# Enhancement of Mechanical Properties of Carbon Fiber Composite by Electrophoretic deposition of Graphene based functional groups

**Sagar Yandrapu*, Pavan Kumar Gangineni, Sohan Kumar Ghosh, Rajesh Kumar Prusty, Bankim Chandra Ray**

**` FRP Composite Materials Group**

Department of Metallurgical and Materials Engineering, National Institute of Technology Rourkela, 769008, Odisha, India

*Corresponding Author E-mail address: sagarjaya119@gmail.com



## Abstract

This work primarily aims to fabricate a fiber reinforced plastic (FRP) composite using hand layup technique with epoxy as the matrix material and carbon fibers modified with graphene based nanofillers (GBN) deposited by the Electrophoretic deposition (EPD) technique as the reinforcement material. Carbon Fiber (CF) was developed into one of the most important reinforcement material used in the fabrication of high performance composites for critical applications. Graphene, a monolayer of $sp^2$-hybridized carbon atoms arranged in a two-dimensional lattice, has attracted tremendous attention in recent years owing to its exceptional thermal, mechanical, and electrical properties. Electrophoretic deposition (EPD) is an attractive technique for manipulation and deposition of nanomaterials, in general, and also for GBN specifically. The feasibility of the EPD process for improving the mechanical properties of the composite has been evaluated. The laminates thus obtained using these fibers were tested using UTM Instron 5967. Composites that were fabricated using graphene oxide modified carbon fibers have shown an improvement of 12% in the flexural strength when compared to that of neat Carbon Fiber Reinforced Polymer (CFRP) composites. Fractographic study using scanning electron microscope further revealed various failure modes of the composites.


## Introduction

- Carbon fibre reinforced composites (CFRP) have been attracting increasing attention as an emerging structural material due to their excellent tensile strength, high stiffness, light weight and great thermal resistance.
- Poor out of plane properties of CFRP composites hinder their full potential utilization in various high performance engineering applications.
- Incorporation of nano-fillers in the CFRP composites by fibre modification has been found to improve the fibre- matrix interface and thereby the out of plane response .
- EPD has multiple advantages over other techniques, such as the effortless control of the film thickness, good surface homogeneity, high deposition rate, and simplicity of up scaling.
- Here in this work cathodic EPD is used to deposit various graphene-based materials on the carbon fibres and the best nano-filler was chosen based on the mechanical properties of the CFRP composites fabricated with these modified carbon fibres.

## Experimental procedure

(Nano filler (1g/ Litre) + Distilled water) Sonication for 1 hour

→ (Methyl Violet(0.5g/ Litre) is added in the suspension) Sonication for 1 hour

→ EPD Process had been carried out for 30 minutes at a current of 5 Amperes on desized CF

→ Soaking of the deposited CFs for 1 hour in the tray of acetone solution to remove extra additives.

→ Thermal annealing at 140°C for 2 hours of the graphene (G) deposited CFs for making the covalent bonding between the G and CFs.

→ The fibers had been used for fabrication of the FRP composite using hand layup method.

→ The laminate obtained is cut to dimensions according to ASTM D7264

→ The samples are tested in UTM Instron5967

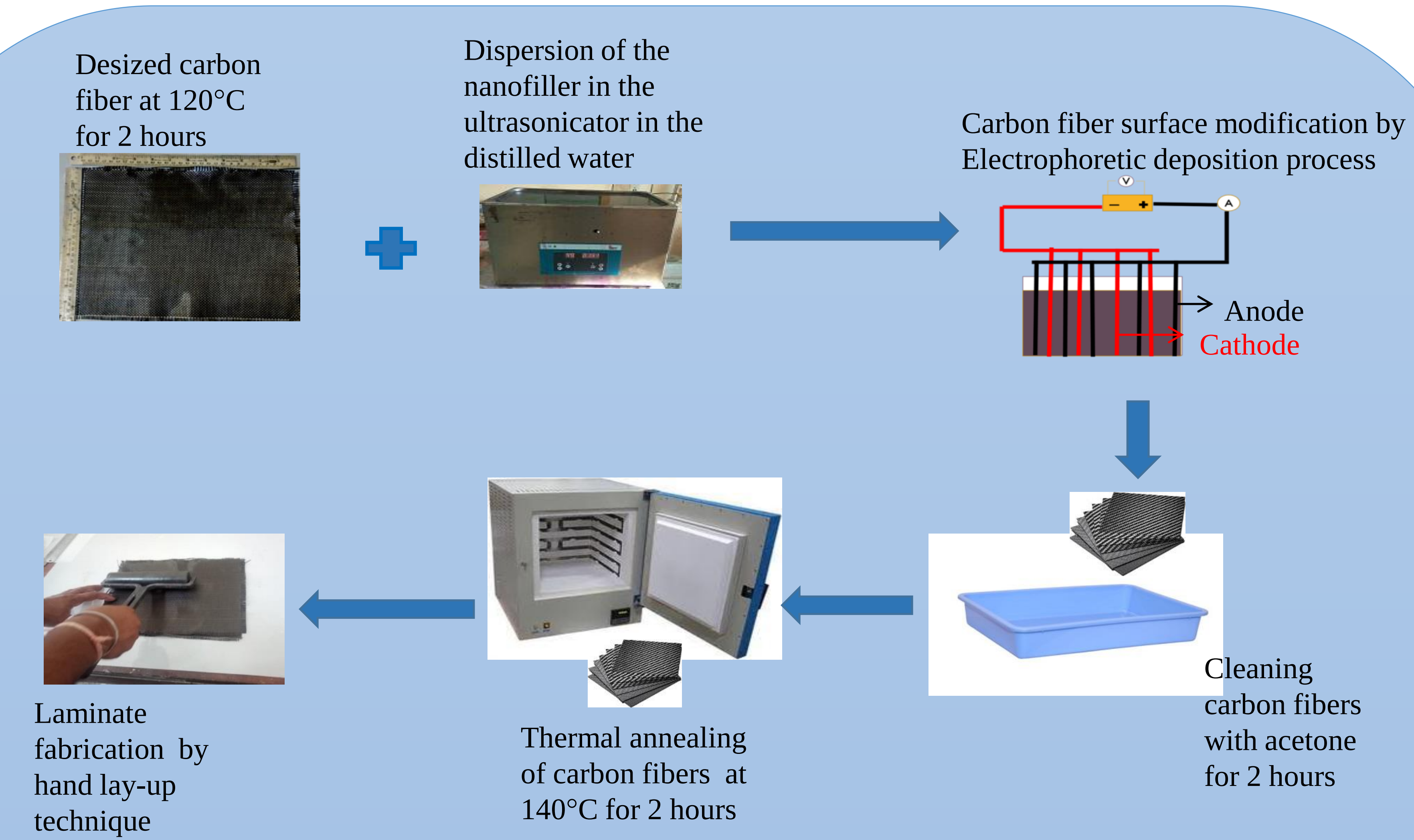


**Fig.1.** Schematic showing the process of electrophoretic deposition

## Results & Discussions

### 1. Flexural Behaviour

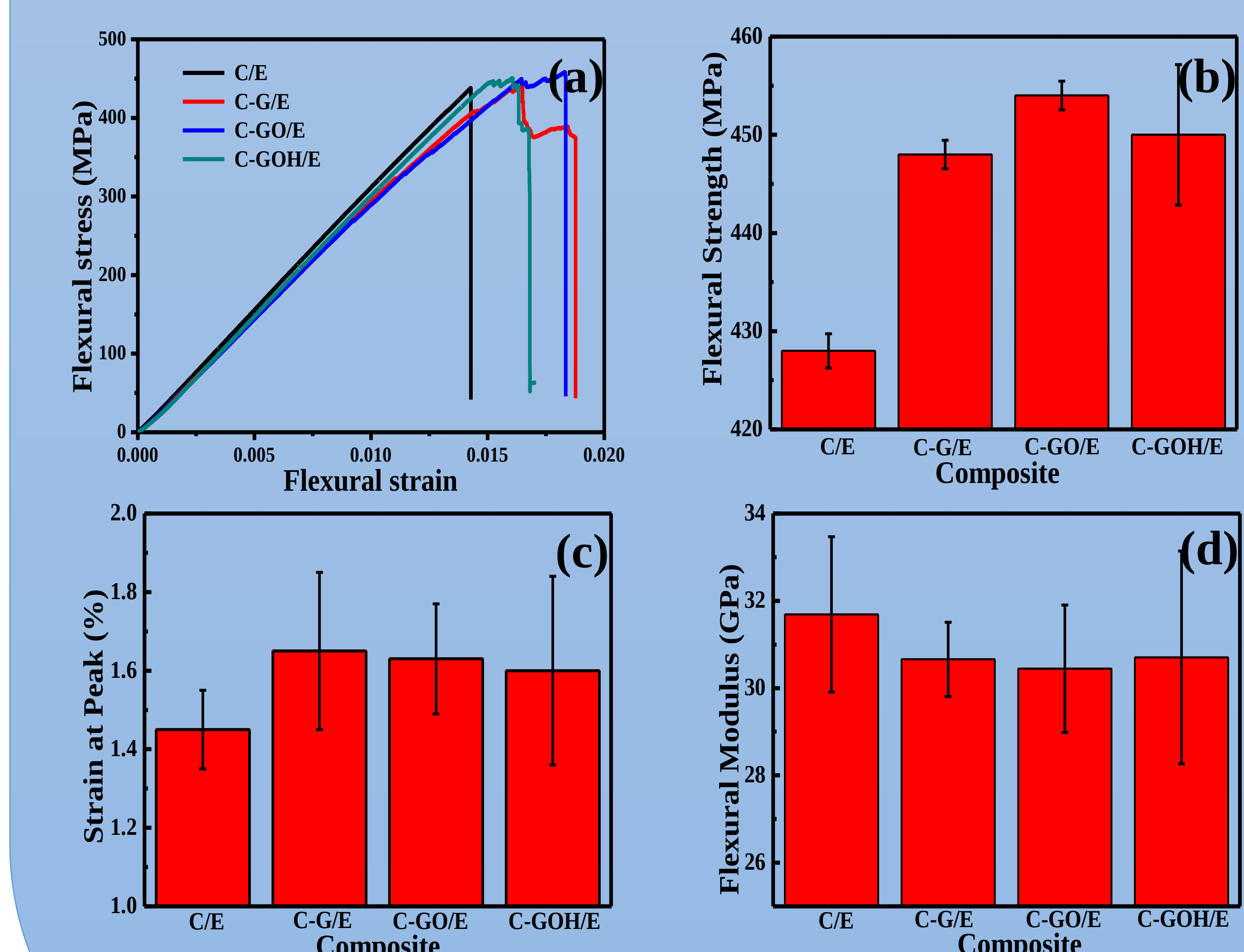


**Fig.2.** Flexural properties of CFRP composites modified with various Nanofillers (a)Stress-Strain Curve (b) Flexural Strength (c) Strain at peak (d) Flexural modulus

- Graphene modified with oxygen based functional groups lead to a better and uniform deposition on the CF as these groups, which are polar, repel each other and thereby avoid agglomerate formation. This is clear from the micrographs of the fibres .
- The key role of the nano-filler is to form a strong bridge between the matrix and the fibre and thereby form a better interface.
- Decoration of CF with nano-fillers smoothly decreased the fracture strain by local stiffening of CF/epoxy interphase.
- Modification of carbon fibre with GO, the flexural strength (FS) of the C-GO/E composite increased by 12 % in as fabricated condition when compared to that of C/E composites.

### 2. Morphology of the modified carbon fibres

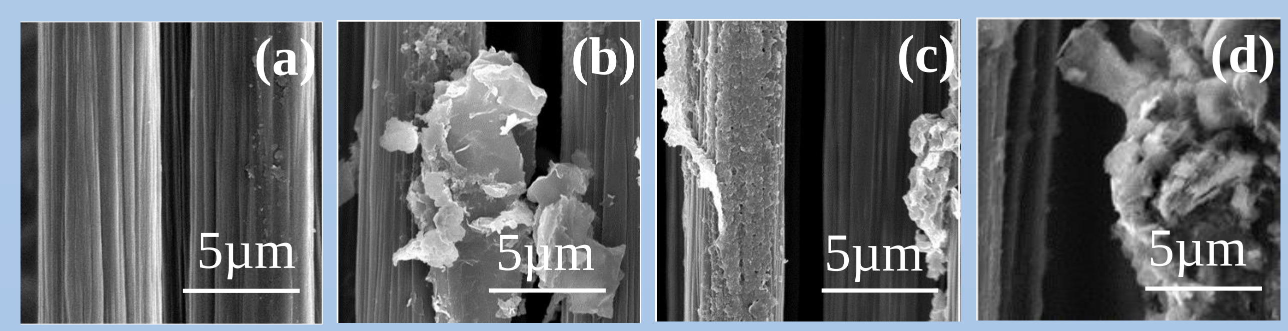


**Fig.3.** SEM images of carbon fibers (a) Without modification (Neat) (b) Modified with G (c) G-O (d) G-OH

### 3. Fractographic study

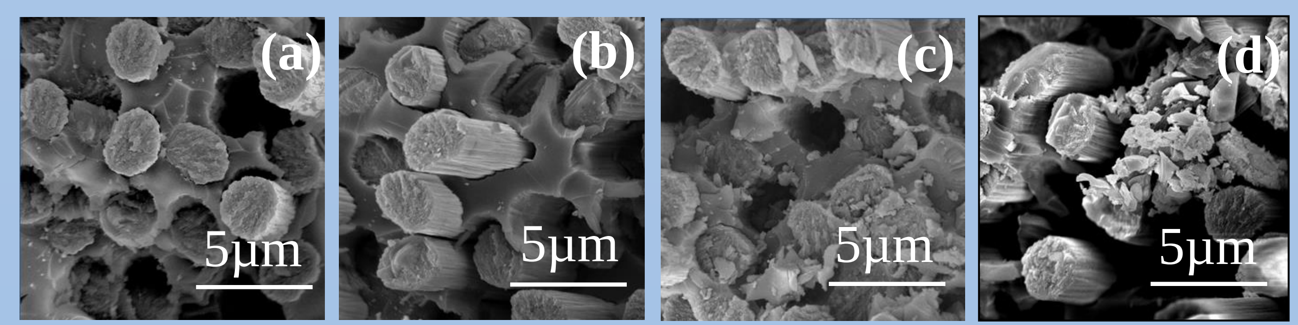


**Fig.4.** Fractography of CFRP composites modified with various Nano fillers (a) C/E(b) C-G/E (c) C- GO/E (d) C-GOH/E

## Conclusions

- Present investigation demonstrates EPD as a promising and successful processing technique for Graphene based nano-fillers modified carbon fibre /epoxy composites.
- With present processing parameters, G-O has exhibited the best deposition morphology and flexural strength increased by 12 % compared to that of the control sample.
- SEM analysis confirmed uniform deposition of G-O, whereas agglomeration was observed in G and G-OH depositions.
- Fractography analysis showed fibre pull-out to be the most prominent mode of failure in CFRP composites.


## Acknowledgement

The authors are heartily thankful to Indian Institute of metals for providing an opportunity to present the aforementioned poster at the NMD ATM-2018, Kolkata. The technical support received from Mr. Rajesh Patnaik is also highly appreciated.


## References


1. C. Wang *et al.*, "Electrophoretic deposition of graphene oxide on continuous carbon fibers for reinforcement of both tensile and interfacial strength," *Compos. Sci. Technol.*, vol. 135, pp. 46–53, Oct. 2016.
2. R. K. Prusty, S. K. Ghosh, D. K. Rathore, and B. C. Ray, "Reinforcement effect of graphene oxide in glass fibre/epoxy composites at in-situ elevated temperature environments: An emphasis on graphene oxide content," *Compos. Part Appl. Sci. Manuf.*, vol. 95, pp. 40–53, Apr. 2017.
3. C. Deng *et al.*, "Influence of graphene oxide coatings on carbon fiber by ultrasonically assisted electrophoretic deposition on its composite interfacial property," *Surf. Coat. Technol.*, vol. 272, pp. 176–181, Jun. 2015.
4. L. Besra and M. Liu, "A review on fundamentals and applications of electrophoretic deposition (EPD)," *Prog. Mater. Sci.*, vol. 52, no. 1, pp. 1–61, Jan. 2007.



**Theme Name : Advances in Material Science & Registration No. NMD-ATM-2018R-00175**