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Editorial

Graphene Nanoplatelets

A. Jiménez-Suárez and S. G. Prolongo *

Area of Materials Science and Engineering. ESCET. University Rey Juan Carlos, c/Tulipán s/n, Móstoles, 28933 Madrid, Spain; alberto.jimenez.suarez@urjc.es

* Correspondence: silvia.gonzalez@urjc.es; Tel.: +34-91488-82-92

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Featured Application: The excellent performance of graphene nanoplatelets turns them into engaging fillers for different materials, offering a wide range of applications from energy harvesting, flexible electronic devices, smart sensors and structural-functional composites.

1. Structure, Morphology, Properties and Behavior

Graphene is regarded as the revolutionary material of the 21st century. It is a single graphite monolayer, whose thickness is one atom (0.34 nm) while its lateral size could be several orders of magnitude larger. Its synthesis is complex and cannot be mass-produced yet. For this reason, graphene nanoplatelets (GNPs) have become an alternative, with a low cost and exciting properties, and the potential for large-scale production. GNPs have few graphite layers, varying in thickness from 0.7 to 100 nm [1].

Their main properties are light weight, high aspect ratio with planar shape, good mechanical properties and excellent thermal and electrical conductivities, together with low cost and easy manufacture. GNPs have numerous applications as isolated materials, neat coatings and fillers of composites. This Special Issue is focused on the use of graphene nanoplatelets as nanofillers [2–4].

2. Current and Future Applications of GNP Nanocomposites

Graphene nanoplatelets are widely employed as nanofillers with different matrices, such as polymers, concretes, metals, among others. The addition of GNP usually enhances the mechanical and tribological behavior, increasing the barrier properties and thermal conductivity, transforming insulating matrices into electrical conductors and acting as a flame retardant.

The manufacture of these nanocomposites is a challenging task to get a suitable GNP dispersion. The added GNP content varies significantly as a function of the nature of the matrix and the required properties. Due to their great versatility, the reasons and expectations raised by graphene nanoplatelets addition are very varied, looking for different performances and therefore applications. The current and future applications of these nanocomposites are unlimited, from materials with enhanced mechanical and thermal behavior up to new functional materials, such as sensors, new electronic devices, energy harvesting, adsorbents, etc. Several specific examples of the wide versatility of nanocomposites reinforced with graphene nanoplatelets are collected in the different works of this Special Issue and they are summarized hereunder.

As was just mentioned, the dispersion of graphene nanoplatelets together with the achieved exfoliation degree affects the properties and behavior of manufactured composites. For this reason, their study is essential in the development of these materials. Terahertz time-domain spectroscopy (THz-TDS) [5] is a new technique to provide information regarding graphene dispersion, analyzing the dielectric behavior of the material. Also, it enables investigating in situ the electronic quality of the polymer nanocomposite.

GNPs are commonly added to polymer matrices to enhance their mechanical behavior, increasing their chemical resistance and therefore their lifetime [6]. GNPs added into polymers reduce their ability to absorb water, increasing their resistance to aggressive humid environments. The barrier properties of GNPs are associated with the formation of tortuous paths for the water molecules, depending markedly on their geometry, thickness and lateral size. This is due to their spatial arrangement which modifies the effective specific surface area of GNPs.

The composites with polyethylene glycol (PGE) matrix present high performance in photothermal energy conversion, showing higher absorption efficiency for solar irradiation [7]. This, together with the enhanced thermal conductivity by GNP addition, makes these nanocomposites in promising materials for solar energy conversion and storage.

GNPs are also added to concrete in order to improve freeze–thaw (F–T) resistance [8]. Concretes reinforced with GNPs have enhanced compressive strength and F–T durability due to their finer pore structure than ordinary concretes. Due to this habitual tendency, there is a specific amount of graphene nanoplatelets which provides the best behavior.

Graphene oxide (GO) nanoplatelets are added to sandwich composites, such as Fe-based metal organic frameworks [9], to enhance their efficiency in the capture of uranium. GO improves the absorption of hexavalent uranium. This is an important advancement for using nuclear energy in a safe way, helping the elimination of water U-contamination. Advanced composite absorbents based on GO have been manufactured with satisfactory radionuclide uptake ability in regard to individual components.

The application of graphene nanoplatelets is very varied, with them being adding to solids, semi-liquids or greases, and also liquids. An example of the reinforcement of liquids is their addition to oils or grease lubricants and water.

Water-based graphene composite [10] presents enhanced thermal conductivity, while its freezing and melting time decrease with the graphene volume added. This behavior of water is interesting for storing electrical energy in batteries or as compressed air storage.

On the other hand, sometimes, the individual GNP addition is not enough, requiring the combination with other fillers to obtain the required behavior. In fact, in these cases, a synergic effect between both nanofillers is looked for. This is the case of the GNP addition in liquid lubricants [11]. The combined use of two additives, GNP and titanium dioxide nanopowders, enhances its wear and friction properties. It is worthy to note that graphene nanoplatelets are enough of a filler to reduce the friction of grease lubricant, without any additive.

All these cases confirm the versatility of graphene nanoplatelets as nanofillers of very different materials, developing nanocomposites with enhanced behavior and new functionalities, which can be used in very different applications. For this reason, graphene nanoplatelets are considered one of the most outstanding nanofillers in the last decade, which will be able to bring about a revolution in society, providing it with new devices and developments.

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References

1. Choi, W.; Lahiri, I.; Seelaboyina, R.; Kang, Y.S. Synthesis of graphene ad its applications: A review. *Crict. Rev. Sol. Stat. Mater. Sci.* **2010**, *35*, 52–71. [CrossRef]
2. Potts, J.R.; Dreyer, R.D.; Bielwski, C.W.; Ruoff, R.S. Graphene-based polymer nanocomposites. *Polymer* **2011**, *52*, 5–25. [CrossRef]
3. Lawal, A.T. Graphene-based nanocomposites and their applications. A review. *Biosens. Biolectron.* **2019**, *141*, 111384. [CrossRef] [PubMed]

4. Navasingh, R.J.H.; Kumar, R.; Marimuthu, K.; Planichamy, S.; Khan, A.; Asiri, A.M.; Asad, M. Graphene-based nano metal matrix composites: A review. In *Nanocarbon and Its Composites*; Series in Composites Science and Engineering; Elsevier Sci LTD: London, UK; Woodhead Publishing: Cambridge, UK, 2019; pp. 153–170.
5. Cui, H.; Zhang, X.B.; Yang, P.; Su, J.F.; Wei, X.Y.; Guo, Y.H. Spectral characteristic of single layer graphene via terahertz time domain spectroscopy. *Optik* **2015**, *126*, 1362–1365. [CrossRef]
6. Arribas, C.; Prolongo, M.G.; Sánchez-Cabezudo, M.; Moriche, R.; Prolongo, S.G. Hydrothermal ageing of graphene/carbon nanotubes/epoxy hybrid nanocomposites. *Polym. Degrad. Stab.* **2019**, *170*, 109003. [CrossRef]
7. Wang, F.; Zhang, P.; Mou, Y.; Kang, Y.; Liu, M.; Song, L.; Lu, A.; Rong, J. Synthesis of the polyethylene glycol solid-solid phase change materials with a functionalized graphene oxide for thermal energy storage. *Polym. Test.* **2017**, *63*, 494–504. [CrossRef]
8. Shamsaei, E.; Souza, B.; yao Xm Benhelal, E.; Akbari, A.; Duan, W. Graphene-based nanosheets for stronger and more durable concrete: A review. *Const. Build. Mater.* **2018**, *183*, 642–660. [CrossRef]
9. Jiahui, Z.; Hongsen, Z.; Qi, L.; Cheng, W.; Zhiyao, S.; Rumin, L.; Peili, L.; Milin, Z.; Jun, W. Metal-organic frameworks (MIL-68) decorated graphene oxide for highly efficient enrichment of uranium. *J. Taiwan Inst. Chem. Eng.* **2019**, *99*, 45–52.
10. Foroutan, M.; Fatemi, S.M.; Shokouh, F. Graphene confinement effects on melting/freezing point and structure and dynamics behavior of water. *J. Molec. Grap. Model.* **2016**, *66*, 85–90. [CrossRef] [PubMed]
11. Penkov, O.V. Graphene-based lubricants. In *Tribology of Graphene*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 193–236. ISBN 978-0-12-818641-1.