PulsePlating



Steve Koelzer • K & K Consulting 709 W. Remington Drive • Sunnyvale, CA 94087 • E-mail: smbk@slip.net

How I Learned to Love Pulse Plating Automation

A pinnacle in pulse plating is its automation. This column has discussed those who have done so for printed circuit board (PCB) manufacture, and also exposed those facets leading up to the knowledge for powering its automation. The concept of "design a surface" originated at the University of Denmark, and the utmost respect is due and offered collectively to those individual researchers.

Designing for Surface Requirements Metallurgical properties, such as alloy composition and method of manufacture, and characteristic surfacing, such as temper, forging or being machined a certain way, dictate the type of pretreatment required. Parts might first need to have the surface blasted or electropolished. This characterizes the starting morphology (macro- and micro-profiles). Pulse plating can then effect the desired ending morphology. Considering the integration of multifactorial equations for the purpose of achieving such pulsed finish is considered later.

Solution Requirements

Chemotact—in order to predict or get close to the right combination of chemicals for electrolyte composition, consideration must be given to factors that influence the plating mechanism. The chemical concentration and ionic mobility of the metallic plating ions need to be known* for considerations in acid copper plating. Other chemi-

cals can be added to provide for various influences, as dictated or defined by the plating mechanism, or considerations as discussed in pretreatment. The (dynamic) viscosity of the electrolyte is also needed. The impedance of the entire work surface in the defined plating electrolyte should be measured: it is difficult to estimate or calculate. Possible influences from any use of anode corroding agents must be considered, especially when using pulse reversal or inert anodes. Effects of pH at varied electrical potentials can help determine the desired data for making Tafel plots, etc. Not all of the above apply in every situation.

The difficult-to-assess chemotactants (things that stick on the surface of the work) are surfactants, brighteners, extenders, etc. They exert an impedance (polarization, or raising the plating overvoltage) and contribute to surface capacitance, which needs to be overcome before plating occurs at the beginning of each forward current. Shortening the time to overcome this inhibitory effect on each pulse cycle can be accomplished by drastic increases of current density, along with pulse on-time reduction such that the transition time limit is breached (the ions have been depleted and water becomes hydrolyzed, producing hydrogen). Another way of handling the surface impedance layer may be by using a short anodic current immediately before beginning the forward current. Even water has a chemotactant effect.

Electrolyte conductivity is worth considering.* By knowing the

magnitudes of solution resistance, or resistance per relative ion concentration, it may be possible to better handle side reactions. Being able to correlate conductivity and concentration to better design diffusion layer thickness may be of benefit by enabling broader windows for pulse on-time and current density selections.

Waveform Requirements

This is a self-limiting area. Because the surface electrolyte response to applied current and voltage must obey the rules (equations) of electrochemistry, new knowledge is still being discovered about how surfaces respond to predictions; at times, much to the surprise of the investigator. Some limitations in understanding may have lingered as the result of an early inability, incapacity, or simply non-expectation of effects from power supply electronics design finesse. Some have argued that aspects of proven concepts don't work. All equations must be evaluated entirely in the context of an electroplating Gestalt, to ensure that they do not become modified. In the case of electrochemistry, they become corroborated by theoretical electronic confirmations of an electrolytically predicted response.

There are pulse power supplies that will deliver *exactly* what you need, as long as you can decide *exactly* what you want. This means having to calculate the requisite current magnitude or sustenance potential, then making or buying such a power supply. This is predicated, of course,

^{*}Modeling Acid Copper Plating I: Influence of Water on Mass Transfer, Koelzer, S.M., SUR/FIN[®] '98, Pulse Plating Technical Session

on the type of electrolyte you have designed, or have considered using.

These were discussed in prior columns:

- Pulse with no additives
- Pulse with specific additives
- Pulse with additives in general

Tricks of the Trade

Some tricks of the trade never see the light of day (for obvious reasons). A reverse cycle incorporated with direct pulsing can alter throw (primary current distribution) by using a more concentrated anodic current for a shorter period of time. This can result in the extreme, reverse throw (reverse dogbone) in certain electrolytes. Perfect throw might be achieved by adjustment of anode geometry or by use of multiple alternating anodesone for forward pulse and another for the reverse (as a cathode, in reverselike a robber). This area has always been difficult, but achieving it by adjusting the pulse waveform should not occur without these anode considerations.

An old trick is to employ reverse instantly before a forward pulse, as

mentioned above. This is done singly in a strike manner to possibly remove some metal along with the work's impedance layer. It is also done as part of a normal waveform to facilitate smoothing or otherwise supplement the power supply. It also depends on electrolyte.

Matching the Faradaic slope (plating during off-time) is a way to approach the smoothing effect, considering electrolyte design constraints. Some metals, such as nickel, always have side reactions, which, when left unaddressed, will alter surface conditions. Nickel oxide inclusion or hydrogen embrittlement come to mind. Apparently, by effecting a slower current descent while powering off of the forward pulse, rather than just turning off, unwanted side effects can be minimized. A quick shot of reverse current to neutralize the surface appears to have been helpful, not only for plating, but also lifting of maskants or otherwise undercutting gold plating.

Though a very complex consideration, a word on the implementation of off-time is in order. It might just be that the complexity of off-time effects (owing to the surface recovery period by Faradaic plating, as well as unwanted side reactions) may be also influenced by its timing. It is known that there are situations where there is benefit from going immediately to reverse, while other times it is not beneficial. Also, there are benefits from going to reverse immediately preceding forward. Trying to force all types of metal plating into the category of pulse reverse with no offtimes before or after forward pulses is only confused by the incapability of the power supply. In other words, the power supply allows a null lag, potentially speaking, prior to, and/or after each cathodic pulse. Rise times will not be discussed here.

Most of the tricks of the trade go unpublished. They eventually get out only by sleuthing the pulse trail and uncovering such effects for further investigation and reporting. It's astonishing how much has been published in the literature. Much of the information simply needs to be linked together in a logical fashion.