Quantitatively characterising the size of graphene defects with Raman spectroscopy

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Abstract

The huge potential of graphene to disrupt many different application areas of technology has been extensively shown in research laboratories over the last decade and has now led to the beginning of an adoption of this 2-D material in industry worldwide. However, the requirement to overcome the practical problems related to 2-D materials, such as quality, reproducibility and contamination, increasingly needs to be met. At the same time, companies in the emerging graphene industry require the ability to accurately, quantitatively and reliably characterise these types of materials to instil market confidence. Raman spectroscopy has been shown to rapidly characterise many different attributes of graphene in a non-destructive manner, attributes such as the number and orientation of layers, strain effects and doping [1]. Raman spectroscopy is arguably also the metrological tool of choice for quantifying the disorder, which is frequently referred to as the 'quality' of graphene and affects many of the supreme properties of graphene that would be important in areas ranging from electronics to filtering.

Raman spectroscopy has already been shown to be invaluable in determining the defect density in graphene, as the ratio of the D- and G-peaks varies in relation to the graphene inter-defect distance, L_D [2,3]. However, this intensity ratio also varies in relation to the graphene defect size, and although this relationship has been mathematically described, it has not been shown experimentally. By introducing vacancy defects into pristine single-layers of graphene using different bismuth and manganese ions, we show the variation in the D- and G-peak intensity ratios with increasing defect size, as shown in Figure 1. The relationship between defect density, size and the phase-breaking length of graphene (the average distance travelled by the photoexcited electron-hole pair during its life-time), L_σ, can be described, and L_σ can be calculated with an accuracy not previously achieved. Scanning tunnelling microscopy (STM) measurements of these introduced defects have also been performed to corroborate these Raman spectroscopy results, as shown in Figure 2.

References

[1] Ferrari and Basko, *Nat. Nanotech.* **8** (2013) 235
[2] Lucchese *et al., Carbon* **48** (2010) 1592
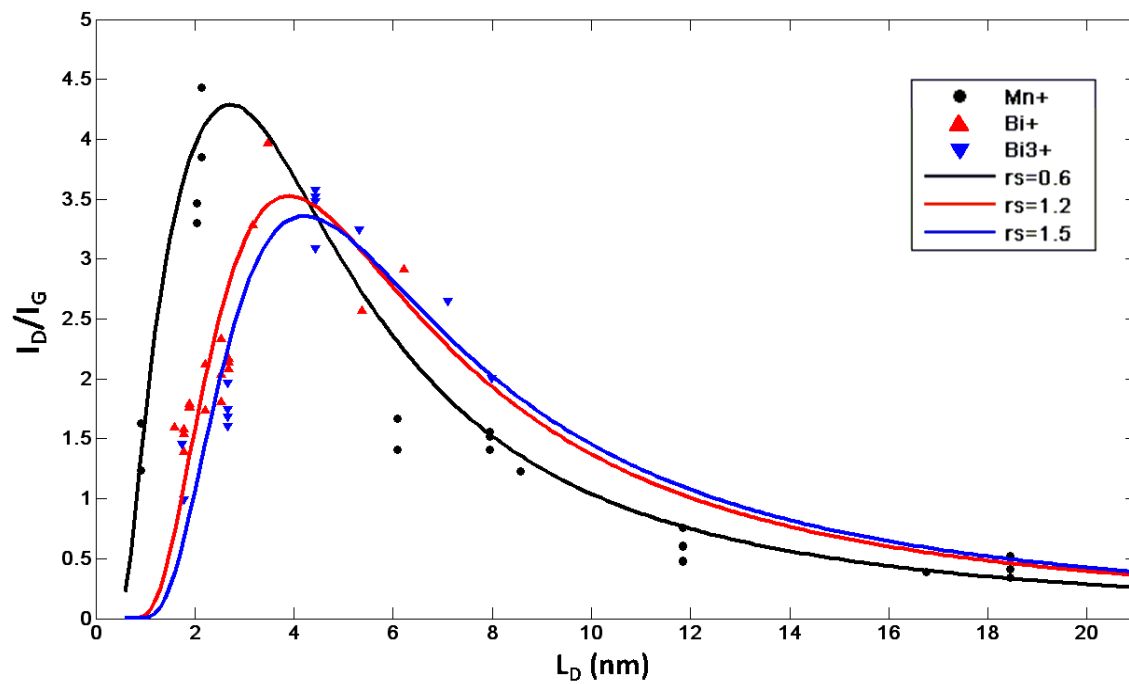[3] Cancado *et al., Nano Lett.* **11** (2011) 3190

Figures

Figure 1: Intensity ratio of Raman D- and G-peaks vs. the average inter-defect distance, L_D, for different size defects in a single-layer of graphene
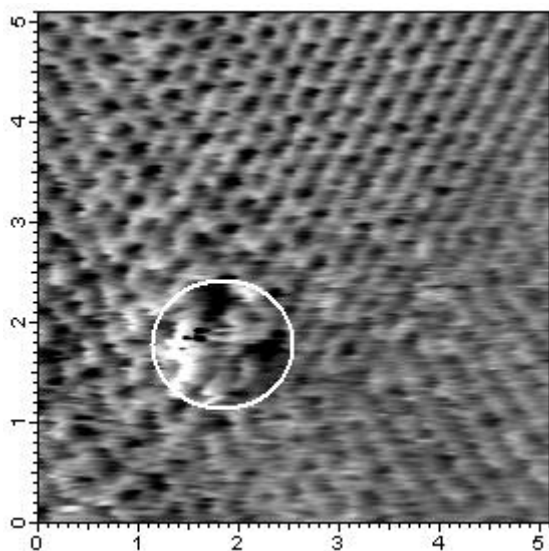

Figure 2: STM image of a defect in a graphitic lattice created by manganese ion bombardment, with scale bars in nanometres