Article **Journal of Technological Engineering**
December 2022, Vol.6 No.18 1-5

Recent advances of graphene-based nanofluids for the application in solar collectors

Avances recientes de los nano fluidos basados en grafeno para su aplicación en colectores solares

ROSALES-GUZMÁN, Miguel†*, DÍAZ-SILVESTRE, Sergio Enrique, CANALES-PATIÑO, Eduardo Luis and IBARRA-SAMANIEGO, Lucía del Carmen

Universidad Tecnológica de Saltillo, Department of Renewable Energies and Industrial Maintenance, Mexico.

ID 1st Author: *Miguel, Rosales-Guzmán* / **ORC ID:** 0000-0002-0955-2309, **CVU CONACYT ID:** 227119

ID 1st Co-author: *Sergio Enrique, Díaz-Silvestre* / **ORC ID:** 0000-0002-6765-3415, **CVU CONACYT ID:** 334151

ID 2nd Co-author: *Eduardo Luis, Canales-Patiño* / **ORC ID:** 0000-0002-4327-2714, **CVU CONACYT ID:** 636576

ID 3rd Co-author: *Lucía del Carmen, Ibarra-Samaniego* / **ORC ID: 0000-0002-6974-4847**, **CVU CONACYT ID:** 483788

DOI: 10.35429/JTEN.2022.18.6.1.5 Received July 10, 2022; Accepted December 30, 2022

Abstract

The present work provides a perspective on the recent research on the application of graphene based-nanofluids in different types of solar collectors such as flat plate, evacuated tube, parabolic and linear Fresnel, among many others available. Although significant advances have been reported in this direction regarding the efficiency and short-time stability of the reported dispersions, there remain challenges that need to be addressed before the full potential of these graphene-based nanofluids can be realized. For example, there are not efficient and green routes for the mass production of nanofluids at relatively low cost. In addition, the need for detailed studies on the effect of graphene nanoparticles on the internal surfaces of solar collectors as well as its effect on the pumping systems used is mandatory. Lifetime of the different nanofluids, environmental concerns and recycling of these nanofluids is still a topic to be explored.

Graphene, Efficiency, Solar collectors

Resumen

El presente trabajo provee una perspectiva acerca de investigaciones reciente en la aplicación de nano fluidos basados en grafeno y su aplicación en diferentes colectores solares tales como los de superficie plana, tubos al vacío, parabólicos y de Fresnel, entre muchos otros. Aunque se han reportado avances significativos en esta dirección relacionados a la eficiencia y estabilidad en periodos de tiempo cortos, todavía existen desafíos que tienen que ser superados antes de que el potencial de estos nano fluidos pueda llevarse a cabo. Por ejemplo, se requieren todavía rutas eficientes y verdes para la producción a gran escala de dichos nano fluidos a costo un costo relativamente bajo. De igual manera, se requieren estudios detallados del efecto de las nanopartículas en las superficies internas de los colectores solares, así como en los sistemas de bombeo utilizados. Tiempo de vida de los nano fluidos, efecto sobre el medio ambiente y reciclado de dichos nano fluidos es todavía un tema que está por explorarse.

Grafeno, Eficiencia, Colectores solares

Citation: ROSALES-GUZMÁN, Miguel, DÍAZ-SILVESTRE, Sergio Enrique, CANALES-PATIÑO, Eduardo Luis and IBARRA-SAMANIEGO, Lucía del Carmen. Recent advances of graphene-based nanofluids for the application in solar collectors. Journal of Technological Engineering. 2022. 6-18:1-5.

* Correspondence from the Author (E-mail: mrosales@utsaltillo.edu.mx)
† Researcher contributing as first author.

Introduction

Energy in all its variations is an essential component of our modern era. Electrical energy, for example, has completely revolutionized our society to the point where it is impossible to imagine a life without, artificial illumination, internet, and mobile phones, amongst many others.

However, the population increase around the world, has led to the necessity of increasing the production of electrical energy. In 2017 it was estimated that the consumption of electrical power in our planet was approximately 108,854 Terawatt-hour, with an astonishing estimated increase of about 28% by 2040 (Shamshirgaran et al., 2018). The concerns have been raised around the world because this demand of energy will not be satisfied by traditional sources of energy such as carbon and petroleum. This is due in part to the fact that these sources are non-renewable, and therefore limited, but also because they have been exploited irrationally. Therefore, the necessity to switch to renewable energies (eco-friendly) is mandatory, being solar energy the main alternative. Along this line, solar collectors and solar cells are the most popular technologies that are taking advantage of a renewable source of energy, the sun. Accordingly, renewable energies can be classified in six big categories:

- Sun energy
- Geothermal energy
- Wind energy
- Hydroelectric energy
- Ocean energy
- Biomass Energy

Solar collectors are one of the most common examples in which the radiation from the sun is converted directly to thermal energy for household applications. Nevertheless, the efficiency of solar collectors is still limited by the use of conventional thermal fluids such as water and ethylene glycol. The alternative is the use of nanofluids that essentially encompass a conventional thermal fluid in which nanoparticles in the order of 100 nm have been dispersed. The main characteristic of nanofluids is an enhanced thermal conductivity and improved heat transfer coefficients in comparison to their base fluids (Chen et al., 2017).

From the great variety of metallic (Au, Ag, Al, Fe, etc.) and non-metallic nanofluids (SiC, ZnO, TiC, C-based) (Nagarajan et al., 2014), probably the ones based on graphene are promising candidates to replace conventional thermal fluids because they are easier to be produced and with relatively low cost.

For this reason, the present review highlights the recent advances in the production of graphene- based nanofluids as applied to solar collectors, current challenges and future perspectives.

Nanofluids

A nanofluid can be defined as a two-phase system in which a continuous fluid matrix contains nanometer-sized particles in the form of a stable colloidal suspension. There are essentially two routes in which a nanofluid can be obtained according to the schematic representation in Figure 1.

a) One-step process: The thermal fluid and nanoparticles are produced simultaneously, for example by ultrasonic energy and appropriate stabilizers.

b) Two-step process: nanoparticles are first produced and then dispersed in the corresponding nanofluid.

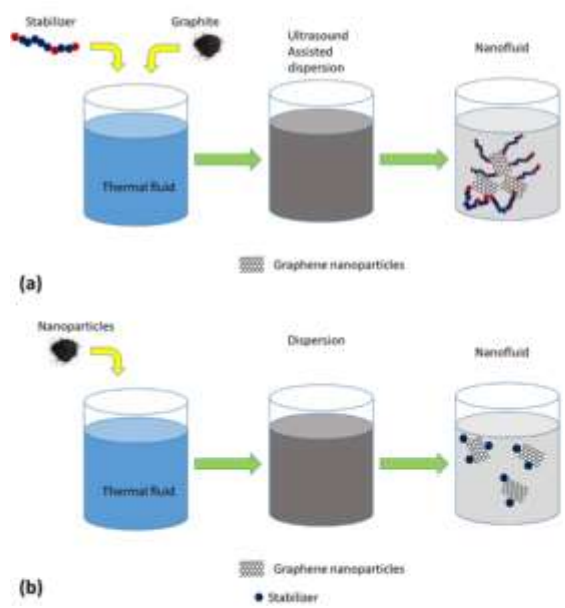

Figure 1 Schematic representation of the production of nanofluids by (a) one-step process and (b) two-step process

ISSN 2523-6776

Types of solar collectors

A solar collector can be defined as a device in which the energy from solar radiation is transferred to a liquid or nanofluid. There are principally two types of solar collectors: Non-concentrating and concentrating (Mahian et al., 2021). With respect to the first one, the following examples can be given:

- Flat plate solar collector.

- Evacuated solar collector.

- Direct absorption solar collector.

Regarding the second one, the following examples can be mentioned:

- Parabolic solar concentrator.

- Fresnel solar collector.

- Solar dish collector.

Some of these solar concentrators can be visualized in Figure 2.

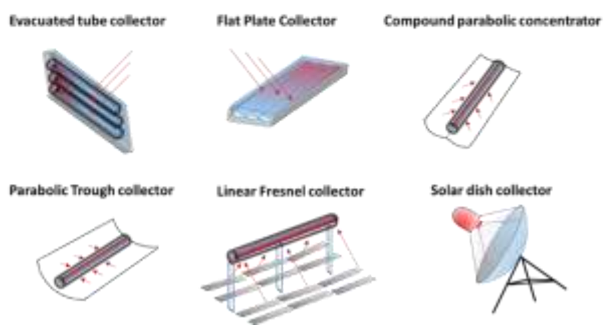

Figure 2 Different types of solar collectors

Recent applications of graphene-based nanofluids in solar collectors

The efficiency of solar collectors is affected by various parameters such as concentration of nanoparticles, flow rate and intensity of radiation in w/m^2. For example, Verma and coworkers concluded that the efficiency of a flat plate solar collector (FPSC) is enhanced by 21.46% at a graphene volume concentration of 0.75 and mass flow rate of 21.46 % in the case of water/graphene nanofluid. Another advantage of using nanofluids is the reduction in area of solar collector. For this same work, a 14.66% reduction in area was obtained at the same particle volume concentration and mass flow rate (Verma et al., 2017).

Later Bioucas and collaborators studied the performance of nanofluids based on graphene and water/ethylene glycol (70:30 % w/w) mixtures at particle concentrations of 0.05, 0.08, 0.10 wt.%. The three different nanofluids were first tested in a controlled environment using a lamp of 1000 W. It was observed that the best performance is obtained at 0.1 wt.% graphene concentration. Later this nanofluid was tested in real conditions resulting in an enhancement of 5.90% in comparison to the base fluid (Bioucas et al., 2018). On the other hand, graphene nanofluids have been studied as potential candidates for applications that involve direct absorption solar collectors (DASC). For example, Shende and collaborators reported an enhance of 18.5% in the thermal conductivity of reduced graphene oxide/deionized water and 17.8% in the case of reduced graphene oxide/ethylene glycol nanofluids(Shende & Ramaprabhu, 2017).

Likewise, the thermal conductivity of water/reduced graphene oxide nanofluids was reported and variations from 9.63% to 33.6% were found in comparison to variations of 7.74% to 26.25% for water/graphene oxide nanofluids when temperature is increased from 30 °C to °80 C (Chen et al., 2017). Both types of nanofluids showed stability after two months. A similar work was carried out and reported, nonetheless, emphasis was given to the stability and antifreeze property of different nanofluids; graphene oxide-water/ethylene glycol and graphene oxide-water with different degrees of reduction using UV-irradiation (Wang et al., 2017). In this research work, dispersions were stabilized with polyvinylpyrrolidone. The zeta potential of the nanofluids based on water/ethylene glycol mixtures at 0.06% mass fraction of graphene oxide was detected to increase with temperature which indicates good stability at relatively high temperatures.

These nanofluids can be used at temperatures as low as -47 °C. In the same work, graphene/oil nanofluids at 0.02, 0.05, 0.1, 0.2, 0.5, 1.0 mg/ml particle concentrations were studied and an increase in the relative thermal conductivity between 4% and 25% was reported. In addition, apparent reduction in the kinetic viscosity of the nanofluids was observed by comparing pure oil and the corresponding graphene/oil nanofluids at ambient temperature.

The instantaneous heat collection efficiency was measured in a simulated environment and found that the maximum value appears at 30 °C but rapidly declines as the inlet temperature increases which was ascribed to heat loss through the walls of the solar collector. Finally, in a recent work, the thermal performance of a two-phase closed thermosiphon with nanofluids based on water and Al_2O_3 or carbon nanotubes (CNT) was studied and reported. Optimum operating conditions were stated for a nanofluid containing 1.5% CNT.(Carrión M., 2022)

Current limitations of graphene based nanofluids

Despite all the apparent increase in efficiency of solar concentrators with the use of graphene nanofluids, there are still some challenges that have to be overcome. For example, large production of graphene is still made from graphene oxide which is at its time produced by Hummer´s method (Olorunkosebi et al., 2021). This method uses toxic chemicals such as sodium nitrate and sulfuric acid that have large environmental concerns. Although alternatives have been proposed (Zhu et al., 2022), there is too much work to perform on this direction. Other aspect that has not been studied in detail is the effect of the nanoparticles on the wear of internal surfaces (Molina et al., 2013) of the corresponding solar collectors and/or system pumps used. Additionally, the efficiency of the reported nanofluids has not been fully tested in real conditions but in controlled laboratory environments.

Recycling of the nanofluids after its life-time is another aspect that has not been studied. There are only some examples in which this can be done (Liu et al., 2021).

Conclusions

In this work the recent advances in the graphene-based nanofluids and its applications to solar collectors is provided. Aspects as graphene synthesis and efficiency of solar collectors is reviewed. Finally a brief discussion of the current limitations on the state of the art is given.

References

I. Bioucas, F. E. B., Vieira, S. I. C., Lourenço, M. J. V., Santos, F. J. V., & Nieto de Castro, C. A. (2018). Performance of heat transfer fluids with nanographene in a pilot solar collector. *Solar Energy*, *172*, 171–176. https://doi.org/10.1016/j.solener.2018.05.040

II. Carrión M., L. M. (2022). *Análisis del rendimiento térmico de un termosifón cerrado de doble fase, usando diferentes configuraciones de aletas y nanofluidos de Al2O3 y nanotubos de carbono.* [Universidad de las fuerzas armadas]. https://repositorio.espe.edu.ec/bitstream/21000/29212/1/T-ESPE-052248.pdf

III. Chen, L., Liu, J., Fang, X., & Zhang, Z. (2017). Reduced graphene oxide dispersed nanofluids with improved photo-thermal conversion performance for direct absorption solar collectors. *Solar Energy Materials and Solar Cells*, *163*, 125–133. https://doi.org/10.1016/j.solmat.2017.01.024

IV. Liu, C., Qiao, Y., Du, P., Zhang, J., Zhao, J., Liu, C., Huo, Y., Qi, C., Rao, Z., & Yan, Y. (2021). Recent advances of nanofluids in micro/nano scale energy transportation. *Renewable and Sustainable Energy Reviews*, *149*, 111346. https://doi.org/10.1016/j.rser.2021.111346

V. Mahian, O., Bellos, E., Markides, C. N., Taylor, R. A., Alagumalai, A., Yang, L., Qin, C., Lee, B. J., Ahmadi, G., Safaei, M. R., & Wongwises, S. (2021). Recent advances in using nanofluids in renewable energy systems and the environmental implications of their uptake. *Nano Energy*, *86*, 106069. https://doi.org/10.1016/j.nanoen.2021.106069

VI. Molina, G. J., Soloiu, V., & Rahman, M. (2013). On the Surface Effects of Nanofluids in Cooling-System Materials. *MRS Proceedings*, *1558*, mrss13-1558-z09-06. https://doi.org/10.1557/opl.2013.1087

VII. Nagarajan, P. K., Subramani, J., Suyambazhahan, S., & Sathyamurthy, R. (2014). Nanofluids for Solar Collector Applications: A Review. *Energy Procedia*, *61*, 2416–2434. https://doi.org/10.1016/j.egypro.2014.12.017

VIII. Olorunkosebi, A. A., Eleruja, M. A., Adedeji, A. V., Olofinjana, B., Fasakin, O., Omotoso, E., Oyedotun, K. O., Ajayi, E. O. B., & Manyala, N. (2021). Optimization of graphene oxide through various Hummers' methods and comparative reduction using green approach. *Diamond and Related Materials*, *117*, 108456. https://doi.org/10.1016/j.diamond.2021.108456

IX. Shamshirgaran, S. R., Khalaji Assadi, M., & Viswanatha Sharma, K. (2018). Application of nanomaterials in solar thermal energy storage. *Heat and Mass Transfer*, *54*(6), 1555–1577. https://doi.org/10.1007/s00231-017-2259-1

X. Shende, R. C., & Ramaprabhu, S. (2017). Application of Few-Layered Reduced Graphene Oxide Nanofluid as a Working Fluid for Direct Absorption Solar Collectors. *Journal of Nanoscience and Nanotechnology*, *17*(2), 1233–1239. https://doi.org/10.1166/jnn.2017.12695

XI. XI. Verma, S. K., Tiwari, A. K., & Chauhan, D. S. (2017). Experimental evaluation of flat plate solar collector using nanofluids. *Energy Conversion and Management*, *134*, 103–115. https://doi.org/10.1016/j.enconman.2016.12.037

XII. XII. Wang, N., Xu, G., Li, S., & Zhang, X. (2017). Thermal Properties and Solar Collection Characteristics of Oil-based Nanofluids with Low Graphene Concentration. *Energy Procedia*, *105*, 194–199. https://doi.org/10.1016/j.egypro.2017.03.301

XIII. XIII. Zhu, Y., Kong, G., Pan, Y., Liu, L., Yang, B., Zhang, S., Lai, D., & Che, C. (2022). An improved Hummers method to synthesize graphene oxide using much less concentrated sulfuric acid. *Chinese Chemical Letters*. https://doi.org/10.1016/j.cclet.2022.01.060