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Pulse transient analysis as a diagnostic tool of soft sparking transition in plasma electrolytic oxidation

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Plasma electrolytic oxidation (PEO) of an aluminum alloy workpiece enables its surface protection beyond anodizing. One salient attribute of PEO is the micro discharges, which accelerate the growth rate, densify the coating, meanwhile damage the coating microstructure and leave pinholes and cracks which are viewed as a major weakness of this technology. Entering the soft sparking regime may produce a coating with the feature of a dense inner layer and lessens the intrinsic porosity problem. The transition of soft sparking is typically identified through the anodic voltage drop under a constant current mode. Fig. 1a shows three soft sparking transitions with anodic current 1.2 A and negative current 1.4 A (1.5 or 1.6 A) of bipolar pulsed DC. The transitions occur at 66 (1.4 A), 54 (1.5 A), 45 (1.6 A) mins. We long suspected that the output voltage drop of power supply is a belated signal, since the micro arc state has been softened before voltage drop. Indeed, our analysis of V-I transients of positive pulse, points out that the fitted time constants R_1C_1, R_2C_2 are transition precursors, since they plunge before the anodic voltage drops. Figs. 1b and 1c show R_1C_1 and R_2C_2 fall simultaneously at 40 mins for three negative currents 1.4, 1.5, 1.6 A. On the study of frequency dependence, Fig. 2a indicates that the soft sparking transition moves forward with increasing frequency of applied current, 54 (50 Hz), 44 (100 Hz), and 29 (500 Hz) min. Fig. 2b shows R_1C_1 also displays a consistent fall at an earlier time, 40, 38, 28 min. The only exception is R_2C_2 at 500 Hz, Fig. 2c, which falls three times, instead of one time. We have thus found a stratified microstructure of the 500 Hz coating, suggesting that the three falls in R_2C_2 correspond to three intensity decreases in local plasma, an indication of sensitive diagnosis.

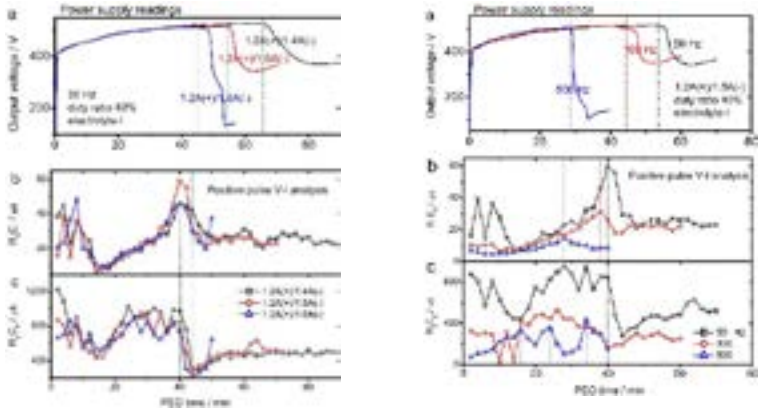

Figure 1: PEO of 1.2A(+)/1.4A(-), 1.2A(+)/1.5A(-), 1.2A(+)/1.6A(-) at 50 Hz. The (a) anodic voltage readings of power supply versus time; the fitted time constants (b) R1C1 and (c) R2C2 values versus time

Figure 2: PEO at 50, 100, 500 Hz of 1.2A(+)/1.5A(-). The (a) anodic voltage readings of power supply versus time; the fitted time constants (b) R1C1 and (c) R2C2 values versus time.

Recent Publications

1. Tsai D S and Chou C C (2018) Review of the soft sparking issues in plasma electrolytic oxidation. Metals 8:105.
2. Rogov A B, Yerokhin A and Matthews A (2017) The role of cathodic current in PEO of aluminum. Langmuir 33:11059–11069.
3. Fatkullin A R, Parfenov E V, Yerokhin A, Lazarev D M and Matthews A (2015) Effect of positive and negative pulse voltages on surface properties and equivalent circuit of the plasma electrolytic oxidation process. Surf Coat Technol. 284:427–437.
4. Liu C Y, Tsai D S, Wang J M, Tsai J T J and Chou C C (2017) Particle size influences on the coating microstructure through green chromia inclusion in PEO. ACS Appl Mater Interfaces 9:21864–21871.

5. Matykina E, Arrabal R, Skeldon P, Thompson G E and Belenguer P (2010) AC PEO of aluminum with porous alumina precursor films. Surf Coat Technol. 205:1668–1678.

Biography

Dah-Shyang Tsai has been a researcher and educator at the Department of Chemical Engineering, National Taiwan University of Science and Technology, Taiwan (Taiwan Tech) since 1985. His expertise is in the synthesis and characterization of inorganic materials coating and related surface issues. These inorganic coatings are designed to upgrade the performance of device, or simply enhance our knowledge on film growth. For example, his research group worked out the reactive sticking coefficients of silane free radicals in CVD, using the trench thickness profiles grown in a hot-wall reactor (2002). In another instance, they prepared Pt/Sn/SnO_2 nanowires on the carbon paper which served as a combination of CO-tolerant electrocatalysts and gas diffusion layer in fuel cells (2010). Recent interests of his research group are focused on the soft sparking mode of plasma electrolytic oxidation (PEO), and improving the electron and ion paths of the porous electrode for electrochemical energy storage device, such as lithium ion hybrid capacitor.

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