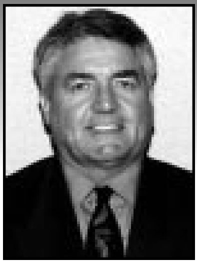

PulsePlating

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Making More Waves

Predictions and new sciences still come several ways. The usual way is to grind through calculations to the point of near exhaustion. This "new millennium" column will deal with the last millennium's column, topic and data generators: pulse electroforming (but not reverse) from the same bath.

The purpose of the research was to assess surface leveling during electroforming using five different waveforms.*

Nickel Pulse Electroforming Conditions

Sulfamate nickel was again used to plate onto SS. The bath composition was nickel sulfamate 44 oz/gal, nickel chloride 2 oz/gal, and boric acid 4 oz/gal, plus 200 ppm SDS surfactant. The pH was 4.2, temperature 50±1°C. Plating occurred on 100 x 30 x 1 mm SS mandrels ground finished on 180 emery papers.

Surfaces were measured with a Talysurf before and after plating. The measured difference indicates microroughness increase.

The types of waveforms (see Fig. 3) include those with off-times: rectangular (square wave) [3], triangular (isosceles) [1], and ramped (right triangle) [2] pulses. Those without off-time are also triangular (isosceles) [4] and ramped (right triangle) [5] pulses. Six peak current densities each were used: 250, 300, 350, 400, 450 and 500 mA cm^{-2}. All experiments used the 100-Hz frequency.

Two sets of plating experiments were performed. They were to plate for one hour (Fig. 1, "to 60 mins") and plate to 30 micrometers (Fig. 2, "to 30 µm"). The average current densities equal half the peak ([3], [4], [5]), except for [1] and [2] where they equal 25% peak current density. Calculated thicknesses for the 60 minute plating and the times for plating to 30 µm are based on the average current densities (Table 1). Note that the highest peak currents for [1], [2] plating rates and times are equal to those of the lowest peak currents for [3], [4], [5].

Table 1

Peak mA cm^{-2}	([1], [2]) µm h^{-1}	([3], [4], [5]) µm h^{-1}	([1], [2]) min to get 30µm	([3], [4], [5]) min to get 30µm
250	77	154	23.4	11.7
300	92	184	19.5	9.8
350	108	215	16.7	8.4
400	123	246	14.6	7.3
450	138	277	13.0	6.5
500	154	307	11.7	5.9

Table 2

[Waveform]	Time, min	Thickness, µm	ASF	Roughness increase, µin.
[2]	60	77	232	1.24 (0.0315 µm)
[1]	19.5	30	279	0.77 (0.0196 µm)

Discussion

Generally, the higher the (average) current density employed, the rougher the work becomes. The only exception is with the case of the triangular waveform with off-time [1]. In Chart "to 30 µm" waveform [2] stays the same microroughness from 232 to 325 ASF whereas waveform [1] dips 38% lower at 279 ASF to only 0.77 microinch increase over starting microroughness. That is an increase of less than 20 nanometers! Thus by plating at an average current density of 70 asf (280 ASF peak) one can plate this smooth at better than 1.5 microns per minute.

Another noteworthy condition is the stability of waveform [2] as seen in Chart "to 60 mins." At 232 ASF it is the lowest roughness promoter of all. Both [2] and [1] plate 92 microns in an hour but compared to [1] produces 22.5% less microroughness. At the same time, [3], [4], and [5] have plated twice as thick and also have doubled the microroughness added. It also appears that if the peak current density were lowered further so also would microroughness. The ASF intercept of the slope for [2] is c. 75 for no increase of microroughness. Next is [4] at 60 ASF.

Let's look at the two best platings of the two experiments (Table 2). It would appear worth starting with [1] for 20 mins. then going to [2]. This would further minimize the increasing microroughness with build. A power supply with programmability is required to do this. And with [2] the length of off-time could be optimized,

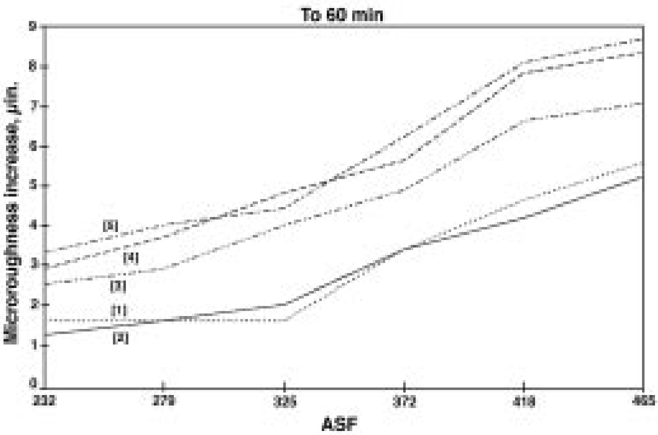

Fig. 1—Plating experiment to 60 min.

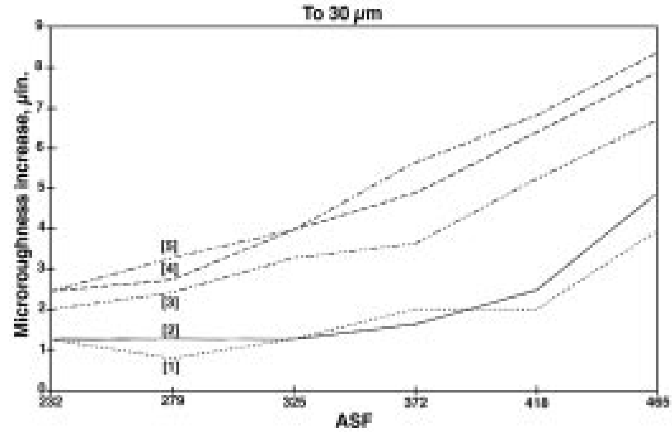

Fig. 2—Plating experiment to 30 µm.

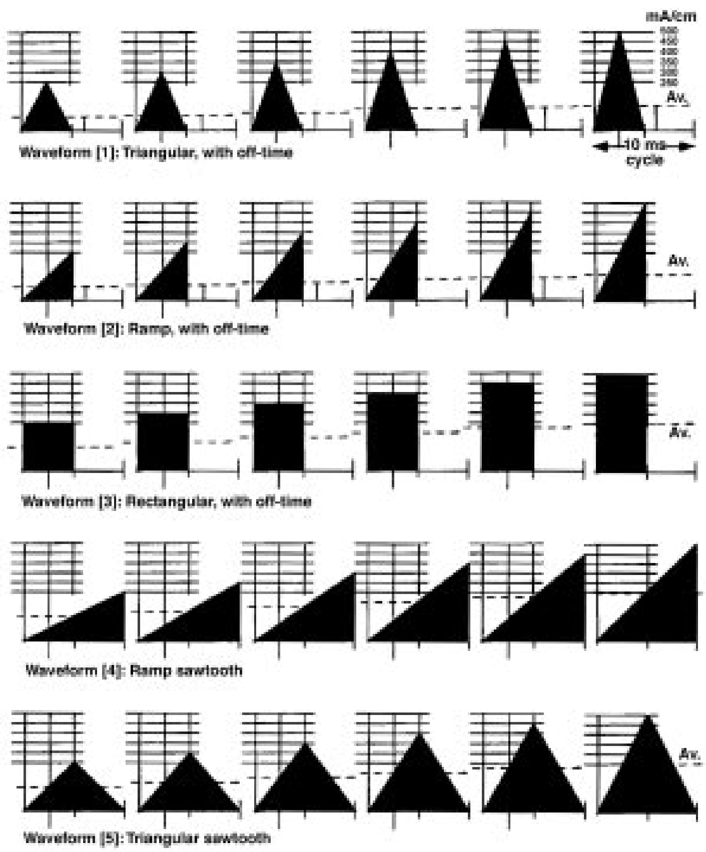

Fig. 3—All waveforms used in the study.

and both, the rate of current rise, or in other words, triangle symmetry.

In any event, microroughness can also be diminished by taking the route of incorporating a certain strong reverse pulse immediately prior to going forward.

The condition of [4] and [5] indicates that without off-time and surface relaxation (conformal Faradaic plating), to an extent, they will always be tending to grow on existing peaks from a lack of nucleation. If one were to look at the oscilloscope trace of [5] one would see something similar to a sine wave and [4] a leaning sine.

The square wave [3] is always in between and it has been beaten to death by volumes of research using this approach. Because of this, much ado about the limitations of pulse plating has created a somewhat bleak picture. I am reminded of the saying, "Absence of evidence is not evidence of absence." P&SF

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* *K.P. Wong, K.C. Chan, T.M. Yue. A Study of Surface Finishing in Pulse Current Electro-forming of Nickel by Utilizing Different Shaped Waveforms.* Surf. Coat. Technol. ***115*** *(1999) 132-9.*