Metrology for Graphene and 2-D Materials: Characterisation and Standardisation for an Emerging Industry

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Abstract

Graphene has already demonstrated that it can be used to the benefit of metrology as a new quantum standard for resistance [1]. However, there are many application areas where graphene and other 2-D materials may be disruptive; areas such as flexible electronics, nanocomposites, sensing, filtration membranes and energy storage [2]. Applying metrology to the area of graphene is now paramount to enable the emerging global graphene industry and bridge the gap between academia and industry. Measurement capabilities and expertise for a wide range of scientific areas are required to address this challenge. The combined and complementary approach of varied characterisation methods for structural, chemical and electrical properties, will allow the real-world issues of commercialising graphene and other 2-D materials, such as determining the suitability and realistic performance enhancement of graphene-enabled products for the many different types of graphene, to be addressed.

Examples of metrology challenges that have been overcome through cross-disciplinary research, newly developed measurement techniques and collaboration with both academia and industry will be discussed, for specific consumer application areas, using both established and emerging measurement techniques such as Raman spectroscopy, tip-enhanced Raman spectroscopy (TERS) and secondary ion mass spectrometry (SIMS).

We will discuss the quantitative determination of the lattice disorder present in graphene layers through studying the evolution of Raman spectra with defect size and density, for vacancy defects created via carefully controlled ion bombardment, and explore how this enables an accurate determination of the phase-breaking length of graphene. This is further extended to other 2-D materials such as MoS_2 and we investigate the application of Raman spectroscopy for quantification of defects in these systems.
We will further discuss understanding the measurement of real-world graphene samples, and the application of routine industry ready techniques, such as controlled mass-selected argon cluster cleaning to remove polymer residues present on the transferred graphene surface, which minimise damage to the underlying graphene. The application of SIMS measurements in these studies will be discussed, and further details of how it can be applied to the understanding of the growth mechanisms of graphene and other 2-D materials on metal catalysts will be explored. Other more novel applications of SIMS in relation to the characterisation of dispersed graphene materials in polymer composites for flexible device technologies, and how it can aid in identifying contamination and the degree of dispersion of different graphene products will also be presented. In addition, how these metrology investigations ultimately lead to the development of international graphene standards will also be described.

References

[1] T.J.B.M. Janssen et al. Rep. Prog. Phys. **76** (2013) 104501.
[2] K.S. Novoselov et al. Nature, **490** (2012) 192.