Non-Destructive Synthesis and Characterisation of 1D Carbon Nanotubes and 2D graphene sheets for the Development of Nanocomposites

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Abstract

1D carbon nanotubes (CNTs) and 2D graphene nanosheets possessing extraordinary mechanical, thermal and electrical properties are tempting reinforcements for the fabrication of ultra-light, high strength and high efficiency metal-matrix composites (MMCs), ceramic-matrix composites (CMCs) and polymer matrix composites (PMCs). By the virtue of their unique structure, size, and shape, they exhibit distinct properties, beneficial for advanced nanocomposites used in structural and functional applications. A graphene nanosheet with ultimate strength of 130 GPa, Young’s modulus of 1 TPa, is one of the strongest materials known. It possess a very high electric conductivity (~6000 S/cm), enormous specific area of (~2600 m²/g) and a great thermal conductivity (~5000 W/mK). CNTs display tensile modulus of ~1 TPa and strength ~50–150 GPa with a failure strain more than 5%. Due to the existence of very large surface area and chemically active sp² and sp³ hybridisation, the chemical bonding of these nanofillers is far different to other conventionally used 3D materials. Graphene is composed of sp² carbon structures arranged in a honeycomb lattice which could be wrapped into 0D fullerenes, rolled into 1D nanotubes or 3D graphite when a number of layers are stacked together. Traditional nanofillers usually include micron sized conventional reinforcements, which require very high loading levels to provide moderate enhancement in the properties of the composites, causing issues in the processing due to their high viscosity whereas, on the other hand, nanofillers in the range of 3vol. % to 5vol. % are capable to achieve the same mechanical properties as compared to 20 wt. % to 30wt. % of micron sized fillers. Thus, nanocomposites have a weight advantage over conventional composites and so nanofillers have emerged as the pleasing candidates for the fabrication purpose. Their increased specific area enables higher interfacial interactions and hence provide higher modulus. The present work describes the innovative non-destructive strategies to synthesize high performance 1D/2D materials. The comprehensive review of the processing routes, parameters and techniques used for the synthesis and characterisation of graphene and multiwalled carbon nanotubes (MWCNTS), which were later incorporated for the development of ceramic based nanocomposites has been illustrated. Nanosized graphene sheets were developed by the intercalation method and modified Hummers method. MWCNTs were processed and prepared by Low pressure chemical vapour deposition (LPCVD) technique. The influence of surface chemistry, processing techniques and functionalization of the nanofillers on the tribological morphology is highlighted. The microstructural characterisation of the nanofillers was done by Optical microscopy, X-ray Diffraction, Field Emission Scanning Electron Microscopy, High Resolution Transmission Electron Microscopy, Raman Spectroscopy, Fourier Transform Infrared Spectroscopy, Atomic Force Microscopy, X-ray Photoelectron Spectroscopy, Particle Size Analysis, Thermal analysis.

Keywords: Graphene, Carbon Nanotubes, MMCs, CMCs, PMCs, Intercalation, Hummers Method, LPCVD.
What is Graphene?

- 1 atom thick layer of graphite
- Honeycomb (hexagonal) lattice
- It is the basic structural element of the other allotropes, including graphite, charcoal, CNTs and fullerences.
- It is the strongest, thinnest material known to exist.

What is CNT?

- CNT is a tubular form of carbon with diameter as small as 1nm.
- CNT is configurationally equivalent to a two dimensional graphene sheet rolled into a tube.
- A CNT is characterized by its Chiral Vector.

Types of CNTs

A. Single Wall CNT (SWCNT)
B. Multiwall CNT (MWCNT)

Exfoliation of Graphite

- allotropes, including graphite, charcoal, CNTs and fullerences.
- graphite, charcoal, CNTs and fullerences.
- is equivalent to a two dimensional graphene sheet rolled into a tube.
- is characterized by its Chiral Vector.

Characterisation

- Young’s modulus
- Thermal conductivity
- Electrical conductivity
- Surface Area

Development of Nanocomposites

- Viscoelastic properties
- Tensile strength
- Hardness
- Impact toughness
- Fatigue resistance

Conclusions

1. Graphene is a novel substitute for CNTs and could serve as a better nanofiller for the development of nanocomposites.
2. Acid intercalation can serve as a cost-effective medium to produce both graphene with least defects.
3. LPCVD process can suppress the formation of defect-free CNTs.
4. Matrix type, shape, size, volume and distribution of nanofillers, filler hardnness are the factors that affect the mechanical behaviour of the nanocomposites.
5. Nanofillers like xGnP and MWCNT are found to be very effective in improving the properties of the composites when added at a lower loading level of 3 vol. %.
6. xGnP/MWCNT nanocomposites were found to have better mechanical properties as compared to Al_{2}O_{3}/xGnP/MWCNT composites.

References