# The Effect of Graphene Oxides Sheets on the Mechanical Properties of Graphene Fibres [⋆]

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**Abstract**

Graphene Oxides (GOs) of different sheet size were prepared by a novel modified Hummers' method. The heating time of expandable graphite, and oxidizing time of expanded graphite are demonstrated in order to have an influence on GO sheet size. Over-heated graphite in the microwave causes the decrease of GO sheet size, leading to a reduction in the performance of graphene fibres' mechanical properties. The oxidation mechanism was proposed by analyzing the chemical structure model of GO and evaluating its functional groups. Aggregation of GO sheets leads to the increase of internal shear stress, thus changing the viscosity of GO dispersion. Viscosity is another characteristic relating to the forming of graphene oxide liquid crystals (GO LC) and its phase transformation, which affects the mechanical properties of graphene fibres in the process of wet-spinning.

*Keywords*: GO dispersion; GO size; heating time; oxidation time; GO LC; viscosity; mechanical properties

# 1   Introduction

Graphene, as the elementary component part of all the graphene-based materials, is a flat two-dimensional (2D) monolayer of sp$^2$-hybridized carbon atoms tightly piled into a honeycomb lattice [1]. It is a rapidly rising star in the field of material science and condensed-matter physics [2]. Due to its extraordinary electronic, mechanical and thermal properties it has attracted continuous attention, which mainly arises from its unique atomic thickness and 2D structure [3]. Nevertheless, studies of graphite tend to utilise increasingly fewer layers for some time. Indeed, it was Geim and his co-workers at the University of Manchester who first isolated single layer samples from graphite in 2004 and discovered a new page for the development of graphene [4]. From then on, promising applications for graphene in electronic devices, sensors and composites have led to an explosion in interest. Among all the applications, the outstanding properties of graphene fibres are optimized in macroscopic aspects by one-dimensional graphene (1D) fibres.

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However, graphene cannot be used to fabricate graphene fibres directly due to inherent deficiencies, such as limited dispersibility in common solvents, which hinders development of the direct scalable assembly of graphene. Whereas, the most accessible precursor of graphene, which is named as chemically oxidized graphene or graphene oxide (GO), with abundant oxygen functional groups on its basal planes and edges, is able to be completely exfoliated. Afterwards, colloidal dispersions of a single sheet are formed in water or other polar organic solvent [5]. The superiority of GO, such as long-term solubility, easiness to handle, and scalable production with low cost makes it reliable in assembling 2D sheets into macroscopic graphene-based architectures [1]. Wet-spinning seems to be the most effective, easy-handle and fastest method to produce large-scale graphene fibres without by-products. The continuous process of fabrication from graphene and graphene oxide to graphene fibres via wet-spinning ensures that high-performance graphene fibres have become widely applied in various domains.

Until now, research efforts have been driven by the application of high-performance 2D films, paper, and membranes in electric double-layer capacitors and pseudocapacitor stretchable electrodes, biosensors, and biomedical applications due to their respectible mechanical strength, electrical conductivity, signal-to-noise ratio and potential biocompatibility [6]. Regarding to three-dimensional (3D) graphene structures, it is evident that achievements in 3D graphene have been made in electrodes of supercapacitors, supercapacitors, conductors with flexibility, and biosensors [7]. Compared with 2D and 3D graphene materials, a one-dimensional (1D) graphene fibre was believed to show high electrical conduction, ultrahigh mechanical strength after stretching, functional possibility, unique flexibility and weavability [8]. Nowadays, 1D graphene fibres have already been prepared and confirmed for possessing multiple superior properties in comparison to conventional large-scale materials.

Here, we report a way of fabricating graphene fibres through wet spinning. By altering the duration of heating process of expandable graphite and oxidizing process of expanded graphite, different mechanical properties of graphene fibres could be achieved. Among them, graphene oxide dispersion synthesized by 30 seconds' heating in microwave and 24 hours' oxidation process could be used to spin the most robust graphene fibres, thereby is endowed with tensile strength as 24.16 MPa and Young's modulus as 4.49 GPa. Besides, the particle size and viscosity of graphene oxide dispersion are also tested to explain the effect to mechanical properties of graphene fibres.

## 2  Experiment

### 2.1  Synthesis of GO

As an important intermediate to fabricate graphene fibres, GO has a crucial role in the overall properties of graphene fibres. The synthesis of GO is based on the modified Hummers' method [9]. Expandable graphite is severed as the raw material.

0.5 g expandable graphite was heated at 750 W in the microwave oven for 20, 30 and 40 seconds respectively. Then, 100 ml of 98% concentrated sulfuric acid and 5 g of potassium permanganate were added to the expanded graphite. The oxidation time of expanded graphite is 24 or 48 hours. The following steps were observed by the Hummers' method. Finally, six groups of GO dispersions were obtained: