe 2005).

Debra Kowal also provided data from a three-part study that attempted to determine the occurrence of GSR in the law enforcement environment (Kowal 2005). In the first part of the study, vehicles from half of the Los Angeles County Sheriff's substations were sampled for GSR in the backseat "cupping area," a well or cutout in the lower portion of the seat where restrained individuals can rest their hands during transport. Two-component particles were detected on 45 of the 50 analyzed samples. Four of the 45 samples also contained three-component PbBaSb particles. Only 5 of the 50 samples were negative for the presence of GSR particles.

Kowal conducted a second study with respect to the secondary transfer of particles from the backseat of a patrol vehicle to a restrained individual's hands. A handcuffed person known to have GSR on the hands was placed in the backseat of a patrol vehicle for approximately 10 minutes, followed by a restrained individual known to have hands free of GSR. Sampling of the second person's hands indicated that 12 three-component and 10 two-component particles were transferred from the seat to the second individual's previously GSR-free hands.

The third part of the study described the transfer that took place when an individual with "clean" hands was handcuffed by an on-duty officer and placed in the backseat of a patrol vehicle for 10 minutes. Of the 41 samples collected from the hands of the previously "GSR-free" individuals, 20 had an average of 5 two-component particles transferred from the law enforcement environment (on-duty officer and/or patrol vehicle), 17 had no GSR-like particle transfer, and 4 contained PbBaSb particles. In 3 of those 4 cases, the officers had qualified with their service weapons during their shifts. The fourth transfer was noted on an individual who was handcuffed by an officer who had last drawn his firearm in the preceding 30 days.

In summary, the authors of the Kowal study demonstrated in the first part that GSR is in the environment of patrol car backseats. In part two, they demonstrated that transfer of GSR between a vehicle backseat and an individual is possible. And in part three, results indicated that GSR can be transferred from a law enforcement environment to an individual's hands. However, there are not sufficient data to statistically calculate a rate of transfer.

Geoffrey Warman noted that contamination might be identified through observation of the collective particle types and distribution observed in the examined residue. His laboratory noted the presence of a new particle type associated with pyrotechnic residues that was found on armed law enforcement officers. These particles contained Ba, Zr, Cr, Mn, with W also occasionally observed, and were concluded to result from the use of flash-bang distraction grenades. Warman concluded that these particles, if found on the subject, give independent evidence of transfer occurring from armed officers (Warman 2005).

Michael Martinez reported on a study of 100 handcuffed subjects who were sampled for the presence of GSR while in the custody of local law enforcement officers. Sampling took place after transport to magistrate court or jail while the subjects were awaiting arraignment. Two-component particles (either PbBa or PbSb) were located on 16 percent of the subjects on their dominant, unwashed hands. None of the subjects in this study had three-component particles on their hands. The authors concluded that the particles were transferred from a law enforcement officer, an inanimate object, or the back of the law enforcement vehicle in which the subjects had been transported (Martinez and Garcia 2005).

Another symposium participant offered information, which had been shared previously on the Forensic SEM listserv, describing a contamination study of different types of law enforcement vehicles, as well as table surfaces and restraining bars in interrogation rooms. No three-component (PbBaSb) particles were found in most of the sampled vehicles, although two PbBaSb particles were detected in vehicles with cloth seats. Table surfaces revealed a much higher rate of transferred PbBaSb particles, reinforcing the need for sample collection prior to leaving the scene. Thus, although the study determined that there is a chance of secondary transfer to subjects from transporting or detaining them, it was relatively low based on the collected data. That observation was corroborated by the majority of the symposium participants.

Further discussion ensued as to how to resolve the issue of contamination from contact between law enforcement personnel and subjects. Michael McVicar provided preliminary data from a study conducted in Ontario that was used to determine the prevalence of GSR on nonshooting police officers. Sixteen volunteers for the study were sampled for GSR on the backs of their left and right hands, the palms of their shooting hands, the shirt sleeves on the side where they carried their service firearms, the handles of their batons, and their handcuffs. Slightly less than half of the officers had no three-component PbBaSb particles on the surfaces tested. Four of the tested officers were plainclothes detectives who tested positive for two-component BaSb and three-component PbBaSb particles. A questionnaire the officers filled out for the study did not indicate any activity that would account for the presence of GSR (Randall and McVicar 2000).

Thus, although unlikely in practice, it was suggested by a large majority of participants that in order to better distinguish between GSR from contact with law enforcement versus a civilian shooting event, a policy such as that set forth in some European Union countries (e.g., Germany) should be set, which mandates that all domestic law enforcement use ammunition with taggants detectable by SEM/EDS (Niewoehner et al. 2005). This approach seems reasonable on a scientific level because most experts further agreed that they do not know of alternative methods to distinguish residue produced by police ammunition.

It was widely agreed that the average person who is not exposed to firearms or ammunition or its components will not be found to have GSR particles on the hands. Michael Martinez conducted an occupational study on 102 random individuals from 74 different occupations. The individuals were residents from the community who had been called for jury duty. Only one person was found to have a two-component particle on his hands. This juror reported that he had cleaned his hunting rifle 12 hours prior to being tested (Martinez 2005). These results indicate that a subject's daily environment can affect the likelihood of finding GSR. James Garcia of the U.S. Army Crime Laboratory reported that because the laboratory provides services in conjunction with investigations of military personnel, it expects to receive specimens with a higher propensity for elevated background levels of GSR. Therefore, the Army Crime Laboratory requires a threshold of at least four PbBaSb particles to report a positive GSR result for these specimens. The threshold was instituted to allow for the possibility of casual contact by subjects with firearms in the performance of their duties. However, levels beyond this value would likely involve greater exposure to GSR particles, namely, the recent discharge of a firearm (Garcia 2005). The FBI Laboratory has established a threshold for the number of GSR particles that is confirmed before an item can be concluded to have been exposed to gunshot residue. The number of particles used to confirm a GSR population is a minimum of three PbBaSb particles. Additionally, other particles consistent with a GSR-type environment also must be present: namely, SbBa, BaPb, PbSb, and/or other elements or element composites routinely found in GSR particle populations.

The majority of symposium participants overwhelmingly agreed that particles can transfer from one surface to another and that bystanders (e.g., a person present at the time of the shooting who does not come into direct physical contact with the shooter, firearm, or any other surface potentially contaminated with GSR) can test positive for GSR. Michael McVicar also shared the results of a study that sought to determine whether a bystander could be reasonably distinguished from a shooter. The conclusion was that the high degree of variability that exists in the deposition of GSR as a result of the ammunition-firearm combination and the number of shots fired produces an overlap between the GSR concentrations obtained from sampling either a shooter or bystander as quickly as 15 minutes postfiring. Therefore, the number of particles cannot be used as a basis for determining if someone fired, or was merely in the vicinity of, a recently discharged firearm (Lindsay and McVicar 2004).

Symposium participants also discussed that given the ease of transfer of GSR between surfaces, routine monitoring of the work environment should be included in a laboratory's standard protocol for GSR testing. At least 31 of the participants currently perform some form of routine testing in their laboratories to determine whether contamination is present.

Michael Martinez described an ongoing study his laboratory is conducting in an attempt to identify any GSR-positive "hot zones" within laboratory space. The results to date have led to a policy that no GSR examiner may enter the GSR instrument room on a day in which prior contact has transpired with any area of the firearms section of the laboratory (Martinez 2005). Michael McVicar stated that the policy of his laboratory restricts access such that no person who has handled a firearm or ammunition component, sampled an item for GSR, or entered the firearms section of the laboratory may enter the SEM laboratory for the remainder of that workday. Ludwig Niewoehner mentioned work that has been presented regarding the use of a clean room to cut down on the number of contamination-control samples that need to be run to ensure a GSR-free environment (Niewoehner and Neimke 1999). Wayne Niemeyer presented similar work regarding contamination studies and the use of a clean room (Niemeyer 2005).

### Case-Acceptance Criteria

Before discussing acceptance criteria, the participants agreed that the most probative value of GSR examination occurs in cases where the subject claims to have not handled or fired a firearm. The great majority of participants agreed that there is no value in collecting separate samples from the back and palm surfaces of the hand because it is more misleading than informative. Furthermore, the analyst should have the discretion to prioritize the samples submitted and discontinue the analysis when GSR is found. The participants also agreed unanimously that it is appropriate for a laboratory to have acceptance criteria or to limit the number of items examined.

Symposium participants also discussed time limits between a shooting incident and the collection of GSR on live subjects. Many participants stated that an acceptable cutoff time is 4 to 6 hours after the shooting event, whereas some felt that up to 8 hours was appropriate. Still others were comfortable accepting lifts taken more than 12 hours after the shooting. The Virginia Department of Forensic Science recommends sample collection within 4 to 6 hours of the shooting event as long as the hands have not been washed. Geoffrey Warman from England's Forensic Science Service commented that subjects could recontaminate their hands up to the time of arrest and that there was no probative value in examining samples taken more than 4 to 6 hours after arrest. He further noted that findings in relation to samples taken many hours after a shooting are better attributed to a more recent event or the redistribution of particles from some other contaminated surface (Warman 2005). For its acceptance policy, the FBI Laboratory uses a cutoff of 5 hours. The Florida Department of Law Enforcement and the Centre of Forensic Sciences in Toronto, Ontario, Canada, both have a stated time limit not to exceed 8 hours (Radcliffe 2005; McVicar 2005). All of the attendees stated that they recommend that samples be collected from the hands as quickly as possible and that laboratories may elect not to analyze lifts from the hands of live subjects 4 to 12 hours after the event in question.

Some of the attending laboratories also have policies in place to exclude analysis of samples collected from victims of gunshot wounds or anyone known to have handled a firearm. Many laboratories accept samples from only the hands, as opposed to other areas of the body, such as the face. This policy is supported by data presented by Douglas DeGaetano from Virginia. In an 18-month study conducted between 1993 and 1994, he reported that of 286 face samples analyzed, GSR was found on the face in only 9 cases in which the hand samples were negative (DeGaetano 2005). Only one-quarter of the participants at the symposium receive GSR lifts collected from the face of a subject. An overwhelming majority of the participants would consider analyzing face samples but agreed they should be examined only if hand samples are negative or unavailable.

When asked if it is satisfactory to use a single stub for sampling both hands and face together as long as tackiness remains, the majority disagreed. One of the concerns cited was the potential for high numbers of cosmetic particles—including bismuth, titanium, and iron-based pigments—on the facial area. These particles can hinder the search for GSR. Keeping the face and hand samples separate alleviates concerns about masking GSR particles on the hands with contaminants from the face. When asked if it is satisfactory to use one stub for sampling both hands together as long as tackiness remains, two-thirds agreed. However, one participant voiced the opinion that sometimes circumstances dictate the use of multiple stubs and that valuable information could be lost if those samples are not collected.

The types of kits that the participating laboratories will accept vary. Some participants stated that they accept "two lifter" kits, some accept "four lifter" kits, and the majority stated that they will accept any type of SEM/EDS GSR kit they receive. It was suggested that when in doubt, if the laboratory did not supply the kits to the contributor, it is wise for the contributor to phone the laboratory prior to sample collection for clarification about acceptable kits.

Under the subject of acceptance criteria, the participants were asked if they perform quality assurance (QA) testing on their supplier's GSR kits before using them in the field. Less than half test the kits themselves, and most are satisfied with the supplier's QA testing assurances.

About half of the participants require that the information sheet with the kits have certain mandatory information filled out before they will accept the kit. Many have no such requirements, and only a few require that the sheet be filled out completely.

## Testing Victims and Suspected Suicides

When asked if GSR testing should be done on suspected suicide victims, almost all participants agreed that these samples should be collected; however, they should be analyzed only if probative value can be shown.

The overwhelming majority of the experts agreed with the following statements:

1. Analyzing lifter samples for GSR from victims can never prove whether the subject is a victim of a suicide, a homicide, or an accident.

2. Particles are expected to be found on a victim shot at close range or within a reasonable distance from the muzzle, up to several feet.

3. Depending on the circumstances, some victims near the shooting may not have GSR particles on them.

In these discussions, Douglas DeGaetano reported that in a 10-year study of 5,231 GSR-related cases in Virginia, 39 percent (2,040 cases) involved possible suicides. Of this number, roughly 13 percent of suicide victims did not test positive for GSR particles. GSR collected from the hands of suicide victims at the scene was positive 92 percent of the time, whereas GSR collected from the hands of suicide victims at the morgue was positive 76 percent of the time (DeGaetano and Harrison 2004).

Michael Trimpe conducted a two-year study at the Hamilton County Coroner's Office (Ohio) during which 80 victims of suspected suicide were sampled for the presence of GSR. Seventy-nine percent of the victims tested positive for either two- or three-component classic GSR particles. Some of the reasons hypothesized for a negative result on 21 percent of the victims tested included medical attention received prior to sampling, bagging of the hands, time delay between the shooting and sampling and subsequent transport of the body, weather conditions, weapon type, number of shots fired, and refrigeration of the body prior to sampling for GSR. In the last scenario, condensation on the skin could remove GSR particles prior to sampling, much as hand washing or heavy perspiration might (Trimpe 1997).

A similar study was conducted by Michael Martinez in Bexar County, Texas, on 126 suspected suicide victims involving at least five different calibers of weapon. Only 48 of the individuals sampled tested positive for GSR. Of this number, 10 percent had only one GSR particle present. Possible reasons for the results included large amounts of blood on the surfaces sampled, a new or cleaned firearm used in the shooting event, an incorrect cause of death reported by medical examiners, and improper sample collection. It was concluded that if further testing was desired, the weapon and ammunition should be submitted (Martinez and Garcia 2005).

Finally, Carol Crowe reported that the Colorado Bureau of Investigation keeps a database to track the rate of positively confirmed GSR on victims of fatal gunshot wounds. Current information revealed that the bureau has classified GSR on 80 percent of homicide victims (94 out of 118 people with at least one PbBaSb particle found) versus a rate of 94 percent for victims of suicide (156 out of 166 people confirmed to have at least one PbBaSb particle on the area sampled) (Crowe 2005).

Discussions confirmed that the presence of GSR cannot determine whether the victim's death was the result of a homicide or a suicide; moreover, some suicide victims can test negative for the presence of GSR depending upon the circumstances and environmental conditions imposed postmortem on the body prior to sampling.

### Testing Clothing

Discussions were also held regarding testing clothing for the presence of gunshot residues. Attendees who have performed research or casework in this area provided details for reference. The sampling technique and materials were described as analogous to hand sampling in an article that originally appeared in the *IAMA Newsletter* (International Association for Microanalysis) (Martinez 2000).

Guidelines for sample submission and acceptance were offered by Michael McVicar (McVicar 2005). These parameters included collecting the sample at the laboratory by trained personnel who have not discharged or been in the vicinity of a discharged weapon within the past 24 hours prior to sample collection. If personnel seizing the clothing have discharged a weapon, at a minimum, they should thoroughly wash their hands, change their clothes, and don gloves prior to evidence collection. With respect to packaging the clothing, paper (bags or wrapping), rather than plastic, is recommended. Additionally, larger garments should be folded with brown paper between the folds in order to prevent the transfer of GSR from one area to another. If the latter step is not taken, it is recommended that the analyst photograph the clothing in its packaging as received to demonstrate why a conclusion cannot be reached as to where the particles originated on the garment. A. J. Schwoeble of the RJ Lee Group in Pennsylvania suggested the use of white "butcher-type" waxed paper as an alternative to the traditional brown kraft paper in order to prevent the introduction of fibers from the paper onto the garment (Schwoeble 2005).

With respect to case acceptance of clothing items, Michael McVicar advised that the Centre of Forensic Sciences also instructs its contributors to ensure that the garment being submitted can reasonably be expected to have had direct contact with or proximity to a discharged firearm. Within this context, a shirt worn inside another layer would not be as probative for sampling purposes as the outer garment. Other items such as shoes would similarly be considered too far removed from the discharge to have received appreciable amounts of residue. Finally, items with a surface relatively free of loose debris or easily shed fibers are preferable.

Carol Crowe provided a study performed by the Colorado Bureau of Investigation in which clothing was tested for GSR residues subsequent to discharging a weapon and laundering the worn garments in a conventional washing machine with warm water and detergent (Chavez et al. 2001). A variety of garments and fabrics were tested both postfiring and postlaundering. Results demonstrated the persistence of three-component GSR particles and/or two-component (supporting) particles on some of the garments even after washing. However, as the authors stated in their conclusions, the presence of GSR on clothing cannot provide confirmation of a recent association with a discharged firearm in the same manner that such findings on a living person's skin (i.e., hands or face) might suggest. In other words, time of GSR deposition on clothing cannot be assessed in the same context as when it is confirmed on specimens taken directly from skin surfaces.

Several participants offered evidence that persistence on fibrous materials is longer than on skin. In particular, a study by A. J. Schwoeble found that the number of PbBaSb particles discovered after clothing was laundered was reduced between 88 and 99 percent. Thus, whereas most PbBaSb particles were found to be in the 1–10-µm size range before washing, only particles less than 2 µm were found afterward.

Other suggestions provided for the analysis of clothing included:

1. Sampling the clothing while it is still worn by the subject rather than packaging it for transport to the laboratory.
2. Carbon-coating all stubs used to sample fibrous material to reduce or prevent charging effects.
3. Dedicating the SEM chamber to only one case when fibrous samples are being analyzed, in the event of particle transfer from charging effects.
4. Using adhesive lifters, which are better suited to GSR examinations of clothing surfaces than vacuuming all matter embedded in the fabric weave, when attempting to locate GSR particles from a recent firing.
5. Sampling areas on the garment where a weapon could be concealed (e.g., pocket interiors).

In conclusion, the participants unanimously agreed that there are circumstances when items of clothing associated with a subject and event should be examined for the presence of GSR (e.g., when hand samples are negative or not available).

### "Instant Shooter" Identification Kits

With respect to combination kits, such as field-use "instant shooter kits" (marketed as ISID, RIFF, or other brands), GSR lifts for SEM should always be taken before the instant shooter swabbing is employed. Unequivocally, taping (using adhesive lifts), as opposed to swabbing, for GSR by SEM is the best form of sampling. The marketed instant shooter kits are essentially an updated version of the dermal nitrate test that uses a color change to detect the presence of nitrates.

Historically, the dermal nitrate test has been shown to produce many false positives and is not specific for the presence of GSR. The use of the presumptive kits now being marketed may cause the loss of GSR particles. Of the kits marketed for rapid detection of nitrates (presumably from nitrocellulose in smokeless powder), extraction procedures are cumbersome, time-consuming, and much less successful at recovering GSR particles than adhesive lifts. This finding was reported by Faye Springer in a recent journal article (Hanson and Springer 2005) and has been independently corroborated at the FBI Laboratory. As a result of discussions among attendees from several laboratories that have observed similar problems, the majority of the group members did not think these kits should be used to collect or test for GSR in place of SEM/EDS analysis, and most were not willing to analyze them for this purpose. Moreover, although there was no strenuous objection to independent laboratories' performing further tests on instant shooter kits for GSR particle retention, some participants advised against it for the reasons stated above.

### Significance and Report Writing

With respect to the significance of the results obtained, most experts felt that even one PbBaSb spheroid particle is enough for a "positive" result. However, almost all of the attending experts agreed that GSR particles alone cannot be attributed to a particular shooting event. It also cannot be determined what actually occurred with respect to a shooter's hands between the time of shooting and sampling. It is understood that GSR particles cannot be used to distinguish between shooters and bystanders. Similarly, the absence of gunshot residues on a sample does not preclude the possibility of that individual's having discharged a firearm. Many of the experts also stated that these caveats are included in some form in reporting out inconclusive or negative results.

Along the lines of interpretation, some experts stated that they list particle counts to report everything found in a search for GSR, whereas others felt that this approach might be misleading to those who are unable to interpret results. More than half of the respondents indicated that the use of particle counts needed to be followed by an opinion statement to provide context to the findings.

A majority of the attendees reiterated throughout these discussions that a qualifying statement is needed in reports. The following example is considered an appropriate qualifying statement to use when particles are found on a person's hands: the findings are "consistent with that person's having fired a weapon, having been in the vicinity of a fired weapon, or having touched an item with gunshot residue on it." For negative results, GSR may not have been detected for reasons that may include:

1. Lack of exposure of the individual to GSR.
2. Removal of particles through physical activity, hand washing, or weather conditions.
3. Lack of traditional GSR components in the ammunition (e.g., organic primer formulations or primers lacking one of the three components associated with GSR).
4. Heavy soil deposition on the surface being sampled.
5. Improper use of the collection kit (e.g., rubbing the sampling surface with the stub rather than dabbing might cause damage to the tape surface).
6. Lack of deposition of an acceptable threshold of GSR particles by the discharged firearm.

Depending on the request, other qualifiers might also be used to convey limitations. Examples include the inability of GSR examinations to determine firing angles, the handedness of the shooter, the hand used to discharge the weapon, and the type of weapon used.

Many of the responding attendees agreed that it is good practice to compare residue found on the suspect to the shooting event through examination of the firearm, spent ammunition from the scene, or the victims' clothing; however, it is not essential to do so. Similarly, slightly more than half agreed that the firearm should be test-fired, when available and applicable in a GSR case, to determine if residues are deposited. It is generally acknowledged that residues released from ammunition during discharge are not all generated from that shooting event (Schwoeble and Exline 2000). Rather, the residue population may also include contributions from ammunitions previously fired from that gun. Therefore, the direct comparison of residue populations from the victim, suspect, and test firings must be interpreted with caution.

### Technical Review

The majority of attendees indicated that their laboratories require that *all* GSR reports be peer-reviewed (i.e., technically reviewed) prior to being released and that they support this policy. The majority agreed that, at a minimum, the American Society of Crime Laboratory Directors/Laboratory Accreditation Board

(ASCLD/LAB), or some other relevant accrediting body, should set a policy as to what percentage of all reports should be peer-reviewed (technically reviewed) by another qualified examiner prior to release.

Some symposium participants work for laboratory systems that do not have a policy for any technical review prior to issuing a report. However, most of the attendees agreed that an administrative review alone is not sufficient to ensure technical accuracy. Further discussion elucidated the idea that the time spent in review is helpful to both the reporting examiner and the reviewer with respect to sharing ideas and minimizing testifying to a report with inaccuracies ranging from typographical errors to technical mistakes.

### Proficiency Testing

With respect to quality-assurance-related topics, the symposium participants all agreed that the European Network of Forensic Science Institutes' (ENFSI) GSR proficiency test should be adopted as an approved test for GSR analysis by SEM/EDS (Niewoehner et al. 2005). This standard sample, prepared by the PLANO Company in Germany in accordance with ISO (International Organization for Standardization) 5725 for the performance of proficiency tests, consists of "synthetic GSR particles" with the composition of PbBaSb precipitated onto a silicon substrate previously coated with a carbon layer. Although it is not a good representation of a real-world GSR sample, it is the best proficiency-testing sample currently available for GSR. It can also be used for system validation.

Most experts also agreed that they would be willing to participate in a round-robin proficiency test in the absence of a standardized commercial GSR testing program. Roughly half of the respondents agreed that they would even participate in a round-robin to the extent that they would accept responsibility for preparing and distributing the test on a rotating basis.

The majority also agreed that examiners who perform GSR analysis should be proficiency-tested specifically in GSR regardless of whether they have already been tested on other materials characterized as "trace" samples.

Finally, the majority of participants agreed that they look for submicron particles in their automated search routines, and therefore, neither a specific test for proficiency nor an instrument vendor should dictate what range of particle sizes should be characterized or studied in an analysis.

### Methodology

The symposium attendees stated that, in general, they conduct GSR analyses using SEM/EDS. Although the vast majority confirmed that they perform these examinations using automated search routines, the group unanimously agreed that manual confirmation should always be performed for at least a representative sample of the population. It was stated unequivocally that automated search routines alone cannot be used reliably to report a positive GSR result.

With the development of test methods that identify multiple components of smokeless powder and its additives rather than only nitrate residues, the group supported participation in research and development in this area. Particular mention was made regarding research into organic residues. New technology recently acquired by two laboratories whose personnel attended the symposium may hold promise in this regard. The instrument of interest is a time-of-flight mass spectrometer capable of real-time, nondestructive analysis of a wide range of materials commonly encountered in forensics. It is expected that research into its applicability to non-lead- based GSR residues will be forthcoming in the literature.

Further discussion and research was also advocated in the area of primers that produce nonclassical GSR residues, such as BaSbAl or TiZn or other non-lead-containing components. Time constraints limited the scope of this topic, and as a result, no definitive statements were offered for consensus voting. However, the area remains one of interest within the community and does warrant future attention.

### ASTM Guidelines

A representative from ASTM International was present at the symposium to provide the attendees with an update as to the progress made to date on the ASTM guide *E1588-95(2001) Standard Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy-Dispersive Spectroscopy*. The group was given an overview of the status of the revision of the guide and encouraged to discuss any problems with the current ASTM guideline. Comments and suggestions were noted for later discussion within the committee.

### Conclusion

At the conclusion of the symposium, several topics remained open for further discussion: namely, the use of time limits in case-acceptance criteria and how to standardize the language used to report the presence of GSR particles. Topics such as these are often dictated by individual laboratory policies, as well as the circumstances of a particular case. Therefore, it is unlikely that universal guidelines and terminology will evolve for the GSR community in these areas.

Some important topics were not discussed because of time limitations, specifically, airborne particles and elemental contributions from different ammunitions. However, the limitations of GSR examinations were unanimously recognized, such that the use of qualifying statements in report writing and testimony was discussed in detail. It is expected that the language of qualifiers will continue to develop in order to provide juries with a sound basis to evaluate the conclusions reached through GSR analyses. Research is also continuing in the areas of retention and contamination or transfer. It is hoped that these studies will be more readily available to the GSR community in the future through the use of Internet listservs and forums such as this one.

### Editor's Note

The FBI recently decided to stop conducting GSR examinations. This decision was made after an internal assessment of the number of requests received for this examination in recent years and the probative nature of those requests.

The FBI Laboratory continues to believe that the GSR examination is valuable but has decided to use the resources previously dedicated to GSR in areas directly related to fighting terrorism, which is the FBI's primary mission.

The FBI Laboratory stands behind the reports it has already issued using this technique. Should a future case require GSR analysis, the Laboratory will send to the requesting agency a list of state, local, and private laboratories that conduct GSR examinations.

### Acknowledgment

This is publication number 06-03 of the Laboratory Division of the Federal Bureau of Investigation. Names of commercial manufacturers are provided for identification purposes only, and inclusion does not imply endorsement by the FBI.

### References

Cardinetti, B. *X-Ray Mapping Technique: Gunshot Residue Particles vs. Aggregates from Environmental Origin*. Presented at SCANNING, Washington, D.C., 2004.

Chavez, D., Crowe, C., and Franco, L. The retention of gunshot residue on clothing after laundering. *IAMA Newsletter* (2001) 2(1):2–7.

Crowe, C. Colorado Bureau of Investigation, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

DeGaetano, D. H. Virginia Department of Forensic Science, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

DeGaetano, D. H. and Harrison, L. G. *GSR by SEM/EDX at the Commonwealth of Virginia—Ten Years of Data from Spreadsheet to Database.* Presented at SCANNING, Washington, D.C., 2004.

DeGaetano, D. H., Maye, S., and Harrison, L. G. Virginia Department of Forensic Science, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Garafano, L., Fratini, P., Minardi, M., Bizzaro, G. P., Tortora, F., and Manna, L. *Further Studies to Discriminate Primer Discharge Residues from Particles of Environmental Origin.* Presented at SCANNING, Monterrey, California, 2005.

Garcia J. D. U.S. Army Crime Laboratory, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Giacalone, J. *Putting the Brakes on Gunshot Residue.* Presented at SCANNING, San Antonio, Texas, 2000.

Hanson, A. M. and Springer, F. A. An evaluation of Instant Shooter Identification (ISid™) gunshot residue kits, *AFTE Journal* (2005) 37:172–178.

Kowal, D. *Gunshot Residue in the Law Enforcement Environment.* Presented at the California Association of Criminalists meeting, Glendale, California, 2000.

Lueftl, K. and Gebhart, E. *GSR-Like Particles from Brake Pads.* Presented at the BKA GSR Symposium, Bad Camberg, Germany, 2004.

Lindsay, E. and McVicar, M. J. *Passive Exposure and Persistence of Gunshot Residue on Bystanders to a Shooting: Can a Bystander Be Differentiated from a Shooter Based on GSR?* Presented at the joint meeting of the Canadian Society of Forensic Science and the Southern Association of Forensic Science, Mid-Atlantic Association of Forensic Science, and Midwestern Association of Forensic Science, Orlando, Florida, 2004.

Martinez , M. V. Bexar County Criminal Investigation Laboratory, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Martinez , M. V. P-GSR detection on clothing and in automobiles, *IAMA Newsletter* (2000) 1(2):2–3.

Martinez , M. V. Bexar County Criminal Investigation Laboratory, and Garcia J. D. U.S. Army Crime Laboratory, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

McVicar, M. J. Centre of Forensic Sciences, Toronto, Ontario, Canada, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Mosher, P. V., McVicar M. J., Randall E. D., and Sild, E. H. Gunshot residue-similar particles produced by fireworks, *Canadian Society of Forensic Science Journal* (1998) 31(2):157–168.

Niemeyer, W. D. McCrone Associates, Inc., Westmont, Illinois, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Niewoehner, L., Andrasko, J., Biegstraaten, J., Gunaratnam, L., Steffen, S., and Uhlig, S. Maintenance of the ENFSI proficiency test program on identification of GSR by SEM/EDX (GSR2003), *Journal of Forensic Sciences* (2005) 50:877–882.

Niewoehner, L. and Neimke, D. *Establishing a Cleanroom for GSR Investigation—A Necessity or Not?* Presented at the ENFSI EWG meeting, Den Haag, The Netherlands, 1999.

Radcliffe, D. T. Florida Department of Law Enforcement, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Randall, D. and McVicar, M. J. *A Study to Determine the Prevalence of GSR on Non-Shooting Police Officers.* Preliminary results presented at the 47th Canadian Society of Forensic Science meeting, Ottawa, Ontario, Canada, November 2000.

Rugh, A. and Crowe, C. *The Prevalence of Gunshot Residue in Law Enforcement Patrol Cars.* Presented at SCANNING, Monterey, California, 2005.

Schwoeble, A. J. *GSR Persistence on Clothing.* Presented (poster form) at the 51st American Academy of Forensic Sciences meeting, Orlando, Florida, 1999. Also presented (oral format) at the 26th Mid-Atlantic Association of Forensic Scientists meeting, Ocean City, Maryland, April 21–23, 1999.

Schwoeble, A. J. RJ Lee Group, Monroeville, Pennsylvania, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Schwoeble, A. J. and Exline D. L. *Current Methods in Forensic Gunshot Residue Analysis.* CRC Press, Boca Raton, Florida, 2000, pp. 92–123.

Springer, F. A. Sacramento County Office of the District Attorney Laboratory of Forensic Services, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

Torre, C., Mattutino, G., Vasino, V., and Robino, C. Brake linings: A source of non-GSR particles containing lead, barium, and antimony, *Journal of Forensic Sciences* (2002) 47:494–504.

Trimpe, M. A. *A Review of Gunshot Residue Test Results in 80 Suicide Cases.* Presented at the American Academy of Forensic Sciences meeting, New York, 1997.

Trimpe, M. A. *Analysis of Fireworks for Particles of the Type Found in Primer Residue (GSR).* Presented at the American Academy of Forensic Sciences meeting, Seattle, Washington, 2001.

Warman, G. Forensic Science Service, London, England, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

White, T. R. Texas Department of Public Safety Crime Laboratory Service, personal communication at the FBI Laboratory GSR Symposium, May 31–June 3, 2005.

## Appendix

The following scientists participated in the 2005 FBI Laboratory GSR Symposium:

Robert Berk, Illinois State Police, Chicago, Illinois

JoAnn Buscaglia, FBI Laboratory, Quantico, Virginia

James Crippin, Western Forensic Law Enforcement Training Center, Pueblo, Colorado

Carol M. Crowe, Colorado Bureau of Investigation, Lakewood, Colorado

Douglas H. DeGaetano, Commonwealth of Virginia, Department of Forensic Science, Richmond, Virginia

John E. Drugan, Massachusetts State Police Crime Laboratory, Sudbury, Massachusetts

Patricia C. Eddings, Tarrant County Medical Examiner's District Crime Laboratory, Fort Worth, Texas

Gamal Emira, Philadelphia Police Department Forensic Science Center, Philadelphia, Pennsylvania

James D. Garcia, U.S. Army Criminal Investigation Laboratory, Forest Park, Georgia

John R. Giacalone, State of Alaska, Department of Public Safety, Anchorage, Alaska

Lawrence Gunaratnam, National Bureau of Investigation Crime Laboratory, Vantaa, Finland

Joseph Harant, Baltimore City Police Department Laboratory, Baltimore, Maryland

Annalivia Harris, Montana State Crime Laboratory, Missoula, Montana

Robert L. Hinkley, Alameda County Sheriff's Office Criminalistics Laboratory, San Leandro, California

James L. Jackson Jr., Harris County Medical Examiner's Office, Houston, Texas

Robert D. Koons, FBI Laboratory, Quantico, Virginia

Debra Kowal, Los Angeles County Department of Coroner, Los Angeles, California

Thomas A. Kubic, TAKA, Inc., Northport, New York

Jozef Lebiedzik, Advanced Research Instruments Corporation, Golden, Colorado

Karl Lueftl, Bayerisches Landeskriminalamt (Bavarian State Criminal Police Agency), Munich, Germany

Michael Martinez, Bexar County Criminal Investigation Laboratory, San Antonio, Texas

Deborah Messina, Connecticut State Forensic Science Laboratory, Meriden, Connecticut

Michael J. McVicar, Centre of Forensic Sciences, Toronto, Ontario, Canada

Wayne D. Niemeyer, McCrone Associates, Inc., Westmont, Illinois

Ludwig Niewöhner, Bundeskriminalamt (BKA, Federal Criminal Police Office), Wiesbaden, Germany

Laila (Benham) Parahinia, Santa Clara County District Attorney's Crime Laboratory, San Jose, California

Elizabeth Patel, North Carolina State Bureau of Investigation, Raleigh, North Carolina

Michael Platek, Rhode Island State Crime Laboratory, Kingston, Rhode Island

Koren Powers, West Virginia State Police Forensic Laboratory, South Charleston, West Virginia

Daniel T. Radcliffe, Florida Department of Law Enforcement, Daytona Beach, Florida

Sandra B. Sachs, Office of the Chief Medical Examiner, San Francisco, California

A. J. "Skip" Schwoeble, RJ Lee Group, Inc., Monroeville, Pennsylvania

Ila Simmons, South Carolina Law Enforcement Division, Columbia, South Carolina

Jenny Smith, Missouri State Highway Patrol Forensic Laboratory, Jefferson City, Missouri

David W. Spence, Southwestern Institute of Forensic Crime Laboratory Services, Dallas, Texas

Faye Springer, Sacramento County District Attorney, Sacramento, California

James N. Stam, San Diego Police Department, San Diego, California

Michael A. Trimpe, Hamilton County Coroner's Office, Cincinnati, Ohio

Dennis C. Ward, FBI Laboratory, Quantico, Virginia

Geoffrey Warman, Forensic Science Service, London, England

Robert S. White, Legal Science, Charleston, West Virginia

Thomas R. White, Texas Department of Public Safety Crime Laboratory Service, Austin, Texas

Diana M. Wright, FBI Laboratory, Quantico, Virginia