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A Review on Advancements and Application of Nanotechnology in Solar PV/T System

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ABSTRACT: Nano-Technology is presently the most promising and widely applicable Technology. In Solar Energy System Nano-sized architect for PV, nanofluid, nanostructure for cooling etc. are introducing in conventional as well as modern hybrid system. Here we are presenting review on advancements and application of nanotechnology in solar energy system towards better energy conversion efficiency. Nanotechnology made it possible to use conventional Photovoltaic (PV) system as Photovoltaic Thermal (PVT) system.

KEYWORDs: *Hybrid PV/T System, Solar cell Cooling, Nanofluid, HTF, Spectral Filtering.*

I. INTRODUCTION

The residential Solar energy is best collected and used by hybrid Photovoltaic and Thermal system as photovoltaic system alone has poor conversion efficiency and Thermal energy is the low grade energy. There are many arrangements and systems available and research is going on to make them more efficient and to search new theories &concepts for better energy conversion. Photovoltaic solar cell converts only visible band of solar spectrum and the remaining energy absorbed by cell dissipated as heat and also with more concentration ratio temperature get increases which cause loss of conversion efficiency of the solar cell. These factors results in lower conversion efficiency of solar PV system. Thermal system has comparatively good efficiency but as it is lower grade energy it's quite less useful. Hybrid Photovoltaic Thermal (PVT) system proves better solution as it gives electrical energy and remaining energy which dissipates as heat collected by Heat Transfer Fluid (HTF), results benefit of temperature control for PV cell and higher efficiency of overall system as extracted heat could be used. For comparison of hybrid energy system exergy analysis is used. Nanofluids are a mixture of liquid (base fluid) and nanoparticles (nanometre sized solid material). The thermal conductivity of solid metals is higher than that of liquid. The suspended particles are expected to be capable of increasing thermal conductivity and heat transfer performance.

II. ARCHITECTURAL DESIGN

Nanowires have recently attracted considerable attention for solar energy harvest, conversion and storage due to their unique physical and chemical properties compared to their bulk counter parts. Size and morphology dependent properties, such as quantum confinement effects in semiconductor nanostructures, provide a rational approach toward a highly efficient solar energy conversion process [6,14]. Nanowires have attracted considerable interest because they represent the smallest dimension for efficient charge generation, separation and transportation. One dimensional nanostructure possesses the unique chemical, structural and physical properties that make them ideally suited for solar energy harvest and conversion [9,19]. The unique geometry of nanowire array scan allows for low optical reflection and enhances the light trapping and absorption within nanowires arrays [9,19]. These unique characteristics motivated nanowires as potential materials for solar energy conversion. For solar energy conversion silicon nanowires (SiNWs) have significant potential because of its features [6,16,22], even though SiNWs performance is lower than bulk Si andmicrometre-scale wires. These one dimensional materials are ideal to study PV characteristics of various semiconductor junctions at the nanoscale. These studies can offer exciting potential inefficient utilization of solar energy. The material selection, optimized geometry and architecture, as well as surface treatment, are important factors to be addressed to realize the full potential of the one-dimensional homogeneous and heterogeneous nanowires for highly efficient solar energy conversion.

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III. SPECTRAL FILTERING

With recent advances in nanofabrication optical filters have seen a step-change in the number of available production methods and materials. Technology has evolved to achieve finely tuned spectral properties of thin films [8,24]. However, fluid-based filters remain relatively underdeveloped. Andrej Lenert et al. present a novel solar thermophotovoltaic (STPV)device, which incorporates a two dimensional photonic-crystal (2D PhC) absorber-emitter to achieve spectral conversion efficiencies >10% [1]. The result was achieved by tailoring the spectral properties of the absorber-emitter through surface nanostructuring of tantalum (Ta) and minimizing parasitic thermal losses using an innovative vacuum enclosed experimental setup. Performance of the STPVs is dependent on the efficient conversion of sunlight to useful thermal emission, which the PV cell can then harness to excite electron-hole pairs and generate power.

The photonic crystal absorber-emitter consists of a 2Darray of high-aspect ratio micro-cavities (Fig. 1) etchedinto both sides of a Ta substrate. These structures werefabricated using interference lithography followed by deepreactive ion etching of Ta [3, 4]. Even at the high operatingtemperatures, the spectral properties of the Ta PhCs exhibithigh-selectivity with a sharp cut-off enabled by the PhCsurface structure.The design of the PhCs is a square array of cylindricalholes with period (*a*), radius (*r*), and depth (*h*) created on atantalum (Ta) substrate. Ta was used because of its highmelting point (3290 K), low vapour pressure and lowemissivity at long wavelengths.

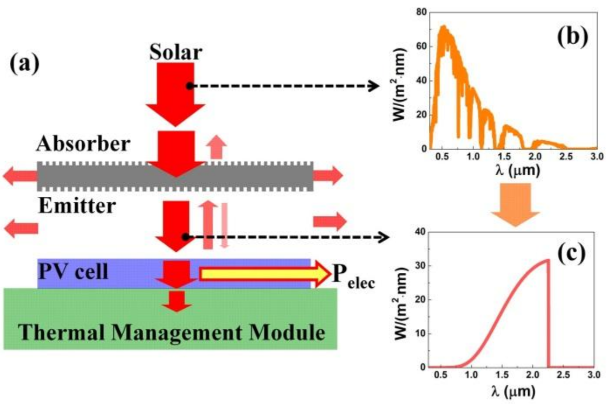

Fig. 1:Operating principle of the STPV device: optically concentrated sunlight is converted into heat in the absorber; the absorber temperature rises; heat conducts to the emitter; the hot emitter thermally radiates towards the PV cell; radiation is ultimately converted into excited charge carriers in the cell and extracted. (a) Schematic of a 2D PhC absorber-emitter that converts solar radiation with a broad spectrum into a tailored spectrum matched to the spectral response of the PV cell [1].

IV. HEAT TRANSFER FLUID

Nanofluid is the mixture of liquid (base fluid) and nanoparticles. Nanofluids have very good thermo physical properties i.e.viscosity,thermal conductivity and convective heat transfer coefficients, as compared to conventional fluids. Use of nanofluid in place of conventional HTF results better performance of solar collector. Chien et al. investigated a two-phase thermosyphon solar water heater [3]. Nanoparticles were employed in the experiment that resulted in a 4% increase of the absorbed heat. Zeinali et al. numerically investigated the convective heat transfer of Al_2O_3/Water,Cu/Water and CuO/Water nanofluids through a channel with a square cross-section in laminar flow with constant-temperature boundary conditions [23]. Their results showed that, for a fixed volume fraction, decreasing the nanoparticle size enhanced the heat transfer. Also, increasing the nanoparticles volume fraction for a fixed particle size increased the heat transfer.

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Yousefi et al. experimentally studied the effects of using Al_2O_3/water or MWCNT nanofluid as a heat absorbing medium in a flat-plate solar water heater [20,21].Results showed that at a constant nanofluid concentration, the increased mass flow rate results to enhanced efficiency of collector. In the experiment Hwang et al. investigated the conductivity of the various kinds of nanofluids such as MWCNT (multiwall carbon nanotubes in water), SiO_2/water andCuO/water[7].They reported a large increase of the fluid thermal conductivity when a small amount of nanoparticles (around 1% by volume) were added to the fluid. Dengwei Jing et al. present a facile one-step preparation of highly dispersed SiO_2/H_2O nanofluid with nanoparticles of sizes 5 nm, 10 nm, 25 nm and 50 nm, respectively [4]. They made arrangement for nanofluids to be circulated both above the PV panel to filter IR part of the incident light, and below the PV cell to remove the heat generated in the photoelectric conversion process. This design is helpful to reduce the operation temperature of PV cell and thus is expected to improve its photoelectric efficiency. Then the effects of silica/water nanofluid of various particle sizes, their flow rates and the incident solar radiation intensity on both thermal and electrical output of PV/T systems were studied. Otanicar et al. [15] investigated the effects of different nanofluids such as silver/water, carbon nanotube/water andgraphite/water on the performance of a micro scale direct absorptive solar collector.They found that the efficiency increases for volume fractions less than 0.5% however for higher volume fractions (such that 0.5%) may even decrease.

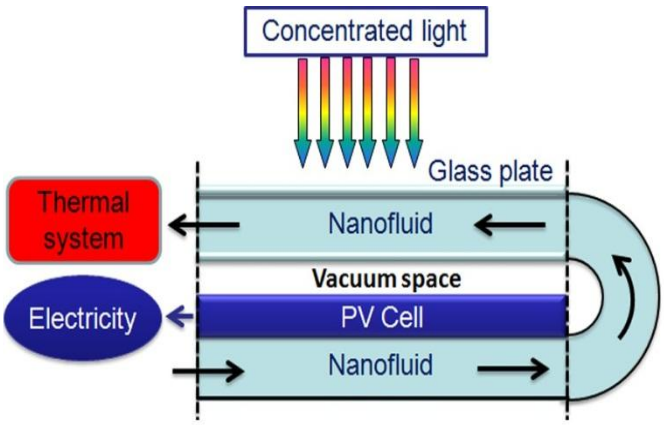


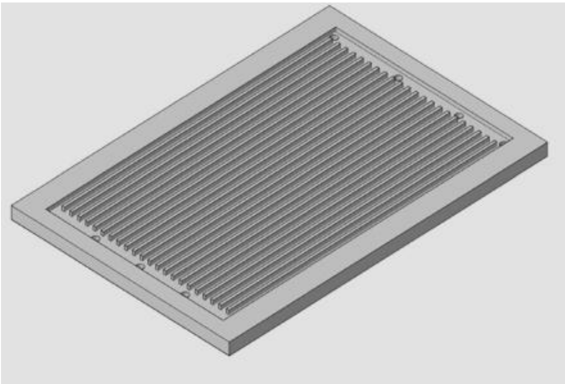
Fig. 2:2D sketch of the de-coupled PV/T system concept [4].

Recently, Saidur et al. [17] studied the potential of aluminum/water nanofluid to use in direct absorption solar collectors. Taylor et al. [11] compared a nanofluid-based concentrating solar thermal system with a conventional one. Their results indicate that the use of a nanofluid in the receiver can improve the efficiency by 10%. Li et al. [10] investigated the effects of three different nanofluids (Al_2O_3/water, ZnO/water, and MgO/water) for tubular solar energy collector. Result shows that ZnO–H2O nanofluid with 0.2% volume concentration is the best selection for this collector.In another experiment Yousefi et al. investigated the effects of two different weight fractions of Al_2O_3/water nanofluid, resulting 0.2% and 0.4% on the efficiency of a flat-plate solar collector [2]. In another study, Chandrasekar et al. [4] used a simple passive cooling system with cotton wick structures in combination with water, CuO/water nanofluid and Al2O3/water nanofluid for flat PV modules.

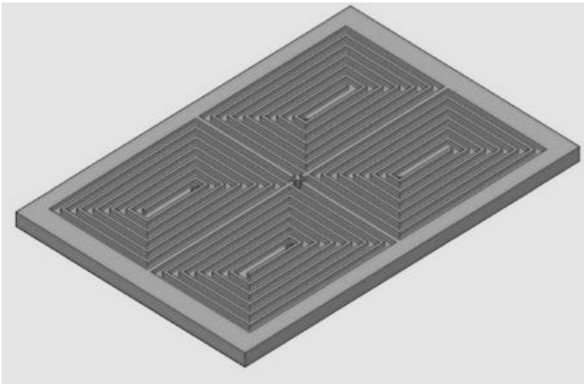
V. MODIFIED FLUID CHANNEL

Nooshin Karami et al. experimentally investigated the cooling performance of channels by water-based nanofluids containing small concentrations of Boehmite (AlOOH·*x*H2O) for the PV cell. The channels were in two different configurations as straight and helical. The nanofluid was prepared by mixing deionized water (as the base liquid) and the Boehmite (AlOOH·*x*H2O) nanoparticles to attain a 0.01%, 0.1% and 0.5% weight fraction solutions. The nanoparticles were dispersed in the deionized water and the solution was sonicated to make a uniformly dispersed solution.

The presence of nanoparticles has the significant effect of decreasing the average temperature of the PV cell compared with that of base fluid (water). The experiment showed that reduction of average temperature is dependent on the particle weight fraction [14]. The best cooling result was achieved with 0.1 wt.% concentration of nanofluid for laminar flow in both the channels and for the other two concentrations of nanofluid the obtained results were different for two channels.



(a)Straight



(b)Helical

Fig. 3: The schematic views of the channels [14].

For the straight channel the nanofluid with 0.01wt.% concentration had best cooling performance while for the helical channel nanofluid with 0.5 wt.% concentration was the weakest one[4]. Experiment results that the helical channel works more efficiently as compared with the straight one. The factors which more affect the cooling performance are the channel geometry, nanofluid concentration and flow i.e. laminar or turbulent.

VI. CONCLUSION

In renewable and sustainable energy system, Nanotechnology contributes for high efficient solar energy conversion as Nanofluid and structural design for spectral filtering. Nanofluids enable to use solar radiation for maximum energy extraction. It also make possible to maintain solar PV cell temperature at low.

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