Raman spectroscopy of carbon materials

Raman spectroscopy for graphene investigation
Graphene comprises one monolayer of carbon atoms packed into a two-dimensional (2D) honeycomb lattice\(^1\). Graphene has many unique properties that make it an ideal material for fundamental studies as well as for potential applications. Today graphene is being a test bed for examining core quantum mechanics principles, and the basis for development of fundamentally new functional devices, structurally smaller than those relying on conventional metals and semiconductors.

Several approaches have been successfully developed to fabricate graphene. The most common one is when it is formed on silicon substrate at random, and if the substrate has a certain amount of SiO\(_2\) film on it, graphene flakes can be detected by optical microscopy. However, it is difficult to distinguish exactly how many layers each graphene consists of.

A quick and precise method for determining the number of layers of graphene flakes is essential for speeding up the research and exploration of graphene. Although atomic force microscopy (AFM) measurement is the most direct way to identify the number of layers of graphene, the method has a very slow throughput. Raman spectroscopy proves to be the most efficient way to identify different layers of graphene without destroying the crystal lattice.

\(1\) Geim, A.K.; Novoselov, K.S. The rise of graphene. Nat. Mater. 2007, 6, 183-191
Raman Mapping of Graphene

With Raman Spectroscopy the number of graphene layers can be distinguished by examining the intensity ratio of G-band and 2D-band – the two well characterized and understood peaks in the Raman spectra of graphene.

Mapping of a substrate with formed graphene allows visualizing the substrate’s surface according to intensities of graphene Raman lines.

Figure 2 - Raman map of graphene flake

In every part of the world scientists are experimenting with new ways of fabricating graphene. In major cases Raman spectroscopy turns to be the only reliable tool to proof the efficiency of a new method.
Instrumental Specifications

Graphene investigations described above have been performed on RamMics M532® Raman Microscope equipped with Standa XY-motorized sample stage.

The size of typical graphene flake is about 5 microns only (if talking about graphene fabricated via mechanical exfoliation in laboratory conditions), and the easiest way to find graphene flakes and distinguish almost transparent single-layer and bilayer graphene is to do Raman mapping. The process of mapping calls for specific equipment with particular requirements which it shall meet.

Raman Microscope RamMics M532® by Enhanced Spectrometry is a truly indispensable tool for various applications and researches. Spatial resolution of 1 µm, spectral resolution 4-6 cm⁻¹ and a high efficiency provide precise quality of measurements at shorter acquisition time. Optionally equipped with a motorized sample stage with adjustable step (from 0.36 µm) RamMics M532® allows mapping of large surfaces at instant quality. RamMics M532® efficiently works on low laser power (tunable) which secures avoiding damaging samples.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>532 nm</td>
</tr>
<tr>
<td>Spectral Range</td>
<td>120 cm⁻¹ – 4000 cm⁻¹</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>4-6 cm⁻¹</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>1 µm</td>
</tr>
</tbody>
</table>

Benefits of RamMics M532:

- Focusing: sample positioning and focusing can be done with a digital camera;
- Continuous performance: precise spectra measurements are achieved at short acquisition time;
- Easy to use: simple and user-friendly interface of EnSpectr Software for 2D mapping, automatic procession of data;
- Affordable price: the cost of a system is remarkably lower compared to similar Raman 2D mapping solutions on the market;
- Safety: no damage to the sample due to low laser power;
EnSpectr 2D-Mapping Software
One of the most important parts of any mapping system is software. EnSpectr has created original software for 2D mapping, which provides a user with intuitive interface, easy to learn and operate, and rapid processing of acquired data. Software supports flexible data management.

Software supports flexible data management and allows adjusting the following settings:

- exposure time and number of averages
- step size and number of steps
- specify lines (by indicating a sector of spectral range)
- adjust the starting position

The result of mapping is outlined on figure 3. The lighter squares correspond to areas with the highest relative line intensity and vice versa.
Raman spectroscopy for carbon nanotube investigation

Carbon nanotubes are tubular cylinders of carbon atoms that have extraordinary mechanical, electrical, thermal, optical and chemical properties. The properties of carbon nanotubes have caused researchers and companies to consider using them in several fields.

Raman spectroscopy has good spatial resolution (~1 micrometer) and sensitivity (single nanotubes); it requires only minimal sample preparation and is rather informative. Consequently, Raman spectroscopy is probably the most popular technique of carbon nanotube characterization.

Raman spectra of carbon nanotube consist of a number of features allowing all kinds of analysis: from routine material validation to fundamental investigation of optical, mechanical, electrical parameters.

Application fields of carbon nanotubes

- Energy
- Healthcare
- Environment
- Effecting materials
- Electronics

Figure 4 – Raman spectra of a single-walled carbon nanotube