Thermo-Optical Performance of Black Anodized Aluminum Coatings for Space Applications

M.A. Horban[1], C.B. Mello[1], G.S. Savonov[1], J.E. May[1]

[1]*Instituto Nacional de Pesquisas Espaciais (INPE), SP, Brazil*
e-mail: marcoahorban@gmail.com

Abstract: Specimens of 2024 and 6061 aluminum alloys were anodized with different sulfuric acid concentrations and then colored with tin sulfate in order to produce high absorptance surfaces. The thermo-optical properties were investigated and their applicability in passive thermal control in satellites evaluated.
Keywords: Aluminum, Anodizing, Absorptance, Aerospace, Thermo-optic.

Introduction

Anodizing of aluminum aims to convert the metal surface into a porous oxide coat, improving its hardness and chemical resistance. Additionally, the open pores can be impregnated with organic and inorganic dyes in order to coloring to the coating. Often these dark coats are utilized in the passive thermal control of satellites, providing radiative heat transfer to intern components. The present paper intends to evaluate the thermo-optical properties of 2024 and 6061 aluminum alloys anodized coatings produced through different conditions.

Experimental Procedure

Black coatings were produced by anodizing of aluminum 2024 and 6061 for 40 minutes in sulfuric acid electrolyte maintaining the solution temperature at 22±3ºC. The samples were produced varying the sulfuric acid concentration in 90 g/L, 120 g/L, and 150 g/L. Later the specimens were electrocolored in a tin sulfate acid solution for 20 minutes in order to achieve a dark coloring. At last, the specimens were submitted to a sealing process in hot water for 60 minutes. In total, 6 conditions were carried out in order to achieve samples with different black tones, as summarized in Table 1.

Table 1 – Samples productions descriptions.

Sample	Description
2c9	2024 aluminum alloy anodized with H_2SO_4 concentration of 90 g/L.
2c12	2024 aluminum alloy anodized with H_2SO_4 concentration of 120 g/L.
2c15	2024 aluminum alloy anodized with H_2SO_4 concentration of 150 g/L.
6c9	6061 aluminum alloy anodized with H_2SO_4 concentration of 90 g/L.
6c12	6061 aluminum alloy anodized with H_2SO_4 concentration of 120 g/L.
6c15	6061 aluminum alloy anodized with H_2SO_4 concentration of 150 g/L

The absorption spectrum was measured by making use of a spectrophotometer system. The system is comprised of an OL 740-20D/IR Light Source (Gooch & Housego), equipped with a 150-watt quartz tungsten halogen lamp capable of operate in a wavelength region of 250 nm to 3500 nm, a OL 750-M-D Double Monochromator (Gooch & Housego), a OL 750-10 Mirror Imaging Optics Module (Gooch & Housego), a 816C-SF-6 Integrating Sphere (Newport) and a OL 750-HSD-300 Silicon Detector Module (Gooch & Housego), capable of operate in a wavelength range of 200 nm to 1100 nm. Besides, it was utilized an OL 750-C Controller (Gooch & Housego), in order to provide communication between the setup and the computer, and an OL 83A Programmable DC Current Source (Gooch & Housego) responsible to control the current input to the tungsten lamp. Relative reflectance measurements were performed by making use of a white standard. The reflectance spectrum obtained range from 350 nm to 1100 nm.

Results and Discussion

Each obtained measurements after reference correction were then divided by the light spectral irradiance in order to calculate the spectral reflectance of the specimens. Since the absorptance corresponds to the ratio of the incident light that is not reflected, the spectral absorptance was obtained by subtracting the spectral reflectance from one. The absorptance spectrums are presented in Figure 1.

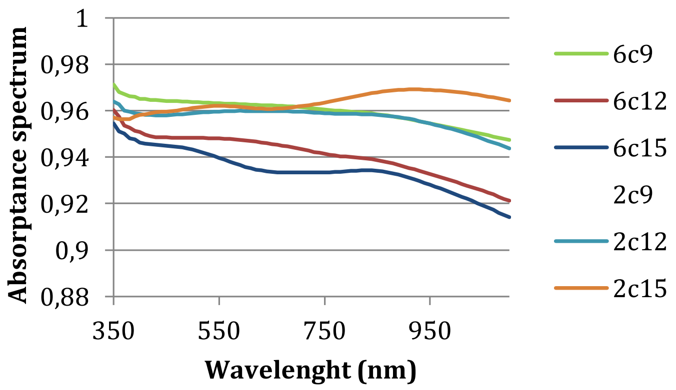

Figure 1: Spectral absorptance X Wavelength (nm) .

It was also possible to obtain the total absorptance value for the wavelength range by dividing the integral of the measurement spectrum (after reference correction) for the integral of the light spectral irradiance. The values for total absorptance can be seen in Table 2.

Table 2 – Total Absorptance.

Sample	*Total Absorptance*
2c9	0.93
2c12	0.96
2c15	0.97
6c9	0.96
6c12	0.94
6c15	0.93

According with the ECSS-Q-ST-70-03C space product assurance norm, black-anodized coatings must present total absorptance of at least 0.93. Based on the results presented, all specimens attain this requirement. The darkest coloring was achieved by the 2c15 sample. Meanwhile, among the 6061 specimens, 6c9 presented the best result. The two alloys have shown a very distinct coloring behavior, while the 2024 aluminum alloy seems to present a better coloring when anodized in the presence of a stronger electrolyte, the 6061 specimens seem to present a darker coloring when anodized with weaker electrolytes. Aluminum alloys with a high amount of copper, as the 2024 alloy, tend to have a minor anodizing efficiency compared to alloys with less copper concentration. Copper tends to compete with aluminum during oxidation reactions and is associated with oxygen evolution during the anodizing process, reducing the film formation efficiency [1] [2]. Studies have found that alloying elements also interfere in the coloring process [3].

Conclusions

Although the 2024 alloy presented a better performance than the 6061 alloy, all dark-anodized coatings produced in this paper achieved the absorptance acceptance criteria stipulated by assurance norms. But, further thermo-optical analyses must be included to determinate which presented condition better suits the intended application.

Acknowledgments

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