Is There Any Similarity between Pulse Plating and Aluminum Pulse Anodizing?

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There is no similarity between pulse plating and aluminum pulse anodizing. In electroplating, pulses are ‘barbering’ conductive metallic coatings to achieve a more uniform thickness. Extra thickness is ‘shaved away’ with reverse currents that do not require high AC power for creating them. On the contrary, in pulse anodizing of aluminum in sulfuric acid electrolytes, a porous coating with dielectric properties is formed, Also, a much higher AC power, than in pulse plating, is needed to form coatings of exceptionally high quality, and reverse currents (if they exist) play no role.

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DC + superimposed-sinusoidal-AC power sources were successfully introduced into practice of hard coating of aluminum in the USA at the end of the 1970s[1-4].

This event coincided with a period of extensive implementation of pulse generators for electroplating. A periodic succession of voltage pulses supplied by pulse generator was in fact a superposition of the AC voltage component over the DC voltage component[5]. In electroplating, pulses are ‘barbering’ conductive metallic coatings to achieve a more uniform thickness. Extra thickness is ‘shaved away’ with reverse currents habitually requiring very low AC power for their creation. Crafting a proper shape of voltage pulses for a particular profile of the electroplated article is the main challenge for achieving the desired properties of the coating.

Using principally the same type of a power supply for both - electroplating and anodizing - made us believe that these processes must have a lot in common.

However, after the recent ‘heat-in-film’ discovery[6-8] it was proved that there was nothing in common between electroplating and aluminum anodizing though both processes use pulse generators. It was discovered that proportion between DC power and AC power sent to the electroplating tank is dramatically different from that sent to the anodizing tank.

The described below anodizing experiment demonstrated how a straight DC anodizing process responded to gradually increasing AC voltage applied across the tank, provided that the flow of Faraday electricity forming the coating was kept constant. This experiment proved that reverse currents, so important in electroplating, play no role in anodizing. Moreover, it is doubtful that reverse currents even exist in the anodizing tank powered from a pulse generator.

Experiment Procedure

A simple schematic was used (see Fig.1) for applying V_{AC} across the anodizing tank besides V_{DC}. A Continuous Mixer of DC power and sinusoidal AC power[9] fed the tank. The mixer was called “Cont-Mix” and marked by ‘1’ in Fig.1. Two knobs control the mixer: a DC knob controls V_{DC} (this voltage is plotted on the DC voltage vertical axes in Fig. 2). An AC knob controls the added sinusoidal V_{AC} of industrial frequency (this voltage is plotted on the AC voltage horizontal axes in Fig. 2).

DC-meter ‘2’ measures V_{DC} (in milliVolt) across a shunt whereas AC-meter ‘3’ measures V_{AC}. Electromagnetic DC-voltmeter ‘4’ measures V_{DC} across the tank. A true-root-mean-square-value (rms) tester ‘5’ measures V_{AC} across the tank. Electrodynamic wattmeter ‘6’ measures total active power spent in the tank.

A standard 170-g/l sulfuric acid electrolyte at room temperature with no agitation was used for anodizing.

The experiment evolved through two stages. In Stage 1, the straight DC power sent to the tank was increased by turning DC knob clock-wise until direct current reached 1.5 A_{DC}/dm^2. This level of current density is habitually used in industrial straight DC anodizing. In Stage 2, the AC sinusoidal power of industrial frequency was added to the tank by turning AC knob clock-wise.

The following provision was observed during Stage 2: the direct current density through the tank (1.5 A_{DC}/dm^2) was kept unchanged. If the raised AC voltage increased DC, then the DC knob would be turned counter-clock-wise to restore the 1.5 A_{DC}/dm^2 level.

Results

Fig. 2 demonstrates measurement results. It is shown that as V_{AC} across the tank increased then V_{DC} would drop close to a half of its initial value (see curve (2) for V_{DC}) provided that direct current was kept unchanged at the 1.5 A_{DC}/dm^2 level. This means that conductivity to the flow of Faraday electricity is doubled thanks, apparently, to disappearance of a certain impediment to this flow.

Discussion

It was proved[10-12] that the impediment to the flow of Faraday electricity in straight DC anodizing was caused by free oxygen collected in the pores of the oxide film. It was also suggested that this oxygen were in a plasma state in the pores. Then, how could the AC voltage superimposed on DC voltage drive the oxygen plasma out of the pores removing, as the experiment demonstrated, the impediment?

Reverse current hypothesis.

Let us consider whether alternating current was a factor in driving the oxygen out of the pores. For a long time I was under the impression that AC played the major role in eliminating oxygen in the oxide film pores. Encouraged by the electroplating experience I believed that in anodizing the reverse current would also increase following increase of AC. A higher reverse current would supposedly release more hydrogen in the pores. This hydrogen would neutralize oxygen thereby wiping away from the pores the impediment to the flow of Faraday electricity.

Figure 2 refutes this reverse current hypothesis. As V_{AC} increases, the alternating current I_{AC} also increases (see curve (5)). However, AC reaches a plateau very soon after its rms value exceeded DC (1.5 A_{DC}/dm^2). The level of AC then remains approximately the same within a rather wide range of V_{AC} increase. Moreover, since the rms value of AC in this plateau is higher than I_{DC}, the reverse current at the beginning of the plateau should be high enough to generate plenty of hydrogen to completely eliminate oxygen in the pores. However, the drop of V_{DC} was negligible at the beginning of the plateau according to the experiment (compare curve (2) for V_{DC} with curve (5) in Fig. 2 at low levels of V_{AC}). This indicates that I_{AC}, apparently, play no role in removing the impediment to the flow of Faraday electricity.

The role of AC power in anodizing.

Figure 2 demonstrates that it is the active AC power that is responsible for reduction of V_{DC} and for driving the oxygen out of the pores. The active AC power W_{AC}(active) (see curve (3)) was calculated by subtracting DC power W_{DC} (see curve (2)) from the total active power W(active) measured by electrodynamic wattmeter '6' (see curve (1)). The higher the active AC power (see curve (3)), the lower becomes the DC power (see curve (2) for W_{DC}). This suggests that the active AC power is pushing oxygen out of the pores. Once plasma was pushed out of the pores it collapsed in the electrolyte. The oxygen, from which plasma was created, returns to the atomic or molecular state. At a high enough level of AC power no free oxygen remains in the pores. The presence of high AC power in the tank prevents the oxygen from accumulating in the pores and creating plasma once more.

If this process is reversed and the AC power decreased, the sequence of events would also reverse. A lower AC power would permit free oxygen to remain in the pores and create plasma requiring additional DC power to maintain it. If V_{AC} is gradually reduced to zero, V_{DC} would increase by closely following curves of Fig. 2 in the opposite direction.

Importance of the voltage waveform.

If a sufficiently high AC power removes half of DC power during anodizing then why should we care about the voltage waveform that did this removal?

It is the plant that cares about the voltage waveform. For example, a 10,000A-power-supply used to feed an architectural anodizing tank consumes over 200 kW of DC electricity at a full load. In order to remove a half of DC power (about 100 kW) we need to send to the tank additionally 100 kW of active AC power (see Fig. 2 that demonstrates removal of up to a half of DC power by the increased AC power).

If this large AC power were carried by sinusoidal voltage the process of removing DC power would be harmless.

On the other hand, if 100 kW of rectangular pulses were sent into the tank, the whole electric power network of the plant would start pulsating – blinking. It can cause disaster in the plant if the anodizing system (or systems) consumed a major portion of energy that entered this plant.

Blinking of power can be escaped if much smaller levels of pulsating AC power (say 10 kW instead of 100 kW) were sent to the tank. However, 10 kW of AC power would be too small to remove any DC power (see W_{DC} curve (2) at low levels of W_{AC}(active) curve (3)). The level of removed DC power in this situation would be as insignificant as it were with straight DC power supplies with the usual ripple.

From the above it follows that we need to send high levels of AC power to the tank using as a carrier sinusoidal AC voltage if we desire to drop DC power consumption in the tank to half of its value in straight DC anodizing.

The industrial frequency of 50 – 60 Hz should be used for the carrier of AC power. Then, no additional transformation of frequency taken from the net is needed.

Conclusions

In electroplating, pulses are ‘barbering’ conductive metallic coatings to achieve a more uniform thickness. Extra thickness is ‘shaved away’ with reverse currents. A rather modest AC power (in comparison to DC power) is used to generate reverse currents.

In aluminum sulfuric acid anodizing, a substantial AC power (as large as the DC power used to form the coating) must be added to the tank to push out of the pores the impediment to the flow of Faraday electricity. This impediment (if not removed) would double the demand for DC power. The excessive DC power heats the coating and harms its quality.

A sinusoidal AC voltage component should be used as a carrier of AC power to the anodizing tank to prevent pollution of the electric power net and the environment with high harmonics of non-sinusoidal voltage.

References

1. M. Lerner, J. Morse, U.S. Patent 4,089,756, (1978).
2. M. Lerner, J. Morse, U.S. Patent 4,133,725, (1979).
3. M. Lerner, B. Fruzstajer, U.S. Patent 4,170,739 (1979).
4. M. Lerner, J. Morse, *Proceedings of 67th AESF Annual Technical Conference, Milwaukee ,WI,* June, (1980) (SUR/FIN® ’80, Section E).
5. M. Lerner, *Proceedings of AESF Third International Pulse Plating Symposium, Washington, DC,* October, (1986).
6. M. Lerner, *Plating and Surface Finishing*, February (2002).
7. M. Lerner, *Proceedings of AESF SUR/FIN 2001 Conference, Light Metals Section, June 25-28, Nashville, Tennessee* (2001)
8. M. Lerner, *Proceedings of AESF SUR/FIN 2002 Conference, Light Metals Section, June 25-28, Chicago, Illinois* (2002).
9. M. Lerner, Patent pending. Based on the U.S. Patent 4,170,739 (1979) by B. Fruzstajer and M. Lerner.
10. M. Lerner, *Plating and Surface Finishing*, November (1998).
11. M. Lerner, *Proc. EAST-forum 1999, May 27-28, (Schwäbisch Gmünd, Germany)*, 15 (1999).
12. M. Lerner, *Galvanotechnik*, D-88348 Saulgau, **90**, (August 1999).

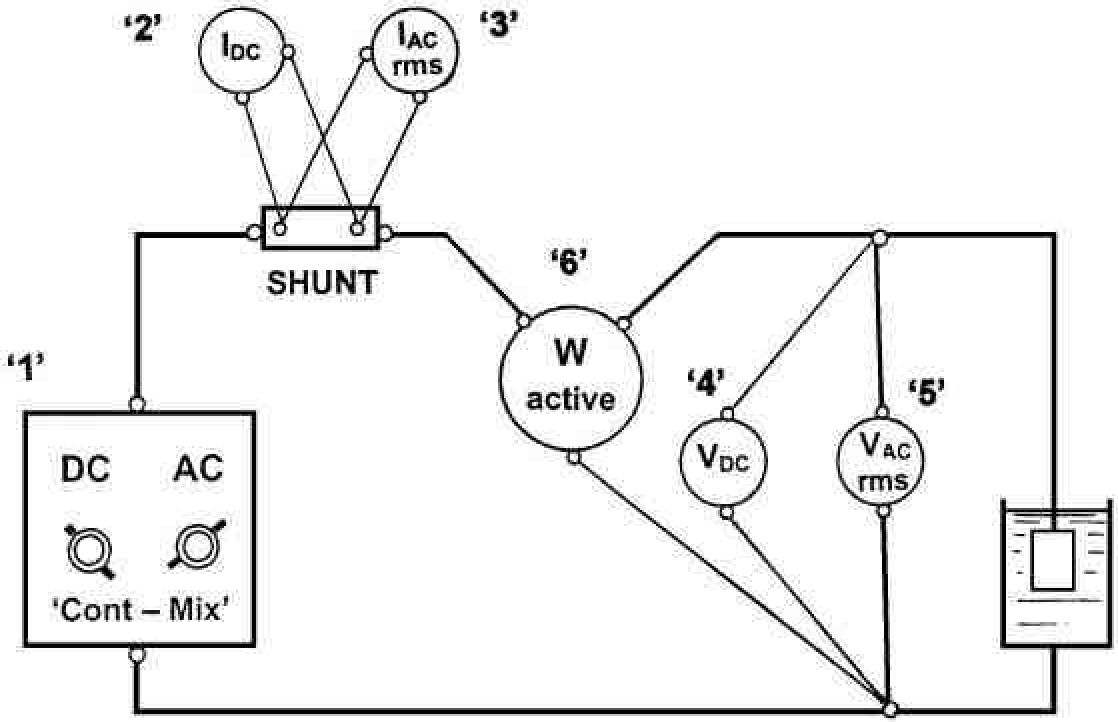

Figure 1 - Schematic of active power measurements.

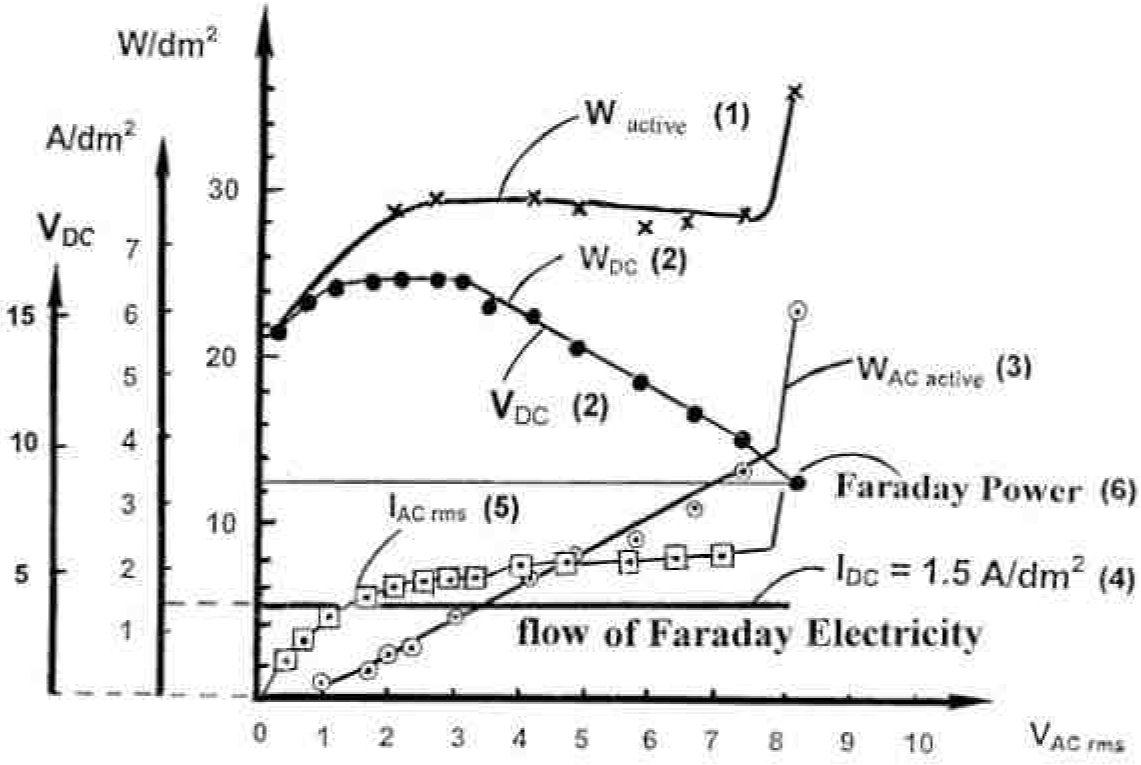

Figure 2 - Test results