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Forensic Science – Chemistry, Physics, Biology, and Engineering – Introduction

Evgeny Katz and Jan Halámek

The word "forensic" originates from the Latin word *forensis*, which means *public, to the forum, or public discussion*. A modern definition of "forensic" is *relating to, used in, or suitable to a court of law* [1]. Any science used for the purposes of the law is a forensic science. Forensic sciences [2–4] deal with the application of scientific knowledge to legal problems and they are vital tools for unearthing the truth in any legal proceeding. Forensic sciences, including forensic chemistry [5–8], forensic biology [9, 10], forensic anthropology [11], forensic medicine [12], forensic materials science [13, 14], forensic engineering [15], computational forensics [16], and so on, are broadly used to resolve civil disputes, to justly enforce criminal laws and government regulations, and to protect public health.

In some subareas of forensic science, for example, in forensic botany [17], simple observation of plant samples collected at the crime scene could be enough for arriving at important conclusions, while in other forensic methods, such as forensic chemistry, sophisticated instrumental analytical methods are required [18]. The most frequently encountered examples of forensic science applications are fingerprints [19] and DNA analyses [20], both aiming at the identification of crime victims or criminals. However, forensic science methods go much beyond these well-known applications and often include various physical and chemical analytical methods. Vibrational spectroscopy (based on IR absorption and Raman scattering) [21] (Figure 1.1), internal reflection spectroscopy [22], mass spectrometry [23], and electrochemistry [24, 25] (Figure 1.2) have been applied for forensic analyses of human or animal hair, fiber, paints and inks, and a variety of human body fluids, as well as for the detection of gunshot residues, controlled substances (e.g., illicit drugs), explosives, and other chemical and biological agents. Spectral analysis of objects found at the crime scene can be subjected to hyperspectral imaging (HSI) to obtain both spatial and spectral information from the sample [26]. This technique enables investigators to analyze the chemical composition of traces and simultaneously visualize their spatial distribution. HSI offers significant potential for the detection, visualization, identification, and age estimation of forensic traces, also allowing forensic analysis of document forgery [27].

A biochemistry-/molecular biology-based subarea of forensic analysis, called forensic serology, deals with the complex task of gathering information on the type

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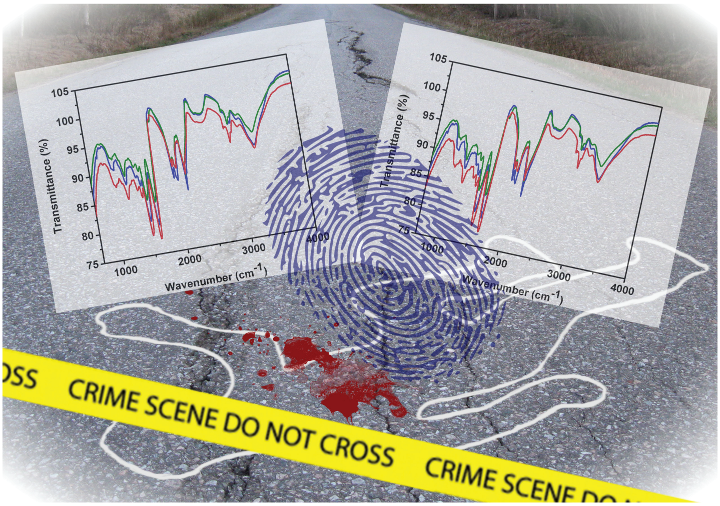

Figure 1.1 Application of vibrational spectroscopy for forensic analysis. (Reproduced from Muro *et al.* [21], with permission of American Chemical Society.)

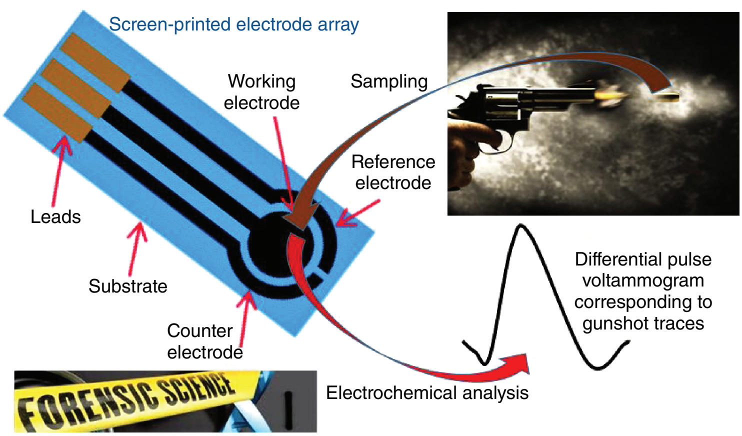

Figure 1.2 Forensic electrochemistry – the electroanalytical sensing of gunshot residues.

of sample, age, origin, or sex from biological fluids (blood, saliva, etc.) found at a crime scene [28]. Analysis of various biomarkers in biofluids found on the crime spot can help in arriving at preliminary conclusions about the race, sex, age, and so on, of possible suspects [29]. DNA typing of criminal suspects or victims can be extended to the DNA analysis of human remains [30], as well as to the analysis of DNA damage and repair in forensic samples [31]. While in most forensic analytical applications the samples collected at the crime scene are sent to a specialized laboratory for sophisticated instrumental analysis, rapid on-site analysis of the recovered samples could be very beneficial for crime investigation; thus, simple

Figure 1.3 Schematic delineating voltammetry of microparticles on a wearable *Forensic Finger*. (a) The *Forensic Finger* shows the three electrode surfaces screen-printed onto a flexible nitrile finger cot (bottom left inset), as well as a solid, conductive ionogel immobilized on a similar substrate (top right inset). (b) "Swipe" method of sampling to collect the target powder directly onto the electrode. (c) Completion of the electrochemical cell by joining the index finger with electrodes to the thumb coated with the solid ionogel electrolyte. (Reproduced from Bandodkar *et al.* [33], Royal Society of Chemistry. Used under a Creative Commons Attribution 3.0 Unported Licence.)

biosensors are finding their place in forensic practice [32]. The sensing devices can be miniaturized and ultimately assembled as a wearable fingertip sensor (forensic finger, Figure 1.3), used, for example, for the rapid on-site voltammetric screening of gunshot residues and explosive surface residues [33].

Forensic analysis of blood stain patterns [34] has become one of the most frequently used and highly important procedures providing key evidence with its ability to potentially map the sequence of events, highlight movement through the crime scene, and identify the minimum number of blows executed. Other materials, particularly left at trace levels, are attracting the attention of forensic investigators, being highly important for the reconstruction of the performed crime [35]. Personal identification methods, for example, based on fingerprints [36], as well as possible complications originating from their spoofing [37] represent an important part of the forensic study.

Various engineering disciplines, including mechanical, electrical, and chemical engineering, fire science, and so on, are also involved in forensic investigations [38, 39], often in civil cases but also in criminal investigations.

This book summarizes the diverse subareas of forensic science briefly outlined above. It aims at highlighting the achievements in this rapidly developing multifaceted research area, providing the background for further progress and helping the reader understand the various aspects in this complex scientific field.

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