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Synthesis and Characterization of Novel (Organic–Inorganic) Nanofluids for Antibacterial, Antifungal and Heat Transfer Applications

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Nanofluids have many applications for modern industries such as: thermal energy storage and release for heating/cooling systems, antibacterial and antifungal for medical applications. Thus, this paper aims to preparation of novel nanofluids have highly antibacterial and antifungal activities to prevent the bacterial and fungal presence for biomedical applications. Also, it have high quality for thermal energy storage and release for heating/cooling of buildings. The (PEG-PVP-TiC-H_2O) nanofluids are fabricated with different weight percentages of polyethylene glycol, polyvinyl pyrrolidone and titanium carbide nanoparticles. The titanium carbide nanoparticle was added to (PEG-PVP-H_2O) fluid with different concentrations of (0, 4, 8 and 12) wt.%. The optical properties and thermal conductivity of nanofluids have been investigated. The experimental results showed that the transmittance of (PEG-PVP-H_2O) fluid decreases and the absorbance increases with the increase of TiC nanoparticles concentrations. The thermal conductivity of (PEG-PVP-H_2O) fluid is increased with the increase of TiC nanoparticles concentrations. The biomedical applications have been included the antifungal and antibacterial activities of nanofluids which are tested against aspergillus, bacillus and streptococcus organisms. Results of test showed the (PEG-PVP-TiC-H_2O) nanofluids have high antifungal and antibacterial activities. The inhibition zone diameter of antifungal and antibacterial tests increases with the increase of TiC nanoparticles concentrations. The prepared nanofluids tested for storage of thermal energy and release, the results found the melting and solidification times are decreased with the increase of TiC nanoparticles concentrations. The (PEG-PVP-TiC-H_2O) nanofluids have high antifungal and antibacterial activities for gram positive organisms and gram negative organisms. Also, the (PEG-PVP-TiC-H_2O) nanofluids have high thermal storage for heating/cooling systems.

Keywords: Biomedical, Energy Storage, Heat Transfer, Nanofluids, Titanium Carbide.

RESEARCH ARTICLE

1. INTRODUCTION

Nanofluids can be considered as a new kind of fluids prepared by squandering (nanometer-sized) materials such as nanoparticles, nanotubes, nanofibers… etc. in base-fluids. Nanofluids are two-phase systems with one phase which is solid phase in another liquid phase. They have enhanced thermal properties such as thermal conductivity and diffusivity, viscosity, and heat transfer coefficients if compared to those of base fluids such as water or oil. It has large prospect applications in considerable fields. The secular variation of energy source and energy demands made needful the evolution of storage system. The saving of thermal energy in the form of sensible and latent heat has become an important part of thermal energy management with the confirmation on efficient use and saving of solar energy in industry and buildings. A good performances of thermal aspects of nanofluids (PCMs) denoted that they have a prospect for replacing classic PCMs in cool storage applications. Energy due to solar is one of the best type of sustainable energy with low environmental effect. Now a day, this technology has been collected with the emerging technology aspects of nanofluids and suspensions of liquid-nanoparticle to make a new type of nanofluid used in solar collectors. Some types of nanoparticles can be use as antibacterial activities or drug-transmission properties.[1]

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Energy costs have climbed rapidly in the last decade and there is giant need for new types of heating/cooling fluids, to improve heating system duty and to reduce equipment size and energy consumption rates. Nanofluids are new seed heat transfer fluids for various industrial and automotive employment because of their superior thermal performance. Despite of these nanofluids have interesting potential and can be used to substitute popular fluids for advanced thermal applications, however they are still in the early stages of development.[2] Some popular applications are:[3] cooling of engine, gas recovery of boiler exhaust flue, electronic circuit cooling, cooling of nuclear system, thermal storage, and bio-medical application. Antimicrobial agents like antibiotics have been widely used to hold or kill microorganisms. The mechanisms that underlie the growth of bacterial resistances to antimicrobial agents and resistance mechanisms of grade bacterial into three groups (three defense lines) as shown in Figure 1: the first defense line is bacterial biofilms, the cell wall, cell membrane and encased efflux pumps including the second defense line, finally, bactericides get into the bacterial cells, intracellular biochemistry and genetic responses perform an important role in resistances and are considered as the third line of defense.[4] In general, the infectious diseases development poses a dangerous impendence to health, particularly with the antibiotic-resistant bacterial strains development. Both positive and negative-Gram bacterial strains are intellect to present a major assembly health problem. For the last years, antibiotics have been used to monitoring infections due to both community and hospital environments. Current profits in the field of nano-biotechnology, especially the capability to supply metal oxide nanomaterials of particular shape and size.[5] This paper aims to preparation of novel nanofluids have highly antibacterial and antifungal activities to prevent the bacterial and fungal presence for biomedical applications. Also, it have high quality for thermal energy storage and release for heating/cooling of buildings and low cost.

2. MATERIALS AND METHODS

The fluids of polyethylene glycol (PEG)-polyvinyl pyrrolidone (PVP) polymer blend as phase change materials are prepared by dissolving 0.5 gm of polymers (50 wt.% PEG and 50 wt.% PVP) in 30 ml of distilled water by using magnetic stirrer to mix the polymers to obtain more homogeneous solution. The TiC nanoparticles are added each one to PCM fluids mixture with different concentrations are (0, 4, 8 and 12) wt.%. The optical properties of nanofluids are measured by using the double beam spectrophotometer (shimadzu, UV-1800 Å) in wavelength (220–800) nm. The thermal energy storage and release of nanofluids PCMs include analyzing the melting and solidification characteristics during heating and cooling processes. The water and nanofluids PCMs were used as the heat transfer nanofluid, whose temperature can be varied from 30 °C to 100 °C with stirrer and measuring the temperature of nanofluids during the heating and cooling processes by digital device. The antibacterial and antifungal activities of (PEG-PVP-TiC) nanofluids PCMs tested samples was examined using a disc diffusion method. The antibacterial and antifungal activities of nanofluids were done by using fungus organisms, gram positive organisms and gram negative organisms are aspergillus, bacillus and streptococcus organisms. The fungus organisms,

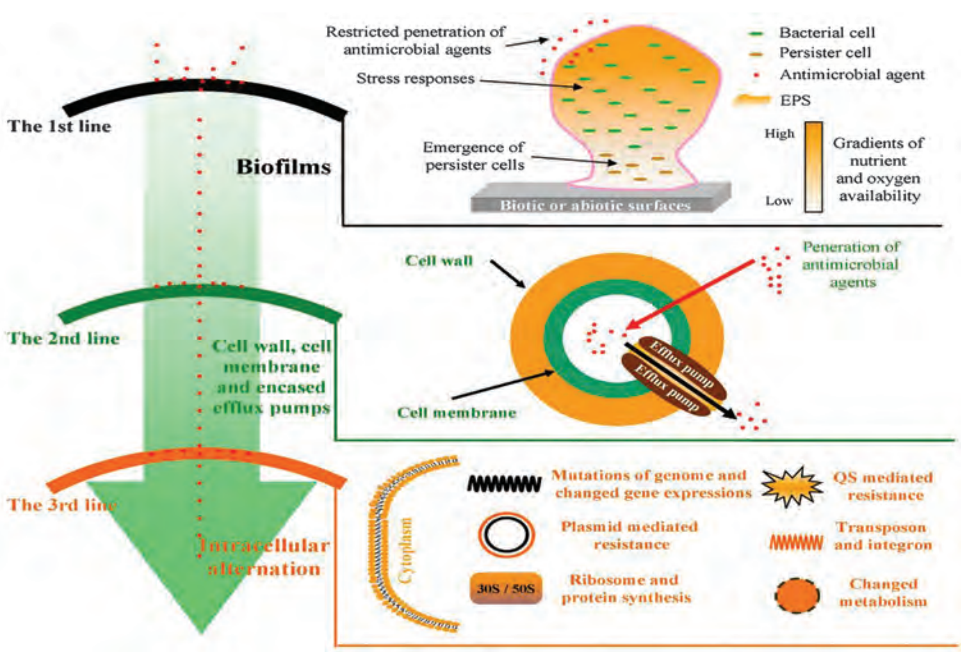

Fig. 1. Schematic representation for the three-defense lines mechanism.[4]

gram positive organisms and gram negative organisms were cultured in Muller-Hinton medium. The (PEG-PVP-TiC) nanofluids were placed over the media and incubated at 37 °C for 24 hours. The inhibition zone diameter of the (PEG-PVP-TiC) nanofluids was measured.

3. RESULTS AND DISCUSSION

The transmittance spectra of the (PEG-PVP-TiC) nanofluids are presented in Figure 2. The major absorption, corresponds to excitation of electron from conduction bands to the valance, is used to define the value and nature of the optical band cavity. The maximum transmittance is 0.61 at $\lambda = 800$ nm in visible region and low transmittance in the UV-region for (PEG-PVP) blend and had a slightly increased in the visible region. In generally, it can be interpreted that single photons with energy greater than the materials band cavity that will be absorbed more and that of extended wavelength will push through (or transmitted) having simply adequate energy to excite electrons. This means that light can be transmitted in wavelength regions confined by the band gap. Figure 2 shows that there is a slight decrease in transmission with raised of TiC concentration for nanoparticles doping, this may be demonstrate in terms of a cross linking reduction, the light transmission will decreases and light absorption will increases as shown in Figure 3. It is obviously that the transmittance displays a ramp decrease at high spectrum photon energy, pointing out the strong absorption bands existence in the UV-region. The photon energy corresponding to the minimum transmittance at the wavelength $\lambda =$ 220 nm besides from the graphs it is observed that the maximum absorption peaks are corresponding to the minimum transmittance peaks. The absorption of an optical medium can be sometimes quantified in terms of the optical density which is sometimes called the absorbance (Fig. 3). The measurement of the essential absorption edge supplies a standard method for the implementing of optically induced electronic transitions and can supplies some conception about the band structure and energy cavity in both (crystalline and non-crystalline) materials. Finally

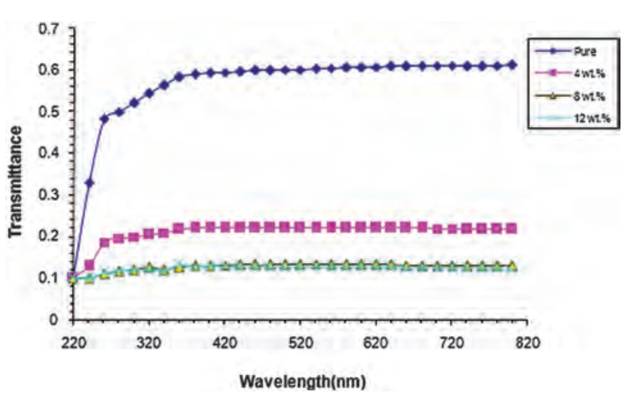

Fig. 2. Transmittance spectra of the (PEG-PVP-TiC-H_2O) nanofluids.

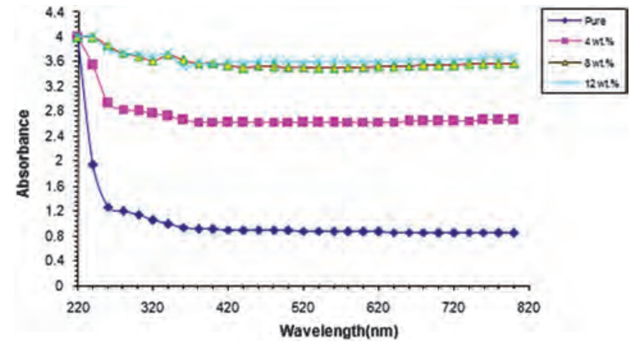

Fig. 3. Absorbance spectra of the (PEG-PVP-TiC-H_2O) nanofluids.

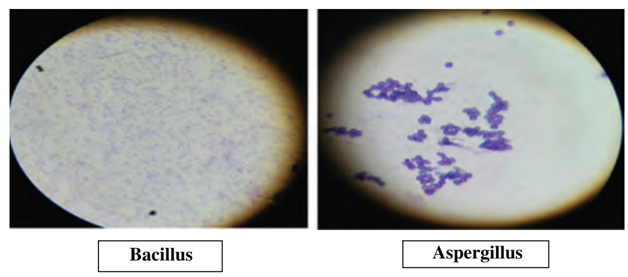

Fig. 4. Images of bacteria organisms and fungus organisms.

increase in absorption may be respected as onset of optical inter band transition.[6] The increase in absorption is mainly due to the increase in TiC nanoparticles concentration causing more and more inter-/intrahydrogen bonding. This can be enlightened more by using Beer's law which states that the absorption of radiation is directly proportional to the number of absorbing molecules in the sample. The shift witnessed in the absorption edge of the doped (PEG-PVP) blend is essentially due to the variation in crystalline parameters which in turn changes the energy band gap.[7] The behavior of absorbance with wavelength consistent with the results of papers.[8–12] The photo images of bacteria and fungus organisms is shown in

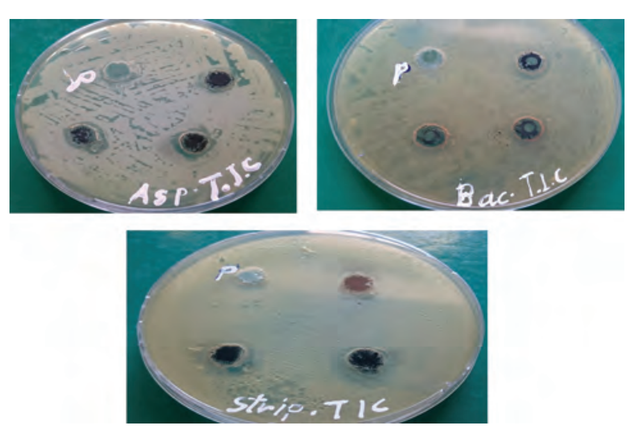

Fig. 5. Antibacterial and antifungal activities of (PEG-PVP-TiC-H_2O) nanofluids against gram-positive organisms and gram-negative organisms and fungus organisms.

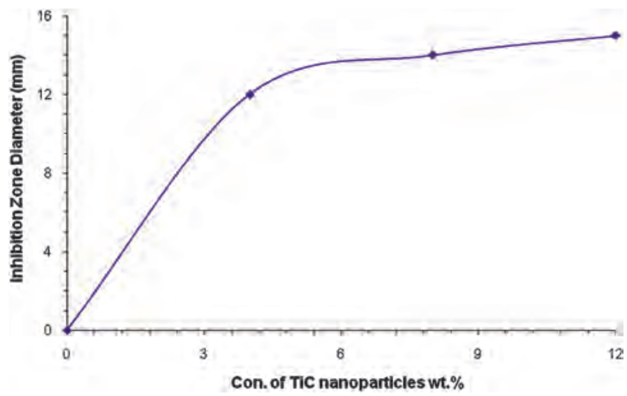

Fig. 6. Antifungal activity of (PEG-PVP-TiC-H_2O) nanofluids against aspergillus organisms.

Figure 4 which are used in this paper. Figure 5 shows the antibacterial and antifungal properties of (PEG-PVP-TiC) nanofluids against fungus organisms, gram-positive organisms and gram-negative organisms are aspergillus, bacillus and streptococcus organisms. This figure presents that the inhibition zone is increases with increasing the nanoparticles concentrations. Small nanoparticles were able to be the most worthy of piercing in bacteria cell bodies involvement with cell membranes, and sequent. The nanoparticles electrostatic interaction with positive zeta potential and surfaces of negatively charged bacteria withdraw the particles to the bacteria and elevate penetration into the membrane. Generation of reactive oxygen species is also a roughly universally qualified mechanism of nanoparticle antibacterial activity. The physical existence of a nanoparticle extreme likely ruptured cell membranes in a manner of dose-dependent.[13] The potential mechanism of work is, the metal nanoparticles are holding the positive charges and the microbes holding the negative charges which generate the electromagnetic attraction between the nanoparticles and the microbes. After the attraction process, the microbes will be oxidized and die immediately. In general, the nanomaterials emitting ions that react with the thiol groups (–SH) of the proteins sitting on the bacterial cell surface which driving to cell lysis.[14] Figure 9 presents the values of thermal conductivity for (PEG-PVP-TiC) nanofluids for different TiC nanoparticles concentrations. As shown in figure, the thermal conductivity increases with increase the titanium carbide nanoparticles, this behavior made a strong structure of network chain, that execute as heat conduction routes presenting anomalously higher thermal conductivity raised if compared to the Maxwell model.[15] Figures 10 and 11 display the melting and solidification

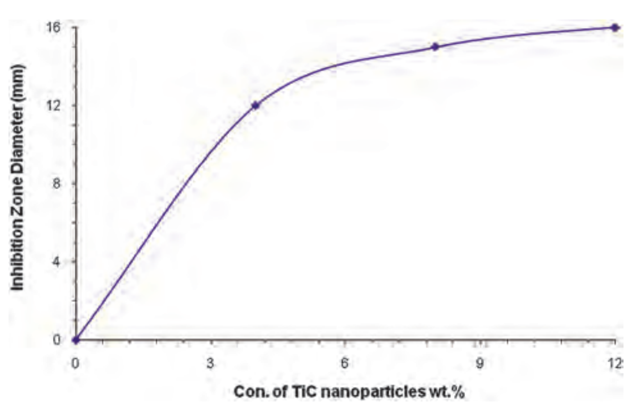

Fig. 7. Antibacterial activity of (PEG-PVP-TiC-H_2O) nanofluids against bacillus organisms.

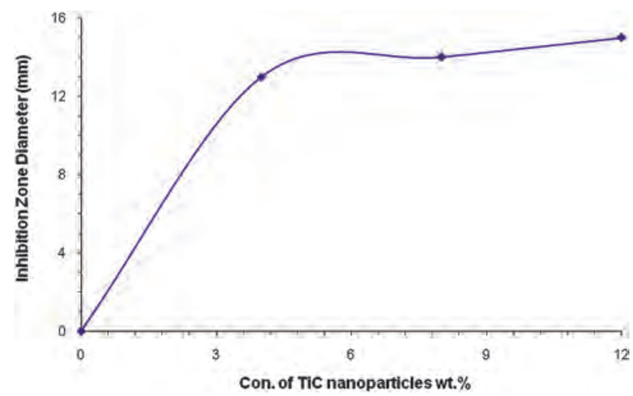

Fig. 8. Antibacterial activity of (PEG-PVP-TiC-H_2O) nanofluids against streptococcus organisms.

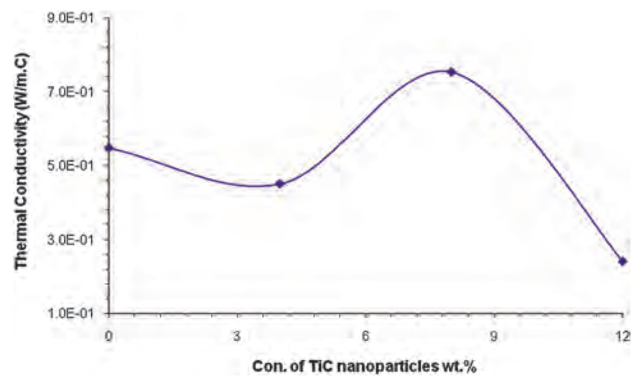

Fig. 9. Thermal conductivity of (PEG-PVP-TiC-H_2O) nanofluids.

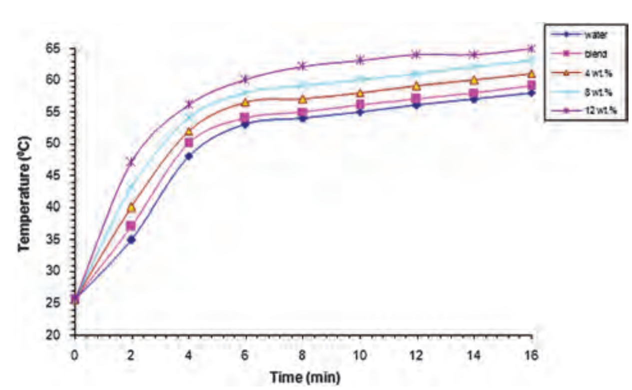

Fig. 10. Melting curves of (PEG-PVP-TiC-H_2O) nanofluids.

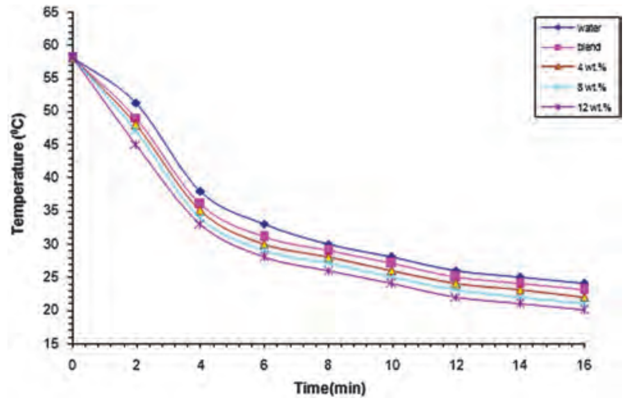

Fig. 11. Solidification curves of (PEG-PVP-TiC-H_2O) nanofluids.

curves for (PEG-PVP-TiC) nanofluids, respectively. The time of melting and solidification decreases with inserting nanoparticles concentrations of TiC, This a good criteria to evolve the entire thermal conductivity of (PEG-PVP) nanofluid. Energy storage and release average are substantial signals to increase the efficiency of heat transfer. The decrease of melting and solidification time related to improve the thermal conductivity. The (PEG-PVP-TiC) nanofluids can be take into consideration as energy storage material to save relief domestic environment.[16–20]

4. CONCLUSIONS

1—The transmittance decreases and absorbance increases of (PEG-PVP-H_2O) fluid with increasing of titanium carbide nanoparticles concentrations.

2—The thermal conductivity of (PEG-PVP-H_2O) fluid increases with increasing of TiC nanoparticles concentrations.

3—The (PEG-PVP-TiC-H_2O) nanofluids have high antifungal and antibacterial activities for gram positive organisms and gram negative organisms.

4—The (PEG-PVP-TiC-H_2O) nanofluids have high thermal storage for heating/cooling systems. The (PEG-PVP-TiC-H_2O) nanofluids can be take into consideration as energy storage material to save relief domestic environment.

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