

## **An Overview on Single-Layer Graphene Production methods with high quality for large-scale applications**

### **Abstract**

Graphene is a single- or few-layered material derived from graphite, consisting of many stacked layers of sp<sup>2</sup>-hybridized carbon atoms in a honeycomb structure. It is a two-dimensional material with remarkable properties such as high electrical conductivity, high thermal conductivity, high strength, lightweight, high sensitivity, and high resistance to corrosion. However, the synthesis procedures for this remarkable material remain challenging, unreliable, expensive, and in the early stages of development, which hinders its large-scale production and industrial applications. Graphene products often suffer from impurities, non-uniform thickness, and defects in their structure. The properties of graphene are greatly enhanced as it becomes single-layered. The single-layer graphene is highly dispersible in many of the solvents and is the most wanted material in most of the industries. So, the production of single-layer graphene in large scale and at low-cost is a thrust area of research. A high quality of graphene is mostly preferred in making composite materials and its loading is very less based on its quality as single-layer/high-quality graphene possesses remarkable properties. Current methods for producing high-quality graphene, such as Hummer's method, chemical vapor deposition, and epitaxial growth, require sophisticated equipment, involve the use of harmful chemicals, and result in low yields. It is crucial to identify simpler methods that maintain the material's quality to facilitate exploration of its applications on a pilot scale. Various strategies, including shear forces, intercalation, microwave irradiation, and electrical energy supply, have been employed to effectively exfoliate graphene sheets from graphite. Various characterization techniques, such as X-ray diffraction analysis, Raman spectroscopy, and scanning electron microscopy, can be utilized to assess the quality of graphene obtained through these methods. The quality of graphene significantly influences its suitability for specific applications. The applications of graphene have expanded to various fields, including electronic devices, coatings, composites, sensors, and energy storage devices, owing to its exceptional properties and potential for innovation. Simple methods such as mechanochemical, electrochemical, liquid phase exfoliation, hydrothermal and microwave irradiation method are reviewed in this article and compared with the conventional method for their efficiency, cost, and scalability. It is identified that these methods are more promising for producing high-quality graphene that matches industrial level standards.

**Keywords**

Carbon material; Exfoliation; Graphene synthesis; Hummer's method; Liquid phase exfoliation