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Investigation on Thermal Performance Enhancement of Solar Boilers by using various Graphene Coating techniques

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Abstract

This paper presents an enhanced Heat Transfer for composite wall of solar boiler by using the heat-transfer characteristic of various graphene coatings. The examination are done to assess the boiling heat transfer coefficient, heat flux and wall superheat for with and without garphene coated surfaces experimentally, and the obtained results are compared with those of the various techniques reported studies and existing empirical correlations. From that point forward, these outcomes are contrasted and the yields like thermal conductivity of solar boiler without coating, with graphene coating and various coating techniques performance. This investigation gives an exploratory reference to the utilization of a graphene covering in against/deicing.

Keywords: *Thermal conductivity; Graphene; Solar Boiler; Various Coating techniques;*.

1. Introduction

Innovations in concentrating solar thermal Power (CSTP) can create power on demand when conveyed with thermal vitality stockpiling, giving a dispatchable wellspring of sustainable power source. [1]. The four fundamental business CST advancements are recognized by the way they center the sun's beams and the innovation used to get the sun-based vitality. parabolic-trough collector (PT), solar tower (ST), linear Fresnel (LF) and parabolic dish (PD) [2]. Two types of CSTE are innovated till now, those are medium- CSTP Innovation and High CSTP Innovation. [3,4]. Till date every all the inventors are concentrating on tower receivers' shapes only. But they are preferring tower material was used copper and other materials. This experimental work represent various Graphene coatings and copper combination of material uses in tower, and investigated how it behaves.

Various graphene coatings

Graphene coating techniques are classified into two basic methods, those are

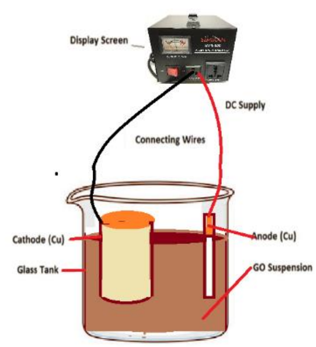
- Dry coating method
- Wet coating method

Chemical vapour deposition (CVD)[5-8],rapid thermal annealing (RTA)[9],&powder spray (electrostatic powder coating and plasma spray coating)[10] are under dry coating technique. electrophoretic deposition (EPD)[11–12],solution spray,[13] dip coating,[14]spin coating,[15]drop casting,[16] vacuum ltration, [17] and brushing [18]are under wet coating technique.

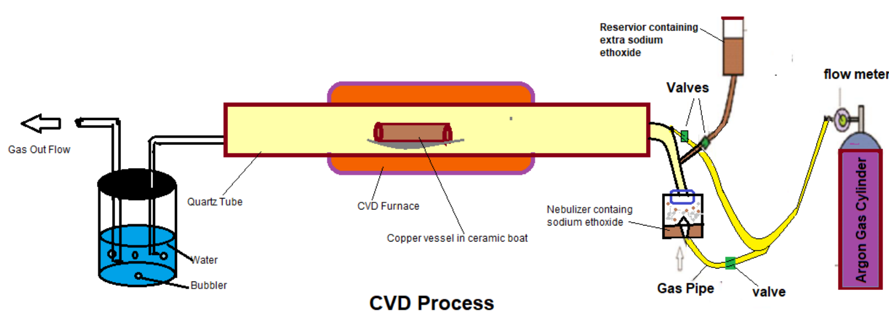
In these two-coating methods CVD is very popular under dry coating method &EPD is very popular under wet coating method. CVD is a high-temperature measure, elective low-temperature measures for graphene statement have been considered. One such technique is EPD which is considered as an attainable and harmless to the ecosystem cycle for statement of graphene movies or coatings on metals from graphene oxide (GO) suspensions [19]. This exploration work analyzes the electrochemical exhibition of graphene coatings stored on Cu by CVD and EPD techniques to decide the best covering for thermal absorber on Cu.

Coating process

EPD coatings were created on Cu vessel tests at a voltage of 5 V for 10 s (ideal boundaries). The examples to be covered were made anode by interfacing with the positive terminal of the DC supply and Cu cathode was utilized. The subsequent covering was dried for the time being at room temperature and marked as EPD-GO. Graphite oxide was delivered following a strategy announced in which was scattered in DI water (2 mg GO in 1 ml DI water) shown in figure [19].



(a)



(b)

Fig. 1. Graphene coating on copper vessel by (a) EPD Process; (b) CVD Process schematic diagram.

For the CVD interaction, sodium ethoxide was utilized as an antecedent which was ready by dissolving sodium metal in ethanol for 2days to finish the response. A specially crafted CVD contraption was utilized for affidavit of the covering as displayed in Fig.1(b). Momentarily, the CVD contraption comprises of a quartz tube, which was embedded in a cylinder heater having a long warming zone. Separated sodium ethoxide arrangement was added to a nebulizer that was associated with the gas stream regulators. Cu substrates were set in a ceramic boat which was situated in the warming zone. Cleansing of the heater was done with argon during warming and cooling. The arrangement of sodium ethoxide was showered alongside argon stream in a quartz tube and the CVD interaction was conveyed at 800, 900, and 1000 °C for 15, 30, 45, and 60 min. The boundaries for the improvement of graphene coating (900 °C and 60 min) were chosen as at these boundaries' coatings gave better thermal conductivity and better corrosive resistance. The coatings delivered at these boundaries were utilized for additional testing and marked as CVD-graphene [19].

2. Experimental setup

The morphology of the coatings was observed by SEM. In order to analyse coatings adhesion on a Cu vessel, samples. Raman spectra were collected using a Micro Ramboss spectrometer with a solid-state laser (λ=532nm) operating at 40 mW. as shown fig.2.The dimensions of the Cupper vessel (Or) boiler (or) absorber are 3mmX190mm X 80mm dia.

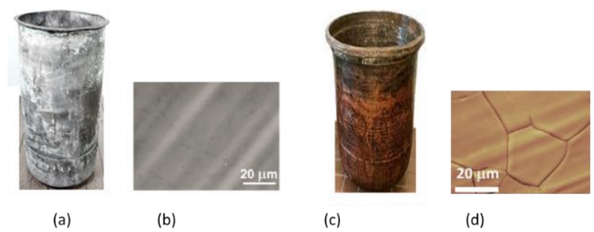


Fig. 2. Graphene coating on copper vessel by (a) EPD Process; (b) EPD process sample SEM picture (c)CVD Process schematic diagram (d)CVD process sample SEM picture.

The prototype modal consists of several parts those are platform, reepers, mirrors, vessel, and tower. The platform or the base we used is a wooden one, whose thickness is 12mm and length, width is 1000mm X 1000mm i.e., $1m^2$. the platform into two halves and combined it using 3 hinges, so that it can be carried or shifted from one place to another place comfortably. Mirrors are the main part of the prototype. Here used mirrors as reflectors because these are the best source for reflection. The size of the reflector we considered is 75mm X 75mm. A copper vessel (with and without coating of graphene) of 1 lit. capacity has been used as an absorber as well as a boiler.

Reeper's are used as the support structure to the reflector. These are made into different sizes as per the field radius calculations. The sizes we took are 50mm , 61mm , 73mm, 84mm , 92mm ,105mm , 113mm.Tower has been used as a support structure for absorber. The height of the tower is 195mm X 95mm and is coated with a silver paint. Finally, assembly of CSTP Prototype modal shown in figure.3

Fig. 3. Prototype of concentrating solar thermal plant (CSTP).

2.1 Boundary conditions

Assumed boundary conditions are the operating pressure of the solar collector is the environmental one. It is expected that the fluid (air) is under enduring state stream condition, and the blower of the volumetric beneficiary creates a stream rate whose worth is assessed for each semi consistent state condition (0.198–0.310 kg/s). The gravitational power can be dismissed because of the low thickness of the liquid and its constrained stream. This suspicion has been contemplated by the reenactment of two cases with a breeze speed of cero and 1.5 m/s, considering buoyancy impacts. These outcomes were contrasted and those assessed without the gravity impact, getting a most extreme deviation lower than 1.2 % for the outlet temperature of the cup. Hence, the impact of the gravitational power isn't critical for this situation. The thermophysical properties of the air stream have been characterized for dry air at climatic weight and the properties of the strong materials were considered at the temperature scope of the chose relentless states. This data was provided by the information sheets of every material as appeared in table.1. [20,21]

Table.1 Cases considered in the evaluation of the wind influence and the return-air effect

Wind velocity, m/s	Wind direction ^{o}	Return-air velocity, m/s	Return air temperature, ^{o}K
0	–	1.34, 0.64	300, 400, 500, 600
1.5	45, 90	1.34	300
3.5	0, 20	1.34	300, 400, 500, 600
	45	1.34,0.64	300, 400, 500, 600
	70,90	1.34	300
5.5	45, 90	1.34	300
7	0, 20	1.34	300
	45	1.34	300, 400, 500, 600
	70,90	1.34	300
	45,90	1.34	300

Wind impact has been considered for the lateral side of the surrounding air subdomain. The velocity-inlet state of the breeze (horizontal side of the surrounding air subdomain) incorporates the encompassing temperature and the parts of the speed vector as indicated by the Cartesian coordinate system. These qualities have been assessed from the speed and the wind direction estimated for the approval procedure, and, then again, they were set considering the conditions characterized in Table.1.

3. Thermal Analysis of a Vessel

A definitive point of leading the investigation is to know the limit of this concentrated solar energy vitality field comprising of 60 reflectors for example to break down the measure of warmth that is made to be focused on the safeguard. watched time to time readings of temperatures utilizing a thermocouple. The perceptions are recorded in the underneath Table.2, Table.3, &Table.4.

A Thermocouple is a sensor used to quantify temperature. Thermocouples involve two wire legs created utilizing different metals. The wires legs are welded together toward one side, making a convergence. This convergence is the spot the temperature is assessed. At the point when the intersection encounters an adjustment in temperature, a voltage is created. The voltage can then be interpreted using thermocouple to calculate the temperature. Figure 4,Figure 5 and Figure 6with (two techniques) and without coating of graphene in copper vessel what are the temperatures obtained at thermo couples (inside and outside of the vessel along with atmosphere temperature).

Table.2 Temperature readings of receiver copper without graphene coating.

Time of sunlight	Ambient temperature ^{O}C T1	Vessel inside wall temperature ^{O}C T2	Vessel out-side wall temperature ^{O}C T3
9:00 AM	26	44	63
9:30 AM	25	46	72
10:00AM	28	46	72
10:30AM	32	57	103
11:00AM	35	62	107
11:30AM	37	68	110
12:00PM	40	71	112
12:30PM	43	70	115
1:00 PM	45	68	120
1:30 PM	45	67	124
2:00 PM	43	69	128
2:30 PM	41	71	130
3:00 PM	39	71	126
3:30 PM	38	69	124

4:00 PM	34	64	118

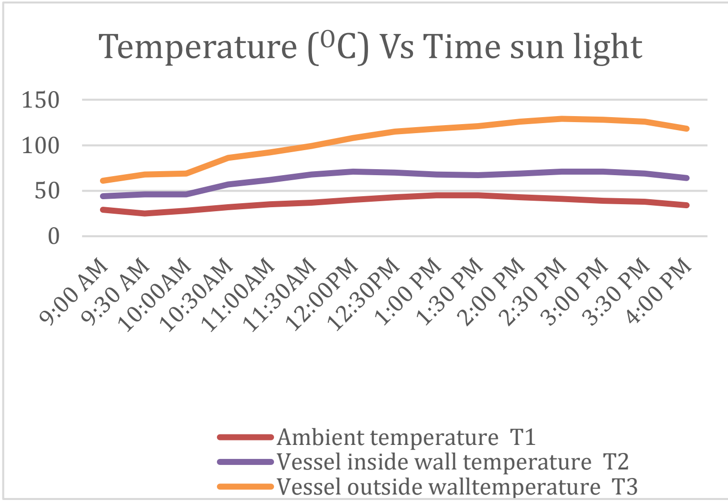


Fig.4 Temperature graph for receiver copper without graphene coating

Table.3 Temperature readings of receiver copper with graphene coating (EPD).

Time of sunlight	Ambient temperature ^{O}C T1	Vessel inside wall temperature ^{O}C T2	Vessel out-side wall temperature ^{O}C T3
9:00 AM	26	44	63
9:30 AM	25	46	73
10:00AM	28	46	76
10:30AM	32	57	106
11:00AM	35	62	109
11:30AM	37	68	112
12:00PM	40	71	115
12:30PM	43	72	116
1:00 PM	45	75	125
1:30 PM	45	76	130
2:00 PM	43	77	134
2:30 PM	41	77	133
3:00 PM	39	76	126
3:30 PM	38	61	121
4:00 PM	34	53	112

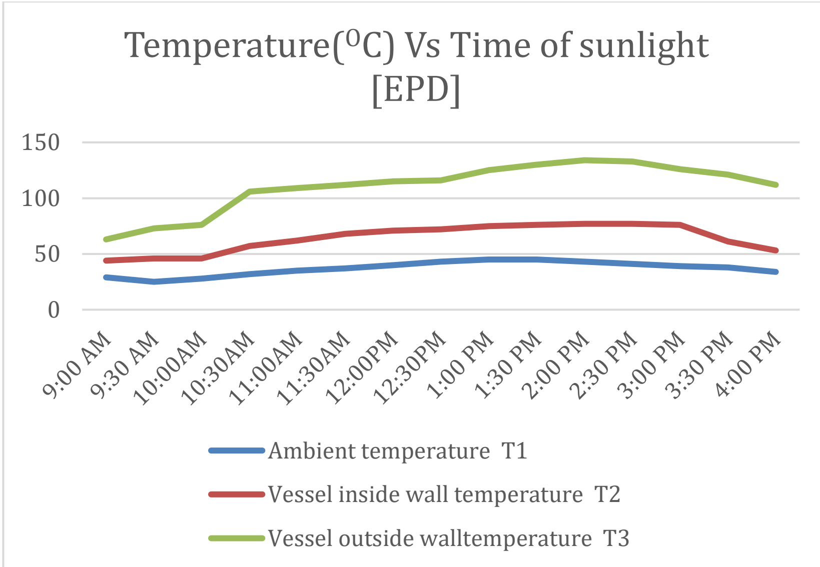


Fig.5 Temperature graph for receiver copper with graphene coating (EPD)

Table.3 Temperature readings of receiver copper with graphene coating (CVD).

Time of sunlight	Ambient temperature °C T1	Vessel inside wall temperature °C T2	Vessel out-side wall temperature °C T3
9:00 AM	26	44	63
9:30 AM	25	45	71
10:00AM	28	48	74
10:30AM	32	56	103
11:00AM	35	61	107
11:30AM	37	67	110
12:00PM	40	69	112
12:30PM	43	72	114
1:00 PM	45	72	121
1:30 PM	45	74	127
2:00 PM	43	76	132
2:30 PM	41	74	131
3:00 PM	39	73	126
3:30 PM	38	63	121
4:00 PM	34	57	116

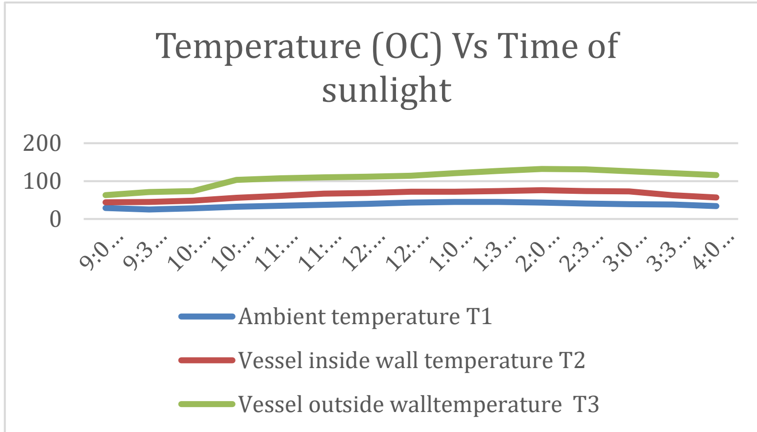


Fig.6 Temperature graph for receiver copper with graphene coating (CVD)

Thermal Conductivity is Thermal transport in graphene is an active area of research which has attracted attention because of the potential for thermal management applications. Early measurements of the thermal conductivity of suspended graphene reported an exceptionally large thermal conductivity of approximately 5300Wm−1K−1, compared with the thermal conductivity of pyrolytic graphite of approximately 2000Wm−1K−1 at room temperature [22].

The thermal conductivity of copper of approximately 397.5Wm−1K−1 at room temperature, graphene-copper thermal conductivity is 500Wm−1K−1 in EPD technique & 5255Wm−1K−1 in CVD technique. [22-28]

Conduction heat transfer$Q = KA\ (T_3 - T_2)/\ t$

Where Copper Thermal Conductivity K=397.5Wm−1K−1 at room temperature,

graphene- copper thermal conductivity K= 500Wm−1K−1 in EPD technique

graphene- copper thermal conductivity K= 5255Wm−1K−1 in CVD technique.

C/S Area Vessel A= 570mm^2=0.00057m^2

Thickness t= 3mm= 0.003m (copper)

Thickness t= 3.025mm= 0.003025m (copper with graphene coating)

To calculate the conduction heat transfer from table.1,2,3 data. It represents Conductivity rate with and without coating of graphene in vessel shown in Table 4 &figure 7.

Similarly, Convection heat transfer between copper and water$Q = hA_1\ (T_3 - T_2)$

h= convection heat transfer coefficient 13.1w/m^{2}k

A_1= water contact area with copper=π d length of vessel= πx0.08x.19

Table.4 Conduction heat transfer readings of receiver copper with graphene coating (CVD)&(EPD) & without graphene coating.

Time of sunlight	Conduction heat transfer copper-W	Conduction heat transfer (EPD) Graphene-Copper-W	Conduction heat transfer (CVD) Graphene-Copper -W
9:00 AM	1283.9	1790.1	1879.586777
9:30 AM	1661.5	2543.8	2572.066116
10:00AM	1737.0	2826.4	2572.066116
10:30AM	2190.1	4616.5	4649.504132
11:00AM	2265.6	4428.1	4550.578512
11:30AM	2341.2	4145.5	4253.801653
12:00PM	2794.3	4145.5	4253.801653
12:30PM	3398.5	4145.5	4154.876033
1:00 PM	3776.1	4710.7	4847.355372
1:30 PM	4078.1	5087.6	5243.057851
2:00 PM	4304.7	5370.2	5539.834711
2:30 PM	4380.2	5276.0	5638.760331
3:00 PM	4304.7	4710.7	5243.057851
3:30 PM	4304.7	5652.9	5737.68595
4:00 PM	4078.1	5558.7	5836.61157

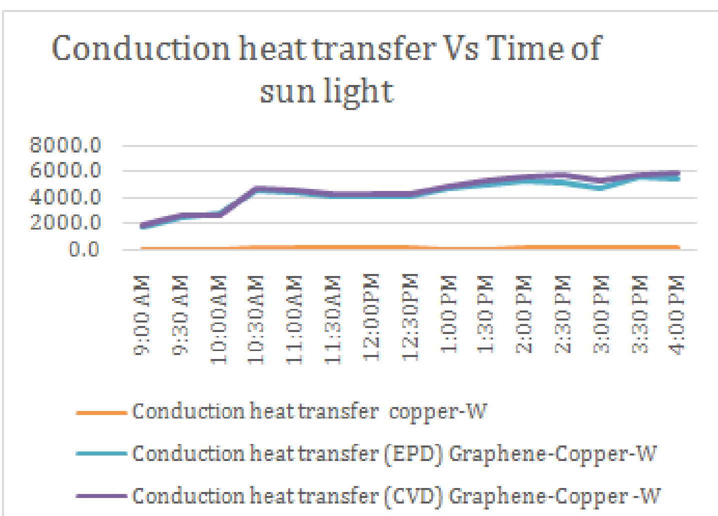


Fig.7 Conduction heat transfer readings of receiver copper with graphene coating (CVD)&(EPD) & without graphene coating

Table.5 Convection heat transfer between copper wall and water readings of receiver copper with graphene coating (CVD)&(EPD) & without graphene coating

Time of sunlight	Convection heat transfer copper-W	Convection heat transfer (EPD) Graphene-Copper-W	Convection heat transfer (CVD) Graphene-Copper -W
9:00 AM	9.343575	9.382875	9.343575
9:30 AM	13.081005	13.136025	12.4581
10:00AM	11.21229	11.25945	12.4581
10:30AM	15.572625	15.638125	14.94972
11:00AM	16.818435	16.889175	16.19553
11:30AM	19.310055	19.391275	18.68715
12:00PM	19.310055	19.391275	18.064245
12:30PM	16.818435	18.140225	18.064245
1:00 PM	14.326815	18.76575	16.818435
1:30 PM	13.70391	19.391275	18.064245
2:00 PM	16.19553	21.26785	20.555865
2:30 PM	18.68715	22.5189	20.555865
3:00 PM	19.93296	23.144425	21.17877
3:30 PM	19.310055	14.387075	15.572625
4:00 PM	18.68715	11.884975	14.326815

4. Result and discussion

This work presents experimentally an estimated daily performance of Concentrated solar power [9]. The minimum temperature obtained at outside of boiler is 63^{o}C, the minimum temperature obtained inside the boiler is 36^{o}C and the minimum temperature of water inside the boiler is 25^{o}C. The pressure obtained in the boiler is below 1kg per cm square. The Maximum temperature obtained at outside of boiler is 134^{o}C in EPD specimen, the maximum temperature obtained inside the boiler is 77^{o}C and the maximum temperature of water inside the boiler is 45 ^{o}C. The pressure obtained in the boiler is below 1kg per cm square.

The values of copper with graphene, A minimum temperature obtained at outside of boiler is 63^{o}C, the minimum temperature obtained inside the boiler is 44 ^{o}C and the minimum temperature of water inside the boiler is 25^{o}C. The pressure obtained in the boiler is below 1kg per cm square. The maximum temperature obtained at outside of boiler is 134^{o}C (EPD) , the maximum temperature obtained inside the boiler is 77^{o}C (EPD)and the maximum temperature of water inside the boiler is 55^{o}C. The pressure obtained in the boiler is below 1kg per cm square.

Observation of Table 4 & 5 thermal conduction is good in EPD process sample compared to CVD Sample, but when sunlight temperature was dropping down EPD sample inner temperature also coming down more compared with CVD sample.

5. Conclusions

The solar tower power plant designed in this work is theoretically & experimentallly capable of producing Steam. Compelling ingestion of reflected light is happened with assistance of graphene covering on the copper cylinder. Thermal conduction in boiler is more due to the graphene coated (by CVD technique) on copper cylinder is used as boiler. So finally, this work can conclude Graphene coating improves thermal efficiency of boiler. Future enhancements for the sun following heliostat and retention region on the recipient. Therefore, the results are taken as reasonable and intuitive for this application

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