International Journal of Scientific Research in Physics and Applied Sciences
Vol.6, Issue.2, pp.52-54 April (2018)

Research Paper

E-ISSN: 2348-3423

Preparation, Characterization and Evaluation of Thermal Efficacy of Nano carbon–MnO_2 Coated Solar Absorber

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Available online at: www.isroset.org

Received: 12/Mar/2018, Revised: 25/Apr/2018, Accepted: 17/Apr/2018, Online: 30/Apr/ 2018

Abstract: The development of nanostructured solar absorbers and their utilization in applied solar devices are the need of the hour and hence the present research. The research results revealed that nano carbon and MnO_2 coated absorbers could be developed by spray coating method. The research results also revealed that the crystallite sizes in the coatings of carbon and MnO_2 based absorbers were in nano ranges. The observation on research results revealed that the thermal durability and thermal efficacy of the nano carbon and MnO_2 coated absorbers (in 70:30 ratio) were acceptable in connection with their utilization in the solar collectors. As the thermal durability and efficacy of nano carbon and MnO_2 coated absorbers were acceptable, it could be concluded that nano carbon and MnO_2 coated absorbers would be integrated in solar collectors so as to improve their thermal performances.

Keywords: Solar absorbers-Nano carbon and MnO_2 based coating-Preparation-Characterization-Thermal durability-Thermal enhancement on absorbers.

I. INTRODUCTION

The solar absorber is the central component of any solar collector. It is designed to absorb incident solar radiation [1]. It is also designed to transfer the absorbed energy by means of conduction to any fluid [2]. It is pertinent to mention here that the nano-composite coated absorber has increased absorption of solar radiation and enhanced heat transfer to working fluid. In this connection, the present research work was devoted (i) to prepare nano composite coated solar absorbers (ii) to characterize the prepared solar absorbers and (iii) to conduct thermal analyses on the prepared solar absorbers. All these objectives were materialized by adopting standard methodology and the research outcomes have been recorded in this research paper. The research outcomes would be beneficial to the researchers in the context of the preparation and evaluation of thermal efficacy of eco-friendly solar absorbers. The research outcomes would also be beneficial to the solar manufacturers in the context of the development of energy efficient and cost- effective solar absorbers. The section I contains the introduction, whereas the section II and section III contain materials, methods, results and discussion. At final, the section IV contains the conclusion of the present research paper.

II. MATERIALS AND METHODS

Preparation of absorptive coating

The carbon blocks were commercially procured. These blocks were made into nano carbon powder by adopting ball milling method.

The prepared powder was mixed with nanosized MnO_2 powder in varied compositions. The mixed powder of carbon and MnO_2 was stirred thoroughly in the conventional absorptive solution by using a mechanical stirrer. The developed absorptive solution was used for coating on solar substrates [3].

Deposition of absorptive coating

The spray head was kept at a distance of 15cm from the pre cleaned galvanized iron substrates. The developed absorptive solution was sprayed at a spray rate of 10 $ml.min^{-1}$ on to the substrates using compressed air as carrier gas. The coatings were checked by naked eyes and the uniformity in coatings on absorbers was confirmed [4].

XRD Characterization

As the XRD is an ideal technique for the assessment of the structural characteristics of the material, the structural

characterization with reference to XRD was carried out on the developed absorber samples. As a result, the diffractogram that contained 2θ, d values, net intensity and relative intensity was obtained. The crystallite size in the coating was calculated by using the Debye-Scherrer formula that has been presented in Equation 1

$$D=K\lambda/\beta\cos\theta \quad (1)$$

Where D is crystallite size, K is correction factor, λ is wavelength of X-ray used, β is the FWHM of the observed peaks and θ is the diffraction angle [5].

Thermal durability

The prepared nano composite coated solar absorbers were kept in a hot air oven at 175°C for four hours. The absorber samples were taken out and they were cooled as per Bureau of Indian Standards (BIS) specifications. The peeling off and fading of coating, if any, was inspected on the thermally tested absorber samples [6].

Temperature measurement on solar absorbers

The prepared nano composite coated absorbers were kept in outdoors for the measurement of temperature on those absorbers in varied meteorological conditions. The temperature of absorbers along with the influencing parameters such as incident solar radiation, ambient temperature and wind speed were measured. It should be noted that the absorber samples were free from fall of dusts, shadows and other influencing materials during the experimental period [6].

III. RESULTS AND DISCUSSION

The preparation, characterization and evaluation of the thermal efficacy of nano carbon-MnO_2 coated solar absorbers is the present research. The technical specifications of the nano carbon-MnO_2 coated absorbers have been presented in Table 1. At the same time, the research outcomes of characterization studies and thermal analyses have been presented in Table 2 and Table 3 respectively.

Table 1 Technical specifications of solar absorber

Solar absorber	Materials/Sizes
Material	Galvanized iron
Length of each absorber	2000 mm
Breadth of each absorber	1000 mm
Area of each absorber	$2m^2$
Thickness of each absorber	0.20 mm

Table 2 Constituents and crystallite sizes

Parameters	Results
Constituents of coating	Nano carbon and MnO_2
Substrate	Galvanized iron
Calculated crystallite size	90 nm

Table 3 Thermal efficacy of solar absorbers

Time (hrs)	Solar radiation (W/m^2)	Ambient temperature (ºC)	Temperature on solar absorber (ºC)		
			On 60C:40 MnO_2 coated absorber	On 70C:30MnO_2 coated absorber	On 80C:20MnO_2 coated absorber
11:00	681.4	33.0	50.6	52.0	51.1
11:30	736.5	33.1	51.4	53.5	52.8
12:00	786.1	33.5	52.9	54.4	53.8
12:30	796.5	33.9	53.6	55.1	54.4
13:00	816.4	34.1	54.2	56.0	55.6

In the present research, the low cost material galvanized iron was used as substrates for nano composite coatings. The length, breadth and thickness of the substrates were fixed as per standard specifications. They were coated with nano carbon-MnO_2 mixed coating in different ratios by

spray coating method. The nano composite coated substrates could serve as effective absorbers and they were used for further investigations [7].

In the present research, the XRD characterization was carried out on the nano carbon-MnO_2 coated absorbers. The crystallite sizes of the constituents in the coating on the prepared absorbers were calculated by using the generated diffractogram and Debye-Scherrer formula. The calculated crystallite sizes were found to be in nano ranges [8].

In the present research, the thermal durability test was conducted on nano carbon-MnO_2 coated absorbers. It was found that there was neither pealing off nor fading of the coatings on the absorbers. So, the prepared absorbers would withstand in stagnant and operative conditions in solar collectors [9].

In the present research, the prepared absorbers were kept in outdoor conditions. The incident solar radiation, ambient temperature and temperature on solar absorbers were measured during the experimental period. It was found that the solar absorber with carbon-MnO_2 coating in the ratio of 70% carbon and 30% MnO_2 had higher temperature than those of the recorded temperatures on other absorbers with different ratios of carbon and MnO_2 in the absorptive coatings. So, the solar absorber with 70% carbon and 30% MnO_2 mixed coating would be used for further applications [10].

IV.CONCLUSION

As the preparation of nano carbon and MnO_2 coated absorbers was feasible, it could be concluded that these energy efficient, cost-effective and eco-friendly solar absorbers would be developed. As the thermal durability and efficacy of nano carbon and MnO_2 coated absorbers were acceptable, it could also be concluded that nano carbon and MnO_2 coated absorbers would be integrated in solar collectors so as to improve their thermal performances.

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