# Development of International Measurement Standards

**Andrew J. Pollard**
*National Physical Laboratory, Teddington, UK*
andrew.pollard@npl.co.uk

Companies cannot efficiently develop new applications in the many technological areas where graphene is predicted to be disruptive, as they do not know the properties of the material supplied to them. Thus, there is a need for reliable, accurate and precise measurements for material testing, which are standardised across the industry and therefore allow end-users to be able to compare commercially-available materials from around the world.
The current state of international measurement standards covering the material properties of the graphene family will be detailed, including the ISO/IEC standard "TS 21356-1 Structural characterization of graphene: Graphene from powders and dispersions". Based on the NPL Good Practice Guide [1] that was developed in collaboration with the University of Manchester, this standard details the techniques and decision making process of characterising the percentage of 'graphene' or 'few-layer graphene', as defined by ISO [2], in materials sold globally. Importantly, the sample preparation, measurement protocols and data analysis are all described, to enable more reproducible comparisons. The development of the understanding of one of the techniques included in the standard, the Brunauer-Emmett-Teller (BET) method will also be reported.
A key part of developing international measurement standards is the validation of protocols through international interlaboratory comparisons. As an example, the initial results of a VAMAS interlaboratory study, TWA 41 Project 1, on Raman spectroscopy of chemical vapour deposition (CVD) grown graphene will be reported. This project will directly support the development of the ISO/IEC standard "PWI 21356-2 – Structural Characterisation of CVD-grown Graphene". This interlaboratory study gathered data from 14 participants across academia, industry (including instrument manufacturers) and National laboratories, revealing key metrology issues that must be considered.

## REFERENCES

[1] A. J. Pollard, et al., Characterisation of the structural properties of graphene, NPL Good Practice Guide 145 (2017)
[2] ISO, Nanotechnologies -- Vocabulary -- Part 13: Graphene and related two-dimensional (2D) materials, 2017

## FIGURES

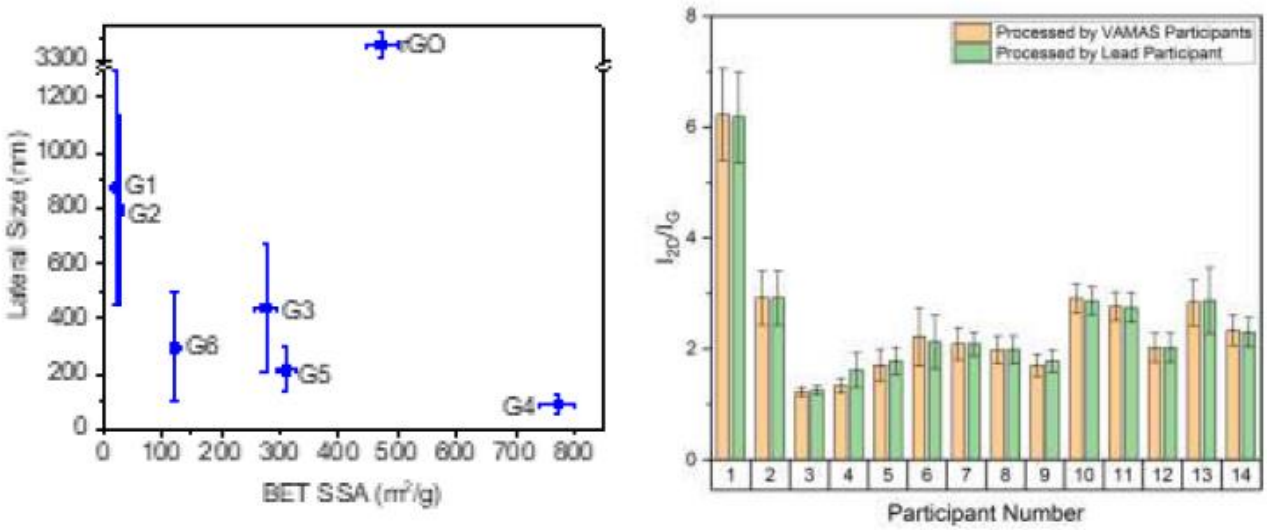


**Figure 1:** (Left) SEM lateral size of flakes from commercial powders vs the BET specific surface area (SSA). (Right) I2D/IG Raman peak intensity ratios of CVD-grown graphene reported in an international comparison. Differences in peak intensity ratios due to the data analysis being performed by the individual (green) and lead (orange) participants are also shown.