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CASE REPORT

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Trajectory Reconstruction Through Analysis of Trace Evidence in Bullet–Intermediate Target Interaction by SEM/EDX

ABSTRACT: A young male was shot to death by a police officer with a Chinese Type 64 7.62 mm pistol when he was dealing with an aggravated assault arising from a traffic accident. By using scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM/EDX), trace deposits on the discharged bullet and the intermediate target, i.e., a concrete telegraph pole at the scene, were identified to be from each other. The result demonstrated the bullet causing the death ricocheted from the concrete telegraph pole before striking the victim, thus indicating the incident was accidental. The case report illustrates the evidential value of trace materials derived, respectively, from discharged bullets and intermediate targets in bullet–intermediate target interaction for trajectory reconstruction. In addition, it indicates that the SEM/EDX method with its nondestructive nature, compared to other methods, may be more helpful in certain situations in determining the origins of trace evidentially valuable deposits on substrates.

KEYWORDS: forensic science, trajectory reconstruction, trace evidence, bullet–intermediate target interaction, ricochet, scanning electron microscopy and energy dispersive X-ray spectroscopy

There is an increasing trend of firearm incidents in many societies in recent years (1–3). For instance, in the United States, firearms are among the leading reasons for unnatural death (4). While in China, though firearms are strictly controlled by the administration and owning a gun privately is prohibited under Chinese laws, the issues on the criminal use of firearms and the justification of shootings by police officers in certain cases attract more attention both from the government and the public than ever.

In casework, forensic scientists are usually required to determine whether an incident involving gunshot fatalities is a murder, a suicide, or an accident. Undoubtedly, trajectory establishment of fired bullets is one of the most critical tasks to reconstruct the event. The following four general areas of physical evidence are sources of information on trajectory and should be considered in trajectory reconstruction work (5):

1. Weapon-associated class and individual markings on projectiles (and, at times, those on cartridge cases);
2. Residues and residue patterns around putative bullet holes and impact points, including those caused by secondary projectiles from intermediate targets;
3. Target-specific markings on and trace evidence from bullets;
4. Holes and markings amenable to geometric techniques for ascertaining and demonstrating trajectories.

In our experience of casework, trace evidence on bullets are least utilized among the above-mentioned physical evidence with regard to trajectory reconstruction. That may partly lie in the fact that, as pointed out in (5,6), potentially valuable trace evidential material present on spent bullets collected at the scene of crimes, or at autopsy, is often unknowingly destroyed during standard processing by many forensic personnel, such as pathologists, firearm examiners, and crime scene technicians. For that reason, the importance of trace evidence on bullets with respect to trajectory reconstruction was emphasized in a few papers (5–9).

As for trace evidence on intermediate targets, most studies focus on gunshot residue (GSR) particles originating from the primer, the projectile (bullet), the propulsive charge, the cartridge case as well as the firearm itself, and containing features of condensation both in the surfaces and within the interiors (10), as they have the potentially evidential value in determination of shooters and bullet entrance holes as well as shooting distance estimation (11,12). However, trace materials from discharged bullets on intermediate targets are little emphasized with regard to their evidential value in trajectory reconstruction.

This paper will present a case where trajectory reconstruction was accomplished through analysis of the two types of trace materials, respectively, from the discharged bullet and the intermediate target involved in a shooting incident by scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM/EDX).

Case

The Incident Details

This incident took place on a night in September, 2007. A traffic accident happened at a crossroad with two cars colliding. Failing to reach reconciliation, both drivers called in, respectively, a group of people to the scene and began to assault each other with knives and logs. Two police officers came to the scene quickly after receiving the report. Considering the situation was urgent, one of the police officers fired a shot to the sky, a general signal of warning used by Chinese police in an emergency. But before the attack stopped, a second shot was fired in turmoil by the same police officer. This shot hit a young male in the head. He was sent to a local hospital and died soon after. One witness claimed that the deceased was caught and the police

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officer fired with the muzzle pointing toward his head at a very close distance. The indignant family of the deceased then charged the police officer with the crime of murder. However, the defendant claimed he had not pointed his pistol to the head of the victim at all and the death was caused accidentally. Who was telling the truth? Obviously, the trajectory of the second shot was crucial to the question.

The Evidence and Trajectory Reconstruction

Scene investigation was conducted immediately, but there was not much progress as it was dark at night. At autopsy, the deceased had a single gunshot wound of the middle forehead, with no blackening or powder tattooing of the surrounding skin. A deformed bullet core was found in the head (Fig. 1). According to this finding, the investigators suspected they were dealing with a shooting incident with ricochet. A more intensive investigation was decided and the scene was revisited, which led to the subsequent critical finding.

An ovoid 1.1- by 1.1-cm hole was found on a concrete telegraph pole at the scene (Fig. 2). The location of the hole was 1.02 m high from the ground. As shown in Fig. 2, a few scrape marks were found to be at the edge of the hole.

After recovery from inside the victim's head, the deformed bullet core was put into a clean plastic evidence bag immediately to avoid contamination. Tape-lift method for SEM/EDX analysis was employed in sampling procedures. As the deposited liquid stains became dried naturally, the lead core was observed under a stereomicroscope and trace materials embedded within or adherent to it were collected with a kind of aluminum stub covered with double-sided conductive carbon tape. Likewise, the deposits inside the hole on the concrete telegraph pole at the scene were collected, and a blank sample for comparison was sampled at a location far from the hole on the pole as well. The bullet core itself was directly put into the SEM chamber for analysis.

SEM/EDX analysis was carried out directly without coating for all the samples mentioned above. Backscattered electron imaging mode of SEM was chosen for particle analysis in that particles with different average atomic number could be distinguished easily by their gray levels and there was relatively low charging effect in this mode. Two kinds of high-gray-level particles with the following elemental compositions were found to be inside the hole of the concrete pole:

FIG. 1—*The deformed bullet core recovered from inside the victim's head at autopsy.*

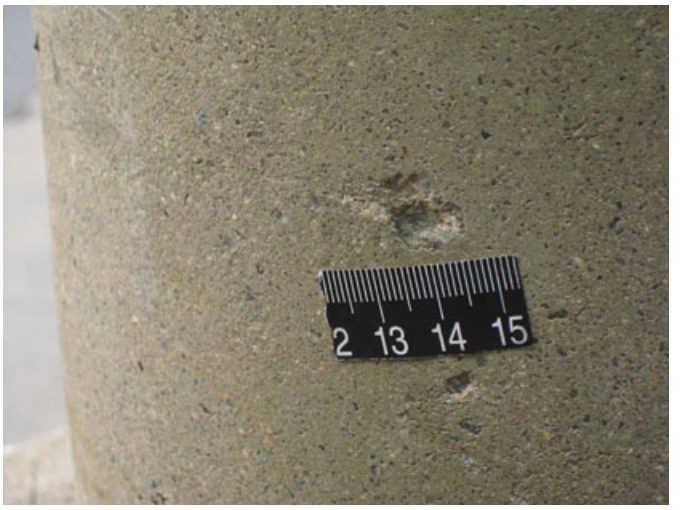

FIG. 2—*The ovoid 1.1- by 1.1-cm hole on the concrete telegraph pole at the scene.*

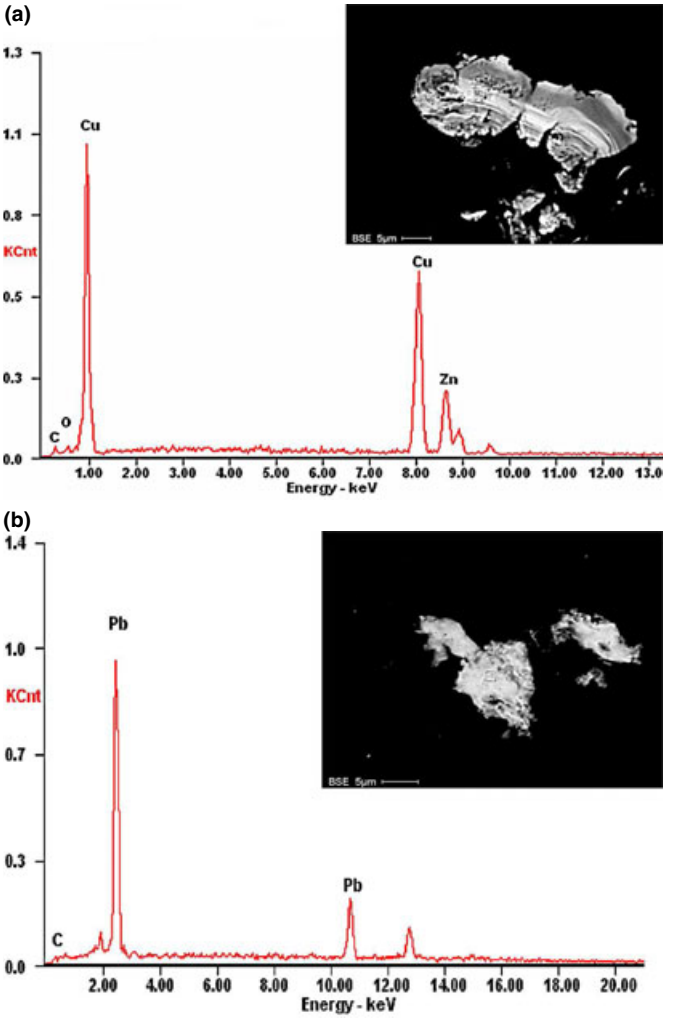

FIG. 3—*(a) BSE image and EDX spectrum of a particle with the composition of Cu and Zn detected on the concrete telegraph pole at the scene. (b) BSE image and EDX spectrum of a particle with the composition of Pb detected on the concrete telegraph pole at the scene.*

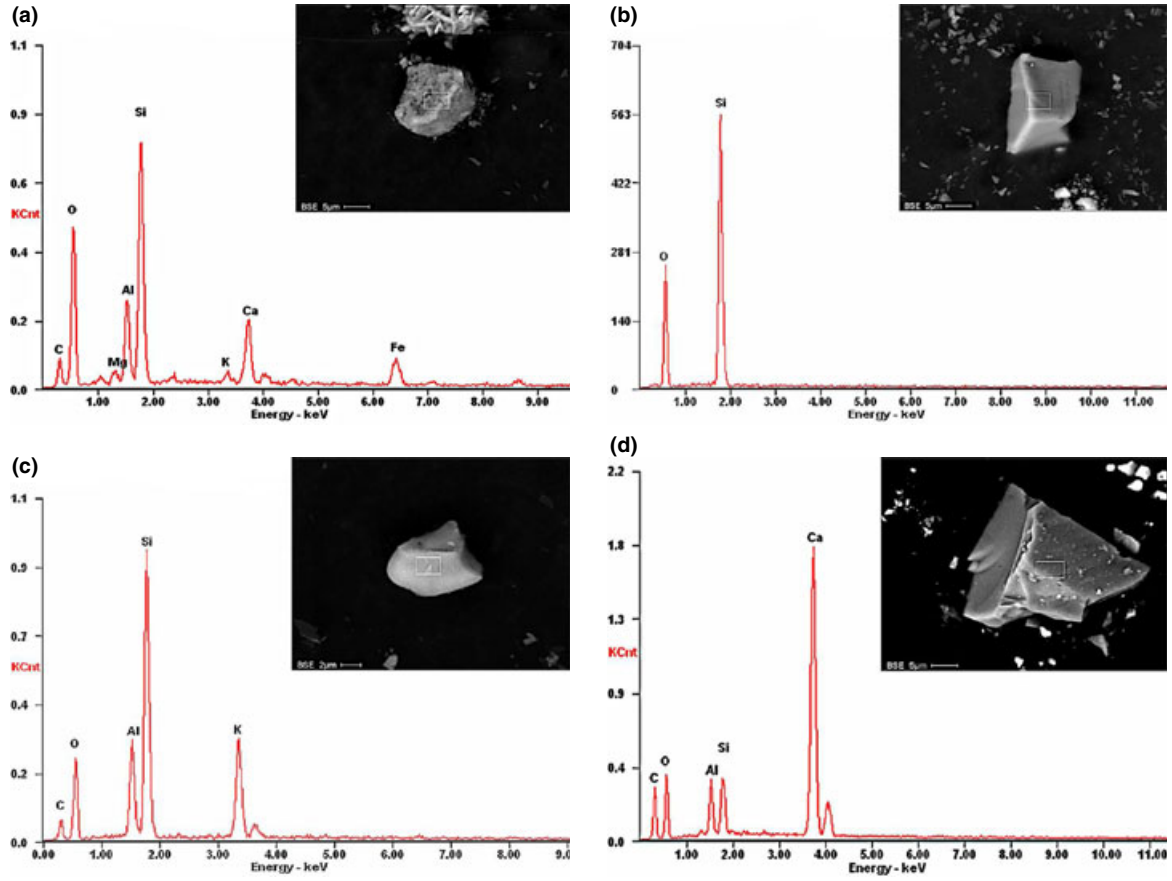

FIG. 4—*(a) BSE image and EDX spectrum of a particle with the composition of C, O, Mg, Al, Si, K, Ca, and Fe on the deformed bullet core recovered from inside the victim's head at autopsy. (b) BSE image and EDX spectrum of a particle with the composition of O and Si on the deformed bullet core recovered from inside the victim's head at autopsy. (c) BSE image and EDX spectrum of a particle with the composition of C, O, Al, Si, and K on the deformed bullet core recovered from inside the victim's head at autopsy. (d) BSE image and EDX spectrum of a particle with the composition of C, O, Al, Si, and Ca on the deformed bullet core recovered from inside the victim's head at autopsy.*

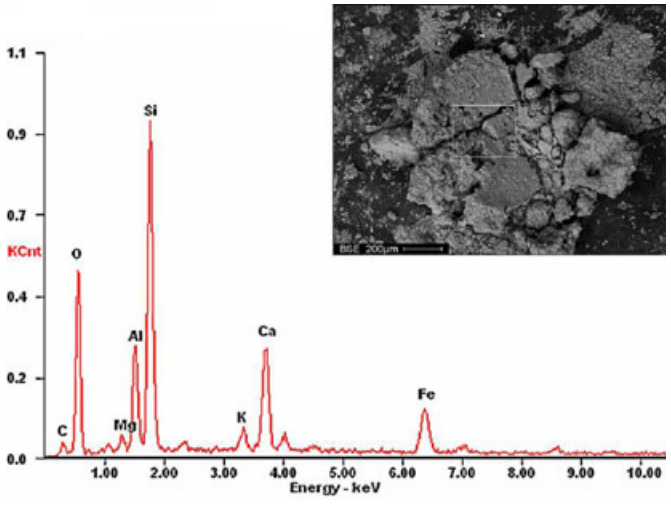

FIG. 5—*BSE image and EDX spectrum of the concrete material of the telegraph pole at the scene.*

1. Cu and Zn (Fig. 3*a*) and
2. Pb (Fig. 3*b*).

Of them, the particles containing Cu and Zn were abundant, while ones containing Pb were a minority. With respect to the blank sample, it was negative for these particles, indicating they must have originated outside. The analysis results also demonstrated that the elemental compositions of the bullet core itself and the high-gray-level particles inside the hole of the concrete pole were, respectively, consistent with those of lead cores and jackets of Chinese Type 64 7.62 × 17 mm ammunitions. A bullet of this type of ammunition is known to contain a lead core covered by a Cu-Zn-alloy jacket (13). SEM/EDX analysis of the other ammunitions unfired in the same pistol in the incident confirmed this.

Besides calcium-phosphorus (bone) particles, most foreign particles detected on the bullet core consisted of the following compositions (Fig. 4*a–d*):

1. C, O, Mg, Al, Si, K, Ca, Fe;
2. O, Si;
3. C, O, Al, Si, K; and
4. C, O, Al, Si, Ca.

Particles with the above-listed compositions were all found in the concrete material of the telegraph pole at the scene, which is heterogeneous in elemental composition. One typical spectrum of this concrete material is presented in Fig. 5.

On this basis, the trajectory of the second bullet in the incident was established and the analysis using SEM/EDX could be interpreted:

When the second shot was fired by the police officer, the bullet first struck the concrete telegraph pole at the scene, resulting in a hole on the pole and the projectile fragmented under the violent impact. Then the bullet core ricocheted from the concrete pole and

entered the head of the victim. During this process, trace materials were transferred between the bullet and the intermediate target. The particles stripped from the bullet left at the impact area, while the concrete material from the intermediate target was transferred to the surface of the deformed lead core. Thus, both trace materials transferred from the bullet and the intermediate target provided crucial information establishing the second bullet's trajectory.

Progress on the Incident Based on the Evidence

The witness admitted that false testimony had been made soon after the evidence was presented. And the family of the victim accepted the conclusion of the investigation that the death of the victim was caused accidentally. The charge of crime of murder against the police officer was dismissed.

Discussion

As Edmond Locard described in the early part of the 20th century, whenever any two objects come in contact, they transfer material from one to the other, and the more violent the contact, the more likely the transfer will occur, which is known as the Locard Exchange Principle (14).

Through detecting and identifying of these transferred trace materials by a variety of methods, forensic scientists can provide key information for decision makers to reach an opinion during investigative proceedings of incidents as well as at trial (14,15).

According to the Locard Exchange Principle, substantial impacts of bullets on intermediate targets, especially on sufficiently resistant ones causing the bullet to ricochet, fragment, or perforate together with a deviation in trajectory, should be favorable conditions for the bidirectional transfer of material. The transfer dynamics on bullet–intermediate target interaction has been discussed in (7).

In the limited case reports (5,9) and experimental studies published (6–8), trace materials such as fragments of tissue, inert material from intermediate targets, and debris related to spent bullets, were of potentially evidential value in associating the people, places, and things involved in the crime and reconstructing the event, for example, indicating a ricochet or documenting the path of a bullet through the body or intermediate target.

A case reported in (5) mentioned a mark containing lead derived from the spent lead bullet on the intermediate target as critical evidence to exclude a police officer's gun as the one killing the deceased. Besides that, there are few papers dealing with the evidential value of trace materials from discharged bullets upon bullet–target interaction with regard to trajectory reconstruction. It was demonstrated in the presented case that the trace materials derived from the discharged bullet and the intermediate target were both crucial to trajectory reconstruction.

Commonly, it is necessary for putting several pieces of evidence together to reach a reasoned judgment. As bidirectional transfer of materials will occur whenever bullet–intermediate target interaction takes place, trace materials from bullets and intermediate targets should not be overlooked in trajectory reconstruction. Thus, awareness of trace evidence for both aspects should be increased for forensic personnel.

SEM/EDX is a powerful tool in forensic science. One of its most important applications is particle analysis of GSR. This method enables a forensic expert to simultaneously observe the characteristic morphology of a GSR and check its elemental content without prior damage of the object, thus is recognized as the most specific method (16). Similarly, SEM/EDX with its nondestructive nature, compared with other methods, may be more helpful in certain circumstances in determining the possible origins of other invisible deposits on substrates by their morphologies and elemental compositions. Although absolute match between two objects is difficult or even impossible in many actual situations, the combined analysis of several findings can be associated to specific things with a high probability. In the case presented here, good matches obtained through SEM/EDX analysis between the particles on the abovementioned substrates and the bullet as well as the intermediate target in elemental composition strongly indicated the particles' origins, and thus provided crucial evidence for trajectory reconstruction.

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