Forensic Science International 273 (2017) 10–19

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

The use of unburned propellant powder for shooting-distance determination. Part I: Infrared luminescence

Rolf Hofer*, Stefan Graf, Stephan Christen

Forensic Science Institute Zurich, Switzerland

ARTICLE INFO

Article history:
Received 12 October 2016
Received in revised form 12 January 2017
Accepted 19 January 2017
Available online 30 January 2017

Keywords:
Shooting-distance determination
Propellant powder
Infrared luminescence

ABSTRACT

Unburned propellant powder particles in gunshot residue (GSR) were detected at near infrared by optical excitation in the visible wavelength range. A series of ammunition (different brands and different manufacturers) was analyzed concerning the luminescence of their propellant.

Shooting target samples with different shooting distances were produced on standard textile tissue and analyzed with this optical infrared inspection. The number of luminescent GSR particles per area was measured and curves with particle density vs. shooting distance were drawn.

The method was applied on three ammunition types with different particle morphology shot with a pistol and one ammunition type shot with a revolver. The shooting series performed with the revolver showed a large particle density variation within the samples of identical shooting distances. In this case, the ratio of the amount of particles within the area around the bullet hole and within a ring with a defined distance from the bullet hole was calculated. These data resulted in measures with much lower standard deviations, which is a prove that the distribution pattern depends on the shooting distance and not on the amount of GSR particles.

It has been shown, that imaging of target tissue with the aid of infrared luminescence is an easy, fast, reproducible and non-destructive method for shooting-distance determination.

1. Introduction

Shooting-distance determination is a standard question in forensic cases of shooting accidents, suicides or homicides for case reconstruction purposes. In most short to very short gun-to-target distance cases, wound-ballistics can answer to this question due to tissue damage/deformation caused by the shooting gas pressure. This gas pressure drops with increasing gun-to-target distance; thus, at higher distances (bigger than a few centimeters, depending on the firearm), its energy is too low to influence tissue morphology [1,2].

Gunshot residue (GSR) produces a concentric pattern of particles around the bullet-hole. It is evident, that the distribution of these particles depends on the ammunition, the gun (especially the length of its barrel), the propellant powder particle size and shape, the shooting distance, etc [2,3]. Thus, for shooting distance reference sample preparation in case work, it is essential to use the same type and brand of gun, identical ammunition as well as the same tissue as involved in the shooting incident. If the incriminated arm is unknown and/or there is no information on the used ammunition (e.g. no cartridge found on the crime scene), the examiner must determine the morphology of unburned propellant particles on the target tissue and use ammunition with the same type of gunshot powder to perform adequate reference material for gun-to-target distance estimation.

The Rhodizonate Test – a very common shooting distance determination method for "traditional" lead-containing ammunition – provides pictures showing the pattern of lead (from gun shoots) [4]. Leadless ammunition does not leave heavy metal particles such as lead, barium, antimony that could be used to visualize this pattern. In these cases, methods such as the (modified) Griess Test [2,5]. or the Chlorindazon Test [6] are applied for the visualization of nitrite or copper and zinc gunshot residues. For both Rhodizonate and Griess Test very different upper gun-to-target distance detection limits are reported [1,7]:

Kneubuehl [1]: 1–3 m

Botello [7]: 12–48 in. (31–122 cm)

* Corresponding author at: Forensic Science Institute Zurich, Forensic Chemistry, P.O. Box 8021, Zurich, Switzerland.

E-mail address: rolf.hofer@for-zh.ch (R. Hofer).

http://dx.doi.org/10.1016/j.forsciint.2017.01.019
0379-0738/

No literature could be found for shooting distance determination with the Chlorindazon method. Tests in our institute resulted in upper shooting distance limits of about 50–80 cm.

The distance determination limit depends strongly on the ammunition and on the gun [7]. But, the more intense the detection – chemical reaction or directly optical – the higher the distance, where GSR traces can be detected, and as a consequence, the higher the upper gun-to-target distance detection limit.

Some of the propellant particles only burn partially during the shooting process [8], especially with short barrel guns. These particles will be described as "non-burned" in this article.

Non-burned propellant particles are visible by the naked eye or by slight magnification (Fig. 2). Detection of these particles were studied by IR-absorption: Infrared photography for the detection of absorbing GSR on dark or black textiles is described by Sellier [9] and on tissue with different colored design by Bailey [10]. Chaklos and Davis reported the use of infrared photography for dark, patterned and blood-soaked clothing [11]. Lake et al. used a Video Spectral Comparator (VSC 2000) for the visualization and documentation of GSR patterns on dark colored and/or blood stained fabrics [12].

The gunshot powder particles consist of the propellant product nitrocellulose and additives. Some of these additives (e.g. stabilizer) are luminescent in visible to near infrared wavelength.

In this study, we introduce a nondestructive, optical method to quantify the propellant powder particles on target tissues. The

Table 1
Morphology and optical reaction of 51 different non-shot lead-containing ammunition types/brands.

Ammunition			Morphology	Luminescence	
Caliber	Gun	Manufacturer		Yes/no	Comments
.22 LR	HG, RE, RG	Eley	RF	Yes	
.22 LR	HG, RE, RG	REM	RG	**No**	
.22 LR	HG, RE, RG	RWS	KFR	Yes	
9 mm Luger	HG	CBC	RF	Yes	
9 mm Luger	HG	CBC	KFR	Yes	
9 mm Luger	HG	China	RG	Yes	Strong luminescence
9 mm Luger	HG	China	RFG	Yes	
9 mm Luger	HG	DAG	KFR	Yes	
9 mm Luger	HG	Federal	RF	Yes	
9 mm Luger	HG	Federal	RG	Yes	
9 mm Luger	HG	Federal	RF	Yes	
9 mm Luger	HG	Federal	KGE	Yes/no	2/3 yes; 1/3 no
9 mm Luger	HG	Fiocchi	BL	Yes/no	2/3 yes; 1/3 no
9 mm Luger	HG	Fiocchi	R	Yes/no	2/3 yes; 1/3 no
9 mm Luger	HG	Fiocchi	BL	Yes	
9 mm Luger	HG	Fiocchi	BL	Yes	
9 mm Luger	HG	Fiocchi	BL	Yes	Weak luminescence
9 mm Luger	HG	Fiocchi	BL	**No**	
9 mm Luger	HG	Fiocchi	BL	Yes	
9 mm Luger	HG	Fiocchi	BL	**No**	
9 mm Luger	HG	GECO	ST	Yes	Weak luminescence
9 mm Luger	HG	GECO	BL	**No**	
9 mm Luger	HG	GECO	BL	Yes	
9 mm Luger	HG	GECO	BL	**No**	
9 mm Luger	HG	GECO	ST	Yes	
9 mm Luger	HG	GECO	ST	Yes	
9 mm Luger	HG	MEN	KFR	Yes	
9 mm Luger	HG	PPU	BL	Yes	Weak luminescence
9 mm Luger	HG	R-P	RF	Yes	
9 mm Luger	HG	Samson	KFR	Yes	
9 mm Luger	HG	Samson	KFR	Yes	
9 mm Luger	HG	S&BP	BL	Yes	Strong luminescence
9 mm Luger	HG	S&BP	KGE	Yes	
9 mm Luger	HG	S&BP	KGE	Yes	
9 mm Luger	HG	Thun	BL	Yes	
9 mm Luger	HG	Thun	KFR	Yes	
.38 SPL	RE	CBC	K	Yes	
.38 SPL	RE	GECO	BL	**No**	
.38 SPL	RE	R-P	RG	Yes	
.38 SPL	RE	S&BP	R	Yes	ca. 90% lumi. particles
.38 SPL	RE	W-W	KFR	Yes	
.357 MAG	RE	S&BP	KFR	Yes	
.40 S&W	HG	S&BP	KFR	Yes	
.45 AUTO	HG	S&BP	RFG	Yes	
7.62 × 39 mm	RG	China	ST	Yes	Weak luminescence
7.62 × 39 mm	RG	Lapua	ST	Yes	Weak luminescence
7.62 × 39 mm	RG	S&BP	KFR	Yes	
.308 WIN	RG	CBC	ST	**No**	
.308 WIN	RG	S&BP	ST	**No**	
SG 12/70	SG	Rottweil	BL	Yes	Strong luminescence
SG 12/70	SG	S&BP	BL	Yes	Strong luminescence

HG: handgun/pistol; RF: flattened balls; BL: flakes; RE: revolver; RG: convex flattened balls; R: tubes; RG: rifled gun; KFR: flattened grains; ST: rods; SG: shotgun; RFG: flattened balls with hole; K: spherical/balls; KGE: grains, crashed.