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BLACK CHROME ON COMMERCIALY ELECTROPLATED TIN AS A SOLAR SELECTIVE COATING

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16. Abstract The reflectance properties of black chrome electroplated on commercially electroplated tin were measured for various black chrome plating times for both the solar and infrared spectrum. The values of absorptance, α , and emittance, ϵ , were calculated from the measured reflectance values. The interdependant variations of α and ϵ were plotted. The results indicate that the optimum combination of the highest absorptance in the solar region and the lowest emittance in the infrared of the black chrome plated on commercially electroplated tin is obtained for a black chrome plating time of between one and two minutes.			
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INTRODUCTION

In research conducted at the NASA-LeRC it was previously determined that black chrome plated on electroplated nickel is a very efficient solar selective coating in that it absorbs strongly in the solar spectrum (0.35 to 2.0 μm) and yet reradiates very weakly in the infrared (2.0 mm to 15 μm) (ref. 1). It is essential that any solar collector operating in the temperature range from 70^o to 300^o C have such a solar selective coating in order to ensure maximum thermal efficiency.

The black chrome and nickel combination, in addition to having high absorptance and low emittance, also has the other essential requirements for a practical solar-selective coating of availability and ease of application. The black chrome-nickel combination also has the significant advantages that it is relatively low cost and has long-term durability under solar radiation. Since the main determining factor in the wide utilization of solar energy is low cost, it is desirable to explore possible alternative methods of application of the efficient black chrome which might yield economies of manufacture and therefore increase its utilization in solar collectors. Even small, linear effects in cost reduction can have exponential effects in increasing application.

In general, one important way to achieve cost reduction in any product is to utilize some material or production equipment which already has wide use in industry. This has the advantage that production for the new use can be based on an industry which is already well established,

and the new product can simply be integrated into existing production and does not need creation of new manufacturing facilities. For example, solar selective black chrome, which was discovered by the Lewis Research Center, was rapidly and widely commercialized because ordinary, basic black chrome (although not produced so as to be solar selective) was already being applied as a decorative finish by the electroplating industry and the basic process and equipment already existed in industry.

One material which could conceivably be used as a substrate for the black chrome in place of nickel is electroplated tin on steel. Use of electroplated tin on steel for solar collectors has the potential advantage of utilization of the economies of existing large scale production and also has the advantages of wide availability. However it was not previously known whether electroplated tin which had been handled and stored by the usual commercial procedure might undergo passivation which might make it difficult to plate with black chrome. It was also not known whether black chrome could be plated on commercial tin and still have the tin maintain low emittance.

Therefore, in the search for a lower cost solar selective black chrome/substrate combination, a study was made of the technical feasibility of achieving optimum optical properties of black chrome plated on a commercially plated tin/steel substrate.

EXPERIMENTAL PROCEDURES DESCRIPTION

OF SAMPLE PREPARATION

In this investigation black chrome was plated over commercially electroplated tin on 10×15 cm steel panels. In order to demonstrate the wide utility and applicability of using commercially available tin plated steel as a substrate for solar selective black chrome, tin plated steel was selected which had been fabricated into containers in the industrial process and were marketed by commercial sources. The containers had been stored but had never been used. The 10×15 cm test panels were cut from these containers. Samples from various sources showed

no significant differences. In all cases the tin plated steel was bright and uncorroded. The samples used for the measurements in this report are all from one source. The thickness of the tin was 0.001 cm (0.0004 in.). A photomicrograph of the tin-steel substrate is shown in cross section in figure 1.

In order to determine the optimum time for plating of black chrome on the tin-steel substrate, black chrome was plated for various times up to 15 minutes. In order to secure accurate timing all samples were introduced into the plating bath with the voltage applied.

The plating sequence for the panels was as follows:

(1) Cleaned by electrolytic alkaline chelating cleaner at 88° C (190° F) and 7.5 to 8.6 amps/m² (70 to 80 amps/ft²). Two cycles, interspersed with acid, were used.

(2) Water rinsed.

(3) Black chrome plated from Harshaw Chemical Company CHROMONYXTM at 24 volts and 21.5 amps/m² (200 amps/ft²) for varying periods of time.

(4) Water rinsed

(5) Air dried

The panels were wrapped in tissue and stored until optical measurements were completed.

DESCRIPTION OF OPTICAL MEASUREMENTS

Optical measurements were made of the reflectance in the visible and the infrared. Absorptance and emittance were calculated from the reflectance measurements.

The measurement of the reflectance in the visible range was made with a TAL Model 2164A Digital Display Alpha Meter. Magnesium carbonate was used as a high reflectance standard and a black cone was used as a low reflectance standard. The absorptance was calculated from these reflectance measurements with the relationship: Absorptance = 1 - Reflectance.

The reflectance in the infrared was measured with a Gier-Dunkle Model DB-100 infrared reflectometer. Gold was used as a standard for low emittance. Emittance was calculated from these reflectance measurements with the relationship: $\text{Emittance} = 1 - \text{Reflectance}$.

The accuracy of the measurement of the visible reflectance and the infrared reflectance is estimated to be ± 0.02 units.

TEST RESULTS AND DISCUSSION

For plating times of 15 seconds to 15 minutes, the general appearance of the panels was similar to that of the black chrome nickel plating time sequence studied in reference 1. At 15 seconds there was only a faint "dusting" of black chrome over the tin. The thin coating of black chrome could be seen by visual observation. At 15 minutes there was a heavy coating of black chrome, but, by visual appearances, this was somewhat less heavy than the coating of black chrome produced by plating dull nickel for 10 minutes as reported in reference 1.

The results of the optical measurements of reflectance of black chrome and the calculation of absorptance and emittance for various plating times are shown in figure 2 and table I. As plating time increases, and consequently black chrome thickness increases there is first a rapid increase in visible absorptance without a significant increase in infrared emittance until a nearly maximum value of absorptance is reached in approximately two minutes. After this time the emittance begins to increase rapidly with no appreciable increase in absorptance. As observed in references 1 and 2 there is even a slight decrease in absorptance in the visible for long plating or conversion times (i. e., heavy coatings of the absorber layer).

The two principal differences between the black chrome plated on tin and the black chrome plated on nickel as reported in reference 1 are in the larger scatter in the data and the somewhat higher emittance of the black chrome-tin combination. The scatter in data is the result of the differences in the emittance of the tin on the various samples as a

result of storage/handling effects on the tin plated steel before the samples were plated with black chrome. The slight scatter in the data indicates that, for bright uncorroded tin on steel, black chrome can be plated on tin plated steel from commercial sources to obtain reproducible solar selective properties.

The emittance of the black chrome on tin is slightly higher than the emittance reported for the same conditions of plating time of black chrome on electroplated nickel. This is due to the emittance of the as received tin on steel (0.06) being higher than the emittance of electroplated nickel. While this emittance of the tin is larger than the emittance of the nickel used in reference 1 the increase is small.

Up until plating times of approximately two minutes the black chrome is so thin that the emittance of the surface is controlled by the substrate. The scatter in the data for the reflectance of the black chrome-tin combination is caused by the variation in emittance of the tin on the samples of tin-steel substrate used. Both the acceptably small increase in emittance of the tin over nickel and also the acceptably small variation in solar selective properties of black chrome plated on tin show that a satisfactory solar selective surface can be prepared using normal, commercial electroplated tin-steel as a substrate.

Also, since the results showed that there was no large, drastic increase in the emittance of the black chrome-tin combination with increasing plating times of black chrome up to the optimum plating time, no reactions were occurring on the tin during the plating of the black chrome which were destroying the desirable low emittance of the tin.

SUMMARY OF RESULTS

Measurements of the visible and infrared reflectance and calculation of the absorptance and emittance of black chrome plated over commercial electroplated tin-steel stock for varying times from 15 seconds to 15 minutes demonstrated that high quality solar selective optical properties can be achieved by using commercial grade tin-steel stock. An absorptance

of 0.97 and emittance of 0.06 were obtained for a plating time of approximately two minutes at a current density of 1.5 amps/m² (200 amps/ft²).

REFERENCES

1. McDonald, Glen E. and Curtis, Henry B.: Variation of Solar-Selective Properties of Black Chrome with Plating Time. NASA TM X-71731, 1975.
2. McDonald, Glen E. and Curtis, Henry B.: Optimized Selective Coatings for Solar Collectors. NASA TM X-73498, 1976.

TABLE I. - SOLAR ABSORPTANCE AND INFRA-RED
EMITTANCE OF BLACK CHROME PLATED
ON TIN FOR VARIOUS TIMES

	Plating time, min						
	0	1/4	1/2	1	2	4	15
Solar absorptance, α	0.25	0.80	0.84	0.96	0.97	0.96	0.94
Infrared emittance, ϵ	.06	.08	.07	.06	.06	.07	.18

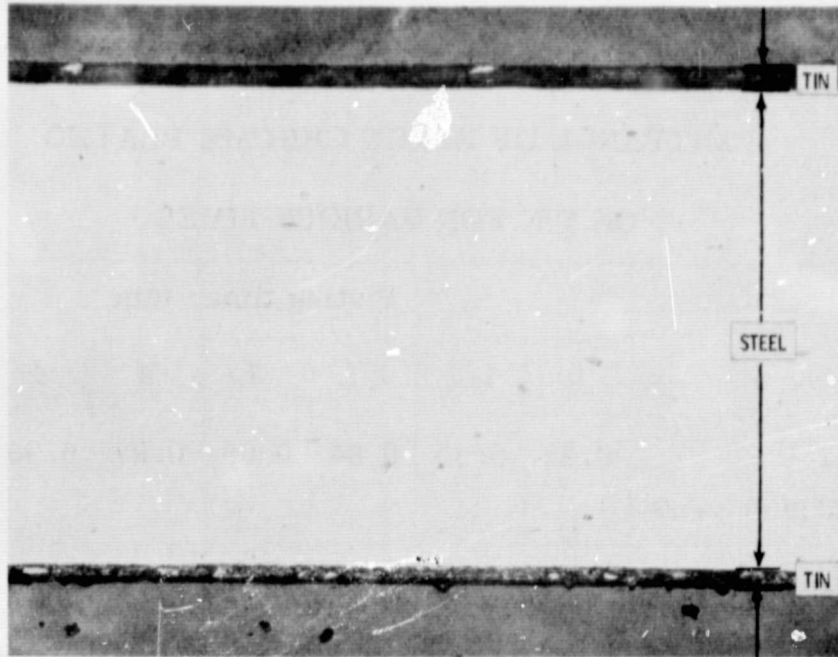


Figure 1. - Photomicrograph of tin clad steel 250x.

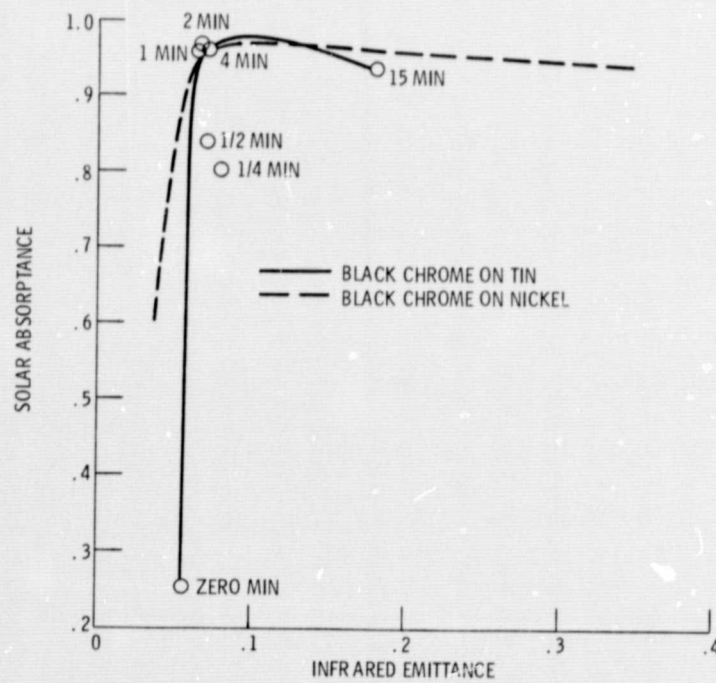


Figure 2. - Absorptance and emittance for black chrome plated on tin for various times.