B42 Advances in the Development of Portable Surface-Enhanced Raman Spectroscopy (SERS) for Rapid, Sensitive, Confirmatory Identification of Human Body Fluids

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Learning Overview: After attending this presentation, attendees will have learned that SERS has the attributes to become a transformative technology that can robustly detect and identify trace amounts of human body fluids in minutes employing an easy-to-use single platform that offers unprecedented sensitivity.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by highlighting how recent advances in the use of a SERS-based methodology for rapid confirmatory identification of dried blood, semen, saliva, vaginal fluid, menstrual blood, and urine from a single portable platform is ready to be employed by forensic scientists at crime scenes and in forensics labs. No such capabilities currently exist in the forensic science community.

Body fluids, such as blood, semen, vaginal fluid, and saliva are among the most important forensic evidence collected at crime scenes. An ideal detection and identification platform for these fluids is confirmatory, rapid, sensitive, highly specific, portable, and easy-to-use, providing crime scene investigators with maximal time for subsequent law enforcement activities. Furthermore, non-destructive and/or highly sensitive techniques are desirable for forensic identification because they leave sufficient amounts of trace biological evidence for other detection platforms, in particular for DNA testing. This presentation demonstrates how recent advances in the development of SERS-based procedures allows SERS to satisfy these forensic attributes in a portable single-platform instrument.

In a new sample preparation protocol, SERS spectra of dried blood, semen, saliva, vaginal fluid, urine, and menstrual blood have been readily obtained using a simple 50% acetic acid (HAc) extraction step. This results in larger signals, and better differentiation, than water or saline extraction. Perhaps most significantly, this novel methodology allows the blood identification signature to be dominated by the SERS spectrum of hemoglobin and minimizes variable background non-specific protein contributions. Identification of unknown body stains are accomplished by unique statistically based identification procedures resulting in analytical sensitivity and specificity >95% for all body fluid classification analyses when combined with this new sample preparation protocol.

High sensitivities have been routinely achieved with this SERS identification and detection procedure. For example, SERS spectra with excellent signal-to-noise of human blood diluted by 10^4 in water can be readily obtained. A dramatic and practical demonstration of SERS sensitivity is further illustrated by spreading a solution of 10μL of blood in 1mL of water over a 1 sq. ft. piece of glass, rubbing a swab with 50% HAc over a 1 sq. in. area, then touching the swab to the SERS chip, resulting in a strong SERS blood spectrum. By using a subtraction methodology, this study has been able to provide confirmatory identification of dried blood stains after they have been presumptively identified by luminol emission.

In another key advancement for practical and routine use of this technology, cotton swabs have been developed for the acquisition of SERS spectra of body fluids via two approaches for this forensics application. In one, the cotton swab is dipped in 50% HAc, lightly rubbed on the dried body fluid stain, then touched to the SERS substrate, and a SERS spectrum is obtained. In the second method, a solution of gold (Au) nanoparticles is pipetted onto the cotton swab, the swab is dipped in the HAc solution, then contacted with the suspected body fluid stain before the swab is directly placed at the focus of the Raman instrument for signal acquisition. High-quality SERS spectra are obtained with both approaches for easy and rapid practical use.

In addition, this presentation shows that the signature of these body fluids is unaffected by the surfaces they are found on. For example, SERS spectra of (1μL) dried blood on nine different materials have been acquired by the Au particle-covered swab technique and result in identical blood SERS spectra. Finally, a number of lab synthesized and commercial Au and silver (Ag) substrates as well as portable Raman instruments capable of rapid SERS use were tested, and an optimized choice for this forensic purpose will be described.

In conclusion, a portable SERS-based methodology has been developed offering a single-platform for confirmatory identification of human body fluids at crime scenes and in forensic lab settings with higher sensitivity and specificity and faster than techniques currently commercially available to crime scene forensic investigators.

SERS, Body Fluids, Identification

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