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Influence of silicon on growth process of plasma electrolytic oxidation coating on Al–Si alloy

J. He, Q.Z. Cai*, H.H. Luo, L. Yu, B.K. Wei

State Key Laboratory of Material Processing and Dies & Mould Technology, Huazhong University of Science and Technology, Wuhan 430074, China

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ABSTRACT

Ceramic coating was formed on the surface of Al–Si alloy via plasma electrolytic oxidation (PEO) technique. The influence of silicon on the growth process, morphology and composition of the PEO coating was investigated. It was observed that the coating was simultaneously formed on the surface of primary α phase and eutectic ($\alpha+\beta$) in the initial stage of PEO process. No plasma discharge occurred on the surface of eutectic Si phase. But the silicon would be oxidized and mixed with Al_2O_3 in coating melted at high temperature. The PEO coating on primary α phase was mainly composed of Al_2O_3. By contrast, the content of SiO_2 in coating formed on eutectic ($\alpha+\beta$) was higher than that of Al_2O_3. With the time increasing, the amount of α-Al_2O_3 in the PEO coating increased because of the transformation from γ-Al_2O_3 to α-Al_2O_3 at high temperature.

1. Introduction

The applications of cast aluminium–silicon (Al–Si) alloys for the machine parts are progressively increasing due to their high strength to weight ratio, excellent castability and pressure tightness, low coefficient of thermal expansion, good thermal conductivity, good mechanical properties, etc. [1–3]. However, poor wear and corrosion resistance often reduce the lifetime of cast Al–Si alloy components and restrict their widespread applications [4]. Surface hardening by means of conventional oxidation treatment, viz. anodic oxidation is commonly used in cast Al–Si alloy to improve their wear and corrosion resistance [5]. But conventional anodized layer cannot meet the requirement of the wear and corrosion resistance, especially in serious environment, because it is porous and brittle. Moreover, it is difficult to produce a protective thick coating on Al–Si alloys by anodic oxidation process due to the hindrance of the silicon phase.

Plasma electrolytic oxidation (PEO) technique [6], known as micro-arc oxidation technique [7], is widely used to deposit thick and hard oxide coatings on aluminium and its alloys. Several researchers have proved that PEO coating provides excellent adhesion with substrate and improves wear resistance, corrosion resistance, chemical stability, high temperature shock resistance, etc. [8–10]. Most of those studies were focused on PEO coating of low silicon (<1.5% Si) content Al–Si alloys or Al–Cu alloys [11,12]. Recently, the applications of PEO process on high silicon content cast Al–Si alloys have attracted attention, because of the rapid growth in application of high silicon content cast Al–Si alloys. Nevertheless, there is limited information available in open literature about silicon effect on PEO process of high silicon content Al–Si alloys, especially in the initial stage of PEO coating formation.

In this work, the cast Al–Si alloy with high silicon content (7% Si) was selected as experimental sample. The PEO process was carried out in alkaline silicate solution. The effect of silicon on growth process, composition and morphology of PEO coating was investigated.

2. Experimental details

2.1. Materials

The Al–Si alloy sample used in this study was a metallic mould casting. The chemical composition is as follows (in wt.%): 6.5–7.5Si, 0.2–0.3Mg, ≤0.5Fe, ≤0.35Mn, Al balance. Rectangular coupons were cut from the casting, and machined to the dimensions of 30 mm × 25 mm × 10 mm. The electrolyte was prepared from a solution of Na_2SiO_3 (15–20 g/L), Na_3AlF_6 (3–8 g/L) and KOH (1–5 g/L). A small amount of stabilizing agent was incorporated to adjust the velocity of oxidizing reaction.

2.2. PEO process

The samples were prepared by polishing on successively finer grade of emery papers up to 1200 grade, followed by degreasing in acetone and rinsing in distilled water, then immersed in the formulated aqueous electrolyte. The typical oscillogram of the bipolar voltage and current was shown in Fig. 1. The experiment was conducted using a high frequency (700 Hz) bipolar current mode. The duty cycle and the mean voltage of the negative electrical pulse

* Corresponding author. Tel.: +86 27 87543876; fax: +86 27 87541922.
E-mail address: caiqizhou@mail.hust.edu.cn (Q.Z. Cai).

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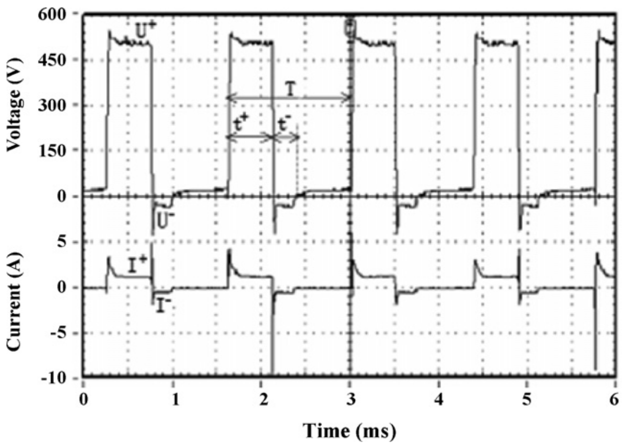

Fig. 1. Typical oscillogram of the bipolar voltage and current utilized in PEO process.

were 0.3 and −60 V, respectively, during the complete PEO process. The temperature of the electrolyte was kept at the range of 25–40 °C. A stainless steel plate was used as the counter electrode. The coated samples were rinsed in distilled water, dried in hot air and then kept in a drying chamber prior to testing.

2.3. Coating morphology, composition and phase analysis

The microstructure and morphology of coating were characterized by optical and Quanta 200 environmental scanning electron microscopy. To analyze the coating cross-section, the coated samples were sawn and mounted in glass-reinforced epoxy, which ensured edge retention during the grinding and polishing. The phase composition was estimated by XRD analysis using a D/Max-IIIB diffractometer (Cu Kα radiation).

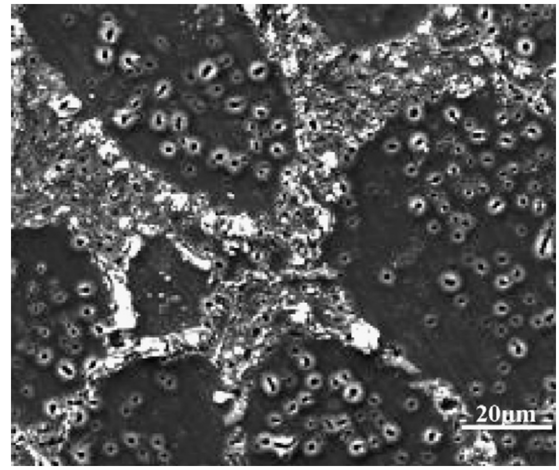

Fig. 3. SEM surface morphology of sample treated for 30 s.

3. Results and discussion

3.1. Morphology of coating in the initial stage of PEO process

The surface morphologies of Al–Si alloy samples at different times of PEO process were shown in Fig. 2. It can be seen that PEO coatings appeared on the surface of primary α phase and eutectic (α + β), respectively. The oxidizing products over eutectic surface formed netlike structures, while they scattered on primary α phase uniformly. Uncoated original surface on primary α phase remained as white, shown in Fig. 2. Moreover, the area covered by PEO reaction products increased with the processing time.

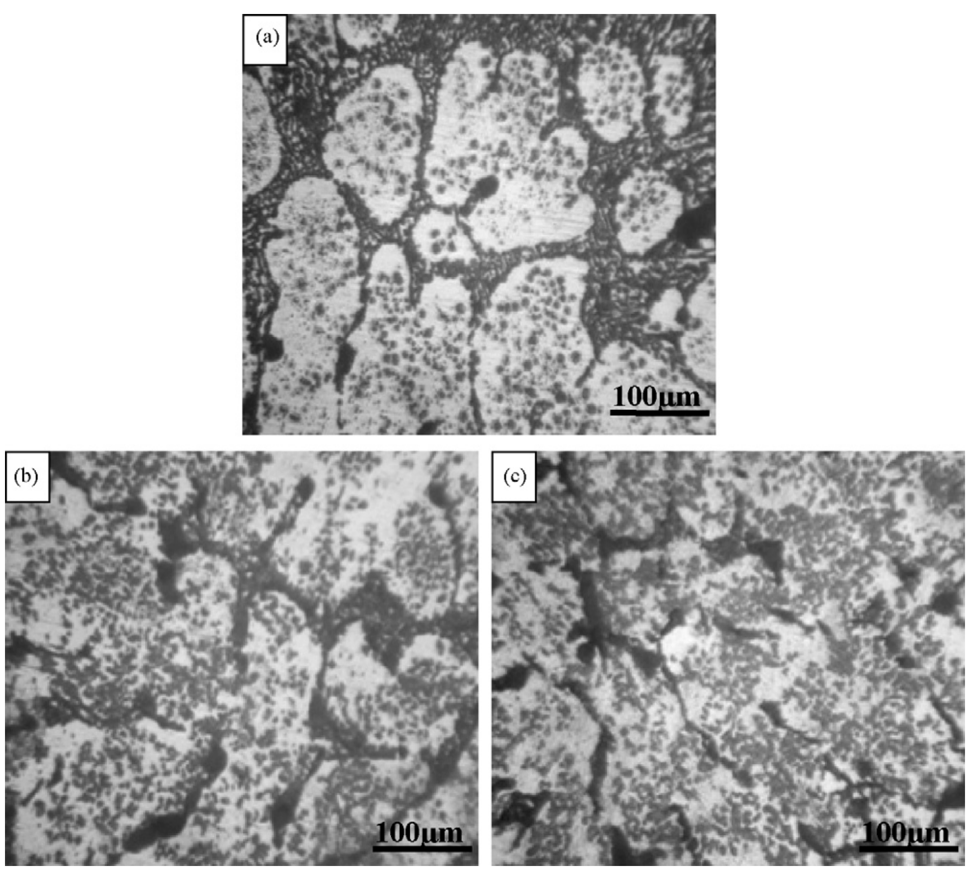

Fig. 2. Surface morphology of Al–Si alloy samples at different times of PEO process: (a) 30 s; (b) 60 s; (c) 90 s.