Nucleation and Growth of the Etch Pits and Structure of the Etch Films of ac Etched Aluminum Foils.

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ABSTRACT

The aluminum foils for electrolytic capacitors were etched in hydrochloric acid (HCl) using a flow cell. The 25 Hz sinusoidal current waveform with a current density of 60 Apeak/dm2, generated via a precision function generator together with a power amplifier, was applied for electrolytic etching. In the meantime, the voltage-current relationship was recorded. The surface of the as-etched Al and the etched Al of which etch film had been removed was observed using scanning electron microscopy (SEM). The detailed morphology and microstructure of the pits and the etch films were characterized using cross-sectional transmission electron microscopy (TEM). In addition, the weight of the etch film and the dissolved Al was measured. Experimental results indicate that the pitted areas and the weight of the etch films and the dissolved Al decreased with increasing HCl concentration, leaving some areas remained unattacked up to 60 s of etching. Cross-sectional TEM further revealed that increasing HCl concentration not only reduced the thickness of the etch film covering the original surface of the Al foil, but also enhanced the propagation of the cubic pits into the Al substrate, forming more vertical-type cubic pits. Furthermore when the HCl concentration was increased, the pitting potential and dissolution time for each anodic half cycle decreased, whereas the induction time for the formation of the pit increased; thereby the effective charge imposed during each half cycle and the accumulated charge for the dissolution of the Al foil decreased with increasing HCl concentration. The longer induction time and shorter dissolution time for pitting in the HCl electrolyte of higher concentration correlate with the more areas that remained unattacked and the less amount of the dissolved Al. Sulfate anions were found to effectively inhibit the nucleation of the pits during the beginning of etching and enhance the formation of the vertical-type cubit pits. In the 0.8M HCl electrolyte, the pitting potential increased with increasing sulfate anions, whereas the dissolution time decreased and the induction time increased with increasing sulfate anions. Conversely, in the 3.2M HCl electrolyte, the pitting potential, the induction time and the dissolution time hardly changed with the electrolyte sulfate anion concentration. In general, the addition of the sulfate anions increased the effective charge imposed during each half cycle and the accumulated charge for the dissolution of the Al foil. The pitting behavior of the Al foil in the 0.8M HCl electrolyte containing 0.24M sodium chloride resembled that of the Al in the 0.8M HCl. Meanwhile, the Al foil etched in the 0.8M HCl electrolyte and in the 0.8M HCl and 2.4M NaCl electrolyte had similar pitting potential, dissolution time and induction time. The weight of the etch film and the dissolved Al in the 0.8M HCl and 2.4M NaCl electrolyte was in between these measured in the 0.8M HCl and 3.2M HCl electrolytes. Finally, the addition of NaCl increased the accumulated charge for the dissolution of the Al foil.

Keywords : electrolytic capacitors, electrolytic-etched aluminum foils, etch film, pitting potential, dissolution time

Table of Contents

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