Graphene growth by one-dimensional nucleation mechanism

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Even though chemical vapour deposition (CVD) has become a popular method to grow large areas of two-dimensional (2-D) materials, the underlying lateral growth mechanism of individual 2-D crystals is still a puzzle. The Burton-Cabrera-Frank (B.C.F.) theory [1] assumes that crystals grow by adatom attachment to thermodynamically rough edges. However, there is also the theory of motion of atomically smooth edges by the one-dimensional (1-D) nucleation mechanism [2], which has been experimentally observed in only peptide growth until now [3]. This work presents the first experimental evidence of graphene growth by the 1-D nucleation mechanism. Our analytical model predicts that graphene crystals grow by the 1-D nucleation mechanism at typical CVD growth conditions. We validate this model by performing growth experiments in our CVD reactor. We found that hexagonal graphene crystals grow exponentially with time, corresponding to the mono-nuclear (1-D nucleation limited) growth regime. This model can be used to predict the lateral growth velocities of all 2-D materials at any CVD growth condition, thus enabling us to control their final grain sizes.

References

[1] W.K. Burton, N. Cabrera and F. C. Frank, Philosophical transactions of the royal society A, 866 (1951) 299-358
[2] V.V. Voronkov, Soviet Physics Crystallography, USSR, 1 (1970) 8
[3] Chen, Jiajun, et al., Science, 6419 (2018) 1135-1139

Figures

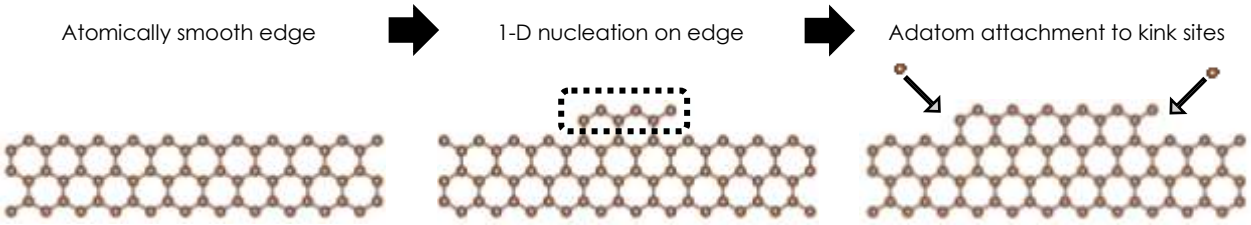

Figure 1: A Graphene crystal grows due to two simultaneous mechanisms: (a) formation of 1-D nuclei on edges and (b) attachment of carbon adatoms to kinks on ends of each 1-D nucleus.

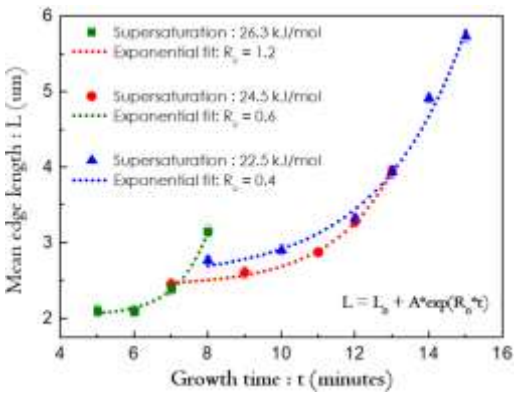

Figure 2: Graphene crystals grow exponentially with time at typical CVD growth conditions. The value of the exponent (R_O) increases with an increase in supersaturation.