Rapid CVD Synthesis of Highly Crystalline 2D Materials: from Large Grain Graphene on Cu, to Turbostratic Graphene on SiC and van der Waals Heterostructures

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During this talk recent achievements in the chemical vapor deposition (CVD) synthesis of high-quality large-area graphene on different substrates (from polycrystalline Cu foil to single crystal SiC) will be discussed. Also, tailored CVD approaches to synthetize van der Waals heterostacks such as graphene on h-BN and WS_2 on graphene will be presented.

Although obtained with a cost effective approach, CVD graphene on Cu was up to recently not preferred for electronic and photonic applications due to its polycrystalline nature and consequently impoverished electronic performances. In the last couple of years significant steps forwards have been made and a number of groups have reported on the synthesis of mm-sized single-crystal graphene on Cu [1,2]. However, long growth processes are typically needed for the synthesis of grains with lateral size of 1 mm [2]. Recently, we showed that single crystals of graphene with dimensions up to 3.5 mm can be obtained in just 3 hours using a commercially available cold-wall CVD reactor [3]. The key-steps of the process are: i) using (ex-situ) passivated Cu foils, ii) pre-annealing in an inert argon atmosphere, and iii) enclosing the sample during growth to reduce the impingement flux. For these crystals, we have measured room-temperature mobilities better than 5000 cm^2/Vs and sheet resistance of about 200 Ω/sq. The development of a process for the quick production of large grain graphene in a commonly used commercial reactor is a significant step towards the wider use of CVD graphene for electronic and photonic applications. The process is also appealing with respect to safety: high crystal growth rates can be achieved without hydrogen and with low methane concentrations. This is key for potential industrial implementation. Also, by using a CVD approach, rather than the classical thermal decomposition of the substrate, it is possible to synthetize turbostratic graphene on the carbon face of SiC (from few layer to about 90 layers) with a low defect density. This material holds potential for optoelectronic applications [4].

CVD can be also successfully used as a scalable technique to synthetize highly-crystalline van der Waals heterostructures. Concerning CVD graphene on h-BN, it has been recently shown that high growth rates (i.e., > 100 nm/min) require complex steps, such as the introduction of gaseous catalysts (e.g., germane and silane) during growth [5]. In contrast, we show that graphene growth rates higher than 100 nm/min

can be achieved on well-prepared bare h-BN substrates [6], thus greatly simplifying the process. Also, by using a cost-effective vapor-phase reaction from solid powders, micron-sized grains of the optoelectronically appealing WS_2 can be flexibly grown on different substrates (from classical 3D dielectrics to novel 2D materials).

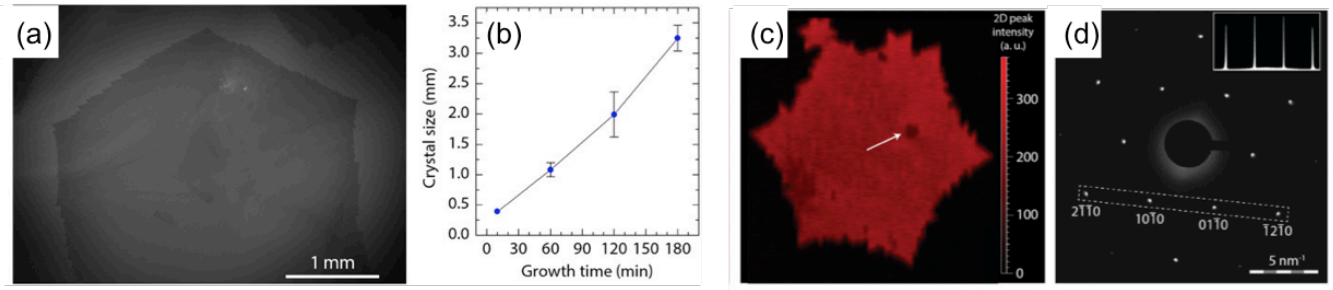

Figure 1: (a) SEM image of a single graphene grain with lateral size of over 3 mm. (b) The size of grains as a function of growth time. (c) Intensity map of Raman 2D peak of a large single grain transferred to Si/SiO_2. (d) Typical SAED pattern of large grain graphene. In the inset the intensity plot of the SAED spots in the dashed rectangle is shown.

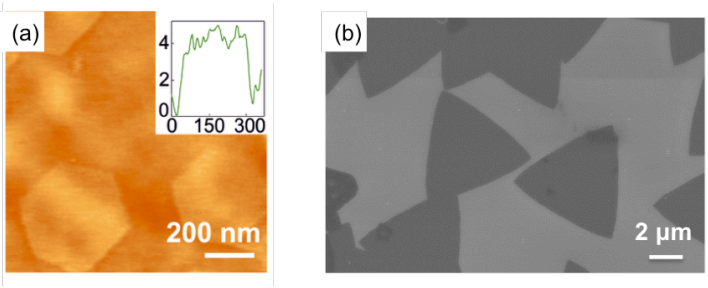

Figure 2: (a) AFM micrograph and line profile of hexagonal graphene pads grown on exfoliated h-BN flakes. (b) SEM image of WS_2 triangular grains obtained on a SiO_2 substrate.

References

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