Application Summary
Buried Landmine Detection with SERS

Introduction

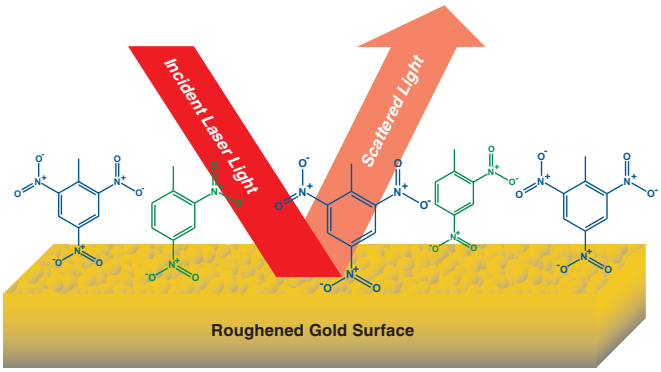
As of 1999, the only artificial systems employed by the U.S. military for the detection of buried landmines were metal detectors.[1] Although these detectors can sense as little as 0.5 grams of metal, and thus maintain a high detection probability, they cannot distinguish between a firing pin or a piece of scrap metal. Furthermore, modern landmines can be constructed without metallic parts and would therefore not be detected with current technology. An ideal sensor would be able to detect the actual explosive material (e.g. TNT, RDX) rather than detect parts used in the construction of the landmine. It would need to be sensitive but also specific so as not to result in a large number of false positive hits that would slow down the clearing process.

Surface Enhanced Raman Spectroscopy

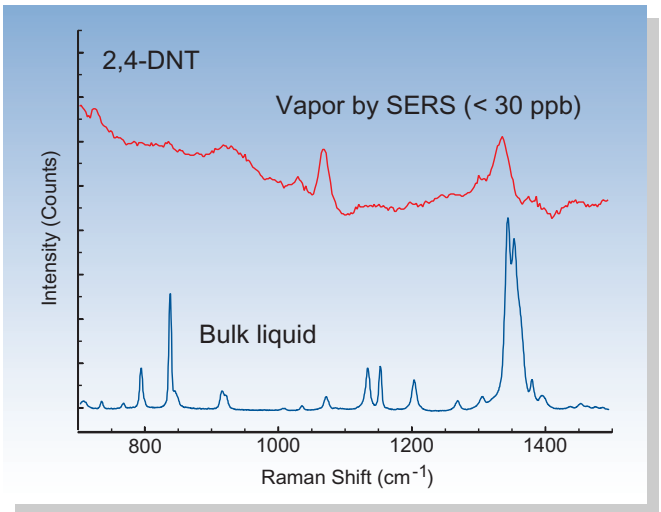
EIC Laboratories has long used the technique of Surface Enhanced Raman Spectroscopy (SERS) for trace detection of chemical contaminants. SERS employs microscopically roughened, or "activated" metals, normally noble metals, which adsorb the analyte of interest. The vibrational modes of the analyte that are involved in the adsorption process to the metal surface are enhanced 10^2-10^8 times when compared to their nonresonant Raman intensities. The enhancement is caused by a variety of chemical and electromagnetic effects. These enhancements allow SERS to detect picogram to femtogram levels of analytes of interest.

Up to now, the majority of trace SERS analyses have been performed in the solution phase. EIC is currently investigating the potential of SERS as a field usable detector of nitrate-based explosive vapors, as part of the high-profile "Electronic Dog's Nose" DARPA program.

When comparing bulk Raman with SERS spectra, the band intensity ratios are different since the vibrational modes associated with the analyte moiety adsorbed to the surface will be the most enhanced. For nitrate-based aromatics like picric acid, TNT or its degradation products, the nitrate is the adsorbing moiety. The key spectral regions are the nitrate stretching region around 1350 cm^{-1} and the out-of-plane bending modes around 820 cm^{-1}. This is of considerable use in the detection of buried land mines since there is little likelihood of detecting naturally occurring nitrate-based aromatics. Nitrogen dioxide will not interfere, as it undergoes a surface catalytic reaction to NO^{3-}, producing a sharp peak at 1035 cm^{-1}.



SERS measurement of 2,4-DNT and 2,4,6-TNT on a gold substrate.



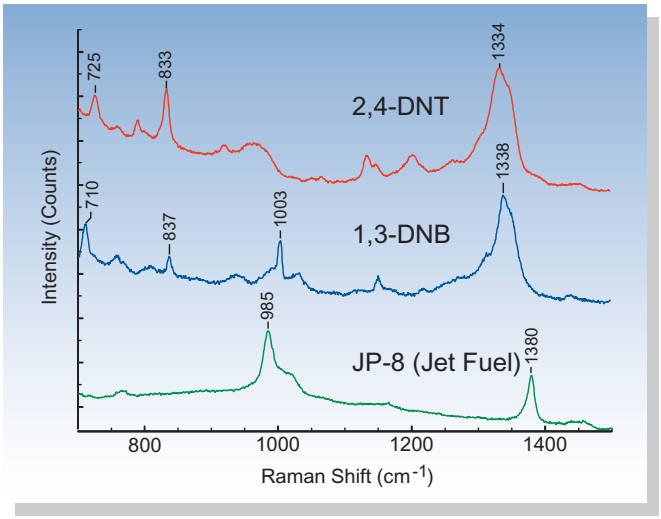
Comparison of SERS data with bulk Raman spectrum.

The Landmine Detection System

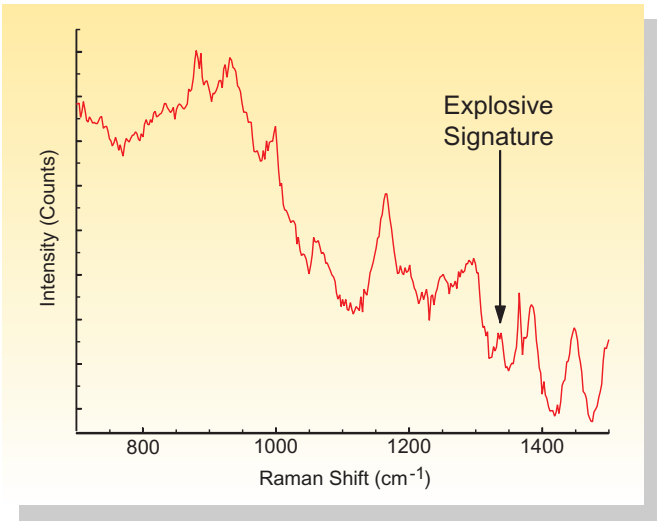
A novel SERS probe is under development that incorporates vapor sampling and optical components. Within the probe body, ambient air is drawn over an activated gold (Au) substrate which is then analyzed with a built-in Raman fiber optic probe. A field-portable spectrograph has also been developed to facilitate measurements in actual mine fields. The system is rugged enough for routine transportation and can withstand variations in operating temperature.

Latest results of this research include the measurement of 2,4-DNT at 5 ppb concentration in less than 10 seconds, and the detection of actual buried landmines with the prototype equipment. Work to improve the renewability of the substrates is ongoing.

Detecting landmines in a test field using a portable spectrograph and SERS probe.[2]



SERS data demonstrating selectivity of the technique for explosives.



Field data from an actual landmine.

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[1]Introductory material courtesy of DARPA web site (www.darpa.mil).
[2]Note: Raman instrumentation used and developed in this application are available from EIC's commercial subsidiary, InPhotonics, Inc. Visit us on the web at www.inphotonics.com.