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Raman Spectroscopy of Graphene: From Metrology and Manufacturing to Qualification in Extreme Environments

The translation of two-dimensional (2D) materials from laboratory research to industrial technologies requires not only scalable manufacturing, but also reliable and reproducible methods for assessing material quality throughout production and applications. Raman spectroscopy is particularly attractive because it is rapid, non-destructive and highly sensitive to the structural properties of graphene and related 2D materials.[1]

Here, I show how Raman spectroscopy can be used across different stages of the 2D-material lifecycle, from standardised characterisation to in-process manufacturing control and assessment of materials operating in extreme environments. First, an international interlaboratory comparison involving 17 laboratories was used to assess the reproducibility of Raman measurements of CVD graphene. The study identified instrument calibration and data-analysis procedures as major sources of variability, demonstrating the importance of harmonised measurement protocols for obtaining comparable quantitative data and supporting international standardisation. [2-4] I then demonstrate the transition of Raman spectroscopy from laboratory characterisation to industrial process monitoring. In-line Raman measurements were implemented during the production of graphene nanoplatelets, providing real-time information without manual sampling.[5]

Finally, we extend Raman-based characterisation to the qualification of solution-processed hexagonal Boron Nitride and graphene for demanding environments. Inkjet-printed films and membranes of hexagonal boron nitride were exposed to γ -radiation up to an absorbed dose of 1500 kGy. Raman spectroscopy, supported by X-ray photoelectron spectroscopy, showed no significant structural degradation of h-BN even at the highest doses investigated, highlighting the remarkable radiation tolerance of solution-processed hBN and its potential for nuclear and aerospace applications. [6] Graphene, in contrast, shows different answer to the γ -radiation depending on the dose and ambient conditions.

Together, these studies demonstrate how Raman spectroscopy can evolve from a laboratory characterisation technique into a practical metrology platform for 2D materials, connecting reproducible measurement, manufacturing quality control and validation of material performance under application-relevant conditions.

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References

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