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In-situ HRTEM Electrical Investigations on Graphene

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Approaches to study free-standing graphene and its adsorbates at high temperatures (300 K - 2000 K) could be already realized in a transmission electron microscope (TEM) with atomic resolution at low acceleration voltage (80 kV). We demonstrated the effect of in-situ Joule heating on graphene membranes during HRTEM studies at temperatures until 2000 K [1] observing the transformation of physisorbed hydrocarbon adsorbates via amorphous carbon monolayers (at 1000 K) into polycrystalline graphene (at 2000 K) [2]. However, the electronic properties could not be studied yet. Here we investigate the electronic properties of graphene by 4-terminal electrical measurements whereas 4 other contacts remain for heating and temperature sensing. The magnetic field of the microscope's objective lens was determined at 80 kV applying a custom-made Hall probe as TEM specimen. This one-time-only calibration procedure allows us to carry out Hall measurements at different temperatures. Characteristics of free-standing graphene membranes were measured in-situ during TEM observation at temperatures up to 500 K before and after in-situ Joule heating. The reliability of the obtained carrier concentration and mobility values could be assured by their temperature dependence. The dependence of the carrier mobility on the pre-annealing temperature will be discussed. These first measurements happened strictly without exposing the sample to the electron beam. Later, TEM images and electrical measurements have been recorded simultaneously in order to reveal the remaining amount of hydrocarbon residues and their influence on the mobility. We observed a continuous drop of the mobility during TEM imaging which might be a consequence of contaminants burnt into the surface by the electron beam. Our results demonstrate the importance of considering the effect of electron irradiation on adsorbates, especially when the task is a clean surface in order to obtain high mobilities.

References [1] B Westenfelder, J C Meyer, J Biskupek, G Algara-Siller, L G Lechner, J Kusterer, U Kaiser, C E Krill III, E Kohn and F Scholz, J Phys D: Appl. Phys. 44 (2011), 055502. [2] B Westenfelder, J C Meyer, J Biskupek, S Kurasch, F Scholz, C E Krill III and U Kaiser; Nano Lett. 11 (2011), p. 5123.