Synthesis and structural characterization of monolayer and quasi-free standing bilayer graphene nanoribbons on SiC(0001)

L.A. Galves[1], J.M.J. Lopes[1] and H. Riechert[1]*

[1] Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany
[*] galves@pdi-berlin.de

Graphene nanoribbons (GNR) offer great potential for nanoelectronics, since they possess unique electronic properties which are dependent on their width, edge termination, as well as number of stacked graphene layers (1-2). Therefore, achieving the controlled and high-quality synthesis of GNRs is anticipated to be of great importance. One of the methods which show great potential is the growth of GNRs on surface facets of SiC(0001) by the surface graphitization method (3). Unlike other methods, it exploits the natural steps present on SiC surface, which allows for gaining more control over the final size of the GNRs. It also avoids the transfer to other substrates in the case of electronic applications.

In this contribution we report on the controlled growth and structural characterization of epitaxial mono- and bilayer GNRs on SiC(0001) surfaces. They were synthesized by utilizing the surface graphitization method at high temperatures and straightforward annealing in air (for the case of bilayer GNRs) (4).

An etching process removed scratches from the SiC(0001) surface as well as led to a step bunching process at the surface. For the growth of the GNRs, Si atoms sublimate from the SiC surface in an Ar atmosphere, leaving a C-rich surface behind. This will originate the growth of a buffer layer (BL), which is similar to a single graphene layer but with ~1/3 of its atoms covalently bound to the substrate. This process starts in the step edges and continues over the terraces. Once the SiC surface is covered by the BL, monolayer GNRs growth starts close to the step edge. By controlling the time and temperature in the furnace, it is possible to vary the width of the monolayer GNRs. Once this structure is formed, it is possible to obtain quasi-free-standing bilayer GNR by oxygen intercalation upon annealing the samples in air at 600 °C (4).

The synthesized nanostructures were analyzed by Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) height and phase contrast images, as well as Raman spectroscopy. This allowed us to determine the GNRs lateral width and surface step heights across the microscopy images, as can be seen in Figures 1 and 2. By analyzing the spectra obtained via Raman measurements, it was possible to verify the thickness of the GNR (either monolayer or bilayer graphene), as shown in Figure 3.

References
[1]   V. Barone et al., Nano Letters 6 (2006) 2748.
[2]   T.S. Li et al., Eur. Phys. J. B 64 (2008) 73.
[3]   M. Sprinkle et al., Nat. Nanotechnol. 5 (2010) 727.
[4]   M.H. Oliveira Jr. Et al., Carbon 52 (2013) 83.
[5]   L.A.G acknowledges CAPES-Brazil for a PhD fellowship (process number BEX 13461/13-3).
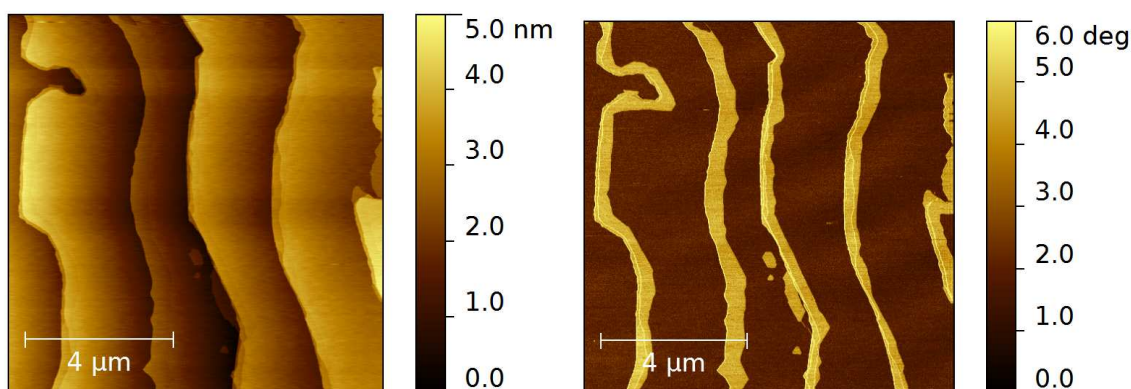
Figure 1: AFM height (left) and phase (right) contrast images where monolayer GNRs can be discerned in a sample grown at 1440 °C for 15 min.
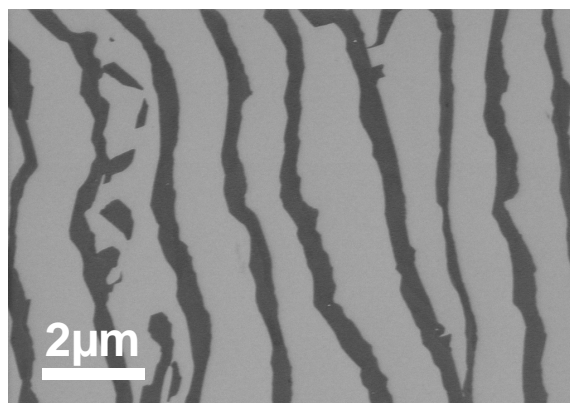

Figure 2: SEM secondary electron image of monolayer GNRs synthesized at 1440 °C for 15 min.
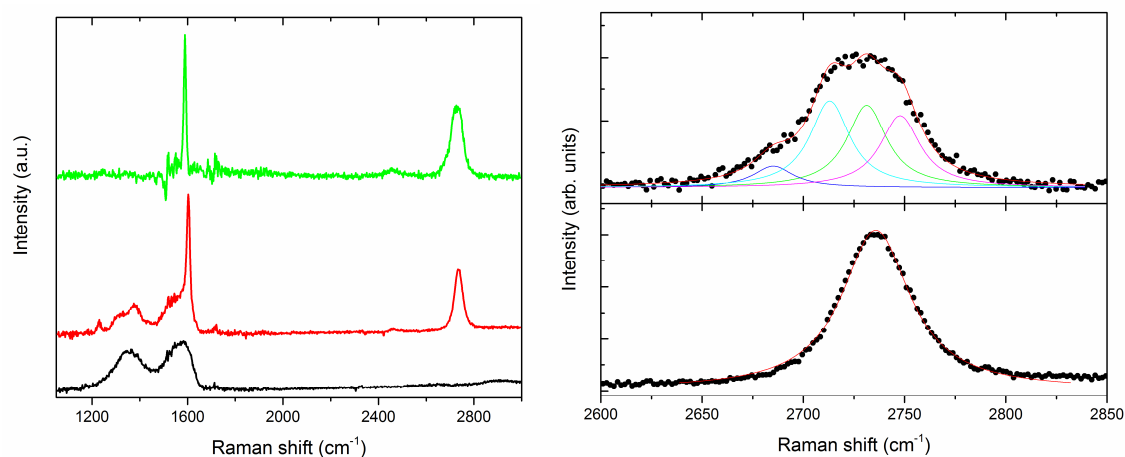

Figure 3: In the left plot, Raman spectra of BL (black), MLG (red) (on top of the BL), and BLG (green) grown on SiC(0001). In the right plot, the 2D peak was fitted by one Lorenzian for the monolayer graphene sample and by four Lorentzians for the bilayer graphene sample.