Opening nm-sized gaps in graphene: the feedback-controlled electroburning

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Graphene-based electrodes are expected to be very promising for application in molecular electronics and spintronics. In particular, single-molecule devices with graphene electrodes are expected to show many improvements with respect to the traditionally used gold junctions. It is therefore of extreme importance to control and optimize the realization of nano-scale gaps in graphene, suitable for contacting single molecules.

Here we report a systematic characterization of the feedback-controlled electroburning (EB) process, which we employed to open nanometer-spaced gaps in different types of graphene both under air and vacuum conditions [1]. The resulting gaps are analyzed by means of I-V measurements in the framework of the Simmons model to estimate the gap size. The EB exploits the chemical reaction of carbon atoms with oxygen at the high temperatures induced by Joule heating at large current densities and it is found to depend both on the type of graphene and on the working conditions. Indeed, for mechanically exfoliated graphene, performing EB in vacuum results in a higher yield of nanogap formation than working in air, while in the case of graphene epitaxially grown on the C-face of SiC the EB process is unsuccessful under vacuum conditions. The EB is also found to work successfully on single-layer CVD graphene transferred onto a SiO_2/Si substrate, both at room and low ($T = 20$ mK) temperature.

The presence of a fast feedback loop (checking the evolution of the junction's resistance during the EB process) is vital to avoid the abrupt breaking of graphene and allows for a more accurate control on the final structure of the nm-sized gap. With that, we were able to increase the yield of the process up to ~ 90 %. Moreover, we demonstrated the versatility of the feedback-controlled EB procedure through the opening of nanogaps in suspended graphene devices with yields comparable to those characterizing substrate-supported graphene [2].

These results show that the feedback-controlled EB is a reliable method to controllably form nanogaps in different types of graphene. This opens the way to the realization of robust graphene-based electrodes for applications in single-molecule (spin-)electronics.

[1] A. Candini et al. Beilstein J. Nanotechnol. 6 (2015) 711
[2] S. Lumetti et al. Semicond. Sci. Technol. (2016) submitted