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Preparation and characterization of a greenish yellow lackluster coating with low infrared emissivity based on Prussian blue modified aluminum

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ABSTRACT

Greenish yellow lackluster coatings with low infrared emissivity were prepared by Prussian blue (PB) surface modified Al powders and polyurethanes. The morphology and component of PB/Al powder were characterized by scanning electron microscopy and X-ray diffractometer. The infrared emissivity, surface gloss and visible light color of PB/Al composite coating were investigated by an infrared emissometer, a glossmeter and a colorimeter, respectively. Mechanical properties of PB/Al composite coatings were studied by using adhesion test and impact strength test. The results indicate that PB/Al powder decreases not only the gloss of the coating, but also its emissivity within the wavelength range of 8–14 μm. The composite coatings have good adherence and impact strength at PB/Al content below 50 wt.%, and then the mechanical properties decrease in the PB/Al content range from 50 wt.% to 60 wt.%. By comparing PB/Al composite coating and Al powder tinting coating with the same color and surface gloss, PB/Al composite coating exhibits significant lower infrared emissivity, which is attributed to closer inter-powder distances of metallic fillers and higher electrical conductivity in the coating.

1. Introduction

It is known that infrared emissivity is an important factor for electromagnetic radiation, where higher emissivity can result in higher radiation energy. Thus, infrared emissivity of some materials is expected to be controlled to fulfill special requirements. For example, low infrared emissivity materials are required for vehicles and aircrafts, which could decrease the radiation energy to cloak these equipments from detection by electromagnetic waves. As we know, coating exterior surface of objects with low emissivity materials is the most convenient method to achieve this requirement. In the past decade, several studies focused on decreasing coating infrared emissivity have been reported, such as nanocomposite films [1,2], multilayer structures [3,4], transparent conductive oxide compounds [3–6], organic/inorganic composite coatings [7,8], as well as Ag and Cu [9,10]. Especially, organic/inorganic composite coatings are promising with advantages of low cost and excellent performance for engineering applications.

In general, organic/inorganic composite coatings are composed of organic adhesives and inorganic pigments. Among organic adhesives, polyurethanes are widely used for their excellent physical and durability properties, as well as high tensile, impact strengths, and resistance to chemicals, corrosion, scratches, abrasion [11–16]. However, polyurethanes contain some strong photoabsorptive groups, which are sensitive in the wavelength range of 8–14 μm [17]. Therefore, special metallic pigments such as Al powders are usually used as fillers to decrease the coating emissivity due to their high spectral reflectance and low infrared emissivity [18,19]. However, the high glossiness of Al powders inevitably leads to compatibility problems with visible and near-infrared light, which constrain their application ranges [20–22]. For this reason, superficial pretreatment is thought to be one way to reduce the gloss and maintain low emissivity of Al power. But to our knowledge, there are very few studies carried out on this approach.

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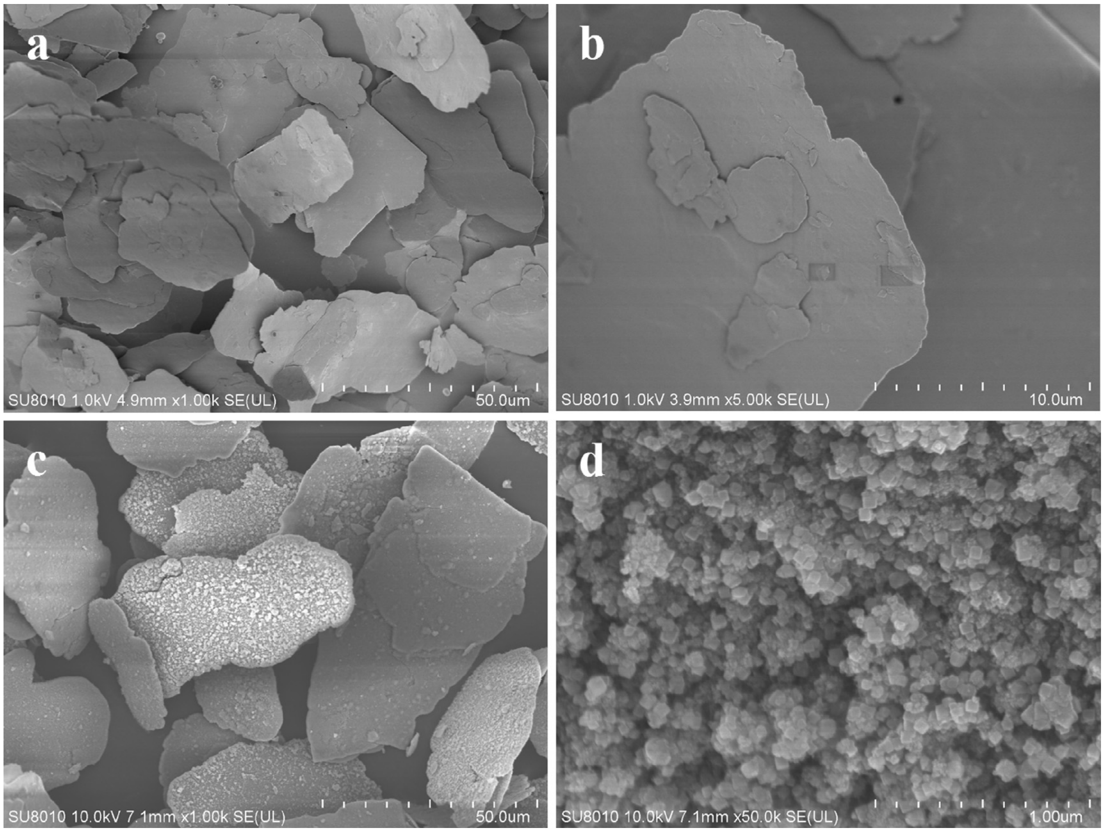

Fig. 1. SEM images of (a and b) Al powders and (c and d) PB surface modified Al composites.

Herein, we demonstrated a convenient method of using PB surface modified Al powders and polyurethanes to prepare low infrared emissivity coatings. The influences of modified Al powder content on the infrared emissivity, surface gloss and mechanical properties were systematically investigated. Furthermore, comparing to Al powder tinting coatings, the effects of PB/Al powder on the infrared emissivity and visible light performances of the composite coatings were also discussed.

2. Experimental

2.1. Materials

All solvents and chemicals were of analytical grade and used without further purification. Potassium ferricyanide ($K_3Fe(CN)_6$), ferric chloride ($FeCl_3 \cdot 6H_2O$), acetic acid and other chemicals were obtained from Shanghai Chemical Reagent Co., Ltd, China. Aluminum powders (particle size is 30–50 μm) were purchased from Zhangqiu Metallic Pigment Co., Ltd, China. $(Cr,Sb,Ti)O_2$, $(Co,Ni,Zn)_2(Ti,Al)O_4$ and $Fe(Fe,Cr)_2O_4$ pigments for tinting were purchased from Heubach Ltd, Germany. The polyurethane resin and universal tinting colorants were kindly supplied by CNOOC Changzhou EP Coating Co., Ltd, China. Deionized water was used throughout the experiments.

2.2. Preparation of PB/Al powders

Firstly, 5 g Al powders were dispersed in 500 ml deionized water. Then, this dispersion was reacted with 2.5 mM $FeCl_3$ aqueous solution (pH 4, adjusted with acetic acid) by ultrasonic agitation for 1 h. After that, 25 mL aqueous solution of $K_3Fe(CN)_6$ (0.1 mol/L)was added drop by drop to this mixture with continuous stirring, and the mixture was maintained at 80 °C for 4 h to yield greenish yellow PB surface modified Al powders. The solid product was then centrifuged and washed with deionized water for several times. Finally, the product was dried at 80 °C for 4 h in an oven.

2.3. Preparation of PB/Al composite coating and Al tinting coating

In the process, tinplate sheets with dimensions of 12 cm × 5 cm × 0.3 cm were used as substrates. The sheets were rubbed using fine abrasive paper and rinsed with acetone. PB/Al composite coating and Al tinting coating were prepared by the following method. First, fixed amounts of PB/Al composites and polyurethane were mixed under continuous stirring for 1 h, or calculated ratios of uniformly dispersed tinting colorants and Al powder were mixed with polyurethane under continuous stirring with the same time. Then the mixture was painted onto tinplate substrates by the sputtering method using an accurate speed motor and appropriate pressure, the spray rate could be adjusted by controlling the rotation speed of the spinner. The distance between substrate and spray gun is about 25 cm and the spray gun should be perpendicular to the substrate during spraying. The coating thickness was controlled about 40 μm. Finally, the coatings were cured in an oven at 80 °C for 2 h or at room temperature for 7 days and kept for further analysis.

2.4. Characterization

The surface morphology and structure of the samples were directly inspected by JSM-5610LV scanning electron microscopy system (Japan). The phase formations of samples were analyzed by Shimadzu-3000 X-ray diffractometer (Japan) with Cu $K\alpha$ radiation source ($\lambda = 0.154056$) operated at 40 kV and 35 mA, and the