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Enhancement of Efficiency of Solar Plate Receiver Using Selective Coating of TiO_2 Nanofluids

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ABSTRACT

The main objective of this paper is to minimize irradiative heat loss and to enhance absorption of incoming solar radiation as much as possible using TiO_2 nanofluids. The cavity receiver is an important part for solar energy collection. Currently efficiency of solar cell is very less around 10 percent. The performance of solar system can be improved by effective coating of TiO_2 nanoparticles at receiver end. The utilization of sunlight from UV to visible range or near IR range is an active issue in this field. The energy transfer process activates the photo catalytic reaction on the surface of TiO_2. On the other hand, plasmonic materials show size dependable surface Plasmon resonance. Due to oscillations of free electrons in the plasmonic metals, strong light absorption take place and can generate large electric field near the surface. Quantum confinement plays the role with particle size reduction thereby causing changes in energy band. Combining both effect using semiconductor nanoparticles (TiO_2) is effective to enhance the efficiency of solar plate receiver.

Keywords : Solar Energy, Tio_2 Nanoparticles, Surface Coating, Quantum Confinement

I. INTRODUCTION

Entire world's facing the problems of global warming due to release of hazardous gases in the atmosphere from fossil fuel consumption. India is the world's third largest electricity generator with total installed capacity of 3,26,832 MW out of which 1,92,162 MW is coal based. Due to increase in population makes larger energy users in the country [1]. The pollution and temperature of world enhancing continuously and world facing the problems of shortage of conventional energy sources such as fossils fuels. Therefore researcher found a renewable source of energy which is non pollutant, clean source of energy and can fulfil the world total energy consumption. Solar energy seems to be the most viable choice to meet our clean energy demand [2]. The sun continuously delivers to the earth almost 5×10^{24} J of energy per year and hits the surface of the earth. This quantity is 10,000 times higher than the actual annual energy consumption of the whole world. [3]. Solar energy has many advantages over any other renewable energy sources. But solar systems are facing the problems of low optical and thermal performance. So researcher need to design a solar collector system using various shapes of collector plate for efficient absorption of solar radiation and to be converted into heat and electricity for useful applications. The receiver cavity is the important components for solar energy receiver. Different types of heat losses observed in case of cavity receiver of solar thermal systems. Various types of receiver are being used in the concentrated solar system such as, cylindrical cavity receiver, conical cavity receiver, spherical cavity receiver etc.

Nanotechnology Boosts Solar Cells Performance

Nanotechnology is the synthesis and applications of ideas from science and Engineering towards the understanding and production of novels materials with small scale [4]. Currently though solar cell is use for conversion of light energy into useful ones but it cannot convert all incident light into useful energy because of poor absorption. Sunlight includes electromagnetic spectrum of all wavelengths and absorption efficiency varies from wavelength to wavelength. Light of energy less than band gap energy does not excite electrons from valence band to conduction band and hence it is not useful. Light of energy greater than band gap energy excite electrons from valence band to conduction band but excess energy is given out in the form of heat. If these excited electrons aren't captured and redirected, they will spontaneously recombine with the created holes, and the energy will be lost as heat or light [5].

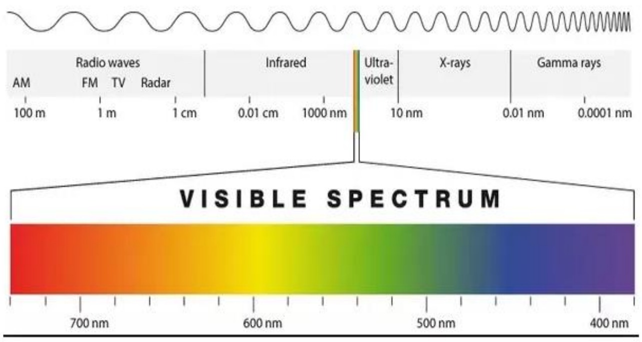

Figure 1. Electromagnetic spectrum

II. EXPERIMENTAL DETAILS/ANALYSIS

2.1 Synthesis of TiO2 nanoparticles

All chemicals used were of analytical grade. Aniline, ammonium persulphate, ammonium hydroxide from SD Fine Chemical, India. Titanium tetrechloride and sulphuric acid from Merk were used as received without further purification. Double distilled water was used throughout this work. The flow chart for the preparation of TiO2 nanoparticles as shown in figure 2.

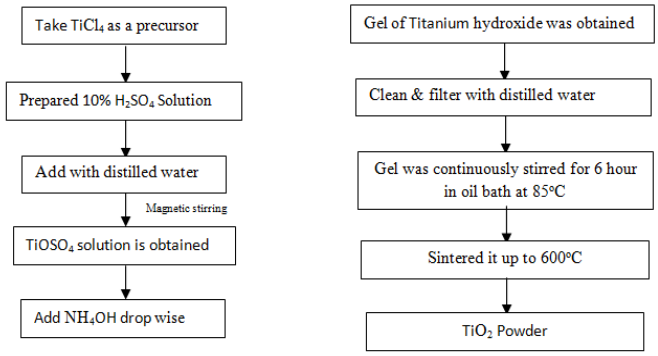

Figure2. Flow chart for synthesis of TiO_2 Nanoparticles

2.2 X-ray Diffractometry (XRD) Analysis

The x-ray difractogram of the nano sized tin oxide is obtained by using a Philips Holland, PW-1710 x-ray difractometer having Cu k_α x-ray radiation of wavelength λ=1.5405A^0 and 1.5443A^0 and a continuous scan of 2^0/ min at 35 KV and 20 mA. The crystal structure of prepared sample was characterized by X-ray diffraction (XRD). A XRD pattern of the prepared TiO_2 powder is shown in figure 3. The broadness of the diffraction peaks as obtained in XRD spectrum gives the direct consequence of the reduced particle size. The diffraction peaks are observed around 25, 35.83, 48.01 and 62.07 respectively. All diffraction peaks can be perfectly indexed to the rutile structured TiO_2, which match well to the reported value for TiO_2 crystal (JCPDS card, No. 41-1445) and but some impurity phases was observed. It is clear to see that the width of the reflections are considerably broadened, indicating a small crystalline domain size.

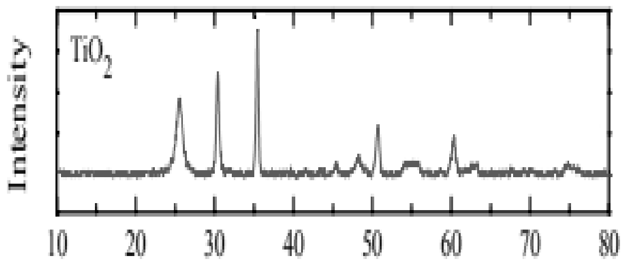

Figure 3. XRD pattern of TiO2 nanoparticles

2.3 Types of Solar Collector

There are three types of solar collectors that are described below.

A. FLAT PLATE COLLECTOR

A simple construction of flat-plate solar collector consists of a waterproof, metal or fiber glass insulated box with dark black colored absorber plate, with one or more transparent glazing. The absorber plates of solar flat collector are typically made out of metal due to its high thermal conductivity and it is painted with special selective surface coatings in order to absorb and transfer heat better than regular black paint. The glazing covers reduce the convection and radiation heat losses to the environment. The collector gains energy from the photons of sun.

B. INTEGRAL COLLECTOR STORAGE SYSTEMS

Furthermore, ICS (integral collector storage) or batch systems contain one or more black tanks or tubes in an insulated, glazed box. The water then continues on the conventional backup water heater, providing a steady source of hot water. Generally it should be installed only in the mild freeze climates because the possibility of to freeze the outdoor pipes in the cold weather.

C. EVACUATED TUBE SOLAR COLLECTORS

They feature parallel rows of transparent glass tubes. In each Evacuated tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar thermal energy but inhibits radioactive heat loss. It is a very popular solar collector is in present time. This is a direct and very effective way to heat the water from the sun, but it is also expensive to set up

III. RESULTS AND DISCUSSION

3.1 Ultrasonic velocity measurement

Ultrasonic velocity measurements were carried out using multifrequency interferometer (Mittal F-83 model) techniques at the frequency of piezoelectric transducers 1MHz with accuracy ± 1m/sec. A Thermostat (Lab Slab) controls the temperature of the liquid to an accuracy of ± 0.1°C. Fig.4 shows the variations of ultrasonic velocity with increase in concentration of TiO2 nanoparticles in methanol at 300K. The variation in ultrasonic velocity initially increases, exhibit a pick at molar concentration of 0.004 and dip at 0.006 molar concentrations. Due to highly polar nature of methanol, it induces dipole moment in TiO2 nanoparticles and methanol molecule gets interact with TiO2 nanoparticles through dipole-induced dipole type of interaction. Therefore the rise in ultrasonic velocity can be concluded as the strong interaction among the components of the mixture, molecular agglomerisation and hence sound will travel faster through the more compact structure by means of longitudinal waves. Hence, there might be particle-fluid interaction which favors increase in the ultrasonic velocity values [6].

3.2 Thermal conductivity Measurement

The thermal conductivity of TiO2 nanofluids are studied at low volume concentration by non destructive techniques using obtained experimental acoustical data at 300K. Author used M. Nabeel Rashin, J. Hemalatha model [7] to determine thermal conductivity of nanofluids from obtained experimental values of ultrasonic velocities. Figure 5 shows the increase in thermal conductivity with rise in concentration of TiO2 nanoparticles in methanol.

The maximum rise in the value of thermal conductivity at 0.004 molar concentration indicates that there is more particle- fluids interaction. This result therefore reflects the influence of addition of nanoparticles in a suspension medium upon thermal conductivity at low volume concentration.

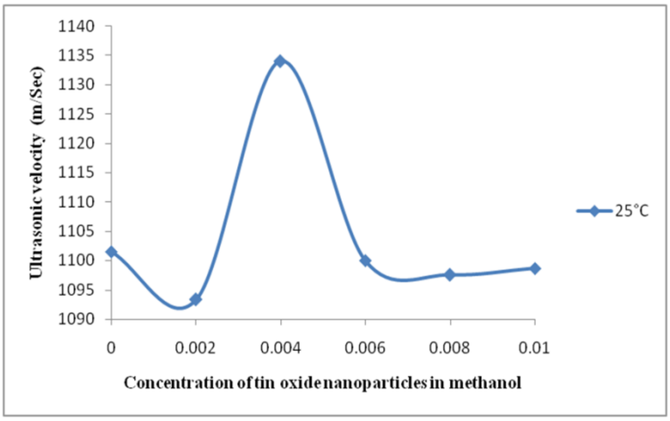

Figure 4. Variation of ultrasonic velocity with concentration of TiO2 NPs in methanol

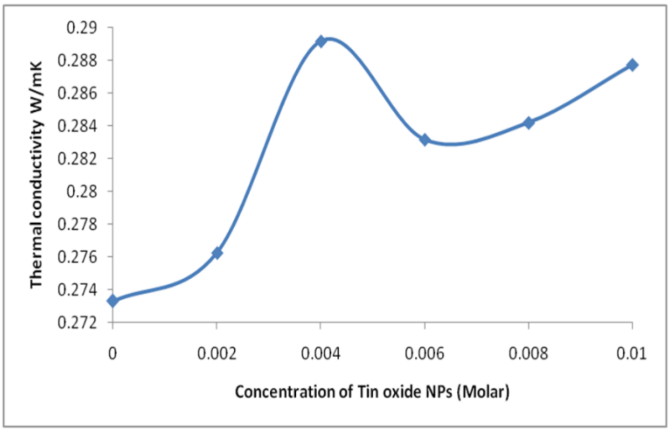

Figure 5. Variation of thermal conductivity with concentration of TiO2 NPs in methanol

3.3 Roll of surface coating of TiO2 nanoparticles

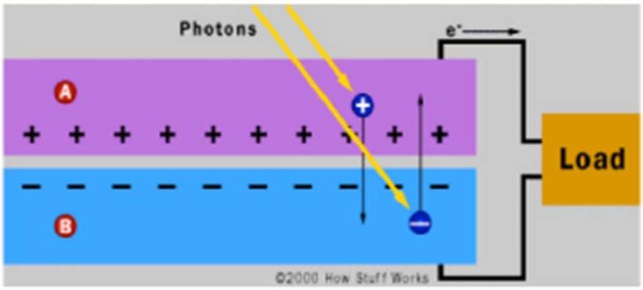

Figure 6. Solar photovoltaic cell

Figure 6 shows the solar photovoltaic cell arrangement. When a photons having energy equal to or greater than band gap energy is incident upon a Collector plate which is coated by TiO2 nanofluids at effective 0.004 molar concentration then photons gets absorbed by the materials and it activate the different processes in the materials. Energy of photons is utilized to excite an electron from valence band to the conduction band thereby creating positive holes in valence band. An atom goes from stable state to unstable state. After 10-3 sec electrons dropped to ground state either by radiative or non radiative transition or electrons in an excited state gets trapped and react with electrons donors or acceptors adsorbed on the surface of photo catalyst. These charge carriers can recombine, non-radiatively or radiatively or get trapped and react with electron donors or acceptors adsorbed on the surface of the photo catalyst. The competition between these processes determines the overall efficiency of TiO2 nanoparticles. For maximum efficiency, electrons should be adsorbed by the photo catalyst. TiO2 can absorb light into the visible light region and convert solar energy into electrical energy for solar cell applications [8]. To obtain reasonable efficiencies comparable to established solar cell technologies, the surface area is enlarged by a factor of 1000, by using nanoparticles of TiO2 with a diameter of approximately 10 -20 nm [9]. The use of TiO2 nanoparticles increases the surface area and enhances the concentration of available surface-active sites, thus leading to higher photo catalytic activity. However, an increase in the surface area increases the number of surface defects which are electron-hole recombination centers. Therefore, an optimization of the crystallinity and of the particle size is required to maximize the efficiency of solar plate [10].

IV. CONCLUSION

The concentration at which particle–fluid interaction is most effective is identified for nanofluids applications by non destructive ultrasonic techniques.

At molar concentration of 0.004, dipole-induced dipole type of interaction between particles and fluids is responsible for rise in ultrasonic velocity. The strong interaction between suspended particles and fluids is considered to be a main reason for thermal conductivity enhancement. Selective materials coating of TiO2 nanoparticles at effective concentration enhance intrinsic as well as extrinsic interaction with surrounding medium through more light absorption, charge generation in material, charge transport, charge trapping either by acceptor or donar catalyst thereby increasing the overall efficiency of solar cell.

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