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Review

A review on the use of carbon nanotubes nanofluid for energy harvesting system

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ABSTRACT

This paper reviews recent progress and applications of CNT nanofluids in energy harvesting system especially solar collectors. In addition to reviewing the efficiency of solar collectors which use CNT nanofluids, the paper also discusses the preparation methods, factors for enhancing thermal conductivity and optical properties of CNT nanofluids. Finally, the challenges and future trends related to the application of CNT nanofluids in thermal solar collector is discussed.

Contents

1. Introduction

In recent years, many researchers have focused on heat transfer enhancement by modifying the thermo-physical properties of the working fluid. Nanofluid, an engineered colloidal suspension of nanoparticles in a base fluid, have demonstrated great potential applications in many engineering applications due to its enhanced thermal conductivity and convective heat transfer coefficient compared to the base fluid [1–6]. Among the early studies, Choi et al. [7] compared the performance of microchannel heat exchanger with nanofluid and that of with water. Results demonstrated excellent thermal performance of a microchannel heat exchanger when nanofluids were used. In 2005, experiments by Lin et al. [8] on

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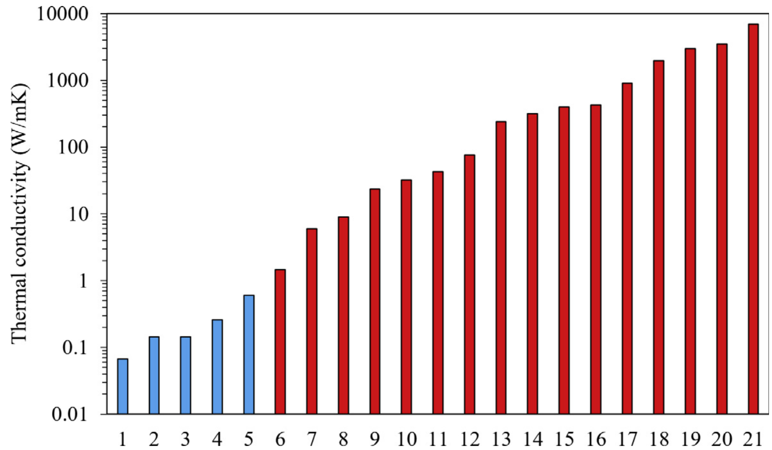

1	Refrigerant (R113) [22]	8	TiO_2 (Rutile) [22]	15	Cu (copper) [23]
2	Poly-alpha-olefin oil [24]	9	ZnO (zink oxide) [23]	16	Ag (Silver) [23]
3	Engine oil [25]	10	Al_2O_3 (Aluminium oxide) [23]	17	C (Diamond) [23]
4	Ethylene glycol [23]	11	MgO (Magnesium oxide) [26]	18	C (Graphite) [23]
5	H_2O (Water) [23]	12	CuO (Copper (II) oxide) [27]	19	MWCNT (14 nm) [27]
6	SiO_2 (Silica) [23]	13	Al (Aluminum) [23]	20	SWCNT (1.7 nm) [7]
7	Fe_3O_4 (Iron oxide) [26]	14	Au (gold) [23]	21	SWCNT (1.0 nm) [28]

Fig. 1. Thermal conductivity of selected metals, ceramics (or metallic oxides), and liquids at room temperature. Note: blue colored bar indicates liquid whilst red colored bar indicates solid. 1. Refrigerant (R113) [22]; 2. Poly-alpha-olefin oil [24]; 3. Engine oil [25]; 4. Ethylene glycol [23]; 5. H_2O (Water) [23]; 6. SiO_2 (Silica) [23]; 7. Fe_3O_4 (Iron oxide) [26]; 8. TiO_2 (Rutile) [22]; 9. ZnO (zink oxide) [23]; 10. Al_2O_3 (Aluminum oxide) [23]; 11. MgO (Magnesium oxide) [26]; 12. CuO (Copper (II) oxide) [27]; 13. Al (Aluminum) [23]; 14. Au (gold) [23]; 15. Cu (copper) [23]; 16. Ag (Silver) [23]; 17. C (Diamond) [23]; 18. C (Graphite) [23]; 19. MWCNT (14 nm) [27]; 20. SWCNT (1.7 nm) [7]; 21. SWCNT (1.0 nm) [28]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

nanofluids containing multiwalled carbon nanotubes showed higher thermal conductivity than the base fluid without CNT. Good performance of nanofluid has also been confirmed by Chein et al. [9], who studied the performance of microchannel heat sink using Cu/water nanofluids as coolants. They found that the performances were greatly improved when compared with that using pure water due to the increase in thermal conductivity of coolant and the nanoparticle thermal dispersion effect. Recently, Beriache et al. [10] noticed that the magnetic nanofluid loaded with drug can be delivered tumor site in cancer treatment. Many other researchers have acknowledged the significant role of nanofluids in many engineering fields [11–17].

The discovery of carbon nanotubes (CNTs) perhaps contributed to the nanotechnology revolution owing to its superior thermal, physical, optical and electrical properties and has ultimately evolved into one of the most intensively studied nanomaterials. Carbon nanotubes (CNTs) was discovered by a Japanese scientist, Iijima [18]. However, according to Monthioux and Kuznetsov [19], it turned out that the discovery of CNTs goes back much further than 1990s. As a matter of fact, CNTs with multi walled configuration, also known as multi-walled carbon nanotubes (MWCNT) was first discovered in 1951 by Russian scientists Radushkevich and Lukyanovich [20]. Forty years later, another type of CNT with single wall, also known as single walled carbon nanotube (SWCNT) was discovered by Iijima and Ichihashi [21] in 1993. Due to unusually high thermal conductivity of CNTs, many researchers have diverted their research focus to further understand the fundamental characteristic of CNTs and their applications in heat transfer system. Thermal conductivity of various metals, metal oxides, and liquids is shown in Fig. 1.

CNT nanoparticles have been dispersed in base fluid to enhance the thermal performance of the mixture. Choi et al. [29] possibly the first group who had studied CNT contained nanofluids. MWCNT nanoparticles with concentrations up to 1 vol% were added into poly-alpha olefin (PAO) oil. They found that the maximum thermal conductivity ratio (k_{nf}/k_{bf}) has exceeding 2.5. Since then, numerous studies on CNT nanofluids can be seen in the literature.

Based on the above brief review, many articles admitted the enhancement of thermophysical properties of fluid when CNTs were dispersed in base fluid. In this paper, further review is conducted to understand the preparation methods, factors for enhancing thermal conductivity, and the application of CNTs nanofluid in energy harvesting system.

2. Preparation methods of CNTs and CNTs nanofluids

Although carbon is ubiquitous in nature, CNTs are not, as it is a man-made form of carbon. Arc discharge, laser ablation, chemical