Correction to: Review on the recent progress in the preparation and stability of graphene-based nanofluids

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1. Original text—Heading section: Abstract

Numerous researches to prepare and stabilize graphene-based nanofluids have been developed.

Correction

Numerous researches have focused on the preparation and stabilization of graphene-based nanofluids, and it is indispensable to create a complete list of the approaches.

2. Original text—Heading section: Introduction

Nanofluids can be divided into two types: metallic nanofluids (metals: Au, Ag, Cu, Al, Fe; metal oxides: Al_2O_3 , CuO , Fe_3O_4 , SiO_2 , TiO_2 , ZnO , etc.) and nonmetallic nanofluids (carbides: SiC, TiC, carbon materials: graphite, diamond, SWCNT/MWCNT, graphene, etc.). There are two primary methods to produce nanofluids: the one-step method by

creating the BF and nanoparticles together and the two-step method by creating them separately and then mixing [2].

Correction

Nanofluids can be divided into two types: metallic nanofluids (metals: Au, Ag, Cu, Al, Fe; metal oxides: Al_2O_3 , CuO , Fe_3O_4 , SiO_2 , TiO_2 , ZnO , etc.) and nonmetallic nanofluids (carbides: SiC, TiC, carbon materials: graphite, diamond, SWCNT/multi-walled carbon nanotube (MWCNT), graphene, etc.) [3]. There are two primary methods to produce nanofluids; the one-step method by creating the nanoparticles and nanofluids simultaneously and the two-step method by creating them separately and then mixing [4,5]

3. Original text—Heading section: Introduction

Nanofluids have some important characteristics for different utilizations, for example, high heat conductivity, ultrafast heat transfer ability, good stability, reduction in erosion and friction coefficient, and good lubrication.

Correction

Nanofluids have some important characteristics for different utilizations, for example, high heat conductivity, ultrafast heat transfer ability, good stability, reduction of erosion and friction coefficient, and good lubrication, as compared to dispersions containing micro particles, nanofluids present higher heat conductivity, better stability, and lower friction coefficient.

4. Original text—Heading section: Introduction

Nanofluids have some important characteristics for different utilizations, for example, high heat conductivity, ultrafast heat transfer ability, good stability, reduction in erosion and friction coefficient, and good lubrication.

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Correction

Nanofluids have some important characteristics for different utilizations, for example, high heat conductivity, ultrafast heat transfer ability, good stability, reduction in erosion and friction coefficient, and good lubrication, as compared to dispersions containing microparticles, nanofluids present higher heat conductivity, better stability, and lower friction coefficient.

5. Original text—Heading section: Introduction

The GNF is well known for its easy synthesis, longer suspension stability, higher TC, lower erosion, corrosion, larger

surface area/volume ratio, and lower demand for pumping power.

Correction

The graphene-based nanofluid (GNF) is well known for its easy synthesis, longer suspension stability, higher TC, lower erosion, corrosion, larger surface area/volume ratio, and lower demand for pumping power [6].

6. Original text—Heading section: Introduction

Fig. 1. Number of articles per year, as reported Web of Science (<http://apps.webofknowledge.com>), from 1997 to August 2018 received via the keyword “nanofluid” in the topic of the paper

Fig. 1. Article number per year, as recorded Web of Science (<http://apps.webofknowledge.com>), from 1997 to December 2019 received using the keyword “nanofluid” in the article title

Fig. 2. Number of articles per year, as reported Web of Science (<http://apps.webofknowledge.com>), from 2009 to August 2018 received via the keywords “nanofluid” and “graphene” in the topic of the paper

Fig. 2. Article number per year, as recorded Web of Science (<http://apps.webofknowledge.com>), from 2009 to December 2019 received using the keywords “nanofluid” and “graphene” in the article title

Correction

7. Original text—Heading section: Introduction

Correction

8. Original text—Heading section: Introduction

GO is a great interest of researchers due to easy access, low cost, and extensive capability to convert to rGO.

Correction

GO is a great interest of researchers due to easy access, low cost, and extensive capability to convert to reduced graphene oxide (rGO).

9. Original text—Heading section: Introduction

The great prospects are expressed about their utilizations in different fields.

Correction

The great prospects are expressed about their utilizations in different fields. Many researches are being performed on modifying the properties of nanomaterials to expand their use [7].

10. Original text—Heading section: Preparation of graphene, GO, and rGO—Subheading section: Preparation of graphene

Pyrolysis provides the simplicity of the procedure and can be extended for production.

Correction

Pyrolysis is a simple solution for graphene production and can be extended for large-scale production.

11. Original text—Heading section: Preparation of graphene, GO, and rGO—Subheading section: Preparation of graphene

Fig. 3 Oxidation process of graphite and reduction process of GO [4].

Correction

Fig. 3. Oxidation process of graphite and reduction process of GO [4], reprinted from Elsevier open access article under the terms of the Creative Commons CC-BY license.

12. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Fig. 4 Scheme for the mechanical exfoliation via ball milling [31].

Correction

Fig. 4. Scheme for the mechanical exfoliation via ball milling [31], reprinted with permission from Royal Society of Chemistry (license number 1,013,955-1).

13. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Fig. 5 Mechanical exfoliation of carbon nanofibers into graphene via ball milling by using melamine [35].

Correction

Fig. 5 Mechanical exfoliation of carbon nanofibers into graphene via ball milling by using melamine [35], reprinted with permission from SpringerNature (license number 4750950332446).

14. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Fig. 6 Scheme of various popular synthesis methods of graphene along with their respective features and their current and prospective applications [40].

Correction

Fig. 6 Scheme of various popular synthesis methods of graphene along with their respective features and their current and prospective applications [40], reprinted with permission from Elsevier (license number 4750951051829).

15. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Moreover, graphene can be made via continuous processing, as a result of the collected material outside the chamber.

Correction

Moreover, graphene can be made via continuous processing, because of the collected material outside the chamber.

16. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Nonetheless, the production yield is poor, and the final product has impurities. In this technique, Choucair et al. heated 1: 1 molar ratio of sodium (2 g) and ethanol (5 mL) in a closed reactor at 220 °C for 72 h to obtain the solid solvothermal product—graphene precursors, which was then quickly pyrolyzed, and the remaining product was cleaned using DI (100 mL).

Correction

Nonetheless, the quality of final product is not high since it has impurities. Using this technique, Choucair et al. heated 1: 1 molar ratio of sodium (2 g) and ethanol (5 mL) in a closed reactor at 220 °C for 72 h to obtain the solid solvothermal product—graphene precursors, which was then quickly pyrolyzed, the remaining product was cleaned using DI (100 mL).

17. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Between the graphite interlayer space, various chemical species can be added to obtain GIC.

Correction

Between the graphite interlayer spaces, various chemical species can be added to obtain GIC.

18. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Also, rapid heating has been considered as a possible solution bringing about significant yields of dispersed carbon powders with a few percents of carbon flakes [46].

Correction

Also, rapid heating has been considered as a possible solution bringing about significant yields of dispersed carbon powders with a few percent of carbon flakes [46].

19. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

These techniques are able to be broadly classified into exfoliation, chemical synthesis, pyrolysis, CVD, see Fig. 3.

Correction

These techniques are able to be broadly classified into exfoliation, chemical synthesis, pyrolysis, chemical vapor deposition (CVD), see Fig. 3.

20. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

For the removal of residual acid content, the sample was washed with DI several times.

Correction

For the removal of residual acid content, the sample was washed with deionized water (DI) several times.

21. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

They carried out the reaction by utilizing CH_4 as the carbon source and H_2 as the carrier gas in a ratio of 4:1, then they stirred the product in HCl solution and washed it several times with DW.

Correction

They carried out the reaction by utilizing CH_4 as the carbon source and H_2 as the carrier gas in a ratio of 4:1, and then they stirred the product in HCl solution and washed it several times with distilled water (DW).

22. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Between the graphite interlayer space, various chemical species can be added to obtain GIC.

Correction

Between the graphite interlayer space, various chemical species can be added to obtain graphite intercalation compound (GIC).

23. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

The graphene nanopowders/flakes, sized from nm to μm , can be produced by chemical reduction in GIO, which is one kind of the conventional procedures for the synthesis of graphene in huge amount.

Correction

The graphene nanopowders/flakes, sized from nm to μm , can be produced by chemical reduction in graphite oxide (GIO), which is one kind of the conventional procedures for the synthesis of graphene in huge amount.

24. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of graphene

Besides manufacturing graphene layers, CVD can be utilized to synthesize GNSs.

Correction

Besides manufacturing graphene layers, CVD can be utilized to synthesize graphene nanosheets (GNSs).

25. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of GO

Fig. 7 Scheme for the various oxidation techniques of graphite into GO and the chemical reduction in GO into rGO [51].

Correction

Fig. 7 Scheme for the various oxidation techniques of graphite into GO and the chemical reduction in GO into rGO [51], reprinted with permission from Elsevier (license number 4750951277846).

26. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of GO

Fig. 8 Schematic procedure for Brodie, Staudenmaier, Hofmann, and HM (c concentrated, f fuming).

Correction

Fig. 8. Schematic procedure for Brodie, Staudenmaier, Hofmann and Hummer's method (HM) (c: concentrated, f: fuming), figure developed from [8].

27. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of GO

MHM has been used by several research groups for the synthesis of GO [59–62].

Correction

Modified Hummers method (MHM) has been used by several research groups for the synthesis of GO [59–62].

28. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of GO

Mehrali et al. [73] used an SHM to synthesize GO and then introduced a technique for preparing NDG by a hydrothermal process with GO as a raw material in an ammonia solution.

Correction

Mehrali et al. [73] used an simplified Hummers method (SHM) to synthesize GO and then introduced a technique for preparing nitrogen-doped graphene (NDG) by a hydrothermal process with GO as a raw material in an ammonia solution.

29. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of rGO

Fig. 10. Schematic procedure for the synthesis of thermally rGO from graphite. Graphite is oxidized to GO, figure developed from [9]

Fig. 9 Schematic representation of the oxidation procedures with graphite flakes as a starting material. Under-oxidized hydrophobic carbon material recovered during the purification of improved, Hummers, and Hummers modified GO [63].

Correction

Fig. 9. Schematic representation of the oxidation procedures with graphite flakes as a starting material. Under-oxidized hydrophobic carbon material recovered during the purification of improved, Hummers and Hummers modified GO [70], reprinted with permission from American Chemical Society, copyright 2020.

30. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of rGO

Fig. 10 Schematic procedure for the synthesis of thermally rGO from graphite. Graphite is oxidized to GO [79].

Correction

31. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of rGO

Fig. 11 Schematic representation for electrochemical reduction approach to the production of electrochemically rGO [84].

Correction

Fig. 11 Schematic representation for electrochemical reduction approach to the production of electrochemically rGO [84], reprinted with permission from Elsevier (license number 4750971321271).

32. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of rGO

Compared to the GO precursor, rGO created by this technique typically presents a substandard EC and surface area.

Correction

Compared to the GO precursor, rGO created by this technique typically presents a substandard electrical conductivity (EC) and surface area.

33. **Original text—Heading section:** Preparation of graphene, GO, and rGO—**Subheading section:** Preparation of rGO

Recently, in most of the nanofluid experimental researches, the nanoparticles have been supplied by the manufacturer.

Correction

Recently, in most of the nanofluid experimental researches, the nanoparticles have been supplied by the manufacturer (SBM).

34. **Original text—Heading section:** Preparation of nanofluids

But the strict condition is required for such a process.

Correction

However, the strict condition is required for such a process.

35. **Original text—Heading section:** Preparation of nanofluids

A higher shear mixing or ultrasonic vibrator is mostly used to homogenize nanopowders with BFs.

Correction

A higher shear mixing or ultrasonic vibrator is mostly used to homogenize nanopowders into BF.

36. **Original text—Heading section:** Preparation of nanofluids

By HM or MHMs, Shende et al. [57], Akhavan-Zanjani et al. [58], Anin Vincely et al. [68], Esfahani et al. [70], Kim et al. [71] produced GONFs of water by sonication or stirring.

Correction

By HM or MHMs, Shende et al. [57], Akhavan-Zanjani et al. [58], Anin Vincely et al. [68], Esfahani et al. [70], Kim et al. [71] produced graphene oxide nanofluids (GONFs) of water by sonication or stirring.

37. **Original text—Heading section:** Stability of nanofluids

Balancing the competing interactions supports nanoparticle dispersion and prevents aggregation and clustering that were investigated as factors increasing TC of nanofluids.

Correction

Balancing the competing interactions supports nanoparticle dispersion and prevents aggregation and clustering that were investigated as factors increasing thermal conductivity (TC) of nanofluids.

38. **Original text—Heading section:** Stability of nanofluids—**Subheading section:** Stability mechanisms

Fig. 13 Electrostatically and sterically stable nanoparticles [209].

Correction

Fig. 13 Electrostatically and sterically stable nanoparticles [209], reprinted from IOP Publishing open access article under the terms of the Creative Commons Attribution 3.0 license.

39. **Original text—Heading section:** Stability of nanofluids—**Subheading section:** Stability evaluation methods for nanofluids

Fig. 14 Scheme for ζ -potential of stable and unstable dispersions.

Correction

Fig. 14. Scheme for ζ -potential of stable and unstable dispersions, figure developed from [10].

40. **Original text—Heading section:** Stability of nanofluids—**Subheading section:** Stability evaluation methods for nanofluids

Fig. 15 UV–Vis spectra of GNF before and after using the nanofluid in the testing cycle duration of 1 week [58].

Correction

41. Original text—Heading section: GO and GNFs

Fig. 16 Plots of viscosity versus the shear rate at various concentrations and temperatures for GNP and GO nanofluids [2, 70].

Correction

Fig. 16. Plots of viscosity versus the shear rate at various concentrations and temperatures for GNP [2], reprinted from Springer Nature open access article under the terms of the Creative Commons CC-BY license and GO nanofluids [70], reprinted with permission from Elsevier (license number 4751020010246).

Fig. 15. UV-vis spectra of nitrogen-doped graphene nanofluids at various sonication time [11], reprinted with permission from SpringerNature (license number 4751001347934)

42. Original text—Heading section: Applications of GNF

Fig. 17 Several utilizations of GNFs [220].

Correction

Fig. 17 Several utilizations of GNFs [220], reprinted with permission from Elsevier (license number 4751010618606).

43. Original text—Heading section: Applications of GNF

The heat exchanger is utilized broadly in industry and particularly in process plants, for example power plants, cooling towers, refineries, etc.

Correction

The heat exchanger is broadly utilized in industry and particularly in process plants, for example power plants, cooling towers, refineries, and so on.

44. Original text—Heading section: Applications of GNF

The authors recommend to further investigate graphene-based nanoparticles with metallic and metallic oxides nanoparticles by changing the concentration, inlet temperature, flow rate, and pumping power.

Correction

The above sentence should be omitted.

45. Original text—Heading section: Conclusions and outlook

Another important research priorities are the investigation of sonication time and power on GNFs and finding the optimal settings.

Correction

Another important research priority is the investigation of sonication time and power on GNFs and finding the optimal settings [12].

46. Original text—Heading section: Conclusions and outlook

Correction

47. **Original text—Heading section:** Conclusions and outlook

The shape of graphene nanoparticles is very important for their properties. There is a need to investigate further the effect of morphological, fluid and thermal properties, and use of different BFs, which helps to increase the thermal and flow performance and improve the production of nanofluids.

Correction

The shape of graphene nanoparticles has significant effect on their properties. There is a need to investigate further the effect of morphological and base fluid type on thermal properties of this type of nanofluids.

48. **Original text—Heading section:** Conclusions and outlook

In different high-temperature thermal applications, the physical phenomenon with other materials should be studied as corrosion, friction.

Correction

In different high-temperature thermal applications such as solar energy applications, the stability control is more critical.

49. **Original text—Heading section:** Conclusions and outlook

Development of more suitable surfactants and methods, the optimum amount of surfactant for better stability of nanofluids will be an interesting topic.

Correction

Development of suitable surfactants and methods, determining the optimum amount of surfactant for better stability of nanofluids will be an interesting topic. Fig. 18 summarizes the future challenges for GNFs.

50. **Original text—Heading section:** Conclusions and outlook

In addition, various functionalizations and heteroatoms of GO can be checked in more detail.

Correction

In addition, various functionalization approaches and heteroatoms of GO can be checked in more detail.

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