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Experimental Analysis of the Effects of CuO Nanostructure Coating on Cuprous Absorber on the Thermal Performance of a Flat-Plate Collector Solar Water Heater (FPCSWH)

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Abstract
In this paper, the effects of CuO nanostructure coating on cuprous absorber on the thermal performance of a flat-plate collector solar water heater (FPCSWH) were experimentally studied. Three types of serpentine cuprous flat-plate collectors were designed, built, and compared: a simple absorber, a black-painted absorber, and a CuO nanostructure-coated absorber. The tests were performed in Zanjan, Iran, in April for different rates of water flows and collector slopes. The results showed a significant improvement in the efficiency of the CuO nanostructure-coated cuprous absorber compared to other absorbers. The improvement equaled 4-12% comparing to the black-painted absorber and 20-35% comparing to the simple absorber. This phenomena was due to the fact that nanostructures cause irregularities in the surface of the absorber, increasing the absorptance and reducing the thermal emittance.

Keywords: Flat plate collector solar water heater (FPCSWH), CuO nanostructures, Solar absorptance, Thermal emittance

Introduction

The Supplying Domestic hot water by solar energy is one of the important matters that has been intentioned by researchers in the past decades. They are trying to improve the performance of solar water heater (SWH) by making a change in its parameters. Flat plate collector solar water heater (FPCSWH) designed for operation in the low temperature range, from ambient to 60°C, or the medium temperature range, from ambient to 100°C. FPCSWH is one of the best system for analyzing the effect of various parameters on the efficiency of SWH. The parameters that affect the performance of a FPCSWH can be divided in two groups; structural and functional. The structural parameters are related to the geometry and the structure of the FPCSWH, such as collector dimensions, Diameter, color and physical properties of tubes, absorber plate specifications (thickness, color, surface coating …). The functional parameters such climatic situation, collector position and the condition of internal fluid are also important [1]. One of the most important structural parameters that has a vital role in the performance of FPCSWH is the surface coating of the absorber plate. A surface that absorbs the most of the solar radiation usually reradiate most of absorbed energy as heat wavelengths. For example a black painted flat aluminum plate absorbs 96% of solar radiation falling on it and will also reradiate much of absorbed energy as heat, it is worth mentioning that the glazing and the temperature of the plate determine the precise amount of absorption. It is very ideally to have a surface that has a high absorption coefficient over the solar spectrum and very low thermal emittance in the IR region for such a surface, $\alpha = 1$ and $\varepsilon = 0$. These surfaces called selective coating that more heat could be transferred to the working fluid [2].

Ortiz et al. [3] studied the coating of the ruthenium oxide films on polished titanium by spraying and dipping method and indicated 0.74 and 0.12 for absorptance and thermal emittance, respectively. Chang et al. [4] represented a low-temperature (<100°C) solution-chemical technique to prepare nanogold absorber coating on a cuprous absorber plate. They reported the coefficient of absorption and thermal emission for this coating equal to 0.846 and 0.09, respectively. Japelj et al. [5] prepared an organic–inorganic nanocomposite by spray coating on PMMAPoly (methyl methacrylate) and reported absorption coefficient of 0.9 and thermal emittance of 0.3 for this coating. Barshilia et al. [6] prepared Ag–Al_2O_3 nanocermet spectrally selective absorber coating at different Ag contents on copper, silicon and glass substrates using an unbalanced magnetron sputtering technique. They reported that the optimized coating shown high absorbance (α = 0.93) in the visible region and low thermal emittance (ε =0.04–0.05) at 82°C.

In this research Experimental Analysis of CuO Nanostructures Coating on Cuprous Absorber effects on the Thermal Performance of FPCSWH was investigated and the FPCSWH tested under different experiments.

Experimental procedure

Experimental set up

In order to have a perfect analyze, three types of even one glass cover FPCSWH were built, calibrated and then coated with different covers. Every FPCSWH consists of a 400*250*0.4 mm cuprous