

Raman Spectroscopy Services

Laboratories

EAG

<u>Raman Spectroscopy</u> is the ideal technique for the qualitative analysis of organic and/or inorganic mixed materials and can also be employed for semi-quantitative and quantitative analysis.

Raman spectroscopy is a vibrational spectroscopic technique based on the Raman effect, which involves the scattering of the incoming monochromatic light by altering its wavelength (or frequency) via the interaction of the light with the sample molecule being probed. The difference in the frequency of the incident photon and the scattered photon is called the Raman shift, and it contains important information regarding the functional groups present in the sample.

Raman scattering is inherently a very weak effect as the majority of the photons are scattered elastically (meaning there is no change in the energy of the scattered photons) after interaction with a sample and only 1 in 10 million photons produces Raman scattering. As a result, a Raman spectrometer requires sophisticated optics as well as good alignment of the instrument to produce the best quality data. A schematic presentation of the Raman technique and instrumentation are shown in Figures 1 and 2.



Figure 1: General schematic of how Raman works



Figure 2: Schematic of a Raman spectrometer

The sample is excited by a monochromatic laser with the wavelength of choice and the scattered light passes through a filter to remove the elastically scattered photons, allowing only the Ramanscattered photons to reach the grating that further disperses the photons with different energies onto a CCD detector. The resulting Raman spectra comprise the intensity of the scattered photons on the y-axis and the Raman shift on the x-axis, as shown in the example data in Figure 3. The



Figure 3: Blue trace: example Raman spectrum obtained from an unknown material. Red trace: reference Raman spectrum of poly (dimethylsiloxane) from the library.

identification of the unknown sample is achieved by matching the Raman spectrum of the sample with reference Raman spectra of known materials from our extensive Raman libraries, or by interpreting the bonds in the spectrum from first principles.

Strengths

- Full compound identification based on the spectral libraries
- Non-destructive technique that typically requires little or no sample preparation
- Powerful technique for carbon allotrope analysis and quantification of their phases
- Minimum analysis area: ~1 µm (better resolution than FTIR for organics and XRD for inorganics)
- Very good detection limits for elemental Si, C, and dyes

Limitations

- Fluorescence (usually much more intense than the Raman signal) can hinder the acquisition of usable Raman spectra
- Limited sensitivities for low level impurities except for Si, C, and dyes
- Challenging to achieve accurate quantitative results as the intensity of the Raman peaks in the spectra are not simply proportional to the concentration of components in a mixture
- Limited surface sensitivity, due to the depth of focus of the laser into the sample

Common Applications

- Identify organic molecules, polymers, biomolecules and inorganic compounds both in the bulk and as individual particles
- Imaging and depth profiling to map the distribution of components in mixtures, such as drugs in tablets and multilayer polymer stacks
- Determine the presence of different allotropic forms of elemental carbon (diamond, graphitic, nano-graphitic, amorphous carbon, diamondlike carbon, graphene, nanotubes, etc.)
- Determine inorganic oxides and their valence state

• Measure the stress and crystalline structure in semiconductor and some other materials

Industry Sectors and Technologies

- <u>Consumer electronics</u>
- Semiconductors
- Semi-equipment
- Carbon technology
- Pharmaceutical
- Medical devices
- Biotechnology
- Polymers
- Failure analysis

Case Study: Raman Mapping

In addition to point analysis to characterize unknown materials, Raman spectroscopy can be performed in a mapping (imaging) mode that can provide valuable information regarding the chemical distribution of different materials in the XY dimension. Here is an example showcasing the application of Raman mapping to study the chemical composition and construction of a multilayered polymer thin film sample. The cross-section of the thin film was produced by cryo-microtome and a Raman map was obtained from an area of ~40 µm by 60 µm in the middle of the cross-section. Initial point analysis on the cross-section revealed that two distinct polymers, i.e., Nylon and ethylene-vinyl acetate (EVA) copolymer, were used to construct the film. The signature amide I peak at ~1636 cm⁻¹ was used to map the distribution of Nylon, whereas the non-overlapping peak at ~492 cm⁻¹ was used to



Figure 4: Raman map obtained from a cross section of a multilayered polymer film sample

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map the EVA component. The resulting Raman map shown in Figure 4 clearly demonstrated a sandwich structure consisting of an EVA layer of 5-micron thickness in between two 20-micron thick layers of Nylon.

Complementary Techniques

FTIR is a vibrational spectroscopic technique that often provides complementary information to Raman analysis. Both techniques provide organic compound identification and are not limited simply to functional group identification. Due to different spectroscopic selection rules, certain functional groups that have a strong response in Raman may have a weak response in FTIR and vice versa. A more comprehensive understanding of the sample can often be achieved via a combination of Raman and FTIR analyses. In addition, FTIR does not suffer from fluorescence like Raman does and thus can be a powerful alternative technique for organic characterization when strong fluorescence is encountered in Raman analysis. XRD (X-ray diffraction) is often used in combination with Raman for inorganic identification as well as stress analysis. Moreover, due to limited surface sensitivity of Raman analysis, TOF-SIMS can be quite useful as a complementary technique for characterizing very thin residues/films.

Raman at EAG

EAG has state-of-the-art Raman instrumentation equipped with lasers covering the UV to visible (red, gree and blue) to near-infrared excitation range (i.e., 325 nm, 415 nm, 532 nm, 633 nm and 785 nm) that offers the flexibility to study a wide range of materials/samples. Our Raman scientists are highly educated and knowledgeable and are leaders in the analysis of complex organic/inorganic mixtures. We pride ourselves in skillful sample preparation, knowledgeable spectral interpretation and extensive experience with many different types of materials and applications. We can push our instruments to the limit, to get the best out of them, based on our many years of experience. We provide accurate data, complete written reports, fast turnaround times, and person-to-person service. Contact us today to learn how we can help you on your next project.



