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A Critical Review: Spinning Methodologies, Properties and Applications of Graphene Fibre ⋆

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Abstract

Inspired by macroscopic high dimensional graphene materials, graphene fibres now have been fabricated in a range of methods, including drawing, solution spinning, thermal process, electrospinning, etc. Among them, most attractive, large-scale and widely used methodology is solution spinning liquid crystal graphene oxide, including wet spinning and dry-jet wet spinning. Properties of different kinds of graphene fibres were discussed in this review. Both neat graphene fibres and hybrid graphene fibres show remarkable mechanical and electrical properties, actuating properties and flexibility. Multifunctional properties provide graphene fibres potential in functional textiles, flexible and wearable sensors, supercapacitors, electrodes of supercapacitors, energy devices, and actuators etc. It is prospected that properties of graphene fibres will be further optimized, and their application will be more realistic and well developed.

Keywords: Graphene Fibres; Spinning; Mechanical Properties; Electrical Properties; Application

1 Introduction

1.1 Introduction to Graphene

Graphene firstly found in 2014, by A.K. Geim and K.S. Novoselov [1], has been widely seen as a honeycomb structure of two-dimensional (2D) atomic crystals with high crystal quality and macroscopic continuity. Graphene can be seen as a single layer exfoliated from multiple layer graphite, a plat structure rolled out from single-wall carbon nanotubes or fullerene molecule [2, 3]. The most attractive factor of graphene is its extraordinary properties, with an ideal tensile strength of 130 GPa, elastic modulus of 1.0 TPa, remarkable flexibility, electrical conductivity of 10^8 S/m, thermal conductivity of 5000 $Wm^{-1}K^{-1}$, transmittance of almost 97% and high temperature, chemical resistance [4]. Owing to these desirable properties, graphene was not only not only made into a neat structure, but also hybrid with other material.

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1.2 Graphene Based Materials

1.2.1 Two-Dimensional (2D) and Three-dimensional (3D) Graphene Materials

First graphene films were prepared by continuous mechanical exfoliation of small mesas of highly oriented pyrolytic graphite. After this simple but reliable method, FLG films were found up to 10 μm in size. However, clearly, unrealistic and unfeasible problem, approach of making single layer graphene should be optimized or substituted. After micromechanical cleavage, several methods were developed and have been widely applied in making experimental graphene, e.g. acid oxidation, chemical vapor deposition etc [5, 6]. Graphene oxide formed in some cases will then be reduced using thermal or chemical methods [7, 8].

Graphene has demonstrated excellent mechanical, electrical, thermal, and optical properties [4, 6-11]. It is assumed that this will bring graphene great potential in many high technical fields both experimental and practical because assembling 2D graphene nanosheets into 3D graphene structure is the most realistic and efficient approach to utilise its extraordinary properties [9]. Therefore, the most important issue of graphene is to transform and fabricate micro scale graphene into macroscopic structures and to make it functional for practical applications.

The assembly of graphene into macroscopic three-dimensional (3D) structures has been attracting intensive interest [10-12]. Till now, three-dimensional graphene aerogel, hydrogel, foams, sponges [9, 13-17] and two-dimensional graphene film/member/paper/nanosheets [5, 18, 19].

For 3D graphene structure, it is illustrated that 3D graphene achievements have been made in graphene 3D structure on their use in electrode of supercapacitor, supercapacitors, conductors with flexibility and biosensors etc [13, 20].

Other improvements in high-performance 2D films, paper, membrane etc. have spurred research efforts on their application in electric double-layer capacitors and pseudo-capacitors stretchable electrodes, biosensor, biomedical applications due to their acceptable mechanical strength, electrical conductivity, signal-to-noise ratio and potentially biocompatible [5, 9, 18, 19].

1.2.2 One Dimensional (1D) Graphene Fibres

In contrast, among macro scale graphene material, 1D graphene fibre was believed to emerge high electrical conduction, ultrahigh mechanical strength after stretching, functional possibility, unique flexibility and weavability compared with the other two kinds of graphene macroscopic materials. Hence, graphene fibre has outstanding potential in wearable smart textile, biosensor etc. Provided that structure of graphene fibre is continuous with 2D carbon monocrystals stacked together along fibre axial direction, graphene fibre is also designed with a purpose of overcoming the shortages of conventional carbon fibre PAN, e.g. vast grain boundaries and polycrystalline nature [21].

Nowadays, one-dimensional graphene fibres have already been prepared and confirmed with multiple superior properties compared with conventional large scale material. As a novel material, graphene fibre is fabricated to fill in gaps of one-dimensional graphene material, and to prepare multifunctional fibres with proper qualities in some specific areas.

In this review, we concluded current methodology with principle of fabricating macroscopic multifunctional graphene fibres. Thermal, electrical, mechanical properties of neat graphene fibres from different methodology were compared and discussed. Strategies of doped graphene