

Raman Spectroscopy Characterisation of Large Area 2D materials

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In this work Renishaw plc used Raman spectroscopy to characterise the quality of large area 2D materials and their 3D precursors. By examining uniformity, strain/stress and defects, we demonstrated that Raman spectroscopy and imaging, with Renishaw's inVia confocal Raman microscope, can be of use for wide scale analysis.

2D materials such as graphene, h-BN and MoS₂ have huge potential in a wide range of technologies, however, for this potential to be realized, improvements must be made to enable the growth of high quality large area material. Industrial production of graphene is already underway with some companies growing material over square metre and larger areas. This is challenging because it is hard to maintain quality over these expanses; the material can become highly defective and have may consist of multilayer regions. Our Raman mapping of industrially sourced graphene highlights the variation in material quality that can be seen on large length scales and demonstrates the caution that should be taken when using such material for test device structures.

Other materials, such as h-BN and MoS₂, are still in the research stage. For example, although it is possible to mechanically cleave h-BN material in the same way as HOPG to create single layers, bulk high quality h-BN crystals are hard to grow. As a result, it is challenging to get the good quality single layer material for devices. We have used 3D Raman mapping to analyse bulk h-BN crystals grown using a temperature gradient method. By examining the peak position, it was possible to estimate the local strain field, which in turn can be used to better understand the growth mechanism. This enables growth conditions to be optimised and provides information on the suitability of such crystals for the production of single layer h-BN by mechanical cleaving.

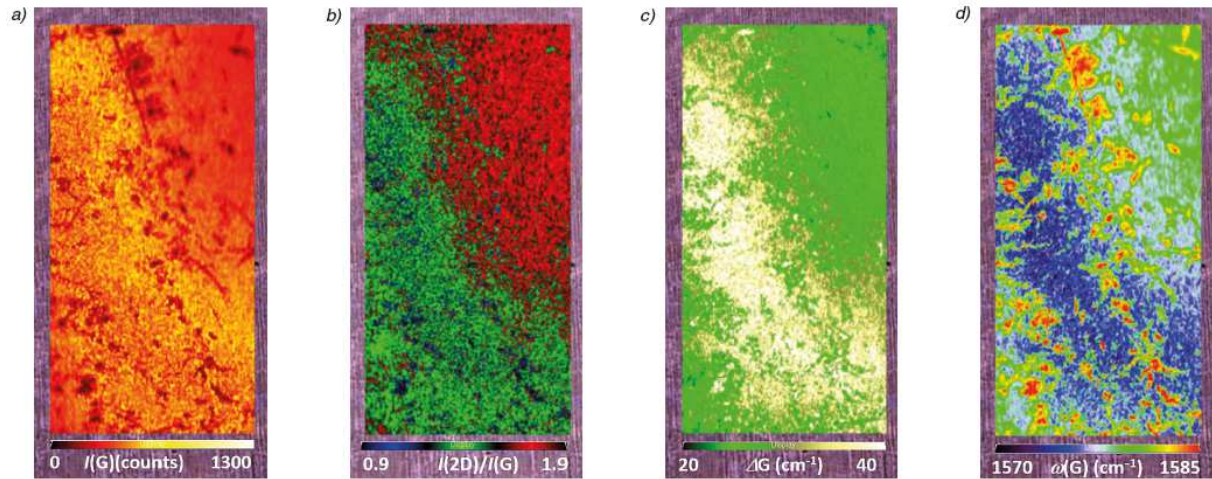


Figure 1: Raman images of CVD graphene grown on a Cu foil. The area mapped was $500 \mu\text{m} \times 1000 \mu\text{m}$. These images illustrate:

- (a) Intensity of graphene G band.
- (b) I_{2D}/I_{1G} ratio. A value greater than 2 is indicative of single layer graphene and 1 to 2 bilayer graphene.
- (c) G band width. Often used to assess material uniformity.
- (d) Peak position of the G band. This is an indicator of strain and electronic properties.

These images all highlight significant variations over what is described as a uniform graphene film.

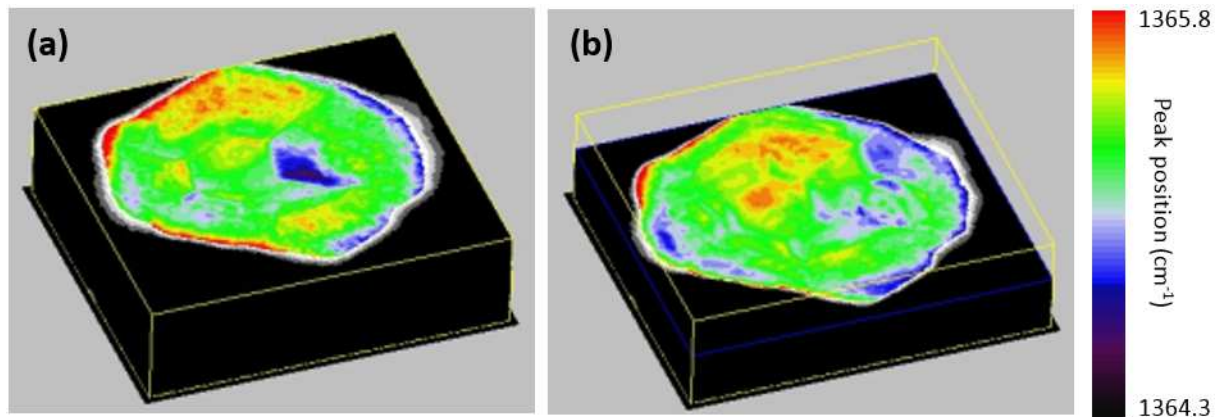


Figure 2. 3D Raman images of a h-BN crystal a) at its surface and (b) at a depth of $100 \mu\text{m}$ beneath the surface. These images illustrate the change in peak position of E_{2g} mode, this mode is sensitive to strain and as such the images help the local strain field to be visualized. The entire mapping area is $900 \mu\text{m} \times 800 \mu\text{m} \times 250 \mu\text{m}$.