Fabrication of Graphene Layers by Means of Chemical Vapor Deposition for Field Effect Device Fabrication

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Abstract - In this paper we report on the fabrication and characterization of graphene layers for graphene field effect devices, which is a modified and advanced approach already developed at ISTN for the in situ fabrication of single walled carbon nanotubes [1]. After the graphene layers are generated by means of chemical vapor deposition using a methane feedstock, the band gap is engineered constricting the lateral dimensions of graphene obtaining graphene nanoribbons. The graphene nanoribbons (GNRs) are contacted by selected metals to form field effect devices with various applications.

I. Fabrication

As substrate highly p-doped silicon wafers are used, which are oxidized in dry ambient at 1000°C to form an oxide of 60 nm. In the following the oxide is patterned by several lithography steps. Subsequently a structured photoresist remains on the wafer surface and a thin aluminum and nickel layer is evaporated on the whole wafer surface and structured via liftoff. After annealing at high temperature (900 °C) in hydrogen atmosphere the Al-Ni layer forms the catalyst. The so called sacrificial catalyst Al transforms itself into an insulator aluminum oxide which is covered with nickel nanoclusters [1]. By means of chemical vapor deposition (CVD) with a methane feedstock, a thin graphene layer grows near catalytic aluminum/nickel areas (see Fig 1).

II. Analysis

The first analysis of the graphene layer by atomic force microscopy AFM (see Fig. 2) shows a layer thickness of around 2.5 nm, which corresponds to five to seven stacked graphene sheets. The conductive AFM (C-AFM) measurement shows that the ultra-thin layer around Al/Ni regions is made of a conductive material (see Fig. 3), as expected for graphene. The scanning electron microscopy image of the probe at the catalyst graphene junction points at a higher resolution of the composition (see Fig. 4), some carbon nanotubes growing from the nickel cluster can be seen, as they are supposed to be [3],[4]. To proof whether the carbon has an amorphous or a lattice structure, the probe was mould in epoxy resin for the structural transmission electron microscopy examination (TEM). Figure 5 shows the TEM examination of a graphene layer on a silicon dioxide surface with fourier analysis. The interplanar spacing of 3.5Å is a strong evidence for the existence of graphene grown by means of CVD.

III. Conclusion and Outlook

The analysis of the produced layer yields several stacked graphene sheets. By constricting the lateral dimensions of graphene to obtain designable band gaps, graphene becomes a viable material for transistor applications, for example as GNR field effect devices. At ISTN, graphene layers produced by means of CVD will be patterned into GNRs using electron-beam lithography followed by reactive-ion etching allowing lateral downscaling in the sub-100 nm range, as already achieved for silicon nanowires [2]. The physical characterization of the GNRs will be prepared by means of AFM while the electrical characterization will be done by Keithley measuring station, already used for the characterization of carbon nanotube field effect devices (CNTFETs).

IV. Acknowledgement

This research is part of the ELOGRAPH project within the ESF EuroGRAPHENE EUROCORES programme.

V. References

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VI. Figures

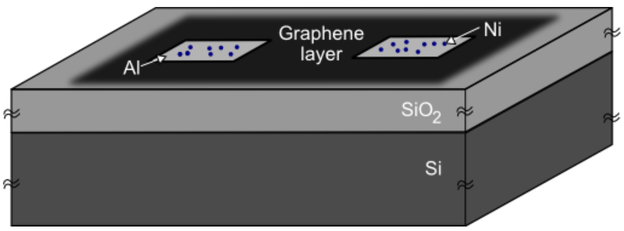

Figure 1. Schematic of silicon substrate covered by silicon dioxide. The graphene layer on top is grown by means of CVD with a methane feedstock near catalytic aluminum/nickel areas.

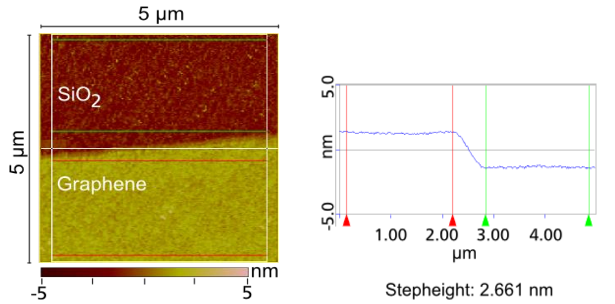

Figure 2. AFM Measurement (left) of the graphene layer on a silicon dioxide surface, (right) corresponding stepheight analysis by average heigth value calculated at the red and green lines.

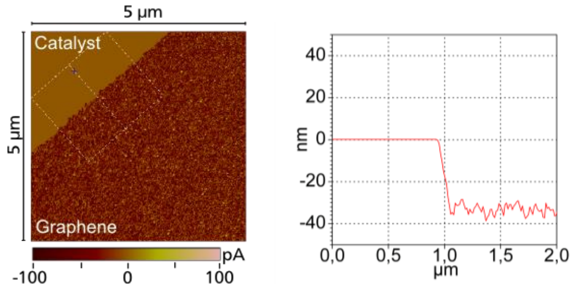

Figure 3. (left) AFM current scan of the graphene layer and the corresponding cross-section within the white square (right).

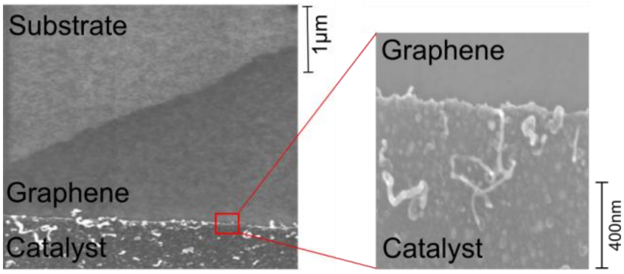

Figure 4. Scanning electron microscopy image of the probe at the catalyst graphene interface.

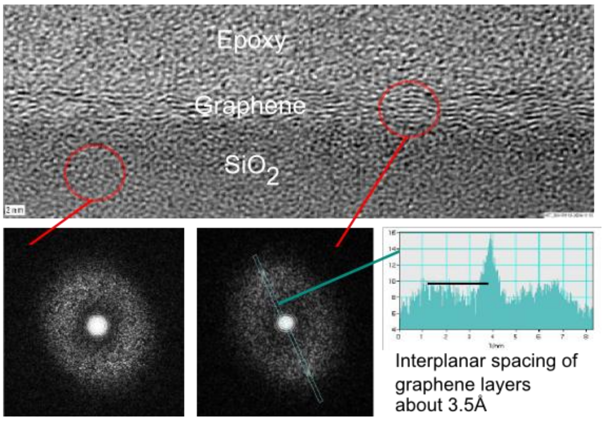

Figure 5. Structural transmission electron microscopy examination of a graphene layer on a silicon dioxide surface with fourier analysis.