Raman spectroscopy for food applications

Identification

Key words: Raman spectroscopy, scattered light, adulteration, Rayleigh scattering, non-destructive technique

Latest version: 2013/02/14
Completed by: UTCN, IRTA

How does it work?

Primary objective: Non-destructive analysis of food substances, food authentication, traceability and quality control.
Raman spectroscopy is a useful technique for determining structural information of solid samples and aqueous solutions [1]. In fact, a Raman spectrum presents well-resolved bands, carrying information on the vibrational band energies of molecules.

In a Raman spectrometer, a laser beam is fired through a window and reflected by a mirror to the filters that guide the photons to the sample. A set of mirrors are gathering the scattered photons reflected by the sample and pass them through the monochromator that reduces stray light. Scattered light is light transformed in a spectrum by a photomultiplier tube [2]. The spectrum is confronted with databases of reference spectrums for chemical identification.

Figure 1: Sketch of a Raman spectrometer set-up. A small amount of the scattered light is shifted in energy from the laser frequency due to interactions between the incident electromagnetic waves and the vibrational energy levels of the molecules in the sample. Plotting the intensity of this "shifted" light versus frequency results in a Raman spectrum of the sample.

Figure 2- Raman and Rayleigh effects. Ext frequency of the incoming (excitation) laser.

Spontaneous Raman scattering is weak and therefore the challenge is to separate it from the intense Rayleigh scattered light, which occurs as light passes through substances, being an elastic effect, with no change in the wavelength of the light. Raman scattering is a form of light scattering where the incoming photon excites a molecule, which passes from an initial energy state to a virtual energy state. As the molecule relaxes, a photon is emitted and passed into a different vibrational state, generating Stokes Raman scattering. If the molecule had an already elevated vibrational energy state, then the phenomena is called anti-stokes Raman scattering (see Fig. 2).

Raman spectroscopy can be used for both qualitative and quantitative determinations, since band areas are proportional to concentration. Not all molecules are "Raman active", since a change in polarisability must be involved. By infrared spectroscopy, on the other hand, only the transitions that cause a change in dipole moment can be observed, leading therefore to different vibrational transitions. This makes the two techniques complementary.

There are different Raman techniques, such as Fourier Transform Raman Spectroscopy (FT-Raman), Surface Enhanced Raman spectroscopy (SERS), Confocal raman Microscopy, Coherent anti-Stokes Raman Scattering (CARS), Resonance Raman Spectroscopy and Raman Sensing. Raman Sensing is related with low-cost fibres optics and miniaturized detectors to be used in remote sensing [3]. For some applications, Raman spectroscopy can be coupled with chemometric analysis (PLS, cluster analysis, etc.) in order to have an appropriate calibration.
### Additional effects
- Fluorescence from impurities of the sample itself can hide the Raman spectrum.
- Sample heating through the intense laser radiation can destroy the sample or cover the Raman spectrum, since the sample absorbs some of the incident radiation when low laser powers are applied to sensitive samples.

### Important process parameters
- Acquisition time, intensity of laser, calibration solutions

### Important product parameters
- Polarizability, intrinsic fluorescence properties at excitation frequency

## What can it be used for?

### Products
- Most food products with weak intrinsic fluorescence at the excitation frequency.

### Operations
- Raw material authentication, quality assessment

### Solutions for short comings
- This technique does not cause chemical decomposition, mechanical disturbance or photo-thermal damage (only in colored samples, and is currently overcame by technical adjustments)
- High sensitivity towards molecular structure and conformation
- Potential use as non-destructive and real-time sensor

## What can it NOT be used for?

### Products
- A Raman signal is weak and often hidden by the intrinsic fluorescence of the product. Products with a high fluorescence in the visible and NIR range are not suitable for Raman spectroscopy.

### Operations
- It can not be used in harsh environment.

### Other limitations
- Significantly higher costs compared to IR instruments.

### Risks or hazards
- This technology can be risky for operators; risks are related with the use of laser light (optical hazard).

## Implementation

### Maturity
- Mainly used on lab-scale. Affordable portable Raman spectroscopy systems are also available on the market.

### Modularity
- It can be used along the production line (continuous). Since measurement can take place through fibre optic and an apropiated probe, the Raman equipment can be located separately from the production line.

### Consumer aspects
- No literature available.

### Legal aspects
- Please check local legislation.

### Environmental aspects
- No literature available.
### Facilities that might be interesting for you

<table>
<thead>
<tr>
<th>Title</th>
<th>Institute/company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous microwave heating system with conveyor - SP</td>
<td>SP</td>
</tr>
<tr>
<td>Continuous tubular microwave heating system - SP</td>
<td>SP</td>
</tr>
<tr>
<td>HIGH STATIC ELECTRIC FIELD FREEZER</td>
<td>ONIRIS-GEPEA</td>
</tr>
<tr>
<td>Microwave heating labscale IRTA</td>
<td>IRTA</td>
</tr>
<tr>
<td>Microwave heating pilot and industrial scale IRTA</td>
<td>IRTA</td>
</tr>
<tr>
<td>Microwave system 2450 MHz FBR</td>
<td>Wageningen UR - FBR</td>
</tr>
<tr>
<td>Microwave system 915 MHz FBR</td>
<td>Wageningen UR - FBR</td>
</tr>
<tr>
<td>Radio Frequency heat treatment pilot system - KEKI</td>
<td>NAIK EKI</td>
</tr>
<tr>
<td>Radiofrequency heating semi-industrial scale IRTA</td>
<td>IRTA</td>
</tr>
<tr>
<td>Shockwave - DIL</td>
<td>DIL</td>
</tr>
</tbody>
</table>

### Further Information

**Institutes**

- University of East Anglia, University of the Basque Country, University College Dublin - Agriculture and Food Science, Walloon Agricultural Research Centre, CSIC - Instituto de la grasa, AFRC Institute of Food Research

**Companies**

- Thermo Scientific, Renishaw, River Diagnostics, HORIBA Scientific, CRAIC Technologies, Ocean Optics

**References**
