Water Affinity to Epitaxial Graphene: Impact of Layer Thickness

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One of the main concerns regarding graphene-based devices that are fabricated and operated in ambient is that their electronic properties are strongly influenced by the interaction with the ambient environment [1, 2, 3]. Since water is the most abundant dipolar adsorbate in ambient, many theoretical [4, 5] and experimental [6, 7] investigations highlighted the unpredictable influence of water on graphene devices and attempted to elucidate the water-graphene interaction from an electronic structure perspective. Nevertheless, there is currently a lack of studies concerned with quantitative aspects and consistent measures of changes in the electronic properties of graphene due to environmental humidity changes.

In the current work, we employ scanning Kelvin probe microscopy (SKPM) to investigate the effect of water on the electronic properties of epitaxial graphene. The information obtained by SKPM is directly correlated with local structural information and electrical transport measurements, in order to provide a systematic evaluation of the impact of ambient exposure on epitaxial graphene, in accordance with its domain thickness. We study the influence of relative humidity (RH=0-70%) changes on the surface potential of one-, two- and three-layer graphene (1LG, 2LG and 3LG, respectively) and also monitor the effect that the change in environment, from ambient to vacuum and to nitrogen, has on the electronic properties of epitaxial graphene. The water-graphene interaction is further examined by adhesion mapping with the sample immersed in de-ionised water, in order to correlate the surface potential data with the degree of wettability associated with 1LG and 2LG.

Our study unambiguously demonstrates that graphene domains of different thicknesses react differently to the change in environment and that the sensitivity to water increases with decreasing domain thickness, with 1LG being the most sensitive to water adsorption and change in environment. This is exemplified in Figure 1, which shows the variation in surface potential for 1, 2 and 3LG in ambient, vacuum and 70% RH environment. A more pronounced change in the work function and carrier (electron) density is observed for 1LG as compared to 2LG and 3LG on ambient-vacuum transition.

References

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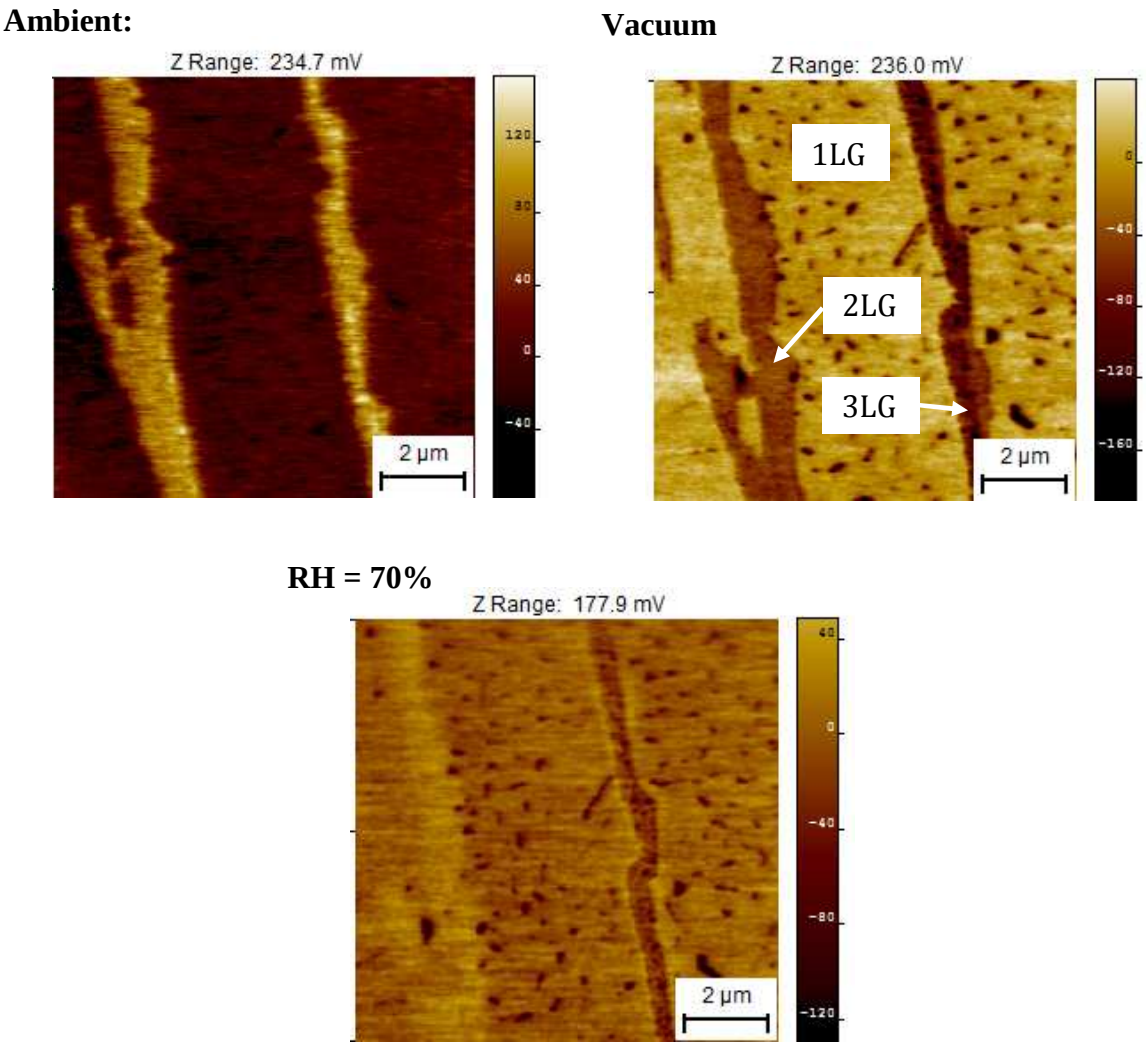

Figure 1: Representative surface potential images recorded by SKPM on the same region of the graphene sample in ambient, vacuum and 70% RH in nitrogen.

The results provide a quantitative evaluation of the effect of ambient humidity and change in environment on the electronic properties of graphene. Understanding the role of 1, 2 and 3LG and their response to various environments will aid the design and development of molecular sensors as no attention is currently paid to thickness-dependent effects of their sensitivity, selectivity or response time. Our results suggest that the sensor characteristics can be affected by graphene domain thickness and will help to correctly model the response of a realistic sensor, which could be extended to sensor designs that deliberately minimize the effects of the ambient.