Journal of the Nigerian Association of Mathematical Physics
Volume **25 (November, 2013), pp 395 – 400**
© J. of NAMP

Investigation into Thermal Emittance of Solar Assisted Electroless Deposition of Cadmium Sulphide Thin Films for Different Deposition Times at 40^0C

[1]Amen-Leleji , A. O., [2]Damisa, J and [2]Ilenikhena, P. A.

[1]Department of Physics, College of Education,
Ekiadolor, Benin City. Edo State, Nigeria
[2]Department of Physics,
University of Benin, Benin City. Edo State, Nigeria

Abstract

Thin films of cadmium sulphide were successfully deposited on polished aluminium sample plates by solar assisted Electrolesss Chemical Deposition (ECD) method at ambient temperature of 40^0C. The thermal emittance of the sample plates were measured using an emissiometer before and after deposition of the thin films. The average thermal emittance value of the polished plates was 0.10±0.01 while the thermal emittance value of the coated plates ranged from 0.21 to 0.24±0.01 depending on the deposition time. The film thickness of the coated sample plates value ranged from 1.273 to 6.825µm ±0.001. The low thermal emittance value of the coated plates compare favorably with spectrally selective surfaces used in solar collectors.

Key words: Thermal emittance, Emissometer, Electroless Chemical Deposition Method , Thin films, Film thickness, Aluminium .

1.0 Introduction

A spectral selective coating is an important requirement for efficient photothermal converters. It is employed for effective conversion of solar energy into heat for various applications such as solar water heaters for hot water supplies in homes and hospitals, solar cookers, solar driers, solar water distillation for production of salt from sea water, solar thermal refrigerators, poultry production, e.t.c [1-4]. A spectrally selective absorber has maximum absorption for solar wavelengths (0.3 to 2.5µm) and minimum emittance for thermal wavelengths (3.0 to 30.0 µm) [5]. The amount of solar energy absorbed by a surface is directly proportional to solar absorbance, while the quantity of radiation energy emitted is proportional to the thermal emittance, [6]. Selective surfaces are good absorbers of solar radiation and poor emittance of thermal radiation [6-8].The advantages of using spectrally selective surfaces for solar energy collectors were first reported on separate papers by [9,10]. Prior to their demonstration, black paint surfaces that were used in solar energy collectors were good absorbers of solar energy with solar absorbance of 95% and also good emitters of thermal radiation with thermal emittance of 90%. For typical selective surfaces, solar absorbance is 90% while thermal emittance is 20% [6]. Selective absorbers are produced using different deposition techniques such as physical vapour deposition (PVD), sputtering and chemical techniques on both metallic and non metallic substrates.

Electroless chemical bath deposition method of producing thin films was used in the production of silver mirrors [11,12].The method is cost effective, simple, convenient, reproducible and widely studied for preparation of thin films on both metallic and non-metallic substrates.

The aim of this work is to fabricate a spectrally selective surface with high corrosion resistance that will enhance the efficiency of solar energy collector. Such surface could be used to provide efficient method for storing the excess heat energy from collectors and extracting them when required.

Corresponding author: ***Amen-Leleji , A, O,*** E-mail: askoghogho123@yahoo.com, Tel.: +2348058813302

2.0 Experimental Studies

2.1 Preparation of sample plates.

A large sheet of size 29cm by 22.5cm, thickness 0.1cm, was cut into small samples measuring 7.5cm x 0.1cm. The cutting of the sheet was done by a manual guillotine cutting machine. The sample plates were cleaned by polishing them with emery papers and gamma polishing alumina using cotton wool. The polished sample plates were washed with detergent solution, rinsed in distilled water and drip dried.

2.2 Preparation of bath solution.

The thin film deposition was done in a 400ml beaker, containing different molar solutions. The bath constituent for deposition of cadmium sulphide thin film were copper chloride ($CuCl_2$) as source of copper (Cu^{2+}), and chlorine ions (Cl^-), and ethylene diamine tetra-acetate (EDTA) as complexing agent. Sodium hydroxide and water was added to raise the volume to a certain level. The mass of chemical reagents for the various molar solutions were calculated from the expression

$$m = \frac{M\,xVxW}{1000} \tag{1}$$

Where *M* is molarity, *V* is volume and *W* is molecular mass of the chemical salt.

2.3 Deposition Of Cadmium Sulphide Thin Films.

The bath constitution for preparation of cadmium sulphide thin films is shown in Table 1.

Table 1: Bath constitutions for preparation of cadmium sulphide for different deposition times:

Sample plate	Deposition time T(mins)	0.3M of Cadmium Chloride ($CdCl_2$) (ml)	0.2M of EDTA (ml)	NaOH 2.0M (ml)	0.3M of Thiourea (ml)	H_2O (ml)
1	45	75	65	45	70	45
2	90	75	65	45	70	45
3	135	75	65	45	70	45
4	180	75	65	45	70	45
5	225	75	65	45	70	45
6	270	75	65	45	70	45

A cleaned sample plate was immersed in each bath for 3 hrs at an average temperature of 40^0C for pretest runs. Then 6 sample plates of aluminium were immersed in each bath for different deposition time ranging from 3 hours to 18 hours at ambient temperature of 40^0C. After deposition the plates were rinsed with distilled water and drip dried.

The most probable reactions for the deposition of CdS thin films is

$$\left.\begin{array}{l} CdCl_2^{+}\,(EDTA) \rightarrow Cd\,(EDTA) + Cl^{2-} \\ Cd(EDTA) \rightarrow Cd^{2+} + EDTA \\ (NH_2)_2\,CS + OH \rightarrow CH_2N_2^{+}\,H_2O + HS \\ HS^- + OH^- \rightarrow H_2O + S^{2-} \\ Cd^{2+} + S^{2-} \rightarrow CdS \end{array}\right\} \tag{2}$$

3.0 Measurements

3.1 Measurement of Thermal Emittance

Thermal emittance of the sample plates was measured using emissometer having a detector that is heated to about 60^0C so that the sample whose thermal emittance is to be measured does not have to be heated up. The thermal emittance is measured after calibration of the detector with a sample of a known thermal emittance. The radiation detector is a differential thermopile. The sensing surfaces are aluminium foil and brake paint. Their combination of which ensures a near constant response to thermal wavelengths of between 3 to 30 microns. The detectors output is 0.93 with a deviation of 0.01 at a nominal voltage of 2.4mV. Its response time is about 10 minutes. A heat sink is used in the calibration and in the final measurements. A scaling digital voltmeter is connected to the emissometer for liquid crystal display of output. Its full scale of 15mV corresponds to a count of 2000. In calibrating the emissometer, a standard aluminium plate whose thermal emittance is 0.04 and a standard black plate whose thermal emittance is 0.93 were used. Thermal emittance of the sample plates is determined from the equation:

$$\frac{E_s}{E_p} = \frac{V_s}{V_b} \qquad (3)$$

Where, E_s is the emissivity of blackbody Surface (0.93)
E_p is the emissivity plate
V_p is the voltage emitted by plate
V_b is the voltage emitted by black body

3.2 Measurement Of Film Thickness

The mass of each sample plate was determined by the use of an electronic balance before and after deposition of film. Film thickness was calculated from [5].

$$t = \frac{m}{2Ad} \qquad (3)$$

where m is the mass of the deposited film, d is the density , A is the area of sample plate covered by the film which is given by 4.87g/cm^3.

4.0 Results and Discussion

Table 2: Thermal emittance of polished and coated stainless steel 430 sample plates at different deposition time.

Plate No	Surface Treatment	Deposition time T(min)	Emissiometer voltmeter		Thermal emittance $E_p \pm 0.01$
			Black plate $V_b \pm 0.01$ (mV)	Sample plate $V_s \pm 0.01$ (mV)	
	Polished and uncoated	-	2.65	0.28	0.10
1	Polished and coated	45.0	2.65	0.35	0.12
2	Polished and coated	90.0	2.65	0.46	0.16
3	Polished and coated	135.0	2.65	6.49	0.17
4	Polished and coated	180.0	2.65	0.51	0.18
5	Polished and coated	225.0	2.65	0.59	0.21
6	Polished and coated	270.0	2.65	0.68	0.24

Table 3: Thickness of thin films deposited on stainless steel 430 sample plates for different deposition time.

Plate No.	Deposition Time T(min)	Mass of Deposited film m±0.01(g)	Area of coated plate A±0.01(cm^2)	Film thickness t±0.001μm	Thermal emittance E_s±0.01
1	45.0	0.06	48.75	1.273	0.12
2	90.0	0.11	48.00	2.352	0.16
3	135.0	0.14	43.25	3.323	0.17
4	180.0	0.20	44.20	4.646	0.18
5	225.0	0.25	46.80	5.484	0.21
6	270.0	0.33	49.64	6.825	0.21

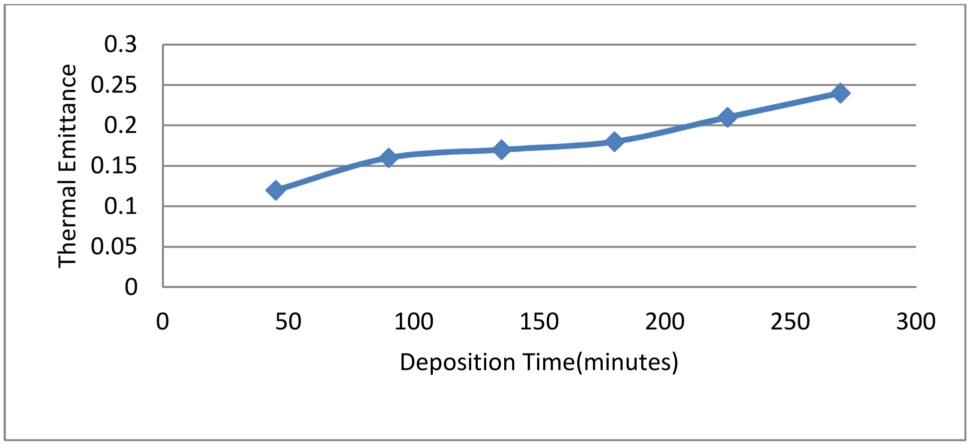

Fig. 1 : Variation of thermal emittance of CdS thin film on aluminium with deposition time.

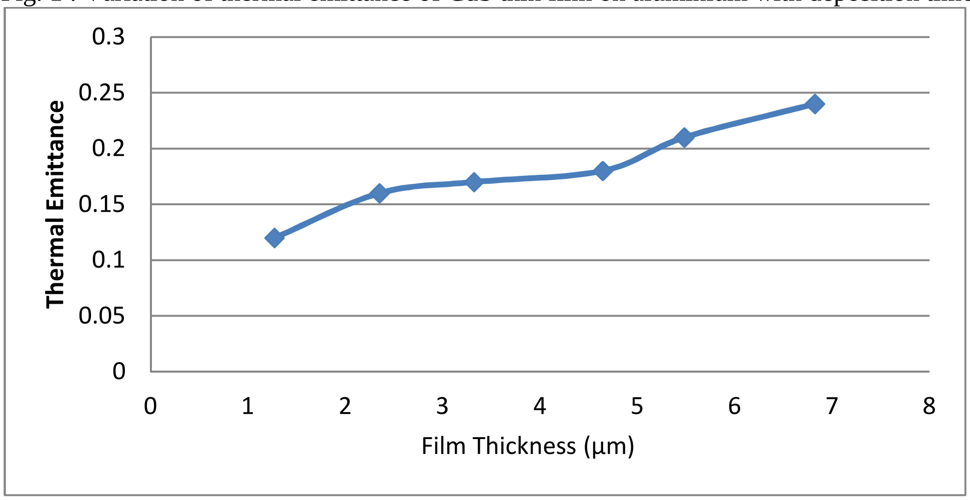

Fig.2: Variation of thermal emittance with film thickness of CdS

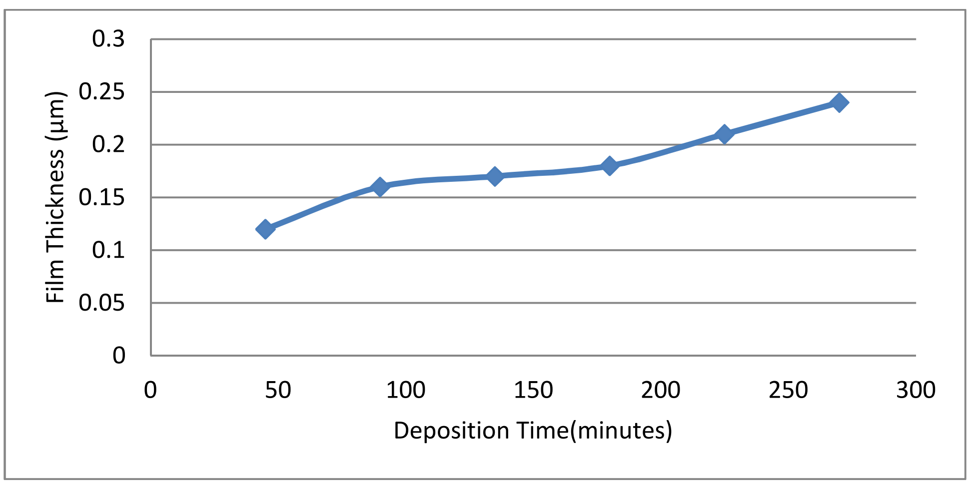

Fig. 3: Variation of film thickness of CdS with deposition time.

The average thermal emittance value of polished stainless steel 430 is 0.10 ± 0.01. These values compares well with thermal emittance of 0.15 ± 0.01 for polished stainless steel 430 [4, 13 - 15] and 0.13 to 0.17 ± 0.01 for polished stainless steel AISI 321 [16]. Table 2 and Figure 1 shows that the thermal emittance value of coated sample plates increases slowly from 0.12 to 0.24 ± 0.01 with deposition time of 45 to 270 minutes at 40^0C .These values compare favourably with thermal emittance value of 0.16 to 0.19 ± 0.01 for the improved electroless chemical bath deposition of stainless steel 430[13] , thermal emittance value of 0.16 to 0.18 ± 0.01 for the solution growth of stainless steel 430 [14], thermal emittance value of 0.15 to 0.19 ± 0.01 for improved chemical bath deposition (CBD) method of stainless steel 430 and also the thermal emittance of 0.18 ± 0.01 for chemically oxidized stainless steel AISI 321 [5]. Table 3 and Figure 2 shows that the thickness of the film increases from 1.273 to 6.825µm with deposition time of 45 to 270 minutes. The relationship between thermal emittance and film thickness for various deposition time is nearly linear as shown in Figure 3. The thickness of the film could be hardened to withstand adverse weather condition and at the same time retaining its minimum thermal radiation losses to enhance the efficiency of the photo thermal converters. Surfaces with poor film thickness are not durable and cannot withstand adverse weather conditions while those with higher film thickness and higher thermal emittance cannot retain much heat to enhance efficiency of photothermal converters.Surfaces with low thermal emittance may be employed in the fabrication of spectrally selective surfaces which could be used in poultry production for the construction of solar chick broader and could provide heat, for warmth and protection for young chicks which have little or no insulating feathers from adverse weather conditions during the day, [1, 4, 17 - 19].

5.0 Conclusion

Thin films of Cadmium sulphide were deposited on the polished stainless steel 430 sample plates using electroplating technique at 40^0C for deposition time of 45 to 270 minutes. An emissometer was used to determine the thermal emittance values of the sample plates before and after film deposition. The average thermal emittance of the polished sample plates is 0.10 ± 0.01. Values of the thermal emittance of the coated plates vary from 0.12 to 0.24 ± 0.01. Their corresponding film thicknesses vary from 1.273 to 6.825 ± 0.001µm. The values of thermal emittance of the coated sample plates are low and increase slightly with increase in the deposition time. The surface with the most favourable thermal emittancevalues of 0.12 to 0.18 ± 0.01 and film thickness of 1.273 to 4.646µm± 0.001obtained for deposition time of 45 to 180 minutes could be employed to fabricate selective absorbers for photothermal converters.

References

[1]. Ileoje, O. C. (1997). Potentials for Renewable Energy Applications in Nigeria, Energy Commission Of Nigeria, 5-16.

[2]. Ilenikhena, P.A. and Okeke, C.E. (2002). Prospects of Solution Growth Cadmium Sulphide (CdS) Thin Film Surfaces at pH of 7-12 and temperature of 320K Nig. Jour. of Physics 14 (1), 34-39.

[3]. Ilenikhena, P.A. and Mordi, P.C. (2005). Radiation Characteristics of Polished and Solution Grown Iron Pyrite Films on Ferritic Stainless Steel 430 for use in Solar Energy Applications, Nig. Jour. of Solar Energy 15, 187-192.

[4]. Ilenikhena, P. A. (2008). Optical Characterization and Possible Solar Energy Applications of Improved Solution Grown Cobalt Oxide (CoO) Thin Films, Afr. Physical Rev. 2, 0008, 68-77.

[5]. Sharma, V.C., Sharma A. and Ilenikhena, P.A.(1988). Chemical Oxidation and Spectral Selectivity of Austenitic Stainless Steel AISI 321, Energy 13 (10), 749-754.

[6].Chritie, E. A. (1970). Spectrally selective blacks for solar energy collection, International Solar Energy Society Conference, Melbourne-Australia, 7 (8). 1-7.

[7]. McDonald G. E. (1975): Spectral reflectance properties of black chrome for use as a solar selective coating, Solar Energy, Vol. 17, 119-122.

[8]. Sharma, V.C and Hutchins, M.G (1979). Radiative Selectivity and Oxidation of Stainless Steels, Proc. ISES Atlanta G.A. 3, 1940.

[9]. Tabor, H. (1955): Solar energy collection design. Trans. of the conference on the use of solar energy, Part 1, Section A.

[10]. Gier, J. T. and Dunkle, R. V. (1955). Selective spectral characteristics as an important factor in the efficiency of solar collectors. Trans. of the Conference on the use of solar energy Part 1, Section A.

[11]. Chopra, K.L. and Das, S.R. (1983). Thin Film Solar Cells, Plenum Press, New York, Chaps. 2 and 5.

[12]. Eze and Okeke. (1997). Growth Characteristics of chemical Deposited Halide Thin films Nig. Jour. Of Renweable Energy 5(1-2), 125-130.

[13].Ilenikena, P.A., Alili, N. and Ofili, J.N. (2007).Effects of polishing treatment and chemically deposited maganesium chloride ($Mgcl_2$) thin films on thermal emittance of stainless steel 430. Nigeria Jour. Of Solar Energy Vol. 8, 58-62.

[14].Ilenikhena, P.A., Harding, E.E. and Chiedu, J.A. (2008).Thermal emittance properties of polished and solution grown cobalt sulphide (CoS) thin films on stainless steel 430 for solar energy collection. Nigeria Jour. Of Solar Energy Vol. 19 (1), pp. 1-5.

[15].Igbinovia, E.O. and Ilenikhena, P.A. (2010). Improved chemical deposition and thermal emittance of tin (iv) oxide(SnO_2) thin films for photothermal conversion of solar energy and possible applications. International Journal of physical science Vol. 5 (11), pp. 1770-1775.

[16].Sharma, V.C. (1982): Effect of polishing treatment and thermal oxidations on the total hemispherical thermal emittance of austentic stainless steel AlSl 321 Energy 7, 607

[17].Ilenikhena, P. A. (2007). Analysis of Beryllium Flouride (BeF) and Strontium Flouride (SrF) Thin Films Deposited by Improved Solution Growth Technique for Industrial Applications, Advanced Material Research Trans. Tech., Pub. Switzerland 18-19, 209-217

[18].Oladipo, E. (1999). Energy Efficiency for Sustainable Development, Keynote Address Presented at the National Workshop on Energy Conservation in Commercial/Institutional Buildings, Nigerian Society of Engineers and Energy Commission of Nigeria, Lagos-Nigeria.

[19].Okonkwo, W. I., Anazodo, U.C.N., Echiogu, E.A., Akubuo, C.O. and Ileoje, O.C.(1992). The Passive Solar Chick Brooder – Further Improvement and Preliminary Testing, Nig. J. Solar Energy 11, 32-40.