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NANO-GRAPHITE-NICKEL OXIDE COATINGS FOR COPPER SOLAR ABSORBERS: PREPARATION, STRUCTURAL CHARACTERIZATION, AND THERMAL PERFORMANCE

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Abstract: This study investigates the development of a novel and cost-effective solar selective coating that demonstrates significantly higher solar absorption efficiency compared to the conventional black coatings commonly employed in solar heating systems. The research confirms that nano-sized graphite and NiO-based absorber coatings can be successfully fabricated using the spray coating technique. X-ray diffraction (XRD) analysis indicates that the crystallite sizes of both nano-graphite and NiO coatings fall within the nanometer range. The findings of this investigation further reveal that absorber coatings comprising nano-sized graphite and NiO in an 80:20 ratio exhibit satisfactory thermal durability and thermal efficiency, making them suitable for application in solar water heating systems. Based on the demonstrated thermal stability and performance, it is concluded that nano-sized graphite and NiO absorber coatings can be effectively integrated into solar water heating systems to enhance their overall thermal performance.

Keywords: Solar absorbers- Nano-sized graphite and NiO based coating-Thermal durability-Thermal enhancement on solar absorbers.

I. INTRODUCTION

Solar desalination systems play a vital role in converting saline water into potable water. Bridging the gap between the demand and supply of fresh water requires not only enhancing the thermal performance of existing desalination technologies but also developing and implementing innovative systems in the real-world applications. In a solar desalination system, the absorber tray serves as the key component [1]. Its primary function is to absorb incoming solar radiation and convert it into heat energy [2], which subsequently facilitates the evaporation of saline water. The resulting vapour is condensed to yield fresh water. Notably, nano-composite coated absorbers exhibit improved solar radiation absorption and enhanced heat transfer characteristics, making them highly promising for desalination applications.

In this context, the present study focuses on: (i) preparing and depositing novel nano-composite coatings for solar absorbers, (ii) characterizing the developed absorber surfaces, and (iii) performing thermal analysis to evaluate their performance. These objectives are achieved through a systematic and standardized methodology. The findings of this work are expected to support researchers in developing eco-friendly absorber materials and assist manufacturers in producing energy-efficient and cost-effective solar absorbers.

II. MATERIALS AND METHODS

Preparation of Absorptive Coating

In this investigation, nano-sized graphite and nickel oxide (NiO) powders were procured and combined in four different weight ratios: 20:80, 40:60, 60:40, and 80:20. Each mixture was thoroughly dispersed into a conventional absorptive medium using a mechanical stirrer to ensure homogeneous blending. The resulting composite absorptive solution was then deposited on pre-cleaned copper substrates using the spray coating technique [3].

Deposition of Absorptive Coating

During the spray coating process, the spray nozzle was maintained at a distance of 15 cm from the prepared copper substrates. The absorptive solution was applied at a controlled spray rate of 10 mL/min, with compressed air serving as the carrier gas. The coated substrates were visually inspected to verify coating quality, and uniformity across the absorber surfaces was confirmed [4].

XRD Characterization

X-ray diffraction (XRD) analysis, an established technique for examining the structural characteristics of materials, was employed to characterize the developed absorber samples. The resulting diffractogram provided key parameters, including 2θ values, interplanar spacing (d), net intensity, and relative intensity. The crystallite size of the coating was determined using the Debye–Scherrer equation, presented in Equation (1):

$$D=K\lambda/\beta\cos\theta \quad \text{---- (1)}$$

where D represents the crystallite size, K is the shape factor, λ denotes the wavelength of the X-ray source, β is the full width at half maximum (FWHM) of the diffraction peak, and θ is the diffraction angle [5].

Thermal durability

To assess thermal durability, the nano-composite coated solar absorbers were subjected to thermal stress in a hot air oven at 175 °C for four hours. Following heating, the samples were cooled in accordance with the Bureau of Indian Standards (BIS) guidelines. The coated surfaces were examined for any signs of degradation, including peeling or fading, to evaluate coating stability under elevated temperature conditions.

Temperature measurement on solar absorbers

The nano-composite coated absorber samples were placed outdoors to record temperature variations under natural meteorological conditions. During testing, absorber temperature and associated environmental parameters, incident solar radiation, ambient temperature, and wind speed were measured. All experiments were conducted under controlled conditions, ensuring that the samples remained free from dust accumulation, shading, and other external interferences throughout the measurement period [6].

II. RESULTS AND DISCUSSION

The preparation, characterization, and thermal efficiency evaluation of nano-sized graphite and nickel oxide coated solar absorbers are comprehensively examined in this study. The technical specifications of the developed nano-composite absorber coatings are summarized in **Table 1**, while the results of the characterization analyses and thermal performance evaluations are presented in **Table 2** and **Table 3**, respectively.

Table 1: Technical specifications of solar absorber

Solar absorber	Material/Sizes
Material	Copper
Length of each absorber	1000 mm
Breadth of each absorber	1000 mm
Area of each absorber	$1m^2$
Thickness of each absorber	0.20 mm

Table 2: Constituents and crystallite sizes

Parameter	Result
Constituents of coating	Graphite and NiO
Substrate	Copper
Calculated crystallite size	41.96 nm

Table 3: Thermal enhancement in solar absorbers

Time (hrs)	Solar Radiation (W/m^2)	Ambient Temperature (°C)	Temperature on solar absorber (°C)		
			On 40 Graphite: 60 NiO coated absorber	On 60 Graphite: 60 NiO coated absorber	On 80 Graphite: 20 NiO coated absorber
10.00 am	523.4	32.4	52.8	50.1	51.2
10.30 am	540.1	32.7	53.5	54.2	55.7
11.00 am	581.4	33.0	54.6	56.3	59.9
11.30 am	661.3	33.2	56.1	58.7	61.8
12.00 pm	716.8	33.5	58.2	59.1	62.8
12.30 pm	752.7	33.6	58.6	59.5	63.4
13.00 pm	801.5	33.7	55.1	58.8	61.3

In the present research, copper is used as substrates for nano composite coatings. The length, breadth and thickness of the substrates are fixed as per standard specifications. They are coated with nano-sized graphite and NiO mixed coating in different ratios by the spray coating method. The nano composite coated substrates serve as effective absorbers and they are used for further investigations [7].

In the present research, the XRD characterization is carried out on the nano-sized graphite and NiO. The crystallite sizes of the constituents in the coating on the prepared absorbers are calculated by using the generated diffractogram and Debye-Scherrer formula. The calculated crystallite sizes are found to be in nano range [8].

In the present research, the thermal durability test is conducted on nano-sized graphite and NiO coated absorbers. It is found that there is neither peeling off nor fading of the coatings on the absorbers. So, the prepared absorbers can withstand in stagnant and operative conditions in solar water heating systems [9].

In the present research, the prepared absorbers are kept in outdoor conditions. The incident solar radiation, ambient temperature and temperature on solar absorbers are measured during the experimental period. It is found that the solar absorber with nano-sized graphite and NiO coating in the ratio of 80% nano-sized graphite and 20% NiO have higher temperature than those of the recorded temperatures on other absorbers with different ratios of nano-sized graphite and NiO in the absorptive coatings. So, the copper solar absorber with 80% nano-sized graphite and 20% NiO mixed coating can be used for further applications [10].

IV.CONCLUSION

The results of this study demonstrate that the fabrication of nano-sized graphite and NiO coated copper solar absorbers is both technically feasible and practically achievable using the adopted preparation and deposition methodologies. The developed coatings exhibit desirable characteristics, positioning them as energy-efficient, cost-effective, and environmentally sustainable alternatives to conventional absorber surfaces. Their compatibility

with large-scale production further supports their potential deployment across various solar thermal application sectors.

The findings from the thermal durability assessment and thermal performance evaluation confirm that the nano-sized graphite and NiO coated absorbers possess adequate structural stability and thermal efficiency under the tested conditions. In particular, the nano-composite coatings deposited on copper substrates maintained their integrity and performance after exposure to elevated temperatures, indicating strong thermal resilience.

Based on these results, it is concluded that nano-sized graphite and NiO coated copper solar absorbers are well-suited for integration into solar water heating systems. Their enhanced absorption properties and improved heat transfer characteristics are expected to contribute to notable improvements in the overall thermal performance of such systems. Therefore, the incorporation of these nano-composite coatings represents a promising pathway for advancing the efficiency and sustainability of solar thermal technologies.

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