Very large monolayer graphene ribbons grown on SiC

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Graphene has emerged recently as a new material with outstanding electronic properties. This includes mass-less Dirac fermions, ballistic transport properties at room temperature and good compatibility with the silicon planar technology. Graphene-based devices are then promising candidates to complement silicon in the future generations of high frequency microelectronic devices. Different techniques have been developed over the past 4 years to fabricate mono or bi-layers of graphene. They range from exfoliated graphite, either mechanically,[1] or in a liquid-phase solution,[2] to chemical vapor deposition on a metal surface,[3,4] and more recently, to substrate-free synthesis when passing ethanol into an argon plasma.[5] The method investigated in this work consists in a controlled sublimation of few atomic layers of Si from a mono crystalline SiC substrate.[6] Such epitaxial growth (EG) of graphene seems to be the most suitable option for industrial applications,[7] but for easy control, it necessitates large and homogeneous sheets of monolayer or few layers of graphene (FLG) covering either a full-wafer surface or a specific area of an AlN pre-patterned SiC substrate.[8]

Unfortunately, whatever the SiC polytype under investigation (4H, 6H or, even, 3C), or the sublimation conditions pressure varying from UHV (Ultra-High Vacuum) below 10^{-9} Torr to more standard SV (Secondary Vacuum) conditions in the range 10^{-8} to 10^{-6} Torr, it is still challenging to grow FLG with homogeneous domain sizes larger than few hundred nanometers.[9,10,11] However, sublimation from the C-face leads to wider domains and higher mobility than the Si-face,[10] but still, it is very challenging to process any set of homogeneous devices on the same wafer. A noticeable exception is the recent result by Emtsev et al.[12] that showed that performing graphitization on a 6H-SiC substrate under Argon at 900 mbar could lead to large, regular, graphene monolayers and bilayers, but unfortunately on the Si-face where the grown FLG mobility is lower. The purpose of this work is to show that there is an alternative way in which very large monolayer graphene ribbons can be grown on the C-face of a graphite-capped SiC sample using only a commercial radio frequency (RF) heated furnace under SV conditions, as normally used for SiC post-implantation annealing.

In such a way, increasing the temperature up to 1700°C, we found out that the intrinsic spontaneous growth is blocked while the nucleation procedure that originates from isolated surface defects is still activated, since less demanding in energy.[13] The increase of the Si partial pressure near the surface forced the graphene growth to expand more in 2 dimensions. It starts from the defect point and follows the natural SiC step structures that are ordered in long terraces. This results in the long graphene islands shown by Optical Microscopy in dark field mode Figure 1. They have the shape of ribbons, about 30 to 300 µm long depending on the processing time, surrounded by the SiC surface not yet converted in graphene.

Raman spectroscopy method was used to control the homogeneity of the ribbon. The spectra were collected at room temperature, in the confocal configuration using the 514 nm line of an Ar^+-ion laser as excitation wavelength. We obtained homogeneous Raman spectrum with a typical signature after subtraction of the bare SiC signal shown on Figure 2. The observed Raman signature of the ribbon is very close to the ones found in the literature for graphene monolayer exfoliated on top of SiO_2/Si.[14,15,16,17,18,19,20]

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Figures:

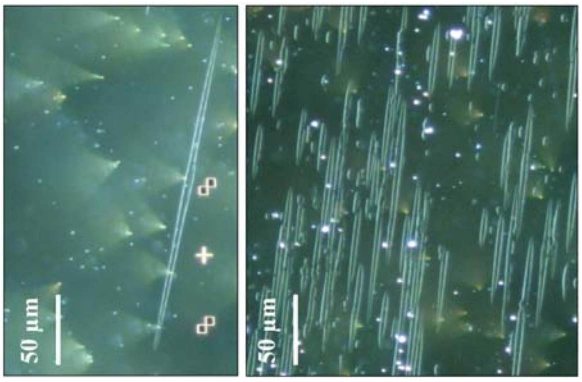

Figure 1. Wide range Optical Microscopy view of samples covered by very long graphene ribbons from 30 to 300 µm long and 5 µm large depending on the sublimation time. Higher density of ribbons is encountered where higher density of defects on the surface of the SiC substrate.

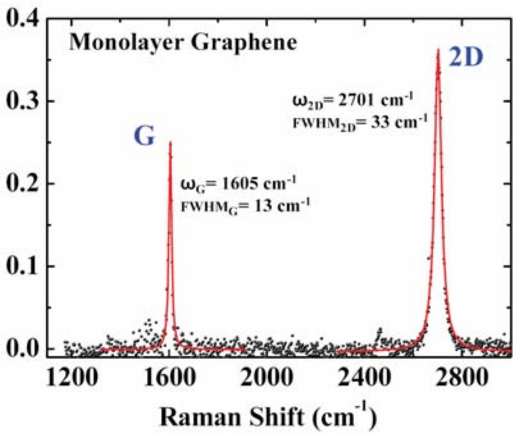

Figure 2. Typical Raman spectrum of a monolayer graphene ribbon.