Forensic Science International 247 (2015) 97–104

Contents lists available at ScienceDirect

Forensic Science International

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

Flattening mountains: Micro-fabrication of planar replicas for bullet lateral striae analysis

Laura Cominato [a], Francesco Valle [a,*], Giovanni Pierini [b], Paolo Bonini [c], Fabio Biscarini [d], Marcello D'Elia [c]

[a] *Istituto per lo Studio dei Materiali Nanostrutturati (ISMN), Consiglio Nazionale delle Ricerche (CNR), Via Gobetti 101, I-40129 Bologna, Italy*
[b] *Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, Università di Bologna, Via Irnerio 49, I-40126 Bologna, Italy*
[c] *Gabinetto Regionale di Polizia Scientifica per l'Emilia Romagna, Via Volto Santo 3, 40123 Bologna, Italy*
[d] *Dipartimento di Scienze della Vita, Università di Modena e Reggio Emilia, Via Campi 183, 41125 Modena, Italy*

ARTICLE INFO

Article history:
Received 28 July 2014
Received in revised form 1 December 2014
Accepted 3 December 2014
Available online 16 December 2014

Keywords:
Micro-fabrication
Profilometry
Replica molding
Nanotechnology
Ballistic

ABSTRACT

The application of replica molding has proven to be a valuable tool in the analysis of different forensic evidences in particular for its ability to extract the toolmarks from complex sample surfaces. A well known problem in the analysis of ballistic evidences is the accurate characterization of the lateral striae of real bullets seized on crime scenes after shots, due primarily to impact deformations and to unpredictable issues related to laboratory illumination setup. To overcome these problems a possible way is to confine over a flat surface all the features still preserving their three dimensionality. This can be achieved by a novel application of replica molding performed onto the relevant lateral portion of the bullet surface.

A quasi-two-dimensional negative copy of the original tridimensional indented surface has been thus fabricated. It combines the real tridimensional topography of class characteristics (land and groove impressions) and of individual caracteristics (striae) impressed by rifled barrels on projectiles, moreover with the possibility of quantitative characterization of these features in a planar configuration, that will allow one-shot comparison of the "whole striae landscape" without the typical artifacts arising from the bullet shape and the illumination issue.

A detailed analysis has been carried on at the morphological level by standard optical and scanning electron microscopy, while the 3D topography has been characterized by white light optical profilometry.

A quantitative characterization of toolmarks of bullets derived from ammunitions shot by guns of large diffusion, as the Beretta 98 FS cal. 9×21 mm, has been performed and will be presented ranging between the whole landscape and the sub-μm resolution. To investigate the real potentiality of this technique, the experiment has been extended to highly impact-deformed projectiles.

1. Introduction

Ballistic samples are among the most crucial evidences that are nowadays used for solving criminal cases. In this frame a key role is played by the search for characteristic features on ballistic evidences found on the crime scene. This kind of toolmarks is at the base of the comparisons performed for associating the evidences to a specific weapon [1]. Different marks are produced by a firearm upon shooting: the firing pin, the breech face and the ejector hit the case head leaving on its surface indentation marks, while the gun rifled barrel, to impart the well known gyroscopic motion, leaves on bullets class characteristics, constituted by a sequence of lands and grooves, and groups of microscopic striations related to a specific firearm [2].

A great effort has been devoted by forensic scientists to understand [3,4] and to develop increasingly accurate methods for evaluating these features [5,6]. In particular the striae pattern has been deeply studied [7,8], because fired projectiles are the evidences often found on crime scenes where have been used firearms. The most typical forensic analysis of bullets is based on the comparison of the striae belonging to different evidences to assess if they can be associated to the same firearm. This process is usually performed by forensic in real time comparative microscopes that enable alignment of the correspondent features

* Corresponding author. Tel.: +39 051 6398512; fax: +39 051 6398540.
E-mail address: f.valle@bo.ismn.cnr.it (F. Valle).

http://dx.doi.org/10.1016/j.forsciint.2014.12.007
0379-0738/

present on two samples. Significative improvements have been made on these instruments to reduce any possible artifacts intrinsic to the white light reflection optical imaging. Few issues are still present, as it has been underlined in seminal work [9–11], and are mainly connected to the illumination and to the shape, generally not planar of the sample. When dealing with a series of quasi-parallel grooves with different depth, a non proper illumination (a too grazing incidence) can enhance some details while hindering others, thus distorting or even changing the detected striae pattern. To overcome these problems it has been recently proposed by some research groups a shift toward a real three-dimensional imaging, because in such manner the topography of a toolmark is not influenced by the above-mentioned factors [7,12,13]. Following the same approach, even automated ballistic identification systems (e.g. IBIS) are presently mapping the 3D topography of case cartridge and bullets.

A second important issue in comparing bullet striae with traditional techniques is due to their intrinsic nature of being a surface distribution of marks over a macroscopically curved object. The projectile has in fact a cylindrical shape that is grooved by a rifled barrel only on the lateral portion, thus on the one hand a non perfect alignment of its axis with the rotation axis of the microscope manipulator may induce distortions of the striae appreciation, as it has been well described by Bonfanti and coworkers [9]; on the other hand in a common microscope the striae do not lay in the same focal plane and, without automated Z-stacking photography systems, it is not easy to acquire well focused images. All these drawbacks are even more crucial when dealing with real evidences that upon impact assume a strongly deformed shape.

In this work we propose a method to overcome the above illustrated issues base on an refined version of a protocol presented elsewhere [14] where high-resolution imaging was combined with extremely accurate replicas [15,16] of fired case head to associate the firing pin marks down to the sub-micrometer level. Here a similar procedure is exploited to produce thin planar replicas of the whole lateral landscape of a bullet that displays, in a straight plane, the three dimensional topography of all the striae sequence. We think that this "replica approach" can be a strong help in the bullet analysis, because it preserve the three-dimensional nature of the grooved striae, thus allowing accurate topographical exams, removing, at the same time, the problems related to long scale curvatures of evidences or to acquisition, by classical optical microscope, of correct images of highly deformated projectiles. (e.g. "mushroomed" bullet).

2. Materials and methods

2.1. Ammunition, shooting tests, and sampling

Fired bullets were kindly provided by the forensic Regional unit of Italian State Police (Gabinetto di Polizia Scientifica per l'Emilia Romagna, Bologna); the gun cartridges cal. 9 × 21 mm and cal. 7.65 Browning (Fiocchi, Lecco, Italy and Winchester, New Haven, USA) have been fired by two different pistols Beretta, model 98FS (Beretta, Gardone, Italy) and a submachine gun CZ, model SKorpion VZ61.

2.2. Replica molding

Polydimethylsiloxane (PDMS) and its curing agent (Sylgard 184, Dow Corning, Midland, USA) were mixed in ratio 10:1, degassed to eliminate air bubbles and poured on the bullet with a iron tongue. The movement of the casting must be circular to allow evenly cover the surface avoiding air bubbles. Curing was performed at 120 °C for 30 min, in a standard thermostatic oven. After peeling

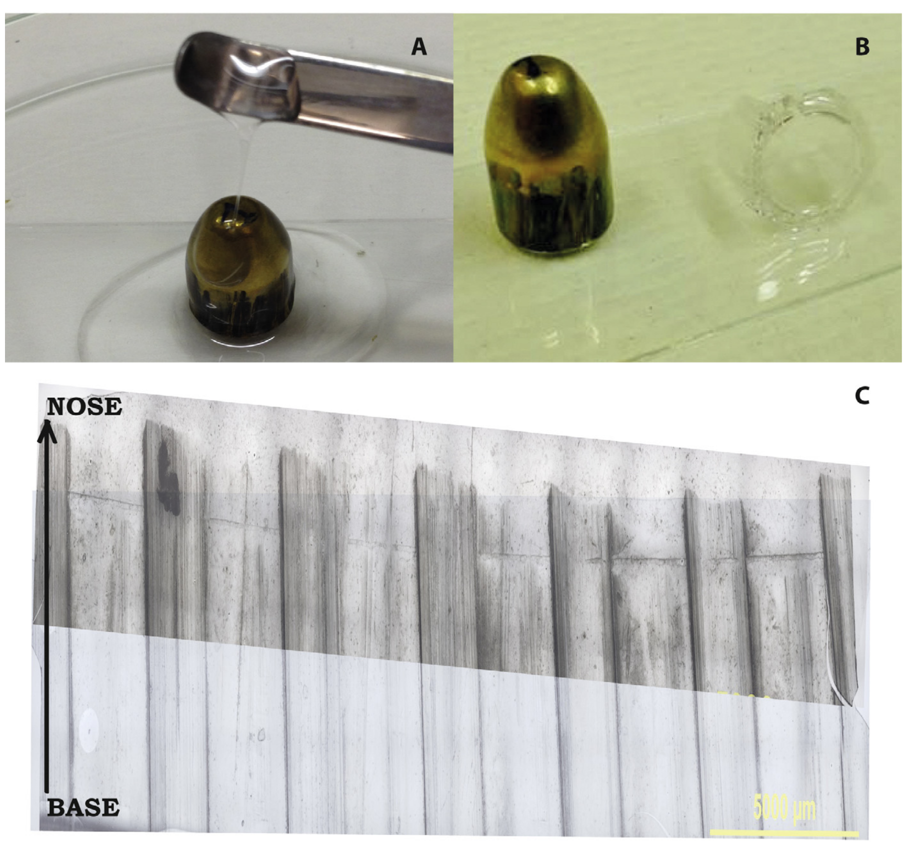

Fig. 1. Description of the method for fabricating replicas of toolmarks of bullet. In (A), the viscous PDMS is poured on the surface to be replicated and upon cross linking a faithful replica, (B) of the sample is obtained. In (C), is shown the partial overlap of two whole replicated profiles of the same bullet after they have been elongated on a plane.