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# OPTICAL PROPERTIES AND AGING CHARACTERISTICS OF BLACKCHROME SURFACES ON DIFFERENT TEXTURES OF ALUMINUM SUBSTRATES

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## ABSTRACT

The investigation of various surface textures of aluminum substrates : rough, smooth non polished and smooth polished surfaces are described in this paper. The results from prepared surfaces reveal slightly differences of solar absorptance ( $\alpha_s$ ) and thermal emittance ( $\epsilon_t$ ). Very good thermal stability is obtained in all cases. It is concluded that substrate preparation techniques (texturizing, chemical polishing etc.,) are not necessary in practice.

## INTRODUCTION

The most popular selective coating being used at the present time is blackchrome prepared from chromonyx bath. The absorptance values are 0.92–0.97 and emittance values are 0.08–0.2.[1] Blackchrome selective surface is suitable in the working temperature range 200-300°C and can be prepared on various metal substrates such as copper, nickel, steel and aluminum.[2]

The previous studies about selective surfaces at King Mongkut's Institute of Technology, Thonburi for the past few years, the optimum conditions for electroplating in Harshaw bath on aluminum and steel substrates; current density, plating time and plating bath composition were obtained by using Gradient Search technique.[3]

In this study, four types of surface textures on aluminum substrates were electroplated with blackchrome in Harshaw bath. Spectral reflectance measurements for the wave length 350–850 nm were used to investigate the optical properties of each sample before and after aging at 200°C. Wear resistance of blackchrome film was also tested on prepared surfaces.

## :RIMENTAL PROCEDURES

In this experiment, $6\times6$ $cm^2$ aluminum samples (thickness of aluminum trates used was 0.072 cm) were cut, surface textured by sand papers and an ropolishing machine, cleaned, coated with an initial nickel coating and electroplated n blackchrome by the Harshaw chemical company at the selected conditions. In h case, the optical properties of the prepared blackchrome surfaces were measured.

### 1 Surface Preparation

To achieve various textures of substrate surfaces, the aluminum plates were polished by sand papers no. 280, 600 and an electropolishing machine. The roughness of each surface was measured by surtonic surface roughness meter.

### 2 Electroplating of Blackchrome

The experimental apparatus was shown in Figure 1. The selected condition for electroplating[4] in this paper was :

| | | |
|---|---|---|
| Chromonyx acid | 312 | g/l |
| Quantity of chromonyx addition agent | 25% | (by volume) |
| Current density | 24 | $A/dm^2$ |
| Plating bath temperature | 24 | °C |
| Plating time | 5 | mins |

The blackchrome plating process was shown the Figure 2.

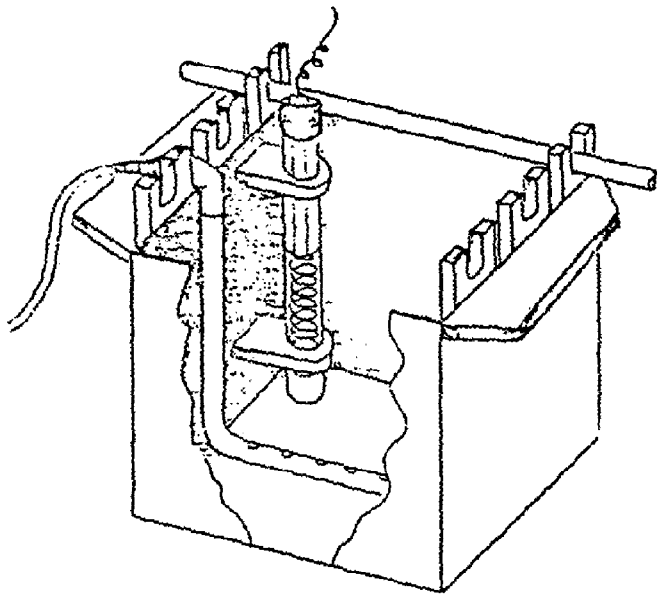

Fig. 1 Electroplating apparatus

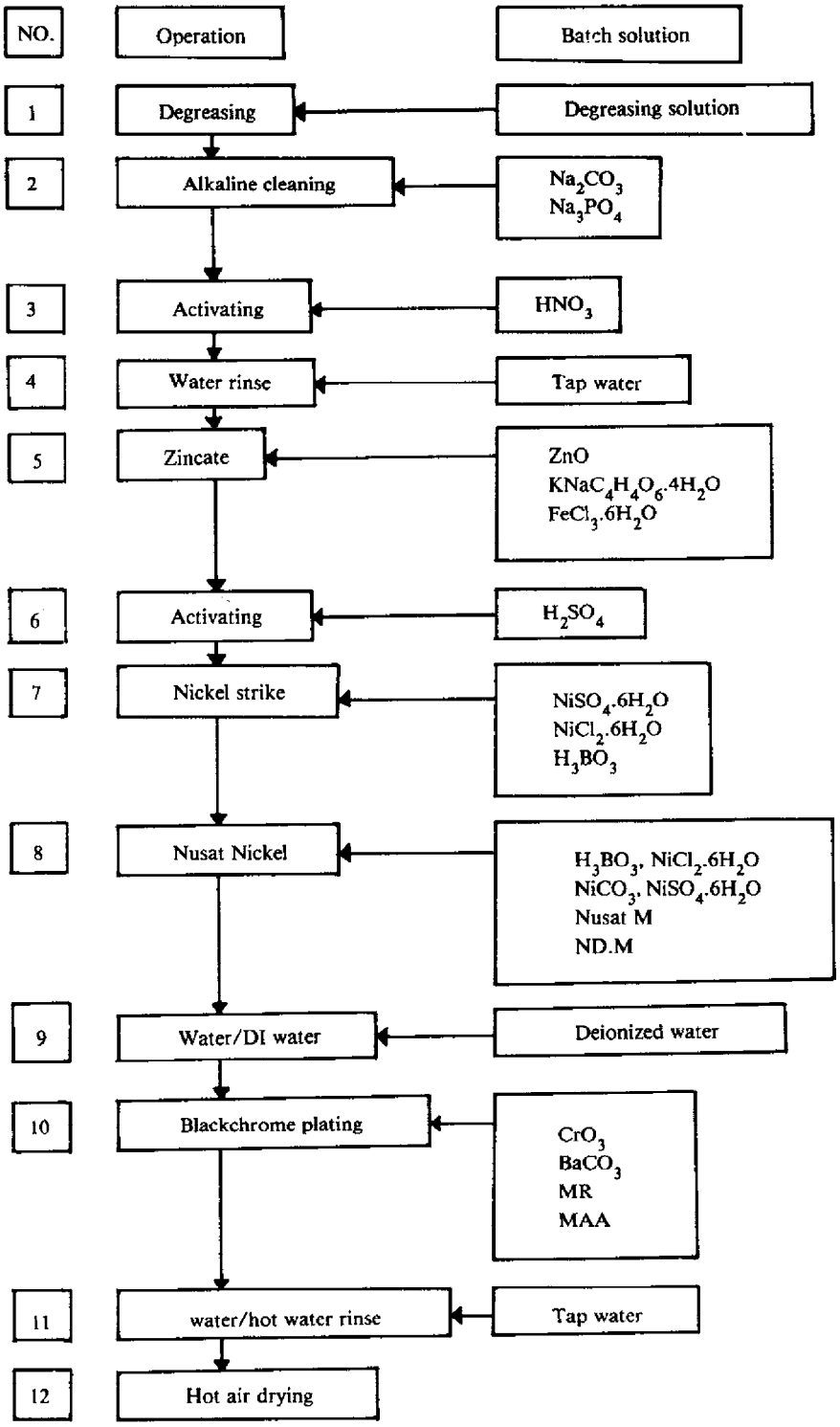


Fig.2 Blackchrome electroplating process

### 3 Evaluation of Optical Properties

Solar absorptance ($\alpha_s$) of blackchrome surface was measured by a VARIAN UV-visible spectrophotometer, model DMS-80, in terms of the diffuse reflectance of surface. The required absorptance is then calculated from Kirchoff's law. Thermal emittance ($\varepsilon_t$) values were measured using a Gier Dunkel Infrared Reflectometer, Model DB-100.

### 4 Aging Characteristics

Blackchrome surfaces on aluminum substrates were aged at 200° C for 5000 hrs. During aging, the optical properties of samples were measured every 200 or 300 hour period.

### 5 Wear Tests

Prepared blackchrome surfaces were rubbed with dry cloth. Optical properties after rubbing were recorded.

## RESULTS

This section concerns spectral reflectance measurements, aging characteristics and wear resistance of blackchrome surfaces. These results bring to the conclusions about the effects of surface textures of blackchrome selective surfaces.

### 1 Optical Properties

In these results both absorptance values and emittance values of 4 types of textures on aluminum substrates : rough, smooth, as is and smooth-polished were measured and averaged as shown in Table 1.

### 2 Optical properties after aging at 200°c for 5000 hrs

Table 2 showed the absorptance and emittance values of blackchrome surfaces after 5000 hrs of aging at 200°C. The variation of optical properties were shown in Table 2 and Figure 3.

### 3 Wear test/mechanical test

All samples were rubbed with dry cloth to test the adhesion between blackchrome film and substrate surface and optical properties were also recorded after rubbing. The results were shown in Table 3.

**TABLE 1 OPTICAL PROPERTIES ON DIFFERENT TEXTURES OF ALUMINUM SUBSTRATES**

| Substrate Texture | | Average Surface roughness (micron) | $\alpha_{(s)}$ | $\varepsilon_{(t)}$ |
|---|---|---|---|---|
| By polishing with sandpaper No.280 (rough) | Before plating | 1.056 | 0.403 | 0.283 |
| | After Blackchrome plating | 1.228 | 0.974 | 0.182 |
| By polishing with sandpaper No.600 (smooth) | Before plating | 0.797 | 0.411 | 0.253 |
| | After Blackchrome plating | 0.900 | 0.973 | 0.164 |
| As is | Before plating | 0.459 | 0.455 | 0.053 |
| | After Blackchrome plating | 0.483 | 0.972 | 0.120 |
| By electropolishing machine (smooth-polished) | Before plating | 0.085 | 0.792 | 0.047 |
| | After Blackchrome plating | 0.165 | 0.972 | 0.11 |

**TABLE 2 OPTICAL PROPERTIES AFTER AGING AT 200° C**

| Aging time (hr) | Substrate texture | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Rough | | Smooth | | As is | | Smooth-polished | |
| | $\alpha_s$ | $\epsilon_t$ | $\alpha_s$ | $\epsilon_t$ | $\alpha_s$ | $\epsilon_t$ | $\alpha_s$ | $\epsilon_t$ |
| 0 | 0.973 | 0.183 | 0.972 | 0.163 | 0.972 | 0.117 | 0.973 | 0.110 |
| 120 | 0.973 | 0.170 | 0.972 | 0.147 | 0.976 | 0.117 | 0.976 | 0.107 |
| 240 | 0.973 | 0.170 | 0.972 | 0.143 | 0.975 | 0.113 | 0.977 | 0.100 |
| 400 | 0.972 | 0.167 | 0.971 | 0.143 | 0.975 | 0.113 | 0.976 | 0.108 |
| 600 | 0.970 | 0.170 | 0.969 | 0.147 | 0.973 | 0.113 | 0.976 | 0.110 |
| 888 | 0.971 | 0.167 | 0.971 | 0.143 | 0.975 | 0.110 | 0.977 | 0.098 |
| 1200 | 0.971 | 0.178 | 0.969 | 0.153 | 0.974 | 0.120 | 0.975 | 0.108 |
| 1650 | 0.971 | 0.173 | 0.970 | 0.153 | 0.973 | 0.113 | 0.975 | 0.108 |
| 2000 | 0.970 | 0.173 | 0.969 | 0.142 | 0.974 | 0.118 | 0.975 | 0.105 |
| 2500 | 0.969 | 0.173 | 0.968 | 0.145 | 0.972 | 0.120 | 0.974 | 0.107 |
| 3000 | 0.970 | 0.172 | 0.969 | 0.145 | 0.973 | 0.117 | 0.973 | 0.110 |
| 4000 | 0.970 | 0.160 | 0.968 | 0.140 | 0.972 | 0.113 | 0.974 | 0.103 |
| 5000 | 0.969 | 0.167 | 0.966 | 0.140 | 0.972 | 0.117 | 0.974 | 0.110 |

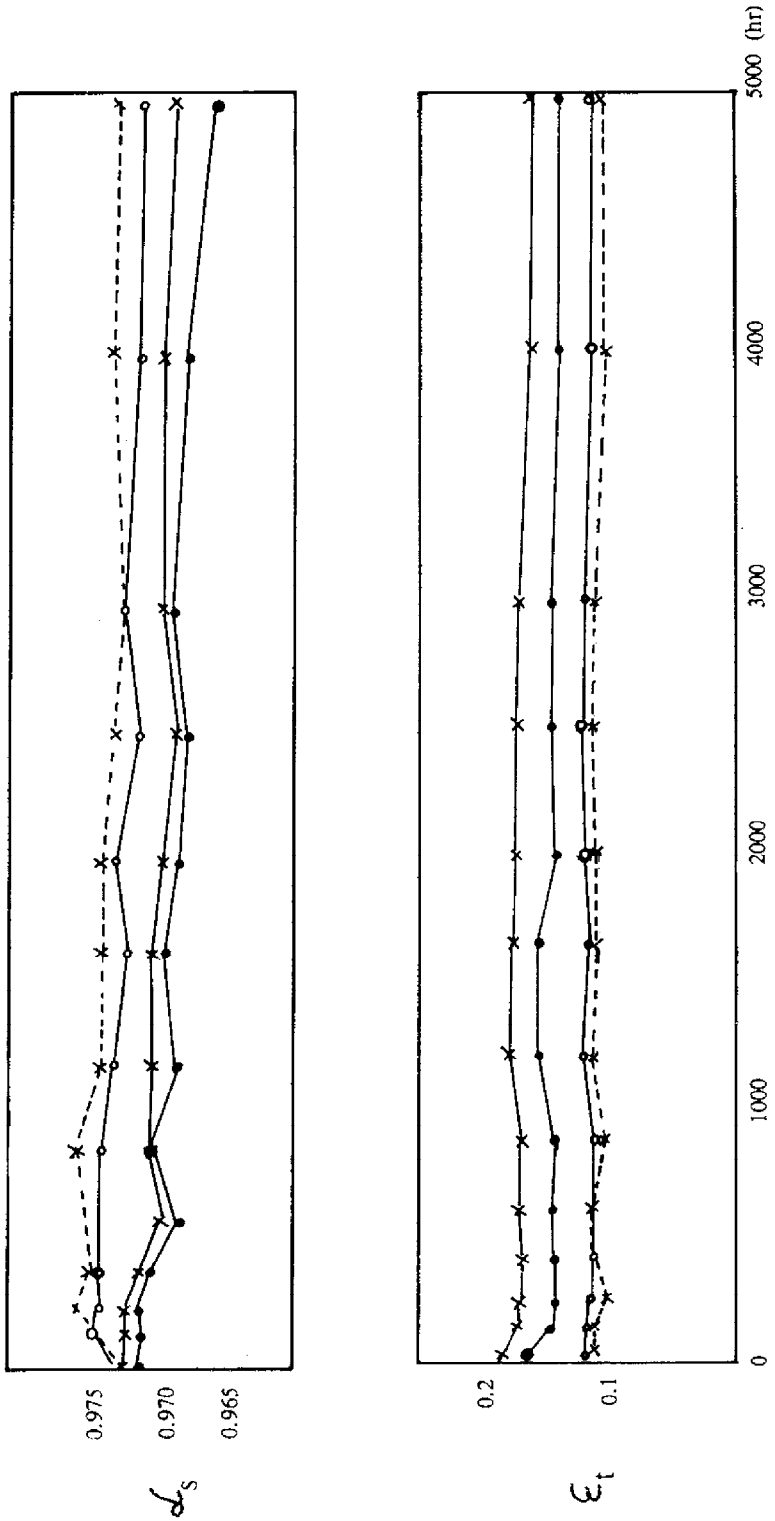


Fig. 3 The variation of optical properties after aging
X——X - rough surface
O——O - as is
•——• - smooth surface
X····X - smooth-polished surface

**TABLE 3 THE OPTICAL PROPERTIES OF SURFACES AFTER RUBBING**

| Substrate Texture | Optical Properties* | | | | | |
|---|---|---|---|---|---|---|
| | Before Rubbing | | After rubbing | | % Variation | |
| | $\alpha_s$ | $\varepsilon_t$ | $\alpha_s$ | $\varepsilon_t$ | $\alpha_s$ | $\varepsilon_t$ |
| Rough | 0.974 | 0.18 | 0.931 | 0.18 | 4.41 | 2.85 |
| Smooth | 0.973 | 0.14 | 0.949 | 0.14 | 2.98 | 3.57 |
| As is | 0.971 | 0.12 | 0.952 | 0.12 | 2.57 | 0.00 |
| Smooth-polished | 0.973 | 0.11 | 0.936 | 0.11 | 3.60 | 0.00 |

* average values

## CONCLUSION

For blackchrome selective surfaces on different surface textures of aluminum substrates, the solar absorptance did not show much difference, the average values were 0.973 ± 0.001 which lied in the acceptable range of using in practice. Only the values of thermal emittance revealed some differences between rough texture, 0.16 and smooth-polished texture, 0.11 because the different morphologies of blackchrome film obtained from different prepared texturing processes.

The results from thermal treatment of blackchrome surfaces at 200°C after 5000 hrs revealed that the smooth surface possessed better optical properties than the rough one. Besides, the adhesion of blackchrome film on substrates was good even after aging 5000 hrs, no sign of blistering was shown at all.

The useful information from this work can be drawn into the conclusion; the process of electroplating of blackchrome on aluminum substrates, the substrates can be used as it is in blackchrome electroplating. The optical properties both solar absorptance ($\alpha_s \approx 0.97$) and thermal emittance ($\varepsilon_t \approx 0.1$) are acceptable in practice. About 6% of operating cost can be reduced in the electroplating/manufacturing process.

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