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A Comparative Study of Quick and Simple Methods for Thickness Measurement of Graphene

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Graphene – a single sheet of carbon – has become one of the most studied and promising materials for the development of tomorrow's technology. One of the biggest hurdles however is still the controllable production of graphene[1,2]. Most of the synthesis and exfoliation methods produce multiple layers of graphene (i.e. few layers-graphene) with the problem being that most of the physical and chemical properties of the material ultimately produced vary with the number of layers. In sight of this issue it becomes crucial to develop easy, fast and reliable methods for assessing the ultimate thickness of the as produced materials.

There are numerous of methods for determining the thickness by transmission electron microscopy (TEM)[3-6]. The most common and fast way is to visually count the step-edges of the flakes. This method is approximate and leads to an underestimation of the number of layers. Electron diffraction can be used to determine single and multiple layers[7], leaving no means of counting the number of layers in few-layers Bernal-stacked nanosheets. Other methods require the identification of monolayers by aberration-corrected electron microscopy (both HRTEM and STEM). These methods are usually not always readily available in common laboratories and are rather time consuming due to slow data acquisition and post-processing.

In our work we discuss a combined approach where bright and dark field TEM, energy-filtered TEM (EFTEM) thickness map and an EFTEM Plasmon imaging are all used in a metrological correlative study. In figure 1 we show an example of a BF-TEM, a DF-STEM, an EFTEM thickness map and an EFTEM Plasmon image acquired on the same region of an as-exfoliated flake. Intensity measurements were performed on the two EFTEM techniques in order to find the number of layers–thickness dependence (figure 2). Hereby we demonstrate that such a correlative approach is fast and reliable and can be used to determine the number of layers in an accurate and readily available way.

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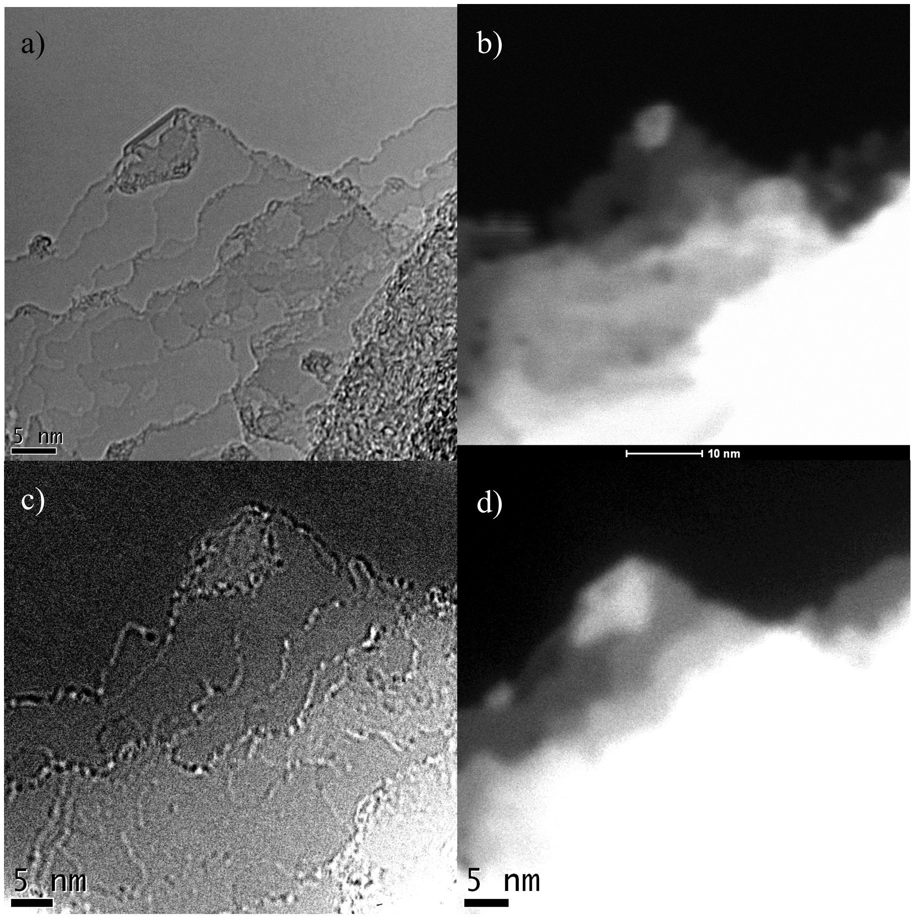

Figure 1. Transmission micrographs of the same region of a graphene sheet; a) BF-TEM b) DF-STEM c) EFTEM thickness map (t/λ) d) EFTEM image of the plasmon peak

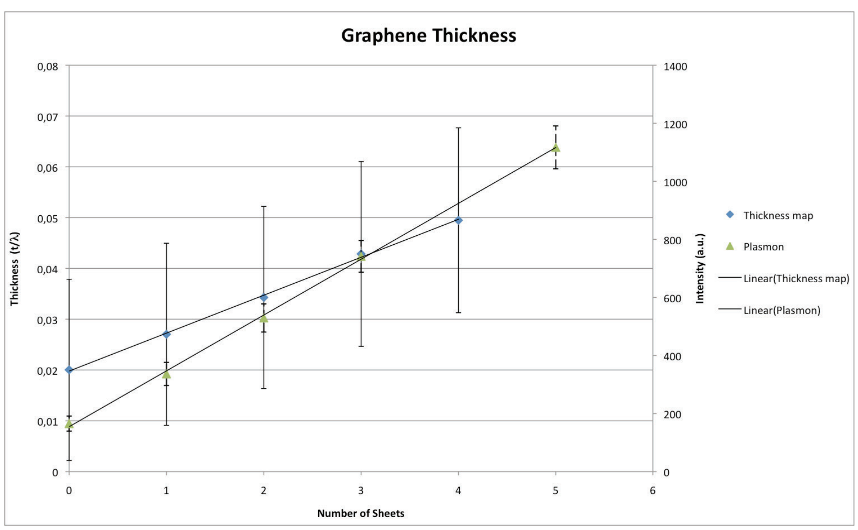

Figure 2. Thickness dependence for the EFTEM thickness map and EFTEM plasmon peak methods.

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