Surface & Coatings Technology 205 (2010) 1679–1688

Contents lists available at ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Surface characterisation of DC plasma electrolytic oxidation treated 6082 aluminium alloy: Effect of current density and electrolyte concentration

R.H.U. Khan [a,b], A. Yerokhin [a,*], X. Li [b], H. Dong [b], A. Matthews [a]

[a] Department of Engineering Materials, The University of Sheffield, Mappin Street, Sheffield, S1 3JD, UK
[b] School of Metallurgy and Materials, The University of Birmingham, Birmingham, B15 2TT, UK

ARTICLE INFO

Available online 29 April 2010

Keywords:
Plasma electrolytic oxidation
Current density
Electrolyte concentration
Direct current (DC)
Residual stresses
XRD $Sin^2\psi$ method
Nanoindentation

ABSTRACT

Plasma electrolytic oxidation (PEO) is a specialised but well-developed process which has found applications in aerospace, oil/gas, textile, chemical, electrical and biomedical sectors. A novel range of coatings having technologically attractive physical and chemical properties (e.g. wear- and corrosion-resistance) can be produced by suitable control of the electrolyte as well as electrical parameters of the PEO process. Oxide ceramic films, 3 to 40 µm thick, were produced on 6082 aluminium alloy by DC PEO using 5 to 20 A/dm^2 current density in KOH electrolyte with varied concentration (0.5 to 2.0 g/l). Phase analysis (composition and crystallite size) was carried out using X-ray diffraction and TEM techniques. Residual stresses associated with the crystalline coating phase (α-Al_2O_3) were evaluated using the X-ray diffraction $Sin^2\psi$ method. Nanoindentation studies were conducted to evaluate the hardness and elastic modulus. SEM, SPM and TEM techniques were utilised to study surface as well as cross-sectional morphology and nano features of the PEO coatings. Correlations between internal stress and coating thickness, surface morphology and phase composition are discussed. It was found that, depending on the current density and electrolyte concentration used, internal direct and shear stresses in DC PEO alumina coatings ranged from -302 ± 19 MPa to -714 ± 22 MPa and -25 ± 12 MPa to -345 ± 27 MPa, respectively. Regimes of PEO treatment favourable for the production of thicker coatings with minimal stress level, dense morphology and relatively high content of α-Al_2O_3 phase are identified.

1. Introduction

Plasma electrolytic oxidation (PEO) is an advanced form of anodic oxidation that utilise an electrolytic plasma discharge to produce oxide ceramic layers [1]. It is mainly applied to valve metals, e.g. aluminium, titanium, magnesium, zirconium, and their alloys [2–5]. There is significant interest in PEO as a means of providing an ecologically friendly alternative to acid-based anodising processes and also to enhance coating characteristics and properties, such as thickness, crystallinity, microhardness, electrical and thermal insulation, adhesion with substrate, wear- and corrosion-resistance [6,7]. The generic term PEO covers several processes, based on anodising of a metallic substrate in an electrolyte, with the applied potential sufficiently high for electrical discharges to occur. Among these, the DC PEO mode is the easiest to implement and the most convenient to study fundamental aspects of the coating formation process in relation to the basic process parameters.

PEO usually features plasma discharge phenomena occurring at the metal/electrolyte interface above the breakdown voltage. Discharge events are discrete short-lived and microscopic; they provide multiple heating–cooling cycles to the coating that determine thermal and chemical conditions at the surface, thus playing an important role in the formation of the coating phase composition, structure and stress state. In the DC PEO mode, discharge characteristics can mainly be controlled by current density [8–10] and electrolyte concentration [2,11,12].

Residual stresses are one important coating characteristics; they may influence directly or indirectly almost all properties of coated materials, including hardness, adhesion, wear- and corrosion-resistance, fatigue crack behaviour, electrical resistivity, optical reflectance, barrier and magnetic ones [13–15]. Therefore, understanding the formation of residual stresses is important to prevent the coating from peeling or cracking during service. In order to gain a better understanding of such residual stress effects, the analysis of the coating stress state in relation to the microstructure is necessary. Previous work was primarily concerned with the effects of pulsed current on characteristics of structure and residual stresses of PEO coatings on Al and Ti [14,16], whereas effects of basic process parameters, such as electrolyte composition and current density in DC PEO mode, were largely ignored. In this work, the influence of current density and electrolyte concentration on the residual stresses in DC PEO coatings is studied and the internal stresses have been evaluated using the XRD $Sin^2\psi$ technique [17,18].

* Corresponding author. Tel.: +44 1142225510; fax: +44 1142225943.
E-mail address: A.Yerokhin@sheffield.ac.uk (A. Yerokhin).

0257-8972/$ – see front matter
doi:10.1016/j.surfcoat.2010.04.052