Received: 22 July 2020 Revised: 14 September 2020 Accepted article published: 10 October 2020 Published online in Wiley Online Library:

(wileyonlinelibrary.com) DOI 10.1002/pi.6140

Preparation and characterisation of poly(ethylene glycol)-adsorbed graphene oxide nanosheets

Ehssan Al-Bermany[a,b] and Biqiong Chen[c*]

Abstract

Polymer–graphene nanocomposites are attracting growing attention of scientists and engineers as graphene-based nanofillers may enhance the properties of polymers significantly. This study aims to understand the adsorption behaviour of polymers on graphene oxide (GO) nanosheets. GO is synthesised using Hummer's method by oxidising graphite. Poly(ethylene glycol)s (PEGs) with different molecular weights are used as polymer models. A series of PEG/GO nanohybrids is prepared by applying different parameters in the solution processing method. Fourier transform infrared spectroscopy, X-ray diffraction, differential scanning calorimetry, thermogravimetric analysis, polarised optical microscopy, scanning electron microscopy and atomic force microscopy are used for characterising the hybrid nanomaterials. The characterisation results confirm the successful preparation of GO and the adsorption of the PEGs onto GO. The maximum amount of adsorbed PEG was 38 wt%. The adsorption amount of PEG increases by 46% after reducing the mixing time from 192 h to 72 h, 1700% due to an increase in the molecular weight from 1k to 100k, 13% for doubling the mixing ratio of PEG:GO from 1.5:1 to 3:1, 44% for applying no further washing procedure and 73% for applying all these parameters concurrently. The adsorption onto GO reduces the crystallinity of PEGs due to chain confinement. Different surface morphologies are observed in the hybrid nanomaterials showing various thicknesses of the PEG layer adsorbed on the GO nanosheets. This study may offer new insights into the manipulation of the interface in polymer–GO nanocomposites.

Supporting information may be found in the online version of this article.

Keywords: graphene; poly(ethylene glycol); nanocomposite; surface adsorption; interface

INTRODUCTION

Polymer nanocomposites have triggered an increasing interest among scientists and engineers over the last two decades.[1,2] They contain a filler of nanometre size which exhibits unique advantages with regard to the enhancements of the polymer properties, such as mechanical,[3] thermal, electrical and/or magnetic properties, without losing optical transparency,[4] compared to their polymer counterparts.[2,5] The properties of a polymer nanocomposite depend not only on the structure and properties of its constituents but also on their interfacial characteristics.[6]

Recently, significant attention has been given to carbon-based nanomaterials, in particular carbon nanotubes[7] and graphene nanosheets, as reinforcing fillers for polymers.[1] Graphene single nanosheet consists of honeycomb lattices with an elastic modulus of 1 TPa, a fracture strength of about 130 GPa and thermal conductivity up to *ca* 5000 W mK^{-1}.[8] Graphene oxide (GO) has oxygenated functional groups such as epoxy and hydroxyl groups on the basal plane and carboxylic acid groups along sheet edges.[9] These functional groups, together with the large surface area to volume ratio[10] and other excellent physical properties,[11] render GO nanosheets attractive fillers.[12]

The polymer at the interface constitutes a significant volume fraction of the nanocomposites.[4] Therefore, understanding the interface and the polymer near the interface is considered of paramount importance.[11] The degree of nanofiller dispersion in polymers influences the interfacial interactions,[13] including hydrogen bonding, van der Waals attraction and/or electrostatic forces between the polymer and filler in the nanocomposites.[14] The interfacial interactions between the polymer and filler further determine the stress transfer.[15,16] Therefore, exploiting the properties of the polymer chains adsorbed on the nanofiller surface and quantitative evaluation of the interphase zone arise as important issues.[6,17]

Barroso-Bujans and co-workers[18] investigated poly(ethylene oxide) (PEO) adsorption onto GO and reduced graphene oxide (RGO). It was found that the amount of adsorbed PEO on the

---

[*] *Correspondence to: B Chen, School of Mechanical and Aerospace Engineering, Queen's University Belfast, Stranmillis Road, Belfast BT9 5AH, UK. E-mail: b.chen@qub.ac.uk*

[a] *Department of Materials Science and Engineering, University of Sheffield, Sheffield, UK*

[b] *Department of Physics, College of Education for Pure Sciences, University of Babylon, Babylon, Iraq*

[c] *School of Mechanical and Aerospace Engineering, Queen's University Belfast, Belfast, UK*