Katz E, et al., J Forensic Leg Investig Sci 2015, 1: 004
DOI: 10.24966/FLIS-733X/100004

HSOA Journal of
Forensic, Legal & Investigative Sciences

Short Review Article

Forensic Science - Multidisciplinary Approach

Evgeny Katz[1]*, Jan Halámek[2] and Saira Bakshi[1]

[1]Department of Chemistry and Biomolecular Science, Clarkson University, Potsdam, NY 13699, USA

[2]Department of Chemistry, University at Albany, State University of New York, 1400 Washington Avenue, Albany, NY 12222, USA

Abstract

The present short review paper is summarizing recent developments in forensic science, particularly emphasizing a multidisciplinary approach to analytical problems, which includes chemistry, biology, physics and engineering subareas.

Keywords: Forensic analysis; Forensic biology; Forensic chemistry; Forensic techniques

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 purpose of law is a forensic science. Forensic sciences [2-4] concern the application of scientific knowledge to legal problems and they are vital tools in any legal proceeding. The 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], etc., are broadly used to resolve civil disputes, to justly enforce criminal laws and government regulations, and to protect public health.

While novel methods used in natural sciences might have some allowance for limited reproducibility and questionable interpretations, adaptation to forensic science, requires absolute reproducibility and non-variability in terms of the results interpretation: evidence is not only a scientific, but legal issue. It should be kept in mind that forensic analysis is strongly regulated by the legal constraints which affect both the work implementation and the results. Forensic science is in a unique position among all other scientific fields because of its important social impact. Indeed, forensic science is at the intersection of the natural sciences and law in civil and criminal cases. Therefore, methods used in forensic science require not only rigorous scientific standards, but also high ethical standards, providing interpretation of obtained results without any possibility of variable interpretation and without allowing for any personal bias. Analysis of substances, including hardly detectable traces, should be performed using non-destructive techniques to preserve evidence for future analysis in case of any dispute.

In some sub-areas of forensic science, for example, in botanical forensics [17], simple observation of plant samples collected at the crime scene could be sufficient to reach important conclusions, while in other forensic sciences, such as forensic chemistry, sophisticated instrumental analytical methods are required [18]. Forensic science applications are commonly associated with fingerprints analysis [19] and DNA typing [20], both of which are aimed at identification of crime victims or criminals. However, forensic science methods are going beyond these well-known applications and often include various physical and chemical analytical methods. Numerous analytical methods such as various spectroscopy techniques and electrochemistry have been borrowed from chemistry and physics, and have tremendously developed many subareas of forensic science. Modern developments are based on multi-disciplinary approaches involving not only physical techniques, but also computational methods. Compiling various databases (e.g., fingerprints) in electronic digital libraries and their rapid screening, analysis and comparison are extremely important for forensic purposes. Computerized facial recognition, for example, is needed for automatic search of suspects in public areas equipped with video surveillance facilities. This could be important not only for finding crime suspects, but also for crime prevention and homeland security and anti-terrorism security measures. Vibrational spectroscopy (based on IR absorption and Raman scattering) [21], Figure 1, internal reflection spectroscopy [22], mass-spectrometry [23] and electrochemistry [24,25] have been applied for forensic analysis of human or animal hair, fiber, paint and ink analysis, analysis of a variety of human body fluids, detection of gunshot residues, Figure 2, controlled substances (e.g., illicit drugs), explosives and other chemical and biological agents. Spectral analysis of objects found at the crime scene can be extended to hyperspectral imaging (HSI) to obtain both spatial and spectral information from a 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 for forensic analysis of document forgery [27].

Biomolecular analytical methods, including DNA analysis, proteomics, metabolomics, biomolecular computing, *in vivo* imaging, etc., have high importance in forensic science, but their use is not exactly the same as in medicine, thus requiring special adaptation to the needs of forensic science. Analysis of various biomarkers found in biofluids at a crime scene, particularly through the use of multi-enzyme biocatalytic reactions, is rapidly progressing towards practical applications [28-30]. The approach, borrowed from unconventional enzyme-based computing [31,32] and originally applied to biomedical analysis [33], demonstrates promising perspectives for novel forensic serology applications. Analytical applications toward rapid identification based on personal characteristics are feasible as a result of this study. New tools (e.g.,

***Corresponding author:** Evgeny Katz, Department of Chemistry and Biomolecular Science, Clarkson University, Potsdam, NY 13699, USA, Tel: +1 3152684421; Fax: +1 3152686610; E-mail: ekatz@clarkson.edu

Citation: Katz E, Halámek J, Bakshi S (2015) Forensic Science - Multidisciplinary Approach. J Forensic Leg Investig Sci 1: 004.

Received: August 29, 2015; **Accepted:** October 28, 2015; **Published:** November 13, 2015

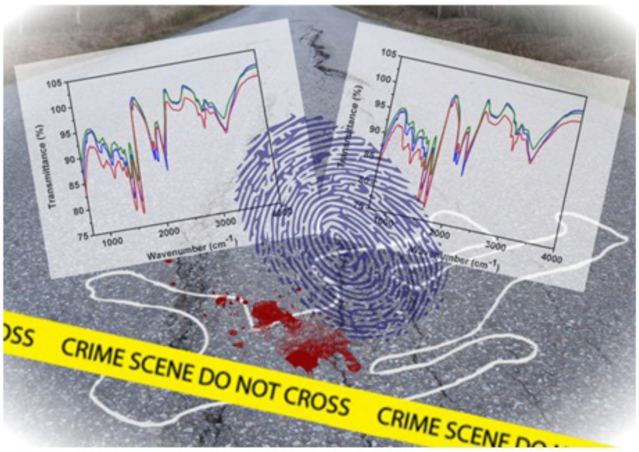

Figure 1: Application of vibrational spectroscopy for the forensic analysis [21].

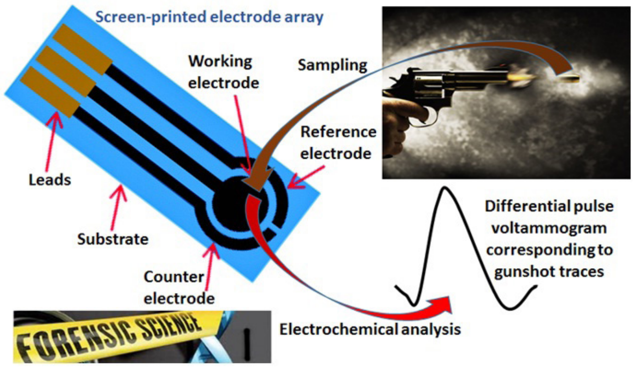

Figure 2: Forensic electrochemistry: The electroanalytical sensing of gunshot residuals.

analytical kits or single-use paper-strips) for the rapid identification of biofluid origin are also expected based on this research. Further development in this area will be directed towards incorporation of the novel methods into portable lateral flow strip-like devices for rapid analysis of biomarkers directly on-site at the crime scene.

A biochemistry/molecular biology-based subarea of forensic analysis, forensic serology, deals with the complex task of gathering information on type of sample, age, origin or gender from biological fluids (blood, saliva, etc.,) found at a crime scene [34]. Analysis of various biomarkers in biofluids found at a crime scene can help in preliminary conclusions about the race, gender, age, etc., of possible suspects [35]. DNA typing for criminal suspects or victims can be extended to the DNA analysis of human remains [36], as well as to the analysis of DNA damage and repair in forensic samples [37]. In addition, while in most forensic analytical applications samples collected at the crime scene are sent to a specialized laboratory for sophisticated instrumental analysis, rapid on-site analysis of samples could be very beneficial for crime investigation, thus, representing another use of simple biosensors in forensic practice [38]. The sensing devices can be miniaturized and ultimately can be assembled as a wearable fingertip sensor (*Forensic Finger*, Figure 3), used, for example, for the rapid on-site voltammetric screening of gunshot residuals and explosive surface residues [39].

Analysis of traces found at a crime scene often requires very sophisticated instrumentation and specific analytical skills, and is thus performed in specialized laboratories, delaying analytical conclusions

Figure 3: Schematic delineating voltammetry of microparticles at a wearable *Forensic Finger*. (A) The *Forensic Finger* exhibiting the three electrode surface screen-printed onto a flexible nitrile finger cot (bottom left inset), as well as a solid, conductive ionogel immobilized upon 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 [39].

about the crime victims and suspects. Using simple portable sensors and biosensors directly at the crime scene operated by a person with minimum scientific training (e.g., a police officer) would be very beneficial for the investigation, providing rapid results and giving immediate information. Thus, substituting multi-functional sophisticated and expensive instrumentation with simple and economical (bio)sensors is a very important trend in modern forensic science scaling down the currently used instrumentation to easy-to-use sensor strips, hand-held analyzers or microchip systems. Portable Raman and IR spectrometers, electrochemical sensors and biosensors, and single-use paper-strip bioanalytical assays continue to become more affordable and accessible to crime investigations. Particularly, electrochemical methods have demonstrated advantages for rapid on-field forensic investigation using low-cost, disposable screen-printed electrodes, indicating considerable promise for field-deployable instrumentation. Presently electroanalytical methods and instrumentation for forensics are still in their infancy; however they are expected to rise rapidly in popularity due to fast technological advances, particularly due to their coupling with wearable and digital devices, such as smartphones, new flexible electrode materials and improved communication of field results. Major research efforts should be directed to preparation of biosensors suited for the samples to be addressed in forensic analysis, enhancing the robustness and reliability necessary to fulfil the requirements for a real applicability to this field. Automation and multiplexing capability as well as the possibility of biosensor integration into remote alarm devices can be identified as important trends for an effective transition of laboratory biosensors to the real world of forensic applications.

Forensic analysis of blood stain patterns [40] 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 getting attention from forensic investigations, being highly important for reconstruction of the performed crime [41]. Personal identification methods, e.g., based on fingerprints [42] as well as possible complications originating from their spoofing [43], represent important parts of the forensic study.

Various engineering disciplines, (including mechanical, electrical, and chemical), and fire science, among others are also involved in forensic investigations [44,45]- often in civil cases, but also in criminal investigations.

Overall, the multi-disciplinary approach, including sub-areas of chemistry, biology, physics and engineering, is very important for the progress of forensic science [46,47]. Thus, collaborative work of experts with different backgrounds is necessary for the further developments in forensic science for the benefit of society.

References

1. http://www.merriam-webster.com/dictionary/forensic
2. James SH, Nordby JJ, Bell S (Eds.) (2009) Forensic Science: An Introduction to Scientific and Investigative Techniques (3rd edn). CRC Press, Boca Raton, USA.
3. Siegel JA and Mirakovits K (2010) Forensic Science: The Basics (2nd edn). CRC Press, Boca Raton, USA.
4. Saferstein R (2014) Criminalistics: An Introduction to Forensic Science (11th edn). Prentice Hall, Cloth, USA.
5. Bell S (2009) Forensic Chemistry. Annu Rev Anal Chem (Palo Alto Calif) 2: 297-319.
6. Bell S (2012) Forensic Chemistry (2nd edn), Prentice Hall, Cloth, USA.
7. Khan JI, Kennedy TJ, and Christian DR (2012) Basic Principles of Forensic Chemistry, Human Press, New York, USA.
8. Houck MM (Ed.) (2015) Forensic Chemistry (1st edn). Elsevier, Amsterdam, UK.
9. Shrivastava P and Guru AK (2002) Recent Advances in Forensic Biology, Anmol Publications Pvt, New Delhi, India.
10. Li R (2015) Forensic Biology (2nd edn). CRC Press, USA.
11. Byers SN (2008) Forensic Anthropology, Pearson Education LTD, Boston, USA.
12. Payne-James J, Busuttil A and Smock W (Eds.) (2003) Forensic Medicine. Clinical and Pathological Aspects. Greenwich Medical Media Ltd, San Francisco, USA.
13. Lewis PR, Reynolds K and Gagg C (2003) Forensic Materials Engineering: Case Studies. CRC Press, Boca Raton, USA.
14. Lewis PR and Gagg C (2010) Forensic Polymer Engineering: Why polymer products fail in service. Woodhead/CRC Press, Boca Raton USA.
15. Noon RK (2001) Forensic Engineering Investigation, CRC Press, Boca Raton, USA.
16. Li CT (2011) Computational Forensics, Digital Crime, and Investigation. Yurchak Printing Inc, Hershey, USA.
17. Coyle HM (Ed.) (2004) Forensic Botany: Principles and Applications to Criminal Casework, CRC Press, Boca Raton, USA.
18. Jackson G and Verbeck G (2015) Forensic Chemistry: Instrumentation and Applications. Wiley, Chicester, England.
19. Lee HC, Ramotowski R and Gaensslen RE (2001) Advances in Fingerprint Technology (2nd edn). CRC Press, Boca Raton, USA.
20. Butler JM (2009) Fundamentals of Forensic DNA Typing. Academic Press, San Diego, USA.
21. Muro CK, Doty KC, Bueno J, Halámková L, Lednev IK (2015) Vibrational spectroscopy: recent developments to revolutionize forensic science. Anal Chem 87: 306-327.
22. Bartick EG, Tungol MW, Reffner JA (1994) A new approach to forensic analysis with infrared microscopy: Internal reflection spectroscopy. Analytica Chimica Acta 288: 35-42.
23. Barron L, Gilchrist E (2014) Ion chromatography-mass spectrometry: a review of recent technologies and applications in forensic and environmental explosives analysis. Anal Chim Acta 806: 27-54.
24. O'Mahony AM and Wang J (2013) Electrochemical Detection of Gunshot Residue for Forensic Analysis: A Review. Electroanalysis 25: 1341-1358.
25. Smith JP, Metters JP, Kampouris DK, Lledo-Fernandez C, Sutcliffe OB, et al. (2013) Forensic electrochemistry: the electroanalytical sensing of Rohypnol® (flunitrazepam) using screen-printed graphite electrodes without recourse for electrode or sample pre-treatment. Analyst 138: 6185-6191.
26. Edelman GJ, Gaston E, van Leeuwen TG, Cullen PJ, Aalders MC (2012) Hyperspectral imaging for non-contact analysis of forensic traces. Forensic Sci Int 223: 28-39.
27. Silva CS, Pimentel MF, Honorato RS, Pasquini C, Prats-Montalbán JM, et al. (2014) Near infrared hyperspectral imaging for forensic analysis of document forgery. Analyst 139: 5176-5184.
28. Katz E and Halámek J (2014) New Approach in Forensic Analysis - Biomolecular Computing Based Analysis of Significant Forensic Biomarkers. Annals of Forensic Research and Analysis 1:article #1002.
29. Bakshi S, Halámková L, Halámek J, Katz E (2014) Biocatalytic analysis of biomarkers for forensic identification of gender. Analyst 139: 559-563.
30. Kramer F, Halámková L, Poghossian A, Schöning MJ, Katz E (2013) Biocatalytic analysis of biomarkers for forensic identification of ethnicity between Caucasian and African American groups. Analyst 138: 6251-6257.
31. Katz E, Privman V (2010) Enzyme-based logic systems for information processing. Chem Soc Rev 39: 1835-1857.
32. Katz E (2012) Biomolecular Information Processing - From Logic Systems to Smart Sensors and Actuators. Wiley-VCH, Weinheim, Germany.
33. Wang J and Katz E (2011) Digital biosensors with built-in logic for biomedical applications. Israel Journal of Chemistry 51: 141-150.
34. Houck MM and Siegel JA (2010) Fundamentals of Forensic Science (2nd edn). Academic Press, Burlington, USA.
35. Halámek J (2014) New age of quick and onsite bioassays for forensics: where are we now? Bioanalysis 6: 429-431.
36. Arismendi JL, Baker LE, Matteson KJ (2004) Effects of processing techniques on the forensic DNA analysis of human skeletal remains. J Forensic Sci 49: 930-934.
37. Ambers A, Turnbough M, Benjamin R, King J, Budowle B (2014) Assessment of the role of DNA repair in damaged forensic samples. Int J Legal Med 128: 913-921.
38. Yáñez-Sedeño P, Agüí L, Villalonga R, Pingarrón JM (2014) Biosensors in forensic analysis. A review. Anal Chim Acta 823: 1-19.
39. Bandodkar AJ, O'Mahony AM, Ramírez J, Samek IA, Anderson SM, Windmiller JR, Wang J (2013) Solid-state Forensic Finger sensor for integrated sampling and detection of gunshot residue and explosives: towards 'Lab-on-a-finger'. Analyst 138: 5288-5295.
40. Peschel O, Kunz SN, Rothschild MA, Mützel E (2011) Blood stain pattern analysis. Forensic Sci Med Pathol 7: 257-270.
41. Stoney DA, Stoney PL (2015) Critical review of forensic trace evidence analysis and the need for a new approach. Forensic Sci Int 251: 159-170.
42. US Department of Justice (2014) The Fingerprint Sourcebook, Office of Justice Programs, Washington, DC, USA.
43. Marcel S, Nixon MS and Li SZ (2014) Handbook of Biometric Anti-Spoofing: Trusted Biometrics under Spoofing Attacks. Springer, London, UK.
44. Brown JL (2012) Forensic Engineering. Civil Eng 82: 28-29.
45. Franck H and Franck D (2013) Forensic Engineering Fundamentals (1st edn). CRC Press, Boca Raton, UK.
46. Katz E and Halámek J (2016) Forensic Science: A Multidisciplinary Approach, Wiley-VCH, Weinheim, Germany, In press.
47. Brettell TA, Butler JM, Saferstein R (2005) Forensic science. Anal Chem 77: 3839-3860.