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Preparation and characterization of the colored coating with low infrared emissivity based on nanometer pigment

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ABSTRACT

Four colored coatings with low infrared emissivity were prepared by using polyurethane as adhesive, aluminum as filler and nanometer pigment as paint, respectively. The influence of nanometer pigment on color, surface gloss and infrared emissivity of composite coating was systematically investigated. The surface microstructure of coating was characterized and the mechanism of nanometer pigment was discussed in detail. These results indicate that the color of coatings changes significantly, the infrared emissivity increases slightly and the surface gloss decreases rapidly by the effect of nanometer pigment. Both flake aluminum and pigment particles show a uniform and compact distribution through the microscopic analysis. Additionally, a theoretical model is proposed to account for this mechanism from the analysis of the color and emissivity, which indicates that pigment particles play important roles in forming different particle arrangements between aluminum and colored pigments during the drying process, and nanometer pigment contribute to prepare the colored coating with low infrared emissivity because of its small particle size, low density and gravity.

1. Introduction

With the rapid development of the infrared detection technology, low infrared emissivity coatings have received extensive attention due to its remarkable infrared stealth capability [1]. Aluminum powders were widely used as filler in the coatings through several years of research, the infrared emissivity of which is low extremely but it leads to monochrome and high surface glossiness at the same time [2]. So it is not beneficial to the visible light stealth of the coating, requiring the same color and brightness with the background in visible wavelengths [3]. In order to realize the compatibility stealth of the infrared and visible light, we need to coordinate two parameters, color and infrared emissivity.

The infrared low emissivity coating is mainly composed of metallic pigment and organic binder [4]. Among these components, aluminum reduces the emissivity of the coating greatly, enhances the mechanical properties of the coating, and gives the color of silver to the coating [5], so aluminum powder is such an important part of the coating that it cannot be removed from the coating. Accordingly, study on aluminum with different colors has been carried out for a long time, Le Yuan [6] has prepared the composite pigments with co-precipitation coated Cr_2O_3 on the surface of Al powders, while the emissivity of powders reached above 0.5 in the wavelength range of 8–14 μm, and there also have been a few reports on composite pigments formed by coating Fe_3O_4 on the surface of aluminum powder [7,8], The lightness L^* can be reduced obviously, while the infrared emissivity is above 0.56 in the wavelength range of 8–14 μm. Guangwen Wu [9] has prepared a coating based on modified aluminum coated with polyethylene wax, and the gloss of the coating is decreased, while its emissivity and chroma are undesirable. Weimin Tan [10] has prepared the Greenish yellow lackluster coatings with Prussian blue (PB) surface modified Al powders, but the infrared emissivity of the coating has been increased to above 0.5. To adjust the color and decrease the lightness, colored pigments of high concentrations were also tried to be added, then the emissivity of the coating is largely increased because most of the colored pigments are highly absorbing materials in the infrared waveband [11]. As the progress of the detection technology moves far ahead, in order to reduce the possibility of being exposed, the stealth coating on the surface of equipment would better to realize the infrared and visible light stealth simultaneously, namely, the emissivity and the surface gloss should be decreased to below 0.3 and 15 respectively. However, according to the above research, the color and the infrared emissivity of the compatible coating is hardly able to meet the demand of the practical application at the same time.

In this paper, we demonstrate a new way to prepare low infrared emissivity coatings compatible with different chroma based on

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nanometer pigment via the sputtering method. As a result, low infrared emissivity and colors were obtained. Photos of different colored coatings were clearly displayed, the CIE$L^*a^*b^*$ value, the infrared emissivity and the surface gloss were systematically investigated, then the mechanism of nanometer pigment and a theoretical model of the formation mechanism of compatible coatings were discussed in detail.

2. Experimental

2.1. Materials

Flake aluminum pigments (particle size is about 20 um)were purchased from Zhangqiu Metallic Pigment Co., Ltd, China. Polyurethane resin and curing agents were obtained from CNOOC Changzhou EP Coating Co., Ltd, China. All Nano pigments were purchased from Shanghai Yi Gao Chemical Co., Ltd, China. The additive of BYK333 was obtained from BYK CO., Ltd. All the solvents were A.R. grade and used without further purification.

2.2. Preparation of compatible coatings

Nano pigments and Aluminum is the 30% quality of the Organic binder, respectively. Firstly, nanometer pigments (Carbon black, phthalocyanine blue, Phthalocyanine green color paste, respectively) and aluminum pigments was added into polyurethane and dissolved by solvent under continuous ultrasonication for 10 min, then the curing agents and additive curing agents were added into the mixture and stirred adequately. The mixture was painted by sputtering method on aluminum sheets (10 cm × 5 cm × 0.1 cm) which were rubbed by abrasive paper and rinsed with ethyl alcohol, and the coating thickness was controlled around 60 um. Finally the coatings were dried at room temperature for 10 h and cured in an oven at 80 °C for 10 h.

2.3. Characterization

The surface morphology and structure of the coatings were directly inspected by scanning electron microscopy system (Hitachi S4800). Infrared emissivity value at the wavelength of 8–14 um was measured by using IR-2 Infrared Emissometer (Shanghai Institute of Technological Physics, China), with an accuracy of 0.01. The surface gloss of the coating was observed by JFL-B60 glossimeter (China), at an incidence angle of 60°. The CIE$L^*a^*b^*$ color data (L^*, a^* and b^*) was tested by X-rite QM200 colorimeter (D65 illuminant).

3. Results and discussion

3.1. Characterization of compatible coatings

3.1.1. Different color of coatings

Photos of four colored coatings were clearly displayed in Fig. 1, compared with the silver (d), which is the color of the aluminum coating without adding colorants, colors of the coating turn gray (a), blue (b) and green (c) respectively after the addition of the nanometer pigments. It is obviously that the surface of the coatings looks to be of high quality and in good condition, and the color is uniform without flooding and floating. The CIE$L^*a^*b^*$ value is an important parameter for the characterization of visible light optical properties, it indicates the samples have different colors according to different CIE$L^*a^*b^*$ values [12]. Among them, L^* is the lightness, a^* is red or green and b^* is yellow or blue. The CIE$L^*a^*b^*$ values of different color coatings were measured and the results are shown in Table 1. It can be seen that the CIE$L^*a^*b^*$ values of the colored coatings changes significantly, which show different colors, compared with the coating without colorant. Therefore, it is beneficial to the visible light stealth in different background.

Table 1
The CIE$L^*a^*b^*$ values of different colors coating.

Colors	L^*	a^*	b^*
Gray	56.45	1.67	3.3
Blue	62.36	−1.53	−21.4
Green	70.11	−18.34	0.7
Silver without colorant	75.9	1	−0.8

3.1.2. Effect of nanometer pigment on the infrared emissivity and surface gloss of compatible coatings

In order to study the effect of nanometer pigment on the emissivity and surface gloss of the coating with different colors, measurements were carried out under the same condition. The results are shown in Table 2. It can be seen that the emissivity of the colored coatings increased slightly and keep less than 0.2, compared with the coating without colorant, which result from the scattering and absorption of infrared waves by colored pigments [13]. The surface gloss decrease from 17.2 approximate to 6 after adding colorant, which is derived from the scattering and absorption of visible light by colored pigments [13]. Accordingly, the colored coatings show both low emissivity and low surface gloss affected by nanometer pigment, and it is helpful to realize infrared compatible with visible light stealth.

3.2. SEM observation

In the following, we take the gray coating as an example to analyze the effect of nanometer pigment on the coating. The SEM images of Al powders and black pigment distribution on gray coating are shown in Fig. 2. From Fig. 2(a), it can be found that the flake aluminum powder remain a good visual distribution despite of the influence of nanometer pigments, and the surface of obtained coating can produce specular reflections so easily that most of the infrared radiation is absolutely reflected, while only little radiation is absorbed, which obviously contributes to a lower emissivity [14]. The distribution of nanometer pigment, which is nano-grade carbon black, can be seen when the

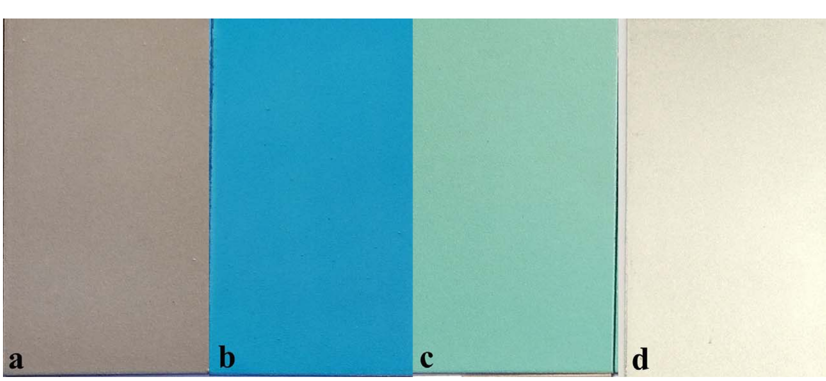

Fig. 1. Photo of coatings with different color: (a) gray (b) blue (c) green (d) silver (non colorant).(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)