White paper

Raman spectroscopy

Introduction to Raman spectroscopy

TruScan G3 Handheld Raman Analyzer

When light interacts with matter, several processes can occur. The light can be reflected, transmitted, absorbed, or scattered. Often, more than one of these processes will occur at the same time. The degree to which each process occurs depends upon the wavelength of light and the molecular properties of the substance.

TruScan G3 Handheld Raman Analyzer

Raman scattering

When light scattering occurs, most of the light is scattered with no change in energy or frequency. This is referred to as elastic, or Rayleigh, scattering. However, a small fraction of the scattered light (approximately 1 in 10^6-10^7 of the scattered photons) undergoes a change in energy (frequency). This change is called a Raman shift and is the basis for Raman spectroscopy, which bears the name of the physicist that first demonstrated the effect in 1927. Raman spectroscopy systems are designed to accurately measure the shifts and intensity of scattered energy which corresponds to vibrational energy changes in molecules making up the substance. This results in a Raman spectrum of the material—a map of intensity versus Raman shift.

An example of a Raman spectrum is shown in Figure 1; intensity is plotted vs. Raman shift in shift wavenumbers (cm^{-1}). Each peak in the spectrum corresponds to a vibrational transition in the substance being illuminated. Thus, a Raman spectrum gives the same type of information as a mid-infrared—also known as FTIR—spectrum. The molecular

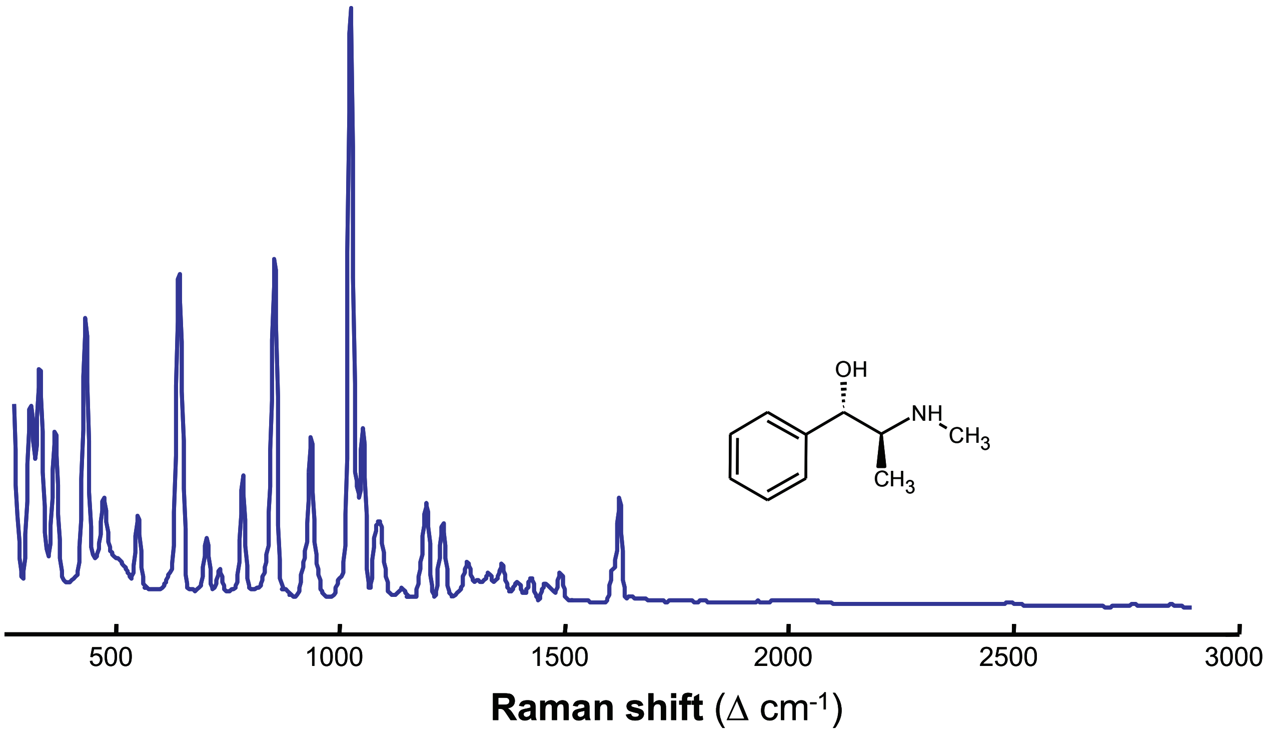

Figure 1.

vibrational frequencies (or energies) for a given molecule are the same in Raman and infrared spectra. However, the vibrational peak intensities are different, and in some cases peaks seen in a Raman spectrum will not be seen in an infrared spectrum, and vice versa. This is because the two techniques depend upon completely different physical mechanisms; FTIR is an absorption technique while Raman is a scattering technique. Raman scattering has also been described as reflection due to changes in molecular polarizability.

Instrumentation and technologies

There are two primary technologies used in instrumentation for Raman spectroscopy: Fourier-transform (FT) and dispersive. The fundamental difference in the two technologies is the way the Raman scattering signal is analyzed. In an FT-Raman system, the spectral analysis is performed using an interferometer and Fourier transforms, while in dispersive Raman systems, the spectral analysis is performed using a grating spectrograph or monochromator. The Thermo Scientific™ TruScan™ G3 Handheld Raman Analyzer employs dispersive technology, utilizing a 785nm near-infrared laser in conjunction with a silicon-based charge coupled device (CCD) detector. This instrumental configuration is lauded for its sensitivity, minimal fluorescence and ruggedness.

Analysis through blister packs enables instant field-based examination for counterfeit materials.

Raman analysis is non-contact through polybags, plastic or glass and can measure liquids, emulsions, gels and solids in seconds.

Applications

Raman spectroscopy is used in many areas and industries, including polymers, both small-molecule pharmaceuticals and large-molecule biopharmaceuticals, semiconductors, art, archeology, biotechnology, environmental monitoring, forensics, security, and hazardous materials response. Applications include raw materials quality control, counterfeit identification, material classification and verification, process monitoring, and quantitative concentration determination. Raman spectroscopy offers several advantages as an analysis technique over the related Fourier-transform infrared (FTIR) and near-infrared (NIR) absorption/reflectance methods. One of the most significant advantages is Raman's ability to analyze substances through glass and plastic. Furthermore, Raman spectroscopy can also analyze materials in aqueous solutions due to the weak Raman signal water emits. Usually, no sample preparation is needed before performing Raman analysis, which is rapid and non-destructive. Finally, each substance has a unique Raman spectrum, making the technique ideal for identification purposes, including raw material verification and counterfeit inspection.

Conclusion

While there is no single technology that is right for all applications, Raman is gaining favor as a quality control tool due to economic gains, speed, and sensitivity accompanying modern electronic and laser production. Instruments that once cost $200,000 and required specialized users are now available for less than $60,000 with decision-making software that enables non-technical personnel to be proficient users. Instruments once relegated to high-overhead laboratory space can now be carried with one hand to a production room or receiving area. The ability of Raman to measure through containers and be independent of environmental humidity makes it an ideal technology for compendial identity tests. Raman technology is also ideally suited for anti-counterfeit and brand security measures throughout the supply chain.

Learn more at **thermofisher.com/truscan**

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