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A Review Paper on Poly-dopamine Doped Nan particles to improve the Performance of Solar Collectors

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Abstract - This paper tells us that with the using of polydopamine doped nanoparticles in the working fluid in the solar collector improves the overall performance of the solar collector. Solar collectors are used in Thermal power plants, solar heaters, heating and cooling for domestic use etc. Solar collectors are also used for solar water distillation in which fresh water is separated by evaporating and condensing the water vapour. Poly dopamine form black nanoparticle, and it is a light absorbing polymer. It is highly light absorbing material for ultra violet radiation. It has extra ordinary heating properties when light falls on it. Sun light absorb by polydopamine is converted into large amount of heat. The temperature on polydopamine nanoparticle due to its extraordinary thermal conductivity and therefore there is increase in the driving force for the vapour transportation. Polydopamine can absorb 99% of photon energy over a broad solar spectrum and rapidly convert it into heat. Polydopamine has wider light absorption range than that of other nanoparticles, it is hydrophilic in nature. So this paper present the application of polydopamine nanoparticles in order to improve the thermal efficiency of solar collector.

***Key Words*:** Solar collectors, Heating, Cooling, Polydopamine, Coating, Efficiency

1. INTRODUCTION

Polydopamine is a polymer, it is the final oxidation product of dopamine. The polydopamine attract much attention as, polydopamine coating can be done easily on any of the surface, and the thickness of the coating is from 10nm to 100 nm. Polydopamine nanoparticles are doped in solar fluid so that will enhance the heating ability. Polydopamine nanoparticles have Brownian motion, so that Brownian motion can increase the thermal conductivity and heat transfer. The polydopamine nanoparticle have high potential to enhance the heat transfer rate so that it can be used in nuclear reactor, solar water heater, solar refrigeration, and other industrial cooling purposes.

2. LITERATURE REVIEW

Bo shao and Yida wang [1] In this polydopamine nanosheet based photo thermal sponges for highly steam generation. In this polydopamine coated on Nickel Cobalt bimetal nano sheet. Xiang Zhao and Xiang Jun Zha [2] Strategy for fabricating polydopamine (PDA) photo thermal layer for achieving wide spectrum and to obtain high solar radiation absorbability. Zhenxing Wang [3] Adhesion mechanism of polydopamine, as well as chemical and physical properties are discussed. Ji Hyun Ryu and Haeshin Lee [4] Polydopamine coating and its mechanical properties and chemical structure and chemical properties of polydopamine. Daniel Hauser and Lukas Steinmetz [5] shows hybrid poly dopamine nanoparticles are promising candidates to increase the efficiency of solid fluid. Ammar H. Elsheikh [6] different method of the steam generation have been discussed, different type of thin material are discussed such as metal based nanoparticles, metals oxides and polymers. Hao Yuan and Yang Wang [7] in this copper nanowire are coated with polydopamine and then thermal conductivity is measured and other physical property such as stress strain also measured. Haoqi Li and Fei Ren [8] In this polydopamine thin film mechanical properties are discussed carbonized polydopamine possess graphite like structure and exhibit high electrical and mechanical conductivity. Xuanhao Wu and Quisheng Jiang [9] photothermal membrane, polydopamine coating is heating by solar light for distillation process. Amit Gupta and Ranganathan Kumar [10] The Brownian movement of nanoparticles enhance the thermal conductivity of the nano fluid. N.L panwar and S.C Kaushik [11] Efforts made for exploitation of sustainable energy source and the limitation of the non renewable sources. M Napolitano and V Chen [12] melanin like biopolymer , Polydopamine (PDA), produced by oxidation polymerization of dopamine and it shows the great potential due to the broad light absorption on polydopamine and has high photo thermal conversion efficiency [13-15]. Taylor et al [16]shows that the heating efficiency increased when the nanoparticles doped into solar fluid.Aluminium oxide, Zinc oxide and magnesium oxide nano particles increase the efficiency of the solar fluids [17].

Silver nanoparticles are investigated for the increasing the heating efficiency of solar fluid [18]. The design of hybrid polydopamine nanoparticles are given which is efficient for converting solar light into heat at a broad range [19]. Thermal conductivity measurement of copper oxide, aluminium oxide nanoparticle suspended in water so the energy transport is affected by the size of the nanoparticles in solar fluid [20]. The solar energy transport or the absorbing power of the nanoparticles also affected by the volume of the dispersed medium [21] . Polydopamine is a mussel inspired polymer applied to a surface having adhesive and hydrophilic properties [22].

Poly dopamine polymer easily coated on any surface and making the synthesis very simple [23]. Poly dopamine polymer exhibit broad range light absorption property and also having extraordinary photo thermal conversion properties [24-25]. Polydopamine and polypyrrole are used as a sun light absorbing polymer due to their lower cost and environment benefits [26]. A double layer steam generating device consisted of polydopamine polymer layer on a wood surface in which wood surface acting as a water transporting medium [27].Understanding of chemical composition of polydopamine and the physical properties of polydopamine which improved the mechanical properties, few investigation of mechanical properties of polydopamine coating have been performed [28-31]. There are several reports published which shows that polydopamine coating enhances mechanical properties of composites [32-33].

3. CONCEPT OF POLYDOPAMINE TO ENHANCE THE HEATING EFFICIENCY OF SOLAR COLLECTOR

Solar steam generation using sun light power for evaporation having minimum environment effect..Polydopamine coating have broad band solar light absorption ability. Polydopamine is a polymer which can easily coated on any surface and it consist of carbon so due to the presence of carbon it has high solar light absorbing capability.

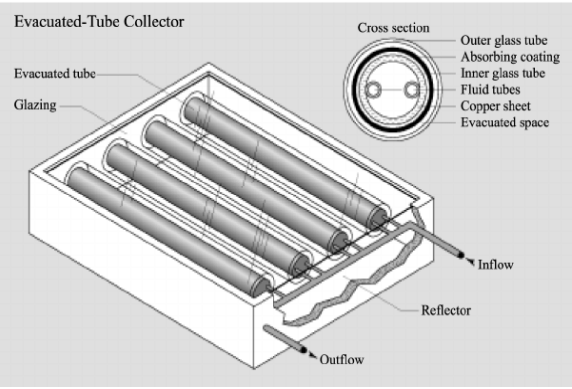

Fig-1: Evacuated tube solar collector

In the figure. 1 the evacuated solar collector is shown which consisting of heat pipe and the heat pipe is surrounded by absorbing coating, the absorbing coating is solar light absorbing polymer polydopamine coating can be use on the copper metal heat pipes which will shows extraordinary heating.

4. POLY DOPAMINE POLYMER COATING ONSUBSTRATE

Xuan et al. [27] developed a double layer SG device consisting of polydopamine as a light absorbing layer smeared on the surface of pine wood like A layer of pumping water. Polydopamine is a highly light-absorbing material. for ultraviolet, visible and even near infrared regions of solar energy spectrum. Wood has a low density and low thermal conductivity allow the device to float on the surface of the water, in addition to limiting the heat converted by sunlight absorbed into the polydopamine layer the steam can be generated after 5 seconds of light irradiation with steam 87% 1 sun generation efficiency. In addition, by increasing the solar irradiation of more than 1 sun caused the explosive evaporation of the water drops in the upper layer where the water is directly transported steam without undergoing phase changes that increase efficiency up to 135% with 3.5 suns. To improve water permeability through the wood, cylindrical wooden blocks with a diameter of 4 cm and 0.5 cm thick with mesoporous channels parallel to the cylinder axis were treated with boiled diluted ammonia to remove fatty acid and gum. The treated wooden blocks were immersed in aqueous dopamine solution for one hour to deposit a homogeneous black polydopamine coating on their surfaces. The wooden channels cannot be blocked from polydopamine since dopamine polymerization requires dopamine monomer and oxygen which do not have enough in the wood channels.Because of the abundance of wood combined with the low cost of polydopamine, as well as the simplicity of the proposed double-layer production process structure, the developed device is considered a promising SG device for commercial applications.

Thin film steam generation technology [6] attracts many researchers to develop more scalable, inexpensive devices that show high conversion efficiency. Compared to conventional solar desalination devices such as solar stills with low efficiency of 30–45%, heat localization thin layer devices can have much higher conversion efficiencies. Conversion the efficiency of some of these devices can be higher than 98% in lighting from one sun, while others may show very high efficiency from 135% to 3.5 sun lighting. A typical thin film based on the steam generator device consists of a broadband absorber. Sunlight absorbing material deposited by a substrate that acts as a mechanical support for absorbent water and wick

volume to the absorbent under capillary action through its mesoporous structure. The support material must have a low thermal conductivity to eliminate the flow of heat from the absorber to the water body towards to obtain the position of the heat on the absorber surface. The absorbent must have good chemical stability. There are different absorber material such as different metal based nanoparticles, metal oxide and carbon based nanoparticles and different polymer such as polydopamine and polypyrrole. Figure 2 shows Thermal images of PDA film coated sponge and uncoated sponge.

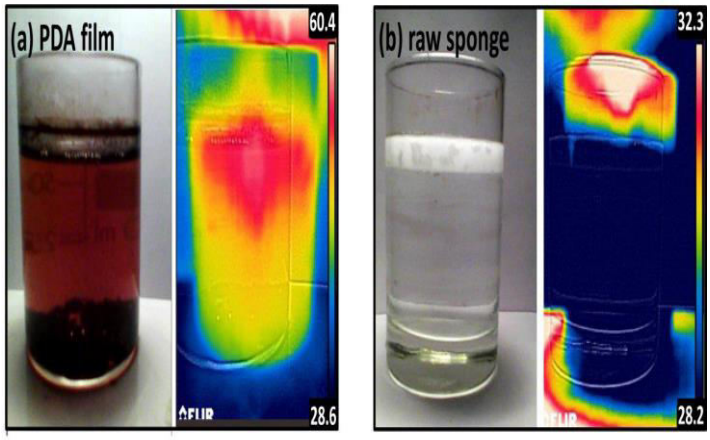

Fig-2:(a) shows the Thermal image of PDA sponge coating on water surface and (b) shows the thermal image ofsimple raw sponge on water.

The work in [34] shows the steam generation devices in which the film technology is used. The thin layer of solar light absorbing material is deposited on the substrate. So in this the different conversion rate efficiency rate shows.

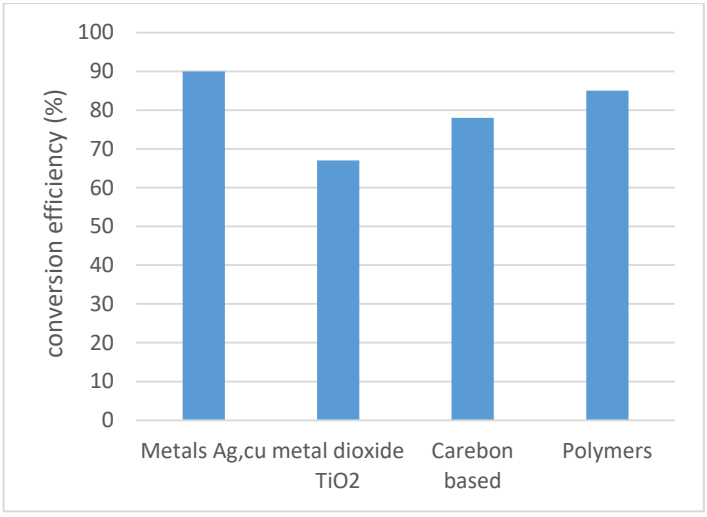

Fig-3: Conversion efficiency of different materials

From the above figure.3 it is clear that Metals like silver (Ag), and copper (Cu) have maximum conversion efficiency rate means having maximum capability to convert solar light into heat. Polymers like PDA polydopamine and Polypyrrole also have high conversion efficiency.

Hao Yuan [7] coated copper nano wire with the polydopamine. The PDA coating can be easily fabricated, with the low PDA coating thickness on nano wire the thermal conductivity is high at 25 nm thickness and when the thickness of PDA coating increased than there is a decrease in the thermal conductivity.

Bo Shao [1] in this the PDA coating with NiCO3 nano particle is fabricated on sponges and then photo thermal effect investigated in order to study the solar radiation effect on PDA coating with the Nickel Carbonates. During steam generation in this case there is decrease in the energy loss by conduction ,convection and radiation. In this it is cleared that it exhibit high evaporation rate and have high light to heat conversion efficiency. Thus the overall system has high efficiency and can be implemented for the various applications.

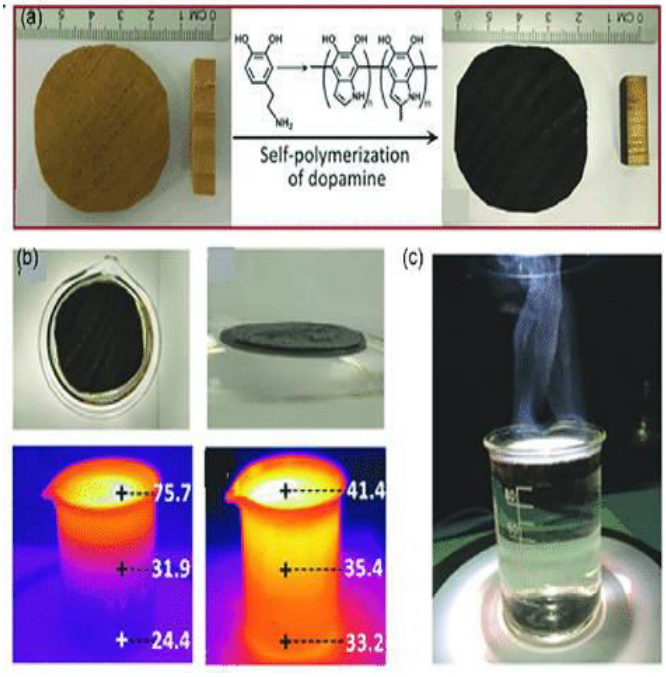

Fig-4:(a) uncoated composite (b) PDA coated composite solar radiation absorbing rate (c) evaporation by PDA coating

In the above figure in Fig.4 (a) the uncoated composite and coated composite with PDA coating is given. And fig (b) shows the solar radiation absorbing rate with PDA coating composite that is 75.7 and simple water radiation absorbing is 41.4 the images are taken out using Infra Red camera.

So it shows that the solar radiation absorbing rate of PDA coating is higher.

Xing Zhao [2] fabricate high thermal composite for solar driven applications. In this PDA@XMene photo thermal layer used for absorbing wide range solar light spectrum. It give light absorption efficiency (~96%) and having high light to heat conversion rate. The PDA@XMene photo thermal layer is mechanically stable and keep light absorption stable and also kept water evaporation stable.

5. THIN LAYER OF POLY DOPMAINE FOR STEAM GENERATION

A poly dopamine layer on any substrate is act as a sunlight absorber. The sunlight on the PDA layer is used as a input energy and it is utilize for evaporation as a output. The solar light heat is used by the PDA layer and it uses for heat up the water and then evaporation of water begin. The PDA coating can easily done on any substrate such as wood, carbon fabric, cotton fabric, non porous nickel, non porous anodic aluminium oxide, and thin sheet of copper and stainless steel mesh.

To create a polydopamine coating on any substrate such as wooden block , the wooden block treated with boiled ammonia solution in order to remove the fatty acids and gum. And after that the wooden block is immersed into aqueous solution of polydopamine for 1 to 1.5 hour. When the block is removed from the solution and put for dry so that the black PDA coating on wooden block is obtain.

6. DISCUSSION

From the previous publications the polydopamine and nano particles are investigated for the steam generations and which are more effective than expectations. The new absorbing film on substrate is deposited in order to enhance the thermal conductivity or to absorb the solar radiation at broad range. Polydopamine is a black nanoparticle polymer which have extra ordinary properties of solar light absorbing capacity, it can covert solar light into heat in very less time. Mainly in the previous articles or researches the PDA coating is used on sponges, woods in order to purification of water by evaporation. In the previous studies or investigation it is observed that PDA can absorb 99 percent of incident solar radiation and convert it into heat in 8 to 10 picoseconds, due to this the super photo thermal ability of PDA coating it can be utilize in fabricating photo thermal material for solar steam generation. Due to its extraordinary property of heat solar light absorption the PDA coating can be used in solar thermal collector top heat up the water that flows through the collector. So the PDA coating can be heat up the water present in the collector very fast. Mainly the solar collectors made up of copper material and PDA can be easily coated on any metal. So for the water absorption solar refrigeration system and solar water heater and other solar heating purposes the PDA coating on solar collector is very much effective. With this water in the collector tube heat up very fast and therefore the efficiency of the solar thermal collector increases. PDA is basically a polymer and it has graphite like structure. Polydopamine nanoparticles can also be used in solar fluid in order to increase the efficiency. But when we are talking about solar vapour absorption refrigeration and solar heating so there can be polydopamine coating on solar water collector is more effective because there is need of instant heating of water in order to obtain the higher efficiency of the system, so polydopamine (PDA) coating is very much effective in these type of solar system.

7. CONCLUSIONS AND PROPOSAL

In this paper the application of Polydopamine coating and Polydopamine nanoparticle are discussed. So it is very cleared that Polydopamine has extra ordinary heating properties when the incident sun rays falls on it, so therefore it can be utilize for any solar based heating system or solar steam generation, it has less cost and it is environmental friendly no harmful for the environment. It can be used for the distillation of impure water. In todays world the use of solar energy increasing day by day because it is renewable source of energy and various solar system are investigated such as solar refrigeration systems, solar heating and cooling system for domestic uses. So by applying PDA coating on copper heating pipes used in solar collectors and Doping of PDA nano particles in the solar fluid the efficiency of the solar system can be enhanced. Here are some properties of the Polydopamine (PDA) which is concluded form investigation and studies.

- Polydopamine is a light absorbing polymer. It is highly light absorbing material for Ultra Violet radiations.
- Polydopamine can easily coated on any surface, so it forms thin coating layer on the surface.
- Polydopamine nanoparticles have Brownian motion, and helpful for fasting the heating rate of the solar fluid.
- The sunlight absorbed on Polydopamine film can convert heat into large amount.
- Poly dopamine has a wider light absorption range than other nanoparticles, The high surface temperature on the top of poly dopamine membrane owing to the excellent photothermal conversion properties.

- The temperature on poly dopamine coating increased due to its extraordinary thermal conductivity and therefore there is increase in the driving force for the vapour transport.
- PDA(polydopamine) can absorbe 99% of incident photon energy over a broad solar spectrum and rapidly convert it into heat with in ten picoseconds.

So from the above properties of polydopamine it is concluded that it is very efficient for solar systems and in future it can be used as a coating on copper heat tube in the solar collectors in order to enhance the heating capability of the solar collector and over all efficiency of the solar system.

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