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Standardisation of terminology and measurement for graphene and related 2D materials

Potential innovators of real-world graphene products 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. This may be because the material has been characterised in a way that leads to large uncertainties, or because a lack of batch-to-batch reproducibility means the original characterisation is only accurate for the initial batch of material. Thus companies developing commercial products do not truly understand the effects the different properties of the material have on the final desired properties of their application.

There is an obvious need for reliable, accurate and precise measurements for off-line material testing that are standardised across the industry and therefore allow end-users to be able to compare materials commercially available around the world. At the same time, these accurate and precise measurement techniques and protocols are required before any reliable quality control (QC) methods can be developed for either the production of material or intermediates in the production chain. Crucially, international standardisation of the terminology and measurement methods is required so that graphene can be a truly global industry, allowing materials to be traded between producers and end-users in the many different countries currently pursuing graphene applications.

The current state of international standardization in this area will be detailed. Importantly, the recent publication of the first ISO (International Organization for Standardization) standard, 'ISO/TS 80004-13:2017: Nanotechnologies -- Vocabulary -- Part 13: Graphene and related two-dimensional (2D) materials'[1,2] will be described, including several of the key terms and definitions.

Furthermore, the new NPL Good Practice Guide entitled 'Characterisation of the structural properties of graphene', developed in collaboration with the University of Manchester, UK, will also be explored, as will how this guide will be the basis of new ISO measurement standards being developed to ensure the reliable, reproducible and comparable characterisation of graphene, worldwide.

References

- [1] ISO, Nanotechnologies -- Vocabulary -- Part 13: Graphene and related two-dimensional (2D) materials, 2017
- [2] A. J. Pollard, C. A. Clifford, *J. Mater Sci* **52**, (2017) 13685–13688
- [3] A. J. Pollard, *et al.*, Characterisation of the structural properties of graphene, NPL Good Practice Guide 145 (2017)