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Optical properties of liquid paraffin contained with Al_2O_3 nanoparticles

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ABSTRACT

The present work is to experimentally investigate the optical properties of liquid paraffin contained with Al_2O_3 nanoparticles for application in glazed envelope. Paraffin-based Al_2O_3 nanofluids were prepared through two-step method and its transmittance spectrum was measured by a TU-19 FTIR spectrometer. Based on the optical properties of liquid paraffin contained with Al_2O_3 nanoparticles obtained by model calculation, the changes of optical properties of liquid paraffin filled with and without Al_2O_3 nanoparticles are compared. The results show that compared with pure paraffin, the presence of Al_2O_3 nanoparticles decreases the transmittance of liquid paraffin by 15.7% in 5 mm optical path when the concentration is 0.001 vol%, and the nanofluids absorption coefficient is about 20.07 m^{-1} in the visible spectrum, which is almost 4 times that of pure paraffin. Meanwhile, the addition of Al_2O_3 nanoparticles makes the reflectivity of paraffin increase by 0.022. This conclusion is useful in analyzing glazed envelope contained Al_2O_3/paraffin nanofluids and provides a method of solar energy harvesting.

1. Introduction

As a clean and renewable energy, solar energy is used to produce electricity, steam and hot water [1]. Besides using appropriate technologies to collect solar energy, the adoption of suitable materials in buildings components can also harvest solar-thermal energy [2]. Phase Change Material (PCM) is a new type of chemical material, which can absorb or release heat by changing phase at a specific temperature. Therefore, it can be used to control the temperature of surrounding environment for reducing energy consumption at a building scale [3].

Recently, there has been a noticeable work on filling the glass envelope with paraffin, for optimizing the shortcomings of window with small thermal inertia [4–6]. This technique absorbs the solar thermal energy directly, which will reduce the heat loss and enhance thermal comfort in building. As a kind of PCM, paraffin has an excellent capacity of energy storage without influence the transmittance of glass [7]. However, the thermal conductivity of paraffin is small and the heat storage time is long, which limit its application in the glass envelope. Scholars studied to strengthen the heat transfer of paraffin, such as placement of metal conductors and embedded metalloid [8–11]. However, these above methods all disturb sunlight transmission, which affect the light transmission properties of the glass envelope.

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With the development of nanotechnology, the addition of nanoparticles with high thermal conductivity in paraffin can achieve the purpose of rapid photothermal conversion and thermal expansion. Meanwhile, Al_2O_3 nanoparticles have unique advantages, such as high thermal conductivity, small size effect, and surface effect [12]. Furthermore, nanofluids, stable suspensions of paraffin containing Al_2O_3 nanoparticles, have numerous prospects of application as a burgeoning kind of material to capture solar energy. It can effectively improve the heat transfer performance, promote the heat absorption, and intensify the paraffin storage process [13]. Also, the optical properties of Al_2O_3 nanoparticle changed widely, which leads to have a special photo absorption property.

The optical properties of nanofluids have gained attention due to their potential use in absorbing solar-thermal energy. Karami et al. [14]. Experimentally investigated the optical properties of CuO nanofluids, and found that the absorption rate increased by 4 times under the same thickness, and the CuO nanoparticles effectively increases the absorption of light at 100 ppm concentration. Especially, even extremely small amounts of nanoparticles can significantly alter the optical properties of base fluid. Said et al. [15] found that SWCNTs-water nanofluids exhibit important enhancement of thermophysical and optical properties at low volume concentration compared to water. Furthermore, the authors demonstrated that the outstanding aptitude of SWCNTs nanofluids to absorb solar energy. Yousefi et al. [16] studied the optical absorption properties of Al_2O_3-H_2O nanofluid suspension composed of Al_2O_3-H_2O. The results show that the water based Al_2O_3 nanofluid had a high solar absorption capacity compared with the pure water. Zhang et al. [17]. Studied the absorption spectra of water-Au nanofluids with different volume concentrations. They observed a clear improvement in the light absorption efficiency of the water-Au nanofluid with addition of only 0.15 ppm of nanoparticles. Although scholars studied the optical properties of nanofluids, less data have been reported on the spectral characteristics of Al_2O_3/paraffin nanofuilds. For enhancing solar-thermal conversion efficient of paraffin in the glass envelope, the exploration of Al_2O_3/paraffin nanofluids spectral properties is important in the utilization of solar energy.

In this work, Al_2O_3/paraffin nanofluids were prepared. The transmittances of nanofluids and pure paraffin in visible spectrum were investigated with different optical paths. Based on the transmittance spectra modeling, the absorption coefficient and reflectivity of Al_2O_3/paraffin nanofluids were calculated. The main purpose of this study is expected to provide optical guidance to design Al_2O_3/paraffin nanofluids in glazed envelope.

2. Material and methods

2.1. Experimental method

Three techniques are applied in producing nanofluids, including single step direct evaporation technique, one step chemical technique, and the two-step technique. Two-step technique is chosen by experimental preparation of Al_2O_3/paraffin nanofluids, as a result of its simply process and economic benefits. Due to the high surface energy and the van der Waals forces between the nanoparticles, it is inevitable produce the phenomenon of clustering, aggregation and sedimentation [18]. Therefore, besides the physical dispersion method, Hexadecyl trimethyl ammonium bromide (CTAB), as a kind of surfactants, is used in the preparation of Al_2O_3/paraffin nanofluids to minimize this problem in experimental process. Moreover, to assess the optical properties of nanofluids, its transmittance spectrum was measured by a TU-19 FTIR spectrometer

2.2. Preparation of nanofluids

The reagent grade chemical reagents are used in the experiment. Nano-Al_2O_3 powders were supplied by Shanghai Macklin, Shanghai Nanotechnology Co. Ltd, and the particle size is 10 nm. The melting temperature of paraffin is 18 °C In the experiment, the temperature of paraffin is keeping 23 ± 1 °C CTAB powders were used to disperse particles of agglomeration. Physical dispersion methods (mechanical agitation and sonication) and Chemical dispersion (dispersant) are used to increase the dispersibility of the nanofluids.

At first, a proper amount of Al_2O_3 and appropriate volume of paraffin were added into a round-bottomed beaker, for producing suspensions with Al_2O_3 concentration of 0.001 vol%. Reference the fraction in previous work, the concentration of CTAB is 0.0005 vol% [19]. Then, the mixture solution was kept fluid state under magnetic stirring. After stirring 30 min, the mixture was then treated for 1.5 h under ultrasonication. The resulting nanofluids were used for subsequent procedure of spectral measurement.

2.3. Transmittance modeling

Assumptions of the model are as follows:

1) All the Al_2O_3 particles are of same size and spread evenly.
2) The transmission spectrum of a pure sample is obtained by using the ratio of transmittance, in order to eliminate the influence from cell.
3) The paraffin and glass are homogenous and non scattering.
4) Optical properties of nanoparticles are homogenous and same as their materials.