Towards a scalable method for the controlled production of high quality 2D materials

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The most promising method for making high-quality sheets of 2D materials by the 'bottom-up approach' is Chemical Vapor Deposition (CVD). In this method, the material for the growth is supplied from the gas phase and a catalytically active substrate enables the separation of the atoms and their reassembly to form a 2D structure.

It is known that formation of defects is prevented by having good control over both the growth conditions and substrate quality [1]. For instance, high-quality graphene can be grown on copper substrates in the molten phase from methane at high temperatures. However, because of the very harsh conditions during synthesis of graphene on liquid copper, only ex situ studies have been reported until now, after the copper has been solidified, possibly affecting the graphene layer that is adhering to it [2, 3].

We have successfully developed a CVD furnace that allows in situ study of the quality, structure and size of graphene flakes during growth. The substrate heater allows for temperatures exceeding 1500 °C, which enables observations on the CVD growth of graphene on liquid copper. The reactor has a special design, preventing the deposition of copper vapor on the optical and X-ray windows as well as preventing overheating of the windows. The system allows for varying process conditions such as gas composition and substrate temperature while the effects of these variations on the growth of the 2D material are observed. Our live-observation tools include synchrotron X-ray techniques (such as diffraction, reflectometry) and optical techniques (such as microscopy, Raman spectroscopy and reflectometry).

This CVD furnace is a very effective tool to investigate the key parameters that affect the growth of 2D materials. We will present a selection of data that demonstrate that the furnace in particular is very suitable for the efficient development of optimal recipes to enhance the chemical and structural characteristics of graphene as grown on a liquid copper surface.

We show that with adjusting the growth conditions, we can produce single-crystalline graphene flakes of which the size is only limited by the dimensions of the sample holder. We will discuss the possibilities to develop the technology further for upscaled production of continuous single-layer sheets of graphene with extremely high crystalline quality.

References

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