Raman spectroscopy for forensics: Identifying body fluid traces and gunshot residue

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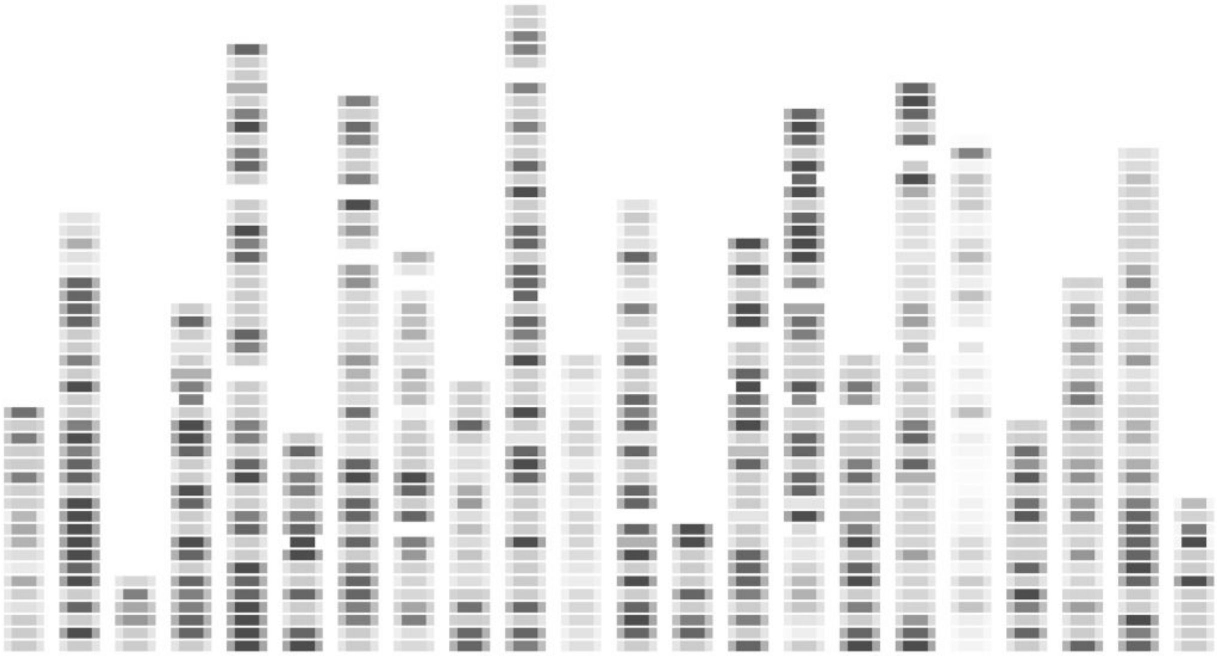

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Here, the Department of Chemistry and the Center for Biophotonic Technology and Artificial Intelligence (CeBAI), investigates Raman spectroscopy for forensic applications, a universal technique for identifying traces of body fluids and gunshot residue

Raman spectroscopy (RS) opens a unique opportunity as a universal, rapid, confirmatory, and nondestructive method for the identification of all main body fluids for forensic purposes. In addition, the ability to differentiate between human and animal blood, as well as between peripheral and menstrual blood, was demonstrated.

The proof-of-concept for determining the time since the deposition of bloodstains, as well as phenotypic profiling, including the determination of the donor's race, sex, and age, was reported. A novel two-step method for detecting organic gunshot residue was developed based on fast fluorescence imaging followed by Raman microspectroscopic identification.

Body fluid traces

RS based on inelastic light scattering has been known as the most selective spectroscopic technique since its discovery almost 100 years ago. The development of miniature, reliable, and inexpensive lasers, as well as highly efficient digital cameras, over the last several decades, has opened up exciting opportunities for numerous practical applications of RS in industry, medicine, forensics, and security.

The Lednev laboratory at the University at Albany, State University of New York, began a systematic investigation of body fluid traces for forensic purposes almost two decades ago. (1) They developed a universal method for nondestructive, automatic, and confirmatory identification for all main body fluids based on Raman microspectroscopy and machine learning. (2) This is an important development for modern forensic science because body fluid traces are the main source of DNA, which is often used as individual evidence. In the criminal court, it is necessary to indicate the source of collected DNA.

It was demonstrated that the method can be used for heavily contaminated samples, (3) biological stains on common substrates (4-6) and for binary mixtures (7,8) of different body fluids. The developed automatic software for body fluid identification was successfully used to identify blood based on a Raman spectrum of a single red blood cell. (9) This means that the method sensitivity is sufficient for identifying traces of blood, which are present in an amount sufficient for DNA analysis.

In addition, the Lednev laboratory demonstrated that the developed method could be used to differentiate between human and animal blood, which is vital for investigating hit-and- run cases. (10,11). Dry traces of menstrual and peripheral blood can also be differentiated with very high confidence. (12) Doty et al. (13) developed a regression model for estimating the time since deposition of blood up to two years, which is essential for determining the time of crime and/or selecting bloodstains relevant to the crime.

Most recently, the Lednev laboratory further expanded the developed methodology for phenotype profiling based on dry tares of body fluids. They have demonstrated for the first time that the sex (14) and race (15) of the donor can be determined based on a dry bloodstain, sex–based on saliva traces (16), and race–based on semen (17), and urine (18) traces.

Doty et al. (19) also demonstrated that the donor age can be estimated based on bloodstains. When fully developed, this method will be used at the scene of crime with a portable Raman instrument. Generating a suspect profile, including sex, race, and age, during the first hour of the crime scene discovery, will be invaluable for law enforcement agencies. A University spinoff, SupreMEtric LLC (https://www.supremetric.com/), is currently commercializing this novel patented technology.

Gunshot residue analysis

Bueno et al. (20) demonstrated that Raman microspectroscopy can be used for the detection and characterization of gunshot residue (GSR). Specifically, they developed a novel method based on tape lifting in combination with RS for the detection of both organic and inorganic GSR. (21) The proof of concept was demonstrated for differentiating ammunitions based on GSR particles. The developed method has great potential to significantly enhance the information available based on GSR recovered during crime investigation.

Khandasammy et al. (22) developed a two-step method for detecting organic gunshot residue, utilizing fast fluorescence imaging followed by Raman microspectroscopic identification. This novel approach has several significant advantages compared to the current method of choice – scanning electron microscopy with energy-dispersive X-ray spectroscopy.

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