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Mass production of CVD graphene, reliable transfer, and co-integration with TMDs

Although graphene has been maturing in university laboratories for over 15 years, further research effort is still required to implement graphene in real-world applications. Besides the great progress made so far, there remains grand challenges on the way to the industrial manufacturing of 2D materials-based electronic and optoelectronic devices. These challenges include (i) the large-scale cost-effective production of ‘’electronic grade’’ graphene, (ii) the development of a non-destructive, clean, reliable and scalable transfer method, and (iii) the co-integration of graphene with other 2D materials. This talk presents the latest developments in our laboratory to facilitate the transition of graphene from academia to functional technologies.

First, we show how the chemical vapor deposition (CVD) method can offer flat, highly crystalline, single-layer graphene with a high throughput. The mass production is achieved by using a series of closely-packed vertically-standing 3-inch wafers coated with a thin Cu film [1]. Thin Cu films evaporated on C-plane sapphire substrates provide a flat and smooth template for the synthesis of graphene and mitigate the formation of wrinkles and cracks [2].

Then, we present how the catalytic substrate surface morphology influences the reliability of the transfer process and graphene physical properties once transferred on a device compatible substrate. We demonstrate that regardless of the selected transfer approach, the Cu template morphology is one of the major sources for the formation of tears and wrinkles as well as non-uniform electrostatic doping and mechanical strain in the transferred graphene sheet [3].

Finally, we present experimental data regarding the formation of 2D heterostructures by direct MOCVD growth of WSe_2 on graphene [4]. Our results reveal that triangular WSe_2 crystals (with a lateral size exceeding 1 micrometer) exhibit an in-plane orientation matching with the underlying graphene. The WSe_2 seeding density is also found to depend on the number and the stacking order of the underlying graphene layers.

[1] *B. Huet, X. Zhang, J. M. Redwing, D. W. Snyder, J.-P. Raskin,* 2D materials, 6(4):045032, (2019).
[2] B. Huet and J.-P. Raskin. Nanoscale, 10 (2018) 21898-21909.

[3] Fundamental limitations for the transfer of graphene grown on Cu substrates. *B. Huet, J.-P. Raskin, J. M. Redwing, D. W. Snyder (to be submitted)*

[4] MOCVD of WSe2 crystals on highly crystalline single- and multi-layer CVD graphene. *B. Huet, T. H. Choudhury, M. Chubarov, X. Zhang, D. W. Snyder, J. M. Redwing. (to be submitted)*