# Chemical and electrochemical exfoliation of graphite in a large scale

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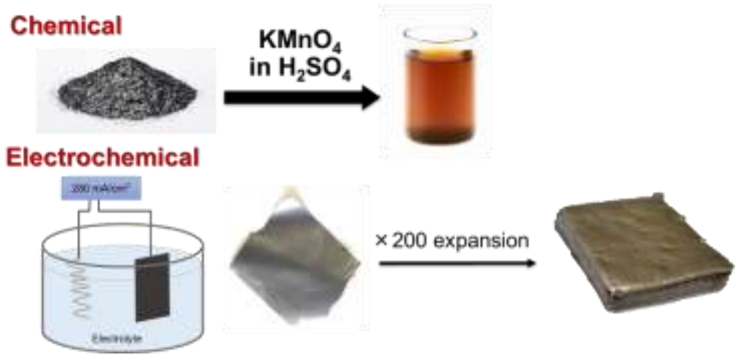
Graphene is the ultimate two-dimensional material with the thickness of a single carbon atom and is expected to be a next-generation material because it has excellent various physical properties required for functional materials such as electrical conductivity, specific surface area, and strength. However, many obstacles must be overcome for practical use. The biggest challenge is to establish a method for producing high-quality graphene on a large scale and with good reproducibility at a low cost. The production methods of graphene include a bottom-up method (chemical vapor deposition method, arc discharge, organic synthesis, etc.) and a top-down method (graphite exfoliation method). Currently, there is a trade-off between cost and physical properties, thus we are required to select an optimum preparation method of graphene depending on the application. For polymer composite materials, lubricating additives, conductive coatings, inks, catalysts, and supercapacitors, ultra-high purity graphene is not necessary. These applications require large amounts of graphene at a reasonable cost. For this reason, two-dimensional nanocarbons similar to graphene have been attracting attention by a top-down method capable of large-scale production using low-cost and easily available graphite as a raw material.

Graphene oxide (GO) obtained by oxidizing and exfoliating graphite will be introduced as an example. We have achieved a 500 g scale production of GO in the laboratory, and 10 kg production in a prototype plant by optimized oxidation method using $KMnO_4$ in $H_2SO_4$. These large-scale productions were achieved by the mechanistic study of the oxidation process using in situ analyses, such as XRD and XANES [1]. Our optimized GO production processes enabled the control of the size, oxidation degree, and functional group distribution on GO [2]. The conventional oxidation of graphite uses a strong oxidant in concentrated sulfuric acid; thus, there are environmental and safety issues. In contrast, the electrochemical oxidation of a graphite electrode has recently attracted considerable attention because it does not require any oxidant or concentrated sulfuric acid [3]. GO produced through the existing electrochemical method is generally lacking in quality, due to the non-uniform destruction of the intermediately oxidized graphite. We developed a method for the non-destructive oxidation of graphite using a specially designed electrolyte [4]. Compared to chemically generated GO, the electrochemically generated GO exhibits similar or better physical and chemical properties toward lithium-ion battery electrodes and water purification membranes. This electrochemical method is also applicable to a continuous flow system, thus promising the mass production of GO for future industrialization [5].




## References

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