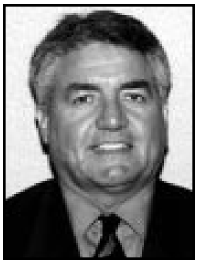

Pulse Plating

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Tackling Current Distribution

The first portion of current is devoted to overcoming surface capacitance due to surface bound or adsorbed atoms, ions or molecules. This adsorbate-induced double layer must get charged and takes a certain amount of time, M, on the amount of current density (CD) applied. In a simple system (*e.g.*, only 0.75 M copper sulfate and Molar sulfuric), the double layer charging time ranges from 0.03 msec at 100 ASF to 1 µsec at 1,000 ASF. When brighteners, surfactants, chloride, etc. are present, capacitances increase.

When current stops, plating continues as the double layer is reestablished during its discharge. Typically, charging and discharging times are similar (as with the presence of adsorbed species). When the exchange current density (the current “consumed” prior to the incipient plating, or faradic, current) is less than one-hundredth of the pulse CD, discharge time is approximately seven times longer than the charging time.[1] Exchange current densities for plating on polycrystalline (small-grained) metals range from a few mASF to several hundred ASF; in acid copper plating with additives, it can reach several thousand ASF. With large capacitances from additive systems designed to achieve higher overpotentials in DC plating, the length of *on* time, or CD, should be sufficiently long or high, so that double-layer charging time is exceeded. Otherwise, the plating behaves more like ripply DC plating. The amount of plating actually occurring during the *off* time double-layer discharge relative to that which would have been plated at the average pulse CD is an index of the "degree of flattening" or damping of the faradic current. Values range from "zero" to "one," with "one" being like DC. Calculations require knowledge of the capacitive current and the variance of faradic current with activation overpotential.

The influence of faradic current damping in simple non-additive containing systems is exemplified by M sulfuric acid + 0.75 M cadmium sulfate plating and by 0.5 M copper plating.[2] Cadmium was plated at 14 ASF average CD by both DC and pulse. The pulse conditions were with damping near "zero" at 14 ASF (929 ASF, 1 msec on, 67 msec off) and damping near "one" at 14 ASF (929 ASF, 0.0007 msec on, 46.7 msec off). The morphology of DC and "one" had poor coverage as well as 20-30 µm-sized grains, whereas "zero" had 2-3 µm-sized grains with uniform coverage (nucleation). Copper plating was done by DC and pulse at 30 ASF average CD on a 0.009-in. pitch 45° sawtooth profile. DC peak-to-trough plating thickness ratio was 4.2. Pulse plating at "one" (92.9 ASF, 0.0002 msec on, 0.0006 msec off) resulted in a ratio of 2.5. So, dampened faradic current can be useful in microprofile conditions for purposes of macroleveling in conjunction with certain baths and asperities. Pulse plating secondary current distribution with lower faradic damping (more toward "zero") is typically less uniform than with DC.

Another approach to leveling involves a coordination of factors to lessen diffusion layer thickness while providing increased nucleation.[3,4] Besides increasing the rate of laminar flow and reducing the kinematic viscosity, pulsing current frequency was varied to affect the (inner) pulsating diffusion layer. Manipulation of this layer by pulsing allowed optimizing brightener adsorption at peaks while limiting brightener diffusion into troughs to allow plating there more so than on peaks. One-third to one-fourth the amount of brightener was used, owing to the activity of an added hydrodynamic modifying agent (0.4 ppm). With data on bright nickel, the palladium and gold-only frequency is reported (optimal at 10-11 Hz), as well as copper (6 Hz) while there is no mention of pulse *on* time, % duty or CD. However, limiting currents were desired to be approached since shorter time on was desired as well as a concomitantly increased pulse CD. (Next: *Pulse electroforming.*)

References

1. *Theory and Practice of Pulse Plating*, J. Cl.Puippe & F. Leaman, Eds., p. 47, 1986. AESF (out of print).
2. *ibid*., pp. 52-3.
3. M. Aroyo, D. Stoychev, N. Tzonev, *Plating & Surface Finishing,* Sept. 1988, pp. 92-7.
4. *ibid*., M. Aroyo, Aug. 1998, pp. 69-76.
5. *ibid*., M. Aroyo, Nov. 1995, pp. 53-7.