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CHARACTERIZATION OF ELECTRODEPOSITED NICKEL-COBALT BASED SELECTIVE COATINGS FOR SOLAR THERMAL ENERGY CONVERSION

N KARUPPIAH AND S JOHN

Central Electrochemical Research Institute, Karaikudi 630 006, INDIA

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Solar thermal collectors represent a widespread type of system to convert solar energy. The economic viability of applications of solar energy may be improved by increasing the quantity of usable energy delivered per unit area of collector. This is achieved by the use of selective black coatings which have a high degree of solar absorption, maintaining high energy input to the solar system, while simultaneously suppressing the emission of thermal infrared radiation. A new electrolyte has been developed for the deposition of black nickel-cobalt selective absorber coatings useful in solar collectors for photothermal conversion of solar energy. The influence of electrolyte composition and operating parameters on the properties of black nickel-cobalt coatings are reported.

Keywords: Selective coatings, black nickel-cobalt, optical properties

INTRODUCTION

Efficient conversion of solar energy to thermal energy requires collector panels which absorb strongly across the solar spectrum (0.2-3.0 micron) and emit very poorly in the infrared region (beyond 3 micron). A coating for solar collector should absorb and retain as much solar energy as possible since by so doing it will reach higher temperatures. The right coating improves the efficiency of the collector and maintains these properties during long term exposure to solar radiation.

Black chrome [1-4] has emerged as a strong candidate for an absorber surface because of its selective properties and long term durability. However, production of such coatings require operation at high currents and cooling facilities for the efficient operation of the bath. Hence, the capital investment is higher and the coating is costly. Black nickel [5] also possesses good selective properties, but its corrosion resistance is moderate. Hence, attempts are being made in this Institute and elsewhere to develop cheap and durable selective coatings for solar energy conversion [6-11]. In this paper, the authors report the development of black nickel-cobalt as a selective coating for solar energy utilization.

EXPERIMENTAL DETAILS

To optimise the electrolyte composition, *p*H and temperature Hull Cell studies have been carried out. The optimised electrolyte is a low concentrated solution which contains nickel sulphate 10 g/l, cobalt sulphate 10 g/l and ammonium acetate 10 g/l. The optimised deposition conditions are *p*H 6.0-6.5 and temperature 303-308 K. Copper plates of 100 x 100 mm size were given conventional pretreatments and bright nickel undercoating was provided to a thickness of 10 µm using Watts nickel plating bath. Black nickel-cobalt coatings were cathodically deposited at different current densities and for various durations of time.

Samples of 10 x 10 mm size were cut from the black coated panels and studied through SEM with and without thin film of gold on the coating. JEOL FINECOAT ion sputtering equipment has been used to coat thin film of gold on the surface to a thickness of 5-10 nm. The samples have been studied using a fine beam of electrons at an accelerating voltage of 15 KV. Secondary electrons emitted from the surface have been taken for imaging purposes. The

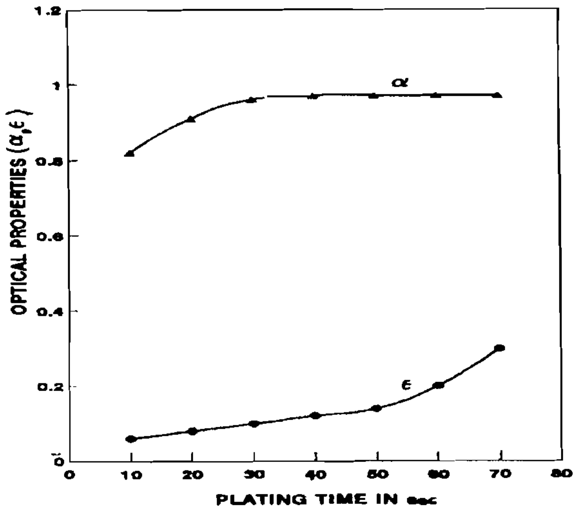

Fig.1: Influence of plating time on optical properties (α ,ε) for an electrolyte containing $NiSO_4$ 10 g/l, $CoSO_4$ 10 g/l, CH_3COONH_4, 10 g/l, 308K, pH 6.2, 4A/dm^2.

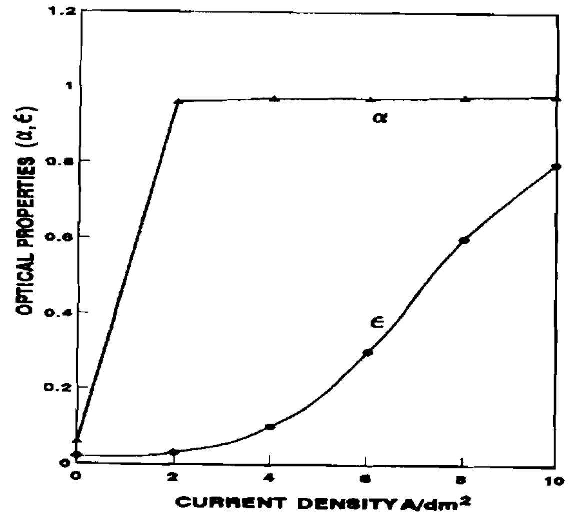

Fig.2: Influence of current density on optical properties (α ,ε) for an electrolyte containing $NiSO_4$ 10 g/l, $CoSO_4$ 10 g/l, CH_3COONH_4, 10 g/l, 308K, pH 6.2, 30 Sec.

micrographs have been taken at desired magnifications. Particle size analysis has been carried out with Malvern Instruments - Easy particle sizer M3.0. Solar absorptance (α) and thermal emittance (ε) were measured using Alphatometer and Emissiometer manufactured by M/s Devices & Services Co., USA. As a comparison, nickel black selective coating produced from an electrolyte containing 30 g/l nickel sulphate and 10 g/l ammonium acetate at 303 K at a *p*H of 5.8 at 4 A/dm^2 for 30 seconds deposition time which exhibits optical properties of $\alpha = 0.96$ and $\varepsilon = 0.11$ [7] was used.

RESULTS AND DISCUSSION

Influence of deposition time on optical properties (α, ε)

Fig.1 shows the influence of deposition time on optical properties (α, ε) for the black nickel-cobalt selective coating

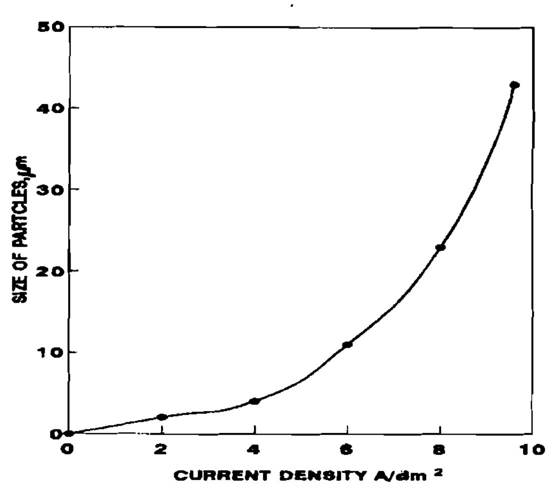

Fig.3: Influence of plating time on maximum size of the particles of the coating deposited from the electrolyte containing $NiSO_4$ 10 g/l, $CoSO_4$ 10 g/l, CH_3COONH_4, 10 g/l, 308K, pH 6.2, 30 Sec.

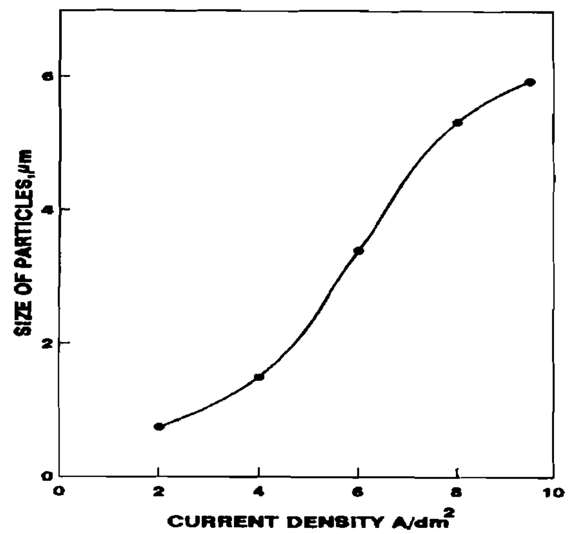

Fig.4: Influence of current density on size of majority of particles of the coating deposited from the electrolyte containing $NiSO_4$ 10 g/l, $CoSO_4$ 10 g/l, CH_3COONH_4, 10 g/l, 308K, pH 6.2, 30 Sec.

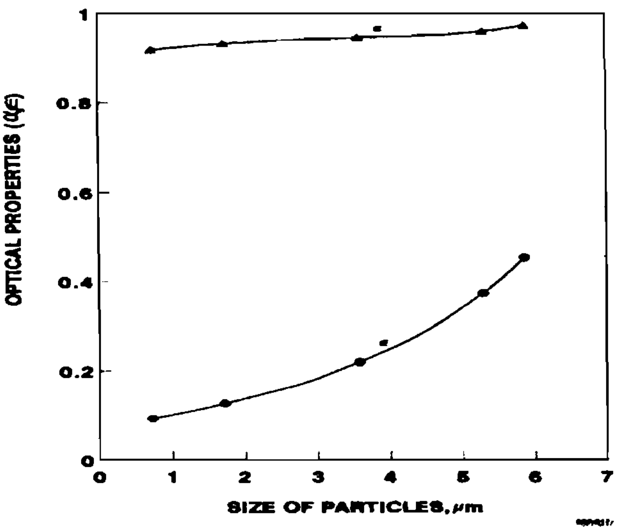

Fig.5: Influence of size of majority of particles of the coating on optical properties (α ,ε)

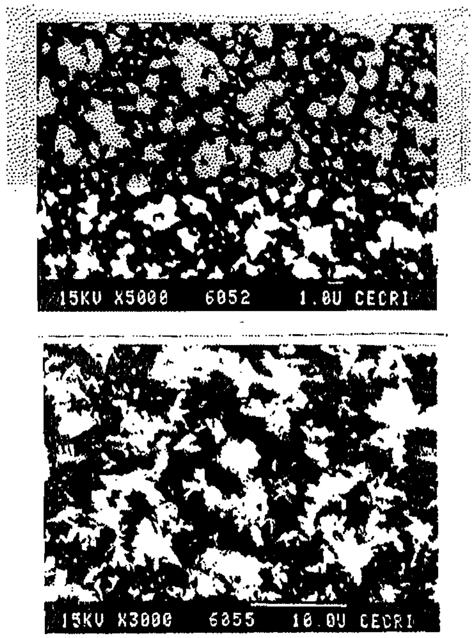

Fig.6: SEM of nickel-cobalt black coating deposited from the bath containing nickel sulphate 10 g/l, cobalt sulphate 10 g/l and ammonium acetate 10 g/l at a pH of 6.2, 30 sec, 308K at current densities of (a) $4 A/dm^2$; (b) $7 A/dm^2$.

produced from the bath containing 10 g/l nickel sulphate, 10 g/l Cobalt sulphate and 10 g/l ammonium acetate. It could be observed from the graph that the deposition time influences both solar absorpance and thermal emittance of the coating. As the deposition time increases from 10 to 70 seconds, solar absorptance increases from 0.80 to 0.98 and emittance also increases from 0.03 to 0.36. Black nickel-cobalt plated for 30 seconds gives the best combination of optical properties (i.e. $\alpha = 0.95$ and $\varepsilon = 0.10$).

Influence of current density on optical properties (α, ε)

Current density employed for the deposition of the coating has a substantial effect on the optical properties of the coating as shown in Fig. 2. Higher current densities require lesser deposition time since the coating thickness determines the optical properties. Coating produced at a current density of 4 A/dm^2 for a duration of 30 seconds yields solar absorptance of 0.95 and thermal emittance 0.10.

Influence of current density on particle size of the coating

Fig. 3 shows the influence of current density on maximum size of the particles of the coating deposited from the nickel-cobalt electrolyte. It could be observed that as the current density increases, the particle size also increases in the form of parabolic curve.

Fig. 4 shows the variation of size of majority of the particles with current density for the nickel-cobalt electrolyte. The particle size increases with current density, but not in a linear way.

Influence of particle size on optical properties of nickel-cobalt deposit

Fig. 5 shows the influence of majority of particle size of the deposit on optical properties (α, ε). It could be seen that the emittance increases rapidly as the particle size increases. However, the absorptance does not show much variation with particle size.

SEM studies

Fig. 6 shows the surface topography of nickel-cobalt black coating produced at two different current densities. This reveals that the particles are of highly irregular size and shape with micro hills and valleys. It also shows the dendritic growth of the particles. It has been established that the absorption of solar radiation by the coating is due to optical interference, surface roughness, band gap absorption, graded index, metal- dielectric cermet coating or a combination of two or more of these effects [12-14]. The irregular orientation, shape and distribution of the particle enhances the surface area and facilities multiple reflection and thereby total absorption of solar radiation in the selective coating.