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Ultrafast synthesis of high quality graphene by slow gas flow

Abstract
Graphene is a well-known 2D material that consists of a single atomic layer of carbon atoms with many potential applications ranging from electronic devices to corrosion protection.[1] One central challenge in graphene research is the production of high quality material at large scale. While chemical vapor deposition (CVD) has shown the ability to form uniform and continuous graphene [2, 3] it requires long process durations which affects its scalability and commercial appeal. The question arises if long growth times are a fundamental limitation of the CVD process or if there are routes to produce graphene in short times without sacrificing the quality of such material.
We here present a detailed study of the gas transport during CVD growth. By employing spatially and time-resolved characterization methods, we find that the growth rate of graphene under normal conditions depends on the concentration of gaseous carbon precursor in agreement with the transport-limited reaction model. Surprisingly, however, we observe that a decrease in precursor flow rate by two orders of magnitude leads to a 1000fold increased growth rate (Figure 1(a)) which contradicts the transport-limited growth situation. Moreover, the diffusion coefficient of the precursor was found to be increased under this condition which results in a uniform distribution of graphene within large catalyst stacks (Figure 1(b)).These counterintuitive changes were explained by an increasing residence time of the carbon precursor which results in a changed growth kinetics and a higher growth efficiency. [4, 5]
We demonstrate that slow flow CVD growth produces high quality and continuous graphene films within 3 minutes instead of 6 hours for traditional growth methods. This result improves the scalability of graphene synthesis and its commercial attractiveness for future industrial applications.

References

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Figures

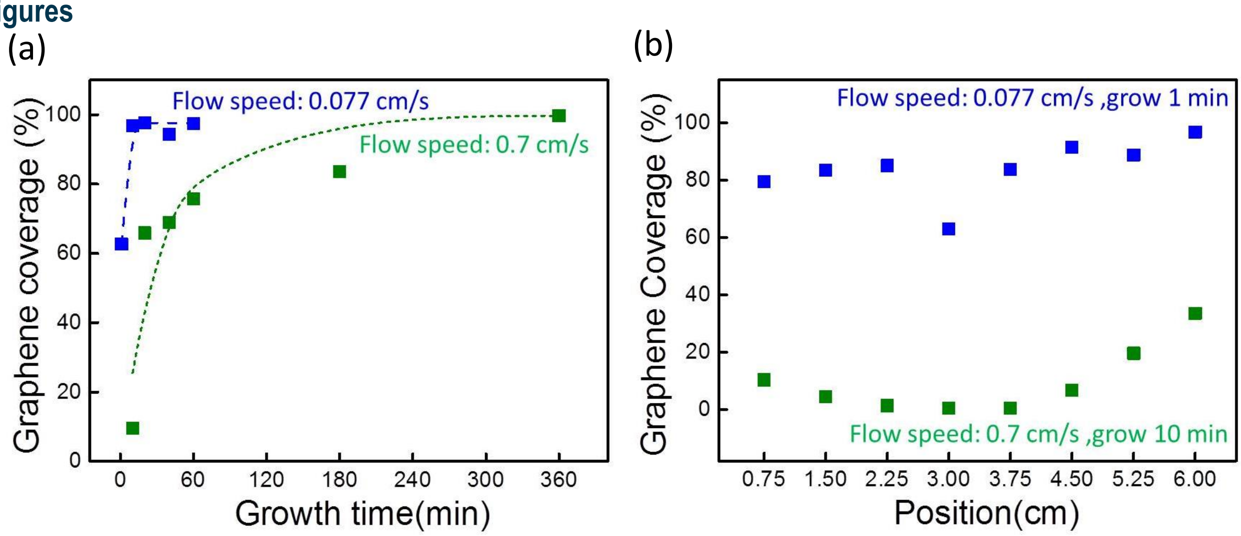

Figure 1: (a) Graphene coverage vs. growth time showing effect of different gas speed on growth rate. **(b)** spatial variation of graphene coverage within confinement showing that low gas flow produces more uniform graphene.