

The Current Status of GSR Examinations

By MICHAEL TRIMPE



© Thinkstock.com

Research and advancements in technology have brought changes to gunshot residue (GSR) examinations over the past several years. While the *Final Report on Particle Analysis for Gunshot Residue Detection*, released in 1977, still stands as an excellent comprehensive report on the analysis and interpretation

of primer GSR, additional research and development have led to improvements and refinements in how authorities detect GSR.¹ Particle analysis by scanning electron microscopy/energy dispersive x-ray spectrometry (SEM/EDS) has become the preferred method of analysis over bulk techniques, such as atomic absorption, because

SEM/EDS provides increased specificity, as well as the ability to conduct analysis without chemicals. Recently, technological advances have made particle analysis quicker and easier, but most current research involves the interpretation of results.

Communication among SEM gunshot residue analysts

has inspired research and studies that, in turn, have brought about enhanced understanding and increased confidence in GSR interpretation. Conversely, media coverage of specific cases involving GSR, as well as articles in nonpeer-reviewed publications, have led to confusion about the meaning of GSR findings.² Reputable scientists always have reported that the finding of GSR cannot indicate the shooter, yet members of the media usually seem surprised to learn that. Nevertheless, GSR findings continue to add value simply because numerous population studies have shown that GSR is not normally found on the average person.³ In addition, exhaustive study into the search for false positive results has strengthened the opinion that SEM/EDS particle analysis can attribute the source of certain particles to the discharge of a firearm.

Primer GSR

A discussion of the collection, analysis, interpretation, and reporting of GSR requires an understanding of the formation of primer residue particles. Most residue originating from the barrel of a gun is burned, unburned, or partially burned propellant (gunpowder) and contains metal particulates, such as lead, copper, brass, or nickel from jacketing material.

Firearms examiners use this type of GSR to determine the distance between the muzzle of a gun and a target. When forensic trace evidence examiners receive a request to look for GSR on the hands or clothing of a suspected shooter, they search for residue from the primer.

The firing pin of a gun hits the back of the cartridge, activating the shock-sensitive primer, which ignites the gunpowder, forcing the bullet down the barrel of the gun and on its path. The heat and pressure within the cartridge vaporize the metals from the primer. Vapors escape from any area of the weapon not gas tight, like the breach area and muzzle. The heat of this explosive reaction and subsequent cooling results in the condensation and

formation of tiny metal-containing particles. These particles fall on anything in the vicinity of the fired weapon, including the hands of the shooter, and typically measure 1 to 10 microns (10^{-6} m) in size (for comparison, a typical human hair is approximately 100 microns in diameter). Finding and viewing primer GSR particles require a high-powered microscope, such as an SEM.

Gunshot residue particles can be removed easily from the surfaces they land on. Regular activities, such as putting hands in pockets, rubbing hands together, or handling items, can wipe them away.⁴ The washing of hands can remove most, if not all, particles. Rates of loss vary widely with the activity of the subject. Depending on

“ Research and advancements in technology have brought changes to GSR examinations over the past several years. ”



Mr. Trimpe, a trace evidence examiner with the Hamilton County Coroner's Office in Cincinnati, Ohio, is the chairman of the Scientific Working Group on Gunshot Residue.

conditions and activity, particles may be removed from a shooter's hands within 4 to 5 hours after a shooting event.⁵ They also can transfer from a surface or person to another individual; the amount depends on the number of GSR particles on the contaminated surface (e.g., a person's clothing or hands) and likely will be a small percentage of the total number of particles present. Tests show that people standing within 3 feet to the side of a shooter may have GSR on their hands, whereas those standing 10 or more feet in the same direction typically will not.⁶ This can vary with the type of gun and ammunition, number of shots fired, and the environment of the shooting. Gunshot primer residue also can travel downrange with each firing of a weapon.⁷ Long guns, like rifles and shotguns, tend to leave less GSR on shooters than handguns.⁸

GSR Samples

Investigators collect primer GSR with adhesive lifters, sometimes referred to in supply catalogs as dabs or stubs. Several companies sell them, usually as a kit with gloves, instructions, an information form, and tape to seal the kit when finished. The adhesive contains carbon, which colors it black and makes it able to conduct electrons in the SEM. Analysts also can use clear adhesive

lifters; however, these require an extra step of carbon coating to prevent charging from the electron beam hitting the sample during analysis.

The adhesive is located on an aluminum stub fixed into the cap of a plastic container. Removing the cap exposes the tape, and the sample collection official can press the adhesive—without ever touching it—to the

When submitting evidence, investigators must realize that forensic testing laboratories can have different case-acceptance criteria.

sampling surface. The submitting officer completes the information form, which provides collection-site data (e.g., condition of the subject's hands, known activity prior to collection, estimated time of shooting, and exact time of collection), as well as the type of gun and ammunition used in the event, if known.

Investigators should use one lifter per collection site. Some kits contain two (left hand and right hand), and others feature

four (left back, left palm, right back, and right palm). One lifter can suffice when sampling an entire hand, front and back.⁹ Lifters from separate hands can be considered and analyzed as one subject's sample at the lab. Finding particles on the left hand versus the right hand or back versus palm holds no significance because analysts do not know the activity of the hands between the time of the shooting and the time of collection and because both hands likely are in the vicinity of the fired weapon. Investigators can press lifters to the face, hair, or clothing if they suspect that the hands have been cleaned between shooting and collection or covered at the time of the event.

For sampling inanimate objects, like clothing, investigators employ the same type of adhesive lifters. The areas of the garment for sampling depend on whether the person wearing the clothes was believed to be firing a gun, carrying one in a specific location, or trying to conceal a gun in a particular manner. Analysts usually avoid excessively soiled or bloody areas of clothing as these materials can inhibit the ability to find GSR particles. Laboratory tests have shown that GSR on clothing will last considerably longer than on hands, but exactly how long remains unknown and greatly depends on the activity of the clothing and the type

of fabric.¹⁰ Similar to hands, however, washing will remove most, if not all, residue from the clothing.¹¹

When submitting evidence, investigators must realize that forensic testing laboratories can have different case-acceptance criteria. For instance, some may not test victims, kits unsuitable for SEM analysis, or samples collected past a specified time limit. Each facility must assess the needs of the community it serves, the importance of the testing, and the cost of analysis. In addition, laboratories must consider the personnel, instrumentation, and time available for the work involved. As one example, the FBI Laboratory no longer accepts GSR cases because of a decision that its resources would serve its community, the United States, better when directed toward fighting terrorism.¹²

Case acceptance criteria applies to all forensic examinations, including those involving GSR, fingerprints, hairs, soils, DNA, and drugs. Therefore, it is common for one GSR testing laboratory to accept victim, back and palm, clothing, and face samples, as well as those collected beyond 5 hours, while another facility does not. Correspondingly, one laboratory might reject DNA samples for lesser crimes while another may accept them. A drug laboratory may not accept syringe or

currency samples and might test only enough samples to reach maximum charge in its jurisdiction. A firearms testing facility may not analyze clothing for distance determinations, perform function tests on firearms, or compare unfired ammunition. Investigators best can maximize the use of GSR analysis results by knowing the laboratory's case acceptance policy and the reasoning behind it.¹³

Contamination

Police officers are trained to collect samples as soon as possible after apprehending, a suspect—preferably, before transportation to the police station—and to clean their

hands and wear gloves when sampling suspects to prevent contamination. While law enforcement personnel could be a potential source of GSR because they carry guns, studies have shown that few of them have particles on their hands because they clean their hands much more often than they touch their weapons.¹⁴ Nevertheless, police officers should avoid contact with a subject's hands before sampling. If armed officers collect the samples, a disposable lab coat, along with proper hand washing and glove use, can minimize the risk of contamination. As police vehicles and interrogation rooms are potential sources of



Hamilton County Coroner's Office SEM/EDS system

contamination, investigators should collect GSR samples before transporting subjects in a police car or questioning them at the station. Studies have indicated a low potential for secondary transfer in these areas and that testing them occasionally may help prove the low risk of contamination.¹⁵

During examination, safeguards can ensure that GSR samples remain uncontaminated in the laboratory. Samples for GSR testing never should be exposed to the firearms area of the facility. Sample stubs are exposed only to the air immediately before and after placement in the SEM vacuum chamber. A positive control (e.g., a stub containing GSR) and a blank (e.g., an unused stub from the submitted sample collection kit or one free of GSR) in each analysis ensure that contamination has not occurred and that the instrument functions properly. To monitor the examination area, personnel place a blank adhesive lifter in the laboratory where clothing is tested for GSR. The examination area and the SEM instrument area should be located far from the firearms section of a laboratory. Additionally, no armed personnel or persons who made contact with the firearms section on the day of analysis should have access to those areas.

Analysis

Analysis of the adhesive stub is performed with an SEM/EDS. At least 140 SEMs used for GSR analysis exist in crime laboratories throughout the world.¹⁶ Usually, such facilities use a sophisticated software program to automatically search adhesive stubs for GSR particles. As the instrument detects particles of suspected GSR, a



During examination, safeguards can ensure that GSR samples remain uncontaminated in the laboratory.



computer stores the coordinates of each one for manual confirmation by trained laboratory personnel upon completion of the automated analysis. Analyst-controlled setup and manual confirmation of results is tedious and time-consuming; the actual automated search of one blank stub can take 2 to 6 hours, depending on the instrument and chosen parameters. If a sample contains a large number of detected particles, the duration of analysis could increase greatly. Once the instrument

finds suspected GSR particles, the analyst relocates and manually confirms a sufficient number of them. The examiner documents and reports confirmed GSR particles.

A particle must meet certain criteria to become characterized as GSR. Three specifications, in particular, determine if a particle originates from the primer of a discharged firearm.¹⁷ The elemental composition of the particle is the most diagnostic criterion. Most primers used in North America consist of lead styphnate (Pb) as an initiating explosive, barium nitrate (Ba) as an oxidizer, and antimony sulfide (Sb) as a fuel; therefore, a combination of these elements in a single particle proves very significant. *ASTM 1588 Standard Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive X-ray Spectrometry (SEM/EDS)* contains a complete list of elemental compositions allowed in primer GSR determinations. Second, the morphology of the tiny condensed primer residue particles typically is spheroid or shows shape characteristics of having been molten.¹⁸

Finally, how the particle relates to the population of particles in the sample is important in determining its source. Studies have shown that certain detonated fireworks, used brake pads, and exploded air bags can

Scientific Working Group on Gunshot Residue

The advancements in GSR examinations over the past 40 years have led to improved analysis and more reliable results. Further, communication among GSR analysts, especially via the Internet, is making difficult interpretation easier to understand by instantly sharing research and developments. This open communication has led to the recent formation of the Scientific Working Group on Gunshot Residue (SWGSR). Consensus among scientists performing GSR analysis is becoming a global reality. The SWGSR consists of an international conglomerate of experienced scientists who conduct research and issue guidelines for GSR investigations, examinations, reporting, and quality assurance to help GSR analyses and results become better understood and more reliable.



Scientific Working Group on Gunshot Residue (SWGSR) logo

have particles with GSR-like elemental composition or morphology.¹⁹ But, each of those materials contains additional elements inconsistent with GSR identification. Therefore, a comprehensive analysis of the sample can eliminate false positives, leaving GSR as the only possible source. In this area, recent research and studies in the search for false positives have only brought about increased confidence in characterizing particles as GSR.

Reporting

A forensic laboratory will issue a report of the findings and, possibly, an opinion in certain cases. No universal

reporting format exists because each jurisdiction abides by the rules and practices governing its court system. A section pertaining to findings, results, or conclusions contains the substance of a forensic report. These results must be not only scientifically accurate but written in terms understandable to a layperson.

In a GSR case, the submitting agency, attorneys, judge, and jury all want to know if the suspect fired a gun. Unfortunately, the presence or absence of GSR on a person's hands cannot answer that question. Rather, as the accepted practice, all positive gunshot residue reports include a qualifier, such

as "The presence of primer residue on a person's hand is consistent with that person having discharged a firearm, having been in the vicinity of a firearm when it was discharged, or having handled an item with primer residue on it." Conversely, negative GSR reports often contain a qualifying statement, such as "The absence of gunshot residue on a person's hands does not eliminate that individual from having discharged a firearm." And, when GSR is found on an inanimate object, like clothing, a qualifier could be, "The presence of primer residue on an item is consistent with that item sometime having been in the vicinity of a firearm

when it was discharged or having come in contact with primer residue on another item.” A forensic GSR report also may list the instrumentation used (e.g., SEM/EDS) and the criteria employed to define the gunshot residue (e.g., elemental composition and morphology).

A laboratory report may reference three- or two-component particles. Most primers produce particles containing lead, barium, and antimony, including any combination of those three components. While two-component particles commonly form upon discharge of a gun, they also are more likely than three-component particles to be found in sources other than primer residue, like fireworks and brake pads.²⁰ When examiners find relevant particles, they should not include the word *unique* in the GSR report. Even though analysts may eliminate all other sources in a particular case, three-component particles containing Pb, Ba, and Sb have been proven not to be unique to gunshot residue.²¹ Also, some types of ammunition contain primers without one or more of those elements. During a routine analysis, examiners also search for the components of these more rare ammunition types. Therefore, a laboratory report occasionally may list other elements found, and analysts perform a comparison of

the fired-cartridge casing in that particular case.

When forensic laboratory personnel find GSR in response to a request, they must report it. While experts expect to find numerous particles on the hands of a shooter immediately after the subject fired a weapon, discovering just one particle with the correct elemental composition and morphology nevertheless constitutes GSR and should

“

A particle must meet certain criteria to become characterized as GSR.

”

be reported. Few forensic laboratories use a scientifically established threshold for reporting gunshot residue results. In those cases, if the number of GSR particles does not meet the established level, examiners should report those particles. Further, the threshold (e.g., three GSR particles) must be specified. Having a threshold of significance may be helpful in isolated cases. For instance, the U.S. Army must consider that all of its cases involve personnel who carry guns.

Testimony

GSR testimony can be challenging because of the difficulty in interpreting the results. An expert assumes the role of teacher when describing gunshot residue and its analysis. After instructing the court on the definition, production, collection, preservation, and analysis of GSR, the examiner then must present the results in a simple, truthful, and unbiased manner. The difficulty lies in the fact that while analysts can report that the particles came from a fired weapon, they cannot describe how they were deposited on the item. Examiners called to testify on GSR results cannot identify the person who discharged a firearm in the commission of a criminal act. A positive GSR finding is most probative in cases where a suspect denies proximity to a discharged firearm because GSR is not common to the average person’s daily environment. A negative finding does not imply that the subject was not in the vicinity of a recently discharged firearm; it only indicates that no evidence of primer residue was found on the items tested.

Often, defense attorneys will raise questions at trial as to why GSR was not collected, under the guise that negative results would have been vital to the defense’s strategy and

ultimately exonerated the suspect. Investigators and prosecutors should not let this potential argument serve as a driving force in requesting GSR examinations that might raise more questions than can be answered effectively.

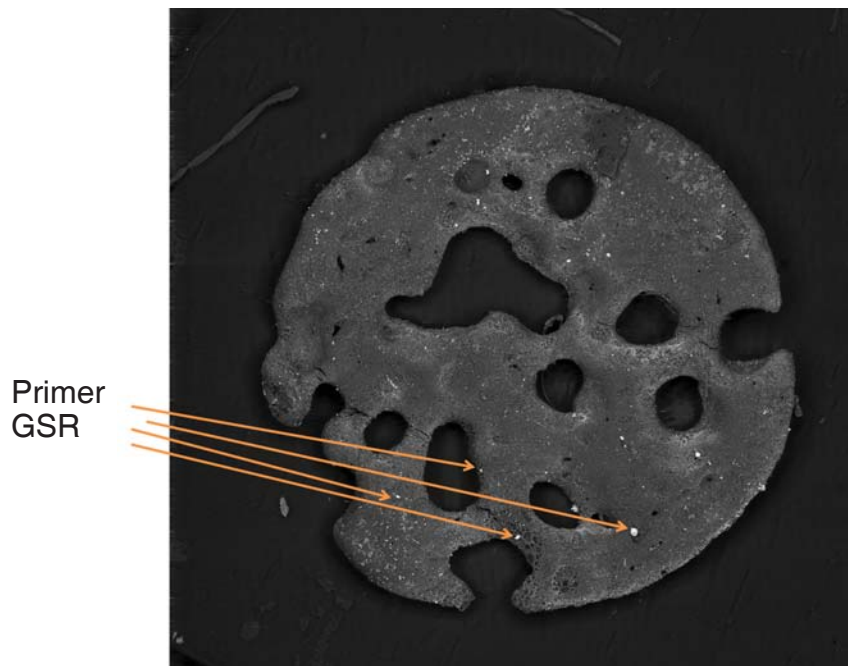
So, the question arises, “Why analyze for GSR?” First, the technology behind the analysis of gunshot residue is unquestionably scientifically sound. SEM/EDS analysis has existed for a long time and been used in GSR analysis since the 1970s. Second, studies have shown that average people do not have gunshot residue on their hands, but someone who fires a gun most likely will for a period of time. Despite efforts by forensic scientists to disprove the uniqueness of GSR to firearms, research only has strengthened the position of naming spheroid Pb, Ba, and Sb particles as having come from a fired weapon. While studies of contamination issues continue, the likelihood of transfer from another source remains small in most cases. The reason for analyzing for GSR lies in the fact that most trace evidence is not conclusive but supportive and circumstantial. Glass, hair, fiber, paint, soil, and, sometimes, shoeprint analyses cannot conclusively identify a common source between a known and an unknown sample. The fact, however, that authorities

located evidence with a possible common source is worth noting for the court. Correspondingly, GSR found on the hands of a suspected shooter is significant and worthy of consideration by the jury. For a court to understand the significance of the findings, experts must discuss all aspects of the sample collection, analysis, and interpretation at trial. Sources of contamination and an explanation as to whether the analyst could account for any anomalies in the findings also should be included in the testimony. In some cases, the sample collection officer should give testimony first to provide context for the results that an analyst may report.

Conclusion

Gunshot residue examinations continue to improve through research, advancements, and more integrated communication among analysts. Further, technology has made GSR analysis quicker and easier. And, understanding of and confidence in GSR interpretation have increased. In light of the importance of GSR analysis to many investigations, these improvements are encouraging to the law enforcement community and the justice system.

To facilitate the best use of resources, field investigators should have a clear understanding of the utility and shortcomings of an examination, such as GSR. Communication with



Primer GSR on a smokeless powder disk

© Michael J. McVicar

the laboratory analyst prior to collection may serve as the best gauge as to whether the analysis of GSR will clarify or muddy an investigative path. ♦

Endnotes

¹ A.R. Calloway, P.F. Jones, G.L. Loper, R.S. Nesbitt, and G.M. Wolten, *Final Report on Particle Analysis for Gunshot Residue Detection* (El Segundo, CA: The Aerospace Corporation, 1977).

² Stephen Kiehl, "Defender Spotlights Faulty Forensics," *Baltimore Sun*, November 5, 2007, http://articles.baltimoresun.com/2007-11-05/news/0711050172_1_forensic-science-forensic-evidence-forensic-methods (accessed May 4, 2010); Lisa Sweetingham, "Expert: Gunshot Residue Does Not Mean Robert Blake Killed His Wife," *COURT TV.com*, January 19, 2005, <http://www.cnn.com/2005/LAW/01/19/blake.trial/> (accessed May 4, 2010); Sam Greenhill and Stephen Wright, "Dando 'Killer' Barry George to Face Retrial After Winning Appeal," *Mail Online*, November 16, 2007, <http://www.dailymail.co.uk/news/article-494180/Dando-killer-Barry-George-face-retrial-winning-appeal.html> (accessed May 4, 2010); and Dennis McGuire, "The Controversy Concerning Gunshot Residue Examinations," *Forensic Magazine*, August/September 2008.

³ Calloway, Jones, Loper, Nesbitt, and Wolten; M. Martinez, "Occupation Study" (lecture, FBI GSR Symposium, 2005); and J. McCullough and L. Niewoehner, "A European Study on the Prevalence of GSR in Random Population and Selected Professional Groups" (lecture, SCANNING 2009).

⁴ J.W. Kilty, "Activity After Shooting and Its Effect on the Retention of Primer Residue," *Journal of Forensic Sciences* 20, no. 2 (April 1975).

⁵ *Ibid.*; Calloway, Jones, Loper, Nesbitt, and Wolten, 49-51; and D.L. Exline and A.J. Schwoeble, *Current Methods in*

Forensic Gunshot Residue Analysis (New York, NY: CRC Press, 2000), 7.

⁶ Calloway, Jones, Loper, Nesbitt, and Wolten, 53; and E. Lindsey et al., "Passive Exposure and Persistence of Gunshot Residue on Bystanders to a Shooting: Can a Bystander be Differentiated from a Shooter Based on GSR?" (lecture, 2005).

⁷ Lindsey et al.; and Exline and Schwoeble.

⁸ Calloway, Jones, Loper, Nesbitt, and Wolten, 73.

“

For a court to understand the significance of the findings, experts must discuss all aspects of the sample collection, analysis, and interpretation at trial.

”

⁹ Calloway, Jones, Loper, Nesbitt, and Wolten, vii; and Nadav Levin and Arie Zeichner, "Collection Efficiency of Gunshot Residue (GSR) Particles from Hair and Hands Using Double-Side Adhesive Tape," *Journal of Forensic Sciences* 38, no. 3 (1993): 571.

¹⁰ M. Martinez, "P-GSR Detection on Clothing and in Automobiles," *IAMA Newsletter* 1, no. 2 (February 2000); and D. Chavez and C. Crowe, "The Retention of Gunshot Residue on Clothing After Laundering," *IAMA Newsletter* 2, no. 1 (March 2001).

¹¹ Chavez and Crowe.

¹² Trimpe and Wright.

¹³ Roger Aaron, "Gunshot Primer Residue: The Invisible Clue," *FBI Law*

Enforcement Bulletin, June 1991, 19-22.

¹⁴ McCullough and Niewoehner; and D. Gialamas et al., "Officers, Their Weapons, and Their Hands: An Empirical Study of GSR on the Hands of Nonshooting Police Officers," *Journal of Forensic Sciences* 40, no. 6 (November 1995): 1086-1089.

¹⁵ R.E. Berk et al., "Gunshot Residue in Chicago Police Vehicles: An Empirical Study," *Journal of Forensic Sciences* 52, no. 4 (July 2007): 838-841.

¹⁶ Personal communication through the Forensic SEM listserve.

¹⁷ *ASTM 1588-08 Standard Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive X-ray Spectrometry (SEM/EDS)*.

¹⁸ Calloway, Jones, Loper, Nesbitt, and Wolten, 17-18.

¹⁹ C.A. Torre, "A Source of Non-GSR Particles Containing Lead, Barium, and Antimony," *Journal of Forensic Sciences* 47 (2002): 494-504; Michael Trimpe and Diana Wright, "Summary of the FBI Laboratory's Gunshot Residue Symposium, May 31-June 3, 2005," *Forensic Science Communications* 8, no. 3 (July 2006); P. Mosher et al., "Gunshot Residue: Similar Particles Produced by Fireworks," *Canadian Society of Forensic Science Journal* 31, no. 2 (September 1998): 157-168; M. Trimpe, "Analysis of Fireworks for Particles of the Type Found in Primer Residue (GSR)," *Midwestern Association of Forensic Scientists Newsletter* 32 (Winter 2003): 68-76; R.E. Berk, "Automated SEM/EDS Analysis of Airbag Residue I: Particle Identification," *Journal of Forensic Sciences* 54, no. 1 (January 2009): 60-68; and R.E. Berk, "Automated SEM/EDS Analysis of Airbag Residue II: Airbag Residue as a Source of Percussion Primer Residue Particles," *Journal of Forensic Sciences* 54, no. 1 (January 2009): 69-76.

²⁰ Torre; Trimpe and Wright; and Mosher et al.

²¹ Torre; Mosher et al.; Trimpe; and Berk, "Automated SEM/EDS Analysis of Airbag Residue I: Particle Identification."