Evaporation of carbon nanotube nanofluid with bubbles under sun illumination

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Introduction

Water and energy are essential elements for life and are closely linked to human beings, for example for biological survival and reproduction, economic development and social progress. As the population grows and industry develops, clean water and energy supplies will receive more attention in the coming decades. The current widespread use of reverse osmosis and membrane distillation technologies in seawater desalination both generate significant energy consumption. Solar energy, as an abundant renewable energy source, is a promising alternative to conventional energy sources for water evaporation. Steam from solar water evaporation has been used as clean water since ancient times, and solar desalination occupies an important place in long-term energy strategies. However, the energy density of solar energy is low and improvements are needed to improve its absorption efficiency, photothermal conversion efficiency

Much research has been devoted to improving photothermal conversion systems. In terms of materials, nanofluids have been extensively studied since the very beginning of volumetric heating systems. Metal-based materials can greatly facilitate evaporation due to their equipartition excitation effect, but are of course generally more expensive. Carbon based materials have a broad spectrum absorption capability and the main evaporation mechanism is thermal relaxation. From a structural point of view, volumetric evaporation to interfacial evaporation to local thermal concentration all contribute to an increase in photothermal conversion efficiency. In this paper, carbon nanotube nanofluids are prepared and bubbles are introduced to promote vapour generation and the vapour generation apparatus is explored. Due to their intrinsic properties, carbon nanotubes have full-spectrum absorption at very low concentrations, resulting in large thermal efficiencies. In addition, the introduction of bubbles greatly expands the light scattering centre and provides a large gas-liquid evaporation interface to enhance mass transfer. A new idea is provided for solar thermal evaporation.

Experimental setup

The porous sintered body is embedded in the bottom of the acrylic column (inner diameter 2 cm, height 4 cm) and the sintered body is connected to an air pump. The power of the pump is adjustable and the connection hose is equipped with a check valve, which ensures the flow of water and stabilises the flow rate and controls the flow pattern. Temperature changes at the gas-liquid interface are measured with an infrared camera and recorded with thermocouples in the middle and bottom of the vessel. A solar simulator (SolaConstant 4000 Single Control), which is standard for experiments, was used as the light source. And the change in the mass of the moisture was recorded. The experiments were carried out under controlled conditions with an ambient temperature of 15°C at atmospheric pressure. The irradiation intensity was kept constant at approximately 700 W/m2.

Preparation of nanofluids

In this paper, a certain 0.025g of carbon nanotube nanoparticles were weighed, 500ml of deionised water was added and then stirred for 15 minutes at 700r/min in a magnetic stirrer. A certain amount of dispersant methylcellulose na was added during the stirring process, after which it was put into an ultrasonic oscillator for ten minutes to fully disperse and obtain carbon nanotube nanofluid. It is worth noting that sodium methylcellulose na is agglomerative and needs to be added slowly and disturbed with a glass rod during the addition process. The higher the sodium methylcellulose na content the thicker the aqueous solution will be, and the thicker the methylcellulose na solution can be added directly to the nanofluid during subsequent preparation, thus saving time in large-scale preparation.

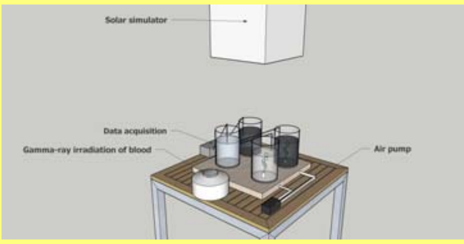

Fig1 Experimental setup diagra

Experiment

The spectral properties of carbon nanotubes were measured by UV3600 to compare the best concentration characteristics. Comparative evaporation experiments were also carried out under a solar simulator. Relevant data were obtained

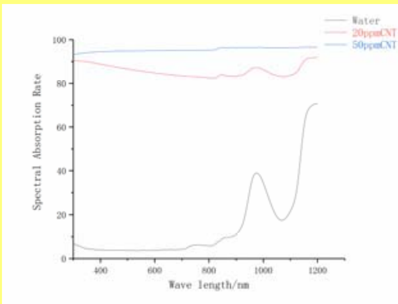

Fig.2 Comparison of absorbance of 10mm cuvettes

Results

Effect of surface temperature changes

The transient surface and bottom temperatures of the working fluids are shown in Figure Fig 5. For the surface temperature of the fluid, the nanofluid has the highest temperature, which is close to 35°C, and is higher than the other three throughout the process. After the bubbling effect is applied to the liquid, the final temperature gradually tends to a stable value and is significantly lower than without the bubbling effect. This is due to the fact that a large evaporation interface is formed on the surface of the liquid and the bubbles evaporate as soon as they reach the surface, creating a dynamic and stable process, a condition that greatly facilitates the evaporation process. This explains the intersection of the pure water line with the two lines where the bubbling action is applied.

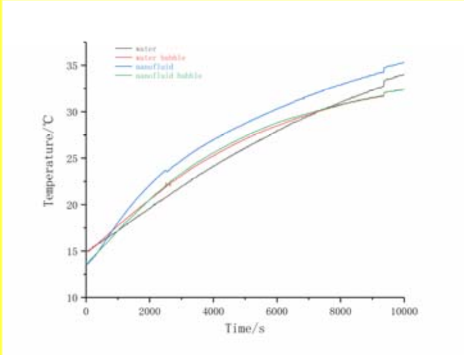

Fig.3Surface temperature change

Fig4 shows the evaporation performance of the CNT nanofluid and it can be seen that either converting the liquid into a nanofluid or applying bubbling to the liquid promoted evaporation to occur. In three hours, 5.4g of pure water evaporated, 11.3g of pure water evaporated after bubbling, 12.8g evaporated after preparation into 50ppm CNT nanofluid, and 19.6g evaporated after applying bubbling to the nanofluid, reaching more than three times the amount of pure water evaporated.

The evaporation rate of the CNT nanofluid alone was 0.543 kg-m-2h-1 which is 2.37 times that of pure water, and the rate of evaporation by application of bubbling was 0.479 kg-m-2h-1 which is 2.09 times that of pure water, while the coupled evaporation rate of the two was a staggering 0.831 kg-m-2h -1 reaching 3.62 times that of pure water. This can be attributed to the broad-spectrum heat collection properties of the nanofluid and the fact that the rupture of the bubbles greatly facilitated the evaporation surface when the bulb was applied.

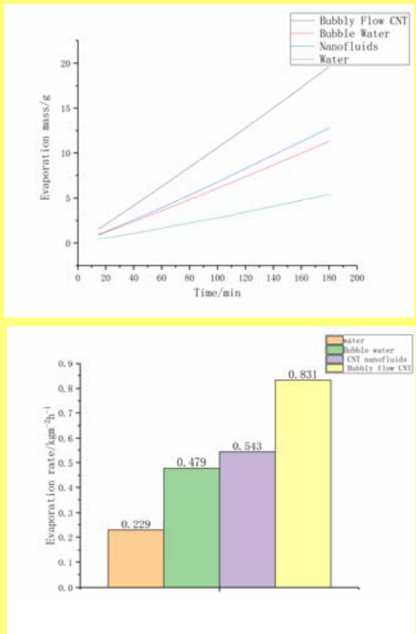

Fig.4 Evaporation volume and evaporation efficiency

Conclusions

The broad-spectrum absorption of the nanofluid, coupled with the huge evaporation interface in the presence of bubbles, can greatly facilitate the production of vapour evaporation, which can reach about three times higher than in the natural case. This provides a new idea for desalination evaporation

References

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