

CVD Growth and Applications of Graphene with Millimetre-Size Single-Crystal Grains and Three-Dimensional Interconnected Graphene Networks

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Graphene has attracted increasing interests because of its unique two-dimensional structure, many fascinating properties such as giant electron mobility, extremely high thermal conductivity, and extraordinary elasticity and stiffness, as well as a wide range of technological applications [1,2]. Large single-crystal graphene is highly desired and essentially important for the applications of graphene in electronics since grain boundaries between graphene grains markedly degrade its quality and property. However, graphene prepared so far is usually stitched together from nanometer to micrometer grains. In addition, integration of individual two-dimensional graphene into macroscopic structures is also very important for the application of graphene. A series of graphene-based composites and macroscopic structures have been recently fabricated using chemically-derived graphene sheets. However, these composites and structures suffer from poor electrical conductivity because of the low quality and/or high inter-sheet junction contact resistance of the chemically-derived graphene sheets.

Here, we show the growth of millimeter-size hexagonal single-crystal graphene grains and graphene films joint from such grains on Pt substrates by ambient-pressure chemical vapour deposition (CVD) [3], which are more than 50 times larger than the biggest hexagonal single-crystal grains reported until now. Moreover, we proposed a bubbling method to transfer these single graphene grains and graphene films to arbitrary substrate, which is nondestructive not only to the graphene but also to the Pt substrates [3]. The Pt substrates can be repeatedly used for graphene growth with almost no limit, and the graphene obtained on a repeatedly-used Pt substrate has almost the same quality as that obtained originally. In contrast, the commonly-used transfer process is mainly based on substrate etching, which not only leads to inevitable damage to graphene, metal residues on graphene, and serious environmental pollution but also greatly increases the production cost. In addition, such etching methods are not suitable for the transfer of graphene from chemically inert substrates. These single-crystal graphene obtained shows high crystal quality with the reported lowest wrinkle height of 0.8 nm and a carrier mobility greater than $7,000 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$ under ambient conditions. The repeatable growth of graphene with large single-crystal grains on Pt and its non-destructive transfer will enable various applications.

Besides two-dimensional growth of graphene, we have also realized the direct synthesis of a three-dimensional (3D) porous graphene macrostructure by template-directed CVD, which we call graphene foam (GF) [4]. This porous graphene bulk material consists of an interconnected network of graphene, which is flexible and has fast transport channel of charge carriers for high electrical conductivity. Even with a GF loading as low as 0.5 weight percent, GF/poly (dimethyl siloxane) (PDMS) composites show a very high electrical conductivity of 10 S/cm, 6 orders of magnitude higher than chemically-derived graphene-based composites. Using this unique network structure and the outstanding electrical and mechanical properties of GFs, as an example, we demonstrate the possibility of GF/PDMS composites for flexible, foldable and stretchable conductors [4]. Recently, we found that this unique 3D macrostructure also show a great potential for high-sensitivity gas detection [5].

References

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