CHROMIUM OXIDE - CHROMIUM AND COPPER OXIDE SELECTIVE ABSORBERS FOR PHOTOTHERMAL CONVERSION OF SOLAR ENERGY

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ABSTRACT

Solar energy can be converted into thermal energy with the help of a solar collector of the flat plate type or of the concentrator type. In a solar collector an absorber surface is used to convert solar radiation into heat which is then transferred to the working fluid. The radiation losses from the heated absorber panels can be minimised and thereby photothermal conversion efficiency of the system can be enhanced by the use of selective absorbers, having high absorption over the solar spectrum and low emittance at the operating temperatures.

Nearly all selective surfaces consist of an absorbing coating on a metal substrate, the coating providing the high solar absorptance and the metal providing the low thermal emittance. Two such surfaces, the chromium oxide - chromium and the copper oxide selective absorbers, have been taken for detailed investigation in the present thesis.

The Cr_2O_3 - Cr composite coatings have been produced on stainless steel and nickel plated mild steel substrates by the chemical blackening process. The coatings are formed by keeping the cleaned substrates immersed in molten sodium dichromate bath at 425 to 450°C for times ranging from ½ minute to 30 minutes. Their selective properties, namely

solar absorptance and thermal emittance, have been studied as a function of the time of immersion in the bath. For the stainless steel samples the solar absorptance is in the range of 0.84 to 0.92 with thermal emittance values in the range of 0.25 to 0.32. The corresponding values for nickel plated mild steel specimens are 0.77 to 0.90 and 0.13 to 0.50 respectively.

The copper oxide films are deposited onto heated aluminium substrates by spraying cupric nitrate. A thin light green coating is formed on the aluminium surface, which upon being heated above 170°C gets converted to black copper oxide. The variation of solar absorptance and thermal emittance with thickness of the deposit has been studied for different concentrations of the spray solution. The effect of baking temperature on the optical properties of the coatings has also been studied. Under optimum conditions, with baking temperature 350°C and spray concentration 0.005 M, solar absorptance of 0.90 with a corresponding thermal emittance of 0.15 is obtained for a film of thickness 1.35 μm.

A detailed study has been carried out on the structure and composition of the deposits, using X-ray diffraction and electron diffraction techniques. The structural studies have clearly established the composite nature of Cr_2O_3 - Cr coatings. The surface morphology is characterised by preferentially oriented needle shaped particles with a mean size of the order of 0.40 μm. The textural discontinuities in the surface features, of the order of solar wavelengths, promote absorption through scattering and multiple cavity reflections of the incident radiation. The periodic structure implies that the absorption in the solar region is mainly governed by the light trapping mechanism.

The X-ray diffractographs and the electron diffraction pattern show that cupric oxide (CuO) is the more dominating constituent of the copper oxide film. The scanning electron micrograph shows that the surface exists as a porous finely structured medium with small copper oxide particles of size 0.40 μm. High absorption of the exterior coating may be due to the surface geometries which are of the dimensional order of the solar wavelengths.

The coatings are subjected to various accelerated laboratory aging tests and the degradation effects on these coatings have been investigated in detail. The Cr_2O_3 - Cr coatings on stainless steel substrate can withstand temperatures upto 250°C. The coatings do not suffer from any change in optical properties when cycled between 0°C and 200°C. Ultraviolet irradiation for 120 hours and humidity exposure for 30 days have not revealed any appreciable effect on the optical properties of the coatings.

The copper oxide films on aluminium substrate are stable upto 200°C. Under thermal cycling between 0°C and 150°C and between 0°C and 200°C, a slight decrease in solar absorptance and thermal emittance is observed. Ultraviolet irradiation and humidity exposure also result in very small changes in the optical properties of the films.

Stagnation temperature measurements have been made for the two selective absorbers and an attempt has been made to estimate the temperature dependence of the overall heat loss coefficient of a solar collector. The Cr_2O_3 – Cr coating on stainless steel substrate attains a maximum stagnation temperature of 134.8°C and 149.5°C, with one glass cover and two glass covers respectively for the enclosure, under a solar flux of 900 W/m^2. The non-selective black surface attains 121.5°C and 132.0°C under identical conditions. The copper oxide film attains a temperature of 131.1°C and 146.5°C, with one glass cover and two glass covers respectively, under a solar flux of 720 W/m^2, whereas under identical conditions the non-selective black surface attains a temperature of 115.9°C and 127.5°C respectively.

List of publications related to thesis work :

1. "Cr_2O_3-Cr composite Selective Absorbers produced by the Ebonizing Process". Solar Energy Materials 6(1981) 113-121.

2. "A Cr_2O_3-Cr composite coating as Selective Surface." presented at the National Solar Energy Convention, Bangalore, India (1981).

3. "Spectrally Selective Copper Oxide Films". Accepted for publication in Applied Energy (1982).

4. "The Cr_2O_3-Cr Composite Selective Absorbers : Durability Tests and Stagnation Temperature Measurements". Communicated to Solar Energy Materials.

Other Publications in related topics :

5. "Spectrally Selective Copper Sulphide Coatings". Solar Energy Materials 5.2 (1981) 129.

6. "Copper Sulphide Coatings for Photothermal Conversion of Solar Energy". Presented at the National Solar Energy Convention, Annamalai University, Tamil Nadu, India (1980).

7. "Spectral Selectivity and Accelerated life testing of Al-PbS Solar Selective Surfaces". Int. J. of Energy Research 6(1982) 169.

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