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SPECTRAL REFLECTANCE PROPERTIES OF BLACK CHROME FOR USE AS A SOLAR SELECTIVE COATING

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ABSTRACT

The NASA-Lewis Research Center has determined that a widely available commercially electroplated decorative finish known as black chrome has desirable solar selective properties. Black chrome electroplated coating has high absorbtance in the solar spectrum and low emissivity in the 250° F blackbody thermal spectrum.

The discovery of the solar selective properties of black chrome adds another high efficiency coating to the older, previously known coatings. Additionally, the black chrome is significant as a solar selective coating, because the current extensive use of black chrome in the electroplating industry as a durable, decorative finish makes black chrome widely available and potentially lower cost as a solar selective coating.

The spectral reflectance properties of a commercially prepared black chrome on steel have been measured. Values are presented for reflectance of the black chrome, and compared with the reflectance of black paint (Nextel) and with two available samples of black nickel which had been prepared for solar selective properties.

The reflectance of black chrome, of the two black nickels, and of black paint integrated over the solar spectrum for air mass 2 were 0.132, 0.123, 0.133, and 0.033, respectively.

The reflectance of the black chrome, two black nickels, and of the black paint integrated over the blackbody spectrum for 250° F from 3 to

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15 microns are 0.912, 0.934, 0.891, and 0.033, respectively. These reflectance measurements indicate absorptivity-to-emissivity (α/ϵ) values of 9.8, 13.8, 8.0, and 1.00, respectively.

INTRODUCTION

Flat plate solar collectors are a candidate for a position as an augmenting energy source. For optimum efficiency and to secure maximum collector plate temperature, the collector plates should possess the maximum possible absorbtance across the solar spectrum and also have the minimum possible emissivity in the infrared, that is, solar selective properties.

Other necessary properties of a practical solar selective coating are ease and availability of application, low cost, and long-term durability under solar radiation.

One historical method of securing a solar selective coating was to coat the collector with black copper oxide by oxidation of a copper surface on the collector (ref. 1) or by thermal decomposition of copper nitrate on the collector surface.

Another solar selective coating was discovered by Tabor who found that electrodeposited black nickel had solar selective properties.

Both of these coatings, in correct application, have high absorbtance in the visible and low emissivity in the infrared.

Work at the NASA-Lewis Research Center has determined that a commercially widely available, decorative electroplated finish of black chrome has desirable solar selective properties of high absorbtance in the visible and low emissivity in the infrared. This black chrome electroplating solution can be prepared independently (ref. 4) or is available as a proprietary mixture from Harshaw Chemical Co.

To investigate the adaptability of electroplated black chrome to solar collectors, samples varying from 4 by 6 inches to collector tube sheets 2 by 4 feet have been prepared. These black chrome samples were prepared at several commercial electroplaters. Visible and infrared spectral reflectance was measured to determine the quality of the solar selective coating.

This paper describes the method of producing the black chrome and the results of the measurement of spectral reflectance.

DESCRIPTION OF BLACK CHROME PREPARATION

In this investigation black chrome was plated on both aluminum tube sheet panels, after appropriate zincating procedure, and steel panels, all 2- by 4-feet, as well as on 4- by 6-inch test panels. The 2- by 4-foot panels were plated by commercial electroplaters using the same tanks, chemicals, and procedures used for decorative finish black chrome such as table legs, metal chair trim, etc. The black chrome was prepared on both steel and aluminum to determine adaptability to various substrates.

The black chrome deposits used in spectral measurements of solar selective properties were electroplated on 4- by 6-inch test panels by Harshaw Chemical Co. These deposits were standard bright, decorative black chrome, a highly specular black mirror. The panels were 0.035-inch cold rolled steel buffed to less than 1/2 microinch RMS finish.

The panels were plated in the following sequence:

(1) Clean by electrolytic alkaline Kelating cleaner 190° F 70/80 amps/ft^2 two cycle interspersed with acid

(2) Bright nickel plated with Harshaw Chemical Co. ZODIAC for 15 minutes at 40 amps/ft^2 to deposit approximately 0.0005 inch of nickel

(3) Black chrome plated with Harshaw CHROM-ONYX at 24 volts and 200 amps/ft^2 for 3 minutes

(4) Water rinsed

(5) Alcohol rinsed

(6) Air dried

The panel was wrapped in tissue and stored until spectral measurements were completed.

The black nickel solar selective coatings used for comparison with the black chrome were secured from outside sources.

DESCRIPTION OF SPECTRAL MEASUREMENTS

The spectral reflectance from 0.35 to 2.1 microns of the black chrome was measured with a Corey 14 spectrophotometer with a spherical diffuse reflector attachment. A Mg O surface, prepared at the NASA-Lewis Research Center was used as a standard. All measurements, 0.35 to 2.1 microns, reported are total diffuse reflectance.

The spectral reflectance from 3.0 to 18.0 microns were measured with a Willey 318-S spectrophotometer which uses a spherical diffuse reflectance attachment. Evaporated gold film was used as a standard. All measurements reported are total diffuse reflectance.

TEST RESULTS

The application of black chrome was determined to be equally feasible on aluminum base or on steel base.

The general appearance of black chrome is so indistinguishable from black nickel that a 2- by 4-foot solar collector panel coated with black chrome by the NASA and a second 2- by 4-foot solar collector coated with black nickel from an outside source were indistinguishable by visual observation by any of a number of people when the panels were placed side by side.

Indeed, since the mechanical design of the black chrome coated panel and the black nickel coated panel were identical, the panels could not be separated by visual appearance, and it was only after secondary markings were checked that the two panels could be correctly identified.

The results of the spectral measurements of reflectance are shown in figure 1 for the black chrome, two samples of black nickel and Nextel black paint. All values for reflectance for black chrome, and for the two samples of black nickel and for Nextel black paint, from 0.35 to 2.1 microns, are integrated values for solar spectrum over air mass 2.

The reflectance from 0.35 to 2.1 microns is plotted on a 5X expanded scale in figure 2 to show the differences between black nickel and black chrome. It is evident that in the visible spectrum both black nickel and black chrome have minimum-maximum reflectance characteristics. It is not known whether this represents electronic band structure or is simply the result of index of refraction - layer thickness combinations which produces interference effects. The two samples of black nickel show considerable differences in reflectance characteristics which are evidently the result of differences in application procedures. Additionally it is seen that the sample of black nickel which has a very low reflectance at 1.0 micron has a corresponding increase in reflectance at 0.5 micron.

There is a slight displacement (approximately 0.5 micron) between the maximum-minimum points on the black nickel and the corresponding points on the black chrome curve.

From figure 1 it is seen that the reflectance versus wavelength increases more rapidly in the infrared for black nickel than for the measured specimen of black chrome. However, the reflectance of the black chrome and the first sample of black nickel are significantly higher than that of the second sample of black nickel. This tends to indicate that variables in coating formation process are more significant than inherent difference between black chrome and black nickel.

The values of absorbtance, α and emissivity, ϵ, and the ratio, α/ϵ, are presented in Table 1. Values from 3 to 15 microns are integrated values over blackbody thermal spectrum.

Figures 3 to 5 are electron photomicrographs of black chrome and black nickel 1 and 2.

For comparison with the reflectance values of the solar selective coatings as given in figure 1, the solar irradiance and the radiation from a 250° F blackbody are given in figure 6.

CONCLUDING REMARKS

Electroplated black chrome has been formed on a 2- by 4-foot solar collector panel and on small test samples. Spectral reflectance measurements from 0.35 to 15 microns indicate that the solar selective properties of black chrome equal those of black nickel within the variation in reflectance produced by process variables in the application of black nickel.

In addition to the discovery that commercial deposits of black chrome are solar selective and thus may be used in place of the previously known solar selective coatings such as black nickel, it is also significant that black chrome is widely available in the electroplating industry as a commercial decorative coating. This ready, wide availability of process and equipment for application of black chrome has potentially an economic advantage in the use of black chrome on solar collectors. The α/ϵ values determined for the black chrome, two samples of black nickel, and black paint are 9.8, 13.3, 8.0, and 1.01, respectively.

REFERENCES

1. Spectral and Directional Thermal Radiation Characteristics of Selective Surfaces for Solar Collectors. D. K. Edwards, J. T. Gier, K. E. Nelson, and R. D. Raddick.
2. Properties of Copper Oxide-Aluminum Selective Black Surface Absorber of Solar Energy. H. C. Hottel, T. A. Unger, Pub. No. 71, MIT Solar Energy Conversion Project.
3. Selective Radiation I Wave-Length Discrimination. H. Tabor, Bull Research Council of Israel 5A, 119 (1956).
4. Metal Finishing P268 (1974). Metals and Plastics Publications, Inc.

TABLE 1. - VISIBLE ABSORBTANCE AND INFRARED EMISSIVITY OF SOLAR SELECTIVE COATINGS

Coating sample number	Absorbtance, α (air mass 2)	Emissivity, ϵ (blackbody integration 3 to 15 microns)	α*/ϵ**
Black chrome 1	0.868	0.088	9.8
Black nickel 2	.877	.066	13.3
Black nickel 3	.867	.109	8.0
Nextel black paint 4	.967	.967	1.0

*Based on solar air-mass-2 spectrum weightings.

**Based on 250° F blackbody spectrum weightings.

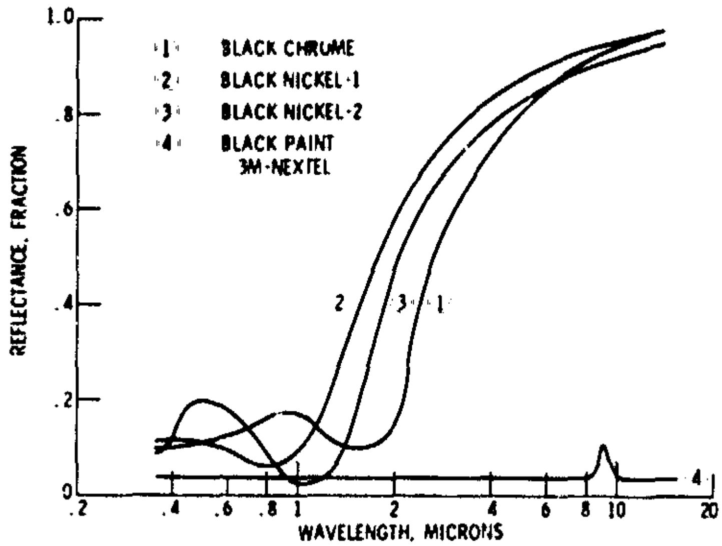

Figure 1. - Reflectance of black chrome, black nickel, and black paint.

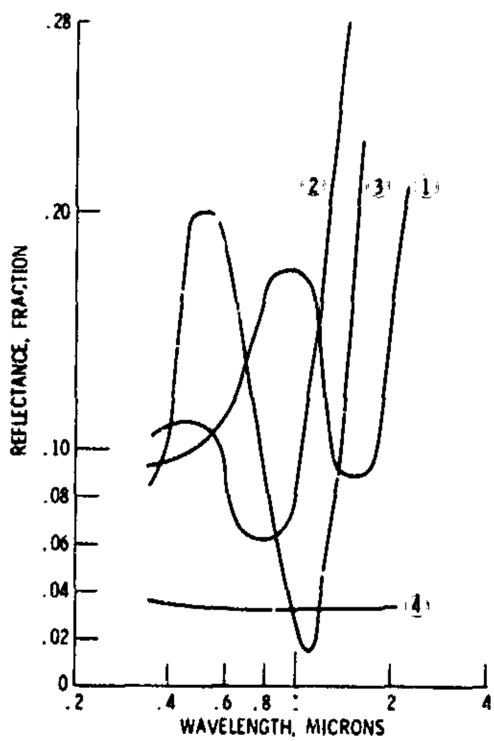

Figure 2. - Reflectance of black chrome, black nickel, and black paint.

Figure 3. - Black chrome, electron-photomicrograph; X15 000.

Figure 4. - Electron photomicrograph of black nickel; X11 000.

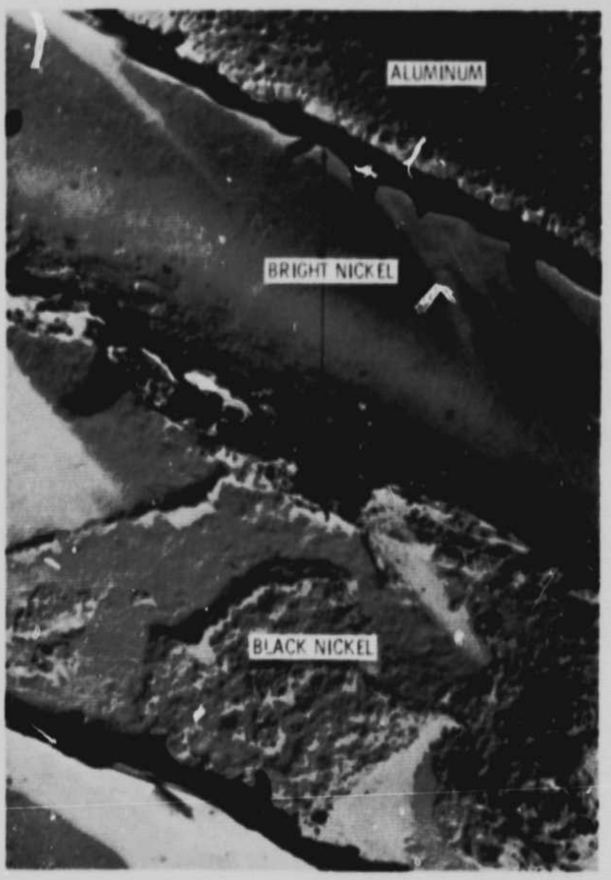

Figure 5. - Electron photomicrograph of black nickel; X11 000.

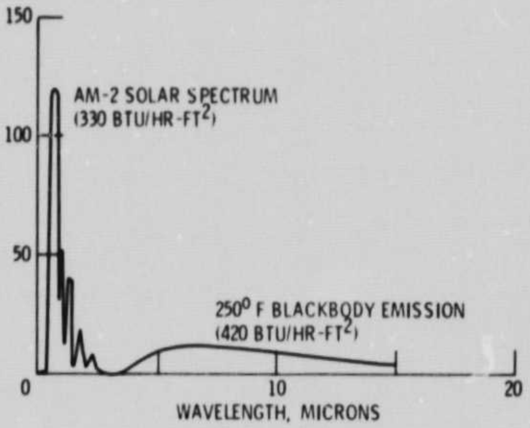

Figure 6. - Solar collector wavelength ranges.

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