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New Findings on the Plasma Electrolytic Oxidation (PEO) of Aluminium

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Abstract : The plasma electrolytic oxidation (PEO) is a particular electrochemical process to produce protective oxide ceramic coatings on light-weight metals (Al, Mg, Ti). When applied to aluminum alloys, the resulting PEO coating exhibit improved wear and corrosion resistance because thick, hard, compact and adherent crystalline alumina layers can be achieved. Several investigations have been carried out to improve the efficiency of the PEO process and one particular way consists in tuning the suitable electrical regime. Despite the considerable interest in this process, there is still no clear understanding of the underlying discharge mechanisms that make possible metal oxidation up to hundreds of µm through the ceramic layer. A key parameter that governs the PEO process is the numerous short-lived micro-discharges (micro-plasma in liquid) that occur continuously over the processed surface when the high applied voltage exceeds the critical dielectric breakdown value of the growing ceramic layer. By using a bipolar pulsed current to supply the electrodes, we previously observed that micro-discharges are delayed with respect to the rising edge of the anodic current. Nevertheless, explanation of the origin of such phenomena is still not clear and needs more systematic investigations. The aim of the present communication is to identify the relationship that exists between this delay and the mechanisms responsible of the oxide growth. For this purpose, the delay of micro-discharges ignition is investigated as the function of various electrical parameters such as the current density (J), the current pulse frequency (F) and the anodic to cathodic charge quantity ratio (R = Qp/Qn) delivered to the electrodes. The PEO process was conducted on Al2214 aluminum alloy substrates in a solution containing potassium hydroxide [KOH] and sodium silicate diluted in deionized water. The light emitted from micro-discharges was detected by a photomultiplier and the micro-discharge parameters (number, size, life-time) were measured during the process by means of ultra-fast video imaging (125 kfr./s). SEM observations and roughness measurements were performed to characterize the morphology of the elaborated oxide coatings while XRD was carried out to evaluate the amount of corundum -Al203 phase. Results show that whatever the applied current waveform, the delay of micro-discharge appearance increases as the process goes on. Moreover, the delay is shorter when the current density J (A/dm2), the current pulse frequency F (Hz) and the ratio of charge quantity R are high. It also appears that shorter delays are associated to stronger micro-discharges (localized, long and large micro-discharges) which have a detrimental effect on the elaborated oxide layers (thin and porous). On the basis of the results, a model for the growth of the PEO oxide layers will be presented and discussed. Experimental results support that a mechanism of electrical charge accumulation at the oxide surface / electrolyte interface takes place until the dielectric breakdown occurs and thus until micro-discharges appear.

Keywords : aluminium, micro-discharges, oxidation mechanisms, plasma electrolytic oxidation
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