EIMC Advanced Plating Technologies

elsyca
electrochemical intelligence

Research and Development Using 3D Modeling and Plating Simulation

Electroplating R&D and Technical Service departments now have a new plating engineering tool. PlatingMaster from Elsyca is used in the evaluation of complex electroplating scenarios that affect chemical process and plating equipment functions in laboratories, pilot lines and customer sites.

The successful electroplating system produces quality-plated deposits, at the lowest possible cost, in the shortest amount of time. The design of the entire plating system, including its chemistry, must consider each of these factors in order to be economically viable.

The electrolytic plating system can be broken down into these basic elements:

- Chemistry & Operating Parameters
- Chemical Process Control
- Equipment Design
- Cathode Configuration
- Anode Configuration

Determining how each of these elements interacts with the others requires sophisticated understanding, accurate analyses and until now, considerable time.

The new plating simulation tool, PlatingMaster, with 3 dimensional modeling and simulation capabilities, offers a method of optimizing all the chemical operating parameters and incorporating them into numerous plating equipment designs.

Originally developed by a French company, the Technical Center for Mechanical Engineering Industries (CETIM), and now available in the Western Hemisphere and Far East from Elsyca, this tool provides accurate simulations of not only the chemical process but the system design as well. This unique plating software engineering tool can be useful in the following ways:

- Electroplating Process R&D, including electroplating additive research
- Customer Service Engineering
- Customer Process Engineering

BASIS OF ANALYSES

PlatingMaster simulation software is based upon a numerical method called boundary element analysis. The software takes into consideration the configuration of the tank, cathode(s), anode(s) and the electrolyte.

In *Figure 1*, the four basic elements of a plating tank are mapped with consideration to the cathodic boundary Γ_C, anodic boundary Γ_A, and plating tank Γ_R. The electrolyte Ω is effectively limited by each of these items.

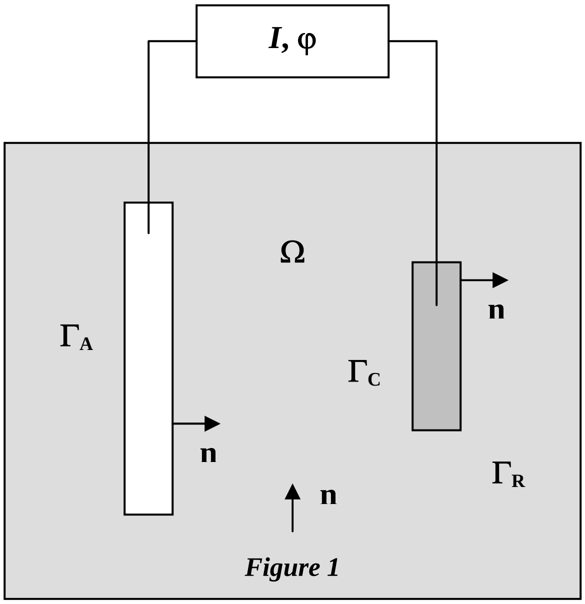


Figure 1

The plating process (P1) can be described by finding the potential $u(x)$ in the electrolytic domain, and the potential difference φ between the two electrodes:

$$
\mathrm{P1}\quad
\begin{cases}
-\nabla^2 u(x) = 0 & \text{in } \Omega \qquad (1)\\[2ex]
\sigma\,(\partial u/\partial n) = f(u(x)) & \text{on } \Gamma_C \qquad (2)\\[2ex]
-\sigma\,(\partial u/\partial n) = g(u(x) - \varphi) & \text{on } \Gamma_A \qquad (3)\\[2ex]
\sigma\,(\partial u/\partial n) = 0 & \text{on } \Gamma_R \qquad (4)\\[2ex]
I = -\int_{\Gamma_C} \sigma(\partial u/\partial n)\,d\Gamma_C & \qquad\qquad (5)
\end{cases}
$$

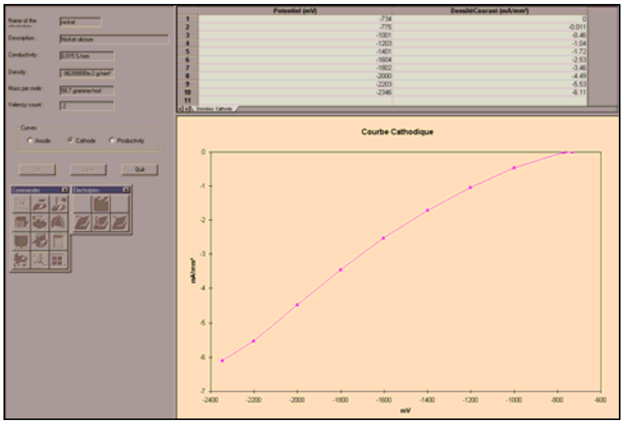
The total current I generated by the rectifier corresponds to the dual quantity φ between the two electrodes. The functions f and g represent cathodic and anodic polarization laws, describing the potential gap at the electrode/solution interface. These electrochemical behavior laws (f and g) are non-linear. Thus the entire system (P1) is non-linear as well. The problem is solved by boundary element analysis, coupled with a Newton-Raphson technique.

At the rectifier, the dual global quantities (current I and potential difference φ) are linked by a non-linear function (a generalized Ohm's law). The resolution of (P1) is inadequate, so an algorithm was developed, monitored by global current I. This current takes into consideration the working current density as recommended by the chemical manufacturer. Calculated current densities are then utilized with Faraday's law to predict and graphically display the plated deposit.

CHEMISTRY AND OPERATING PARAMETERS

Designing and operating a plating system must take into consideration the plating chemistry to be used. Differences in the types and level of organic additives (brighteners), bath components, metal concentrations, agitation, and temperature can produce unique and varying results.

A thorough analysis is best achieved by characterizing the plating bath chemistry. After data is gathered on conductivity, cathodic efficiency, metal properties, and other parameters, the software manipulates this data, along with user inputs (plating cycle time, current density etc.), to develop unique cathodic/anodic polarization laws for each electrolyte. These polarization laws can be immensely useful, for instance, to organic plating additive research and development. PlatingMaster modeling software stores this important chemistry information in a database.



Name of the electrolyte : nickel
Description : Nickel silicium
Mass per mole : 58.7 gramme/mol
Valency count : 2

	Potentiel (mV)	DensitéCourant (mA/mm²)
1	-734	0
2	-775	-0.011
3	-1001	-0.46
4	-1203	-1.04
5	-1401	-1.72
6	-1604	-2.53
7	-1802	-3.46
8	-2000	-4.49
9	-2203	-5.53
10	-2346	-6.11
11		

Figure 2

Curves are developed (illustrated in *Figure 2*), and accessed during the simulation analysis, to predict the behavior of the plating process. This capability allows the user to experiment with different types of plating bath parameters to optimize the plating system.

PlatingMaster analysis utilizes the unique characteristics of the electrolyte in simulating the plating process being studied, especially the characteristics imparted by various organic plating additives.

Example: acid copper electrolyte properties can subtly vary from one additive vendor to another. These differing properties affect the polarization curves of the respective electrolytes and the differences are reflected in the performance of that electrolyte in real plating situations. Accurate simulation can uncover these differences and enhance better understanding of the functional properties of organic additives.

Another example of plating additive R&D or a Technical Service function is the capability to model existing or potential customer applications where the current density extremes are unknown. A plating additive system is formulated to function in specific current density ranges. Though the amperage input per sq. ft. of cathode area might be the same for 2 different plating set-ups, the current density extremes can be different.

Figures 3 and 4 depict two completely different tank set-ups in the same plating plant. Both are designed to plate 18X24 circuit boards at 15 asf for 1½ hrs. Notice the extremes in plating thickness distribution found in both set-ups. They are indicative to the plating engineer, for example, that organic additive function in one of the tanks is subject to higher operating current densities than the other even though "average" current density is the same.

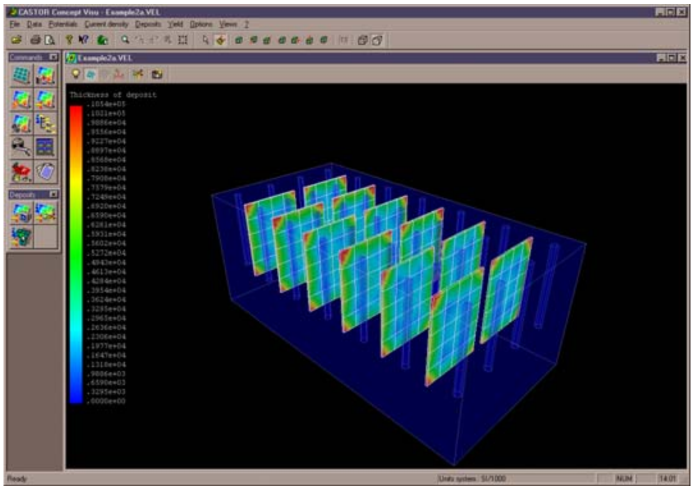


Figure 3

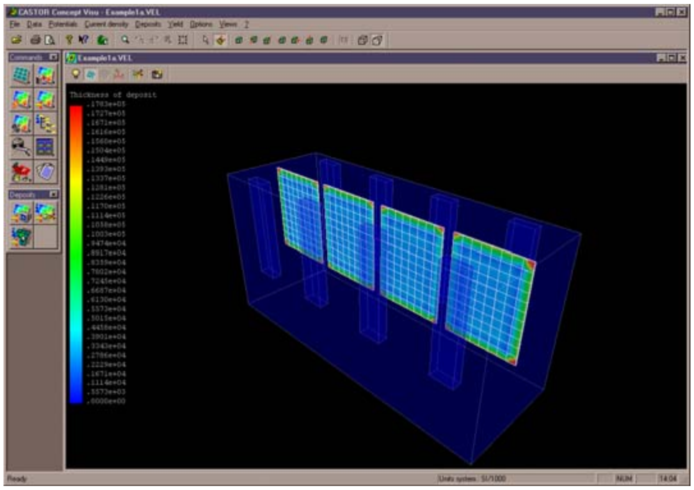


Figure 4

EQUIPMENT DESIGN –

This simulation analysis can be performed in such a way as to mimic the plating tank. In the past, equipment design and process chemistry integration have often been based on previous experience, gut-level instinct and "trial and error" experimentation.

Typically, this has resulted in plating tanks that essentially duplicated past designs: rectangular or square configuration with a flat bottom, parallel-opposed anode bars with anodes, and a center cathode. Because this was relatively easy to manufacture and use, little attention was paid to the effect that the tank design itself has upon the plated deposit.

CATHODE DESIGN

The R&D and Technical Service Pilot lines of chemical process and equipment suppliers perform many functions. One of the most important is duplicating, as closely as possible, the customer's plating conditions in the pilot line or plating laboratory environment. PlatingMaster is a powerful tool in this effort.

PlatingMaster has the capability to import the CAD data file associated with the part to be plated. The plating or electrode potential of the part is interpreted relative to its location on the rack and in the plating tank. The part is then "racked" and plating simulation occurs.

For Technical Service functions it would be very helpful, for instance, to include customer operating conditions, e.g. the customer's tank/anode/cathode configurations, in a field Tech Service request to the lab for HELP in solving a plating problem.

In any plating or pilot line, optimizing the cathode entails consideration of the rack design, the number and configuration of the parts on the rack, and potential use of current thieves or plating shields.

A typical scenario: numerous parts are placed on a rack. Overplating of the outer parts occurs while trying to electroplate the required minimum thickness on the inner parts. Overplating, or non-uniform plating, has a detrimental effect on the plating cycle time and the consumption of metal.

Figure 5 is the photograph of a flight bar/plating rack configuration holding 216 pulleys. These pulleys are utilized in the manufacture of automobile engines, and are plated with alkaline zinc. In order to achieve the specified plating thickness, serious over-plating occurred on the outer edges of the exterior rows of pulleys. This resulted in a high rate of scrapped parts, potentially constituting the entire outer rows of (40) pulleys, or up to 38% of the total.

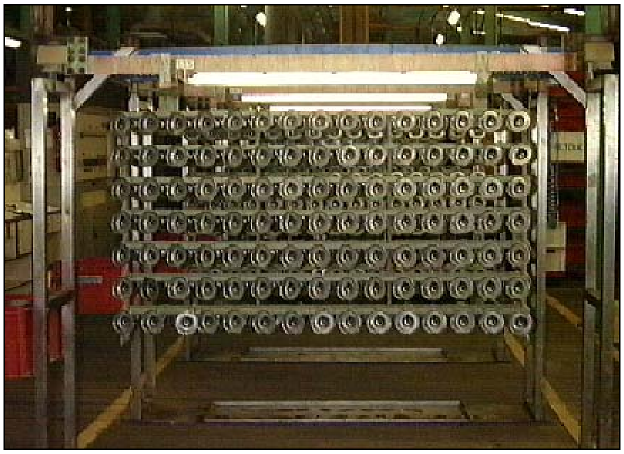
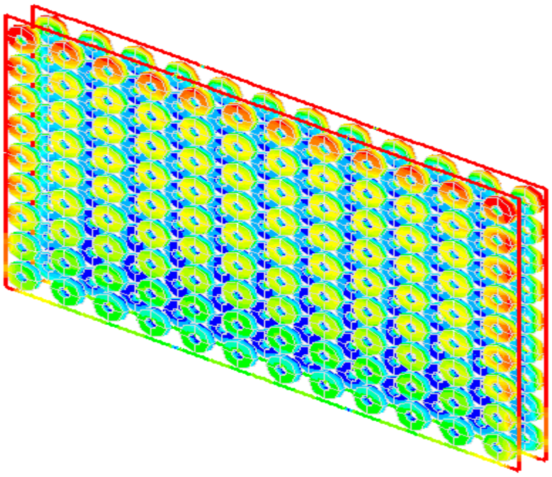


Figure 5

Analysis of the process utilizing 3D modeling (*Figure 6 below*) showed that individual pulleys were being over-plated around the perimeter edge by nearly 100%. For a component that must be properly balanced in order to provide a smooth running automobile engine, this overplating clearly was unacceptable.



In Figure 7, the color red represents the thickest deposits. The specified thickness is displayed as a light blue color.

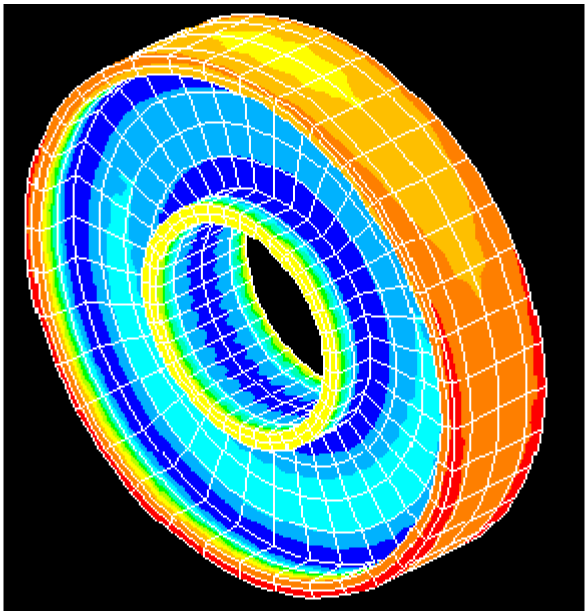


Figure 7

As this example was an existing plating operation, the ability to change equipment configurations was limited. The optimization effort therefore focused on optimizing the rack configuration. Using PlatingMaster modeling, it was found that the addition of current thieves, and subsequent shielding of the rack and parts, produced substantially better results. Virtually no parts were scrapped.

TANK DESIGN

It's possible to optimize the system design, long before the equipment is built. This effort can provide significant economic benefit by improving the overall success of the plating system. Optimizing the tank configuration primarily centers on the size and shape of the tank, the location of components, and the anode-to-cathode distance.

A typical plating tank is configured with a cathode and two sets of anodes. Often, an air sparger or solution return sparger from a filter system is mounted across the tank bottom. In operations where plating uniformity is extremely important, such as in the previous example, the location of a sparger may have a detrimental effect on the results.

In other words, is the sparger sufficiently low enough so as not to obstruct the plating current path? For a single sparger located directly below the cathode, the likelihood of affecting plating is low. For spargers that are located between the anode and cathode, whether on the tank bottom or raised up in solution, this likelihood may increase significantly. The use of PlatingMaster modeling and plating analysis optimizes this configuration, or at the very least, advises the optimum setup to diminish the shielding effect of spargers.

The anode-to-cathode distance is usually a more serious consideration in the tank design. A customer might, rather than use past experience and/or recommendations from a process chemical or equipment vendor, experiment with different scenarios on his own. In some instances, it may be that a 6" recommended distance might work well but perhaps 3-4" would be even better.

If the shorter distance does indeed produce better results, the tank could be built to narrower specifications, resulting in a smaller footprint for the plating machine overall. This has a "snowball effect", like reducing the amount of chemicals required to fill the tank or impacting potential ventilation requirements. Ventilation requirements, for instance, in the circuit board plating illustration would obviously vary from one tank to the other even though the same asf is used.

The engineering benefit of PlatingMaster modeling and analysis is that "what if" scenarios can be examined before action is ever taken or capital equipment costs are appropriated for a production plating line or an R&D/Tech Service pilot line. PlatingMaster can, of course, be used to characterize existing plating and chemical parameters as a first step to better set-up.

ANODE DESIGN

The majority of plating systems incorporate either round or rectangular anode baskets. Choosing one over the other can have very important consequences. *Figure 8* illustrates a circuit board plating tank. Two rows of round anode baskets are placed on either side. Areas of high current density on the anodes are depicted in red, while the yellow color represents lower current densities.

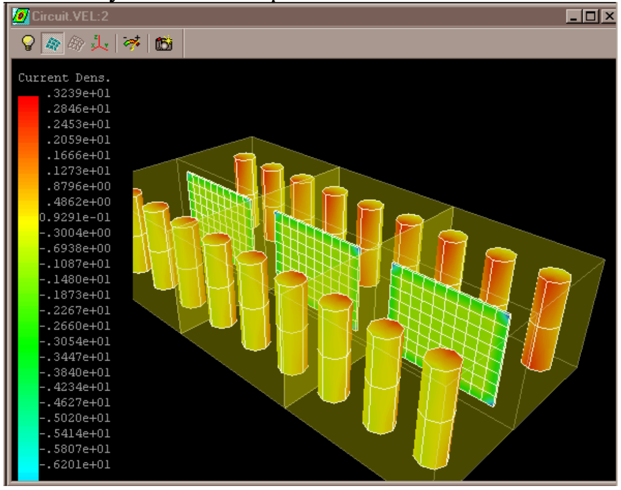


Figure 8

Higher current densities on the boards are green, while the yellow areas are lower. As can be seen, over-plating will occur around the perimeter of each board.

Figure 9 illustrates the use of rectangular anodes. The layout has been optimized to produce a uniform deposit on the boards. High current densities on the boards are still around the perimeter, but are much less relative to those at the center. In this particular example, it can be proven that the plating tank is best configured with fewer anode baskets and that they be rectangular in shape.

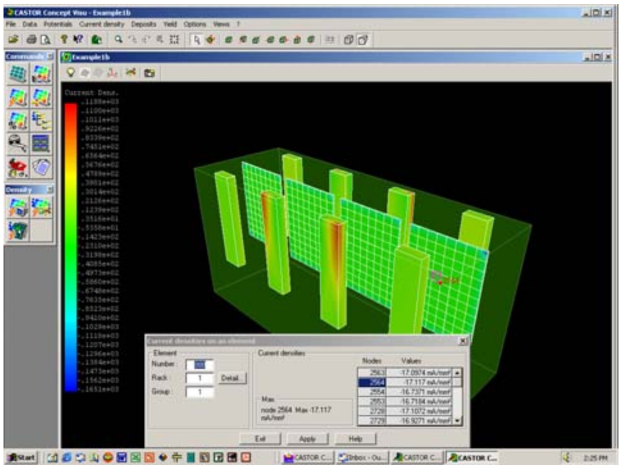


Figure 9

The use of shields for "focusing" current can be modeled as well. For example, plating the circuit boards in Figure 9 may not produce adequate results after optimizing the anode configuration. Shielding can be considered but designing shields is often a time-consuming and costly proposition.

Intuitively, one might consider a shield designed to focus current towards specific areas of the circuit board. Holes in the shield allow the current to pass, while solid areas effectively block the current. *Figure 10* shows what the side and front of a single board shield might look like.

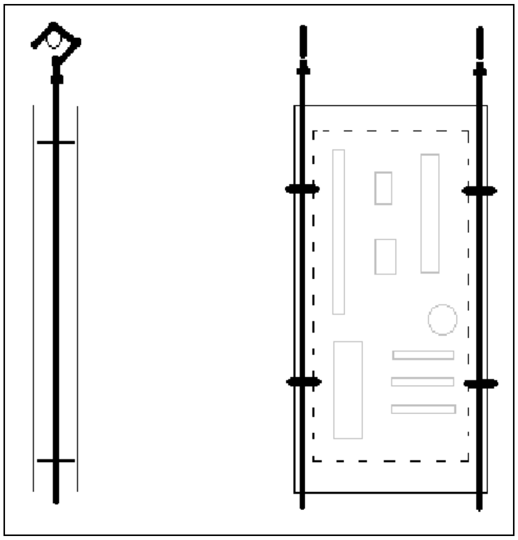


Figure 10

A proper shield design requires a full understanding of the electrode potentials of both the cathode and anodes. *Figure 11* depicts a shield design utilizing 3D modeling and analysis, using the same circuit board as an example.

As can be seen, optimizing shields is not necessarily intuitive, and can actually be completely opposite of what one might think!

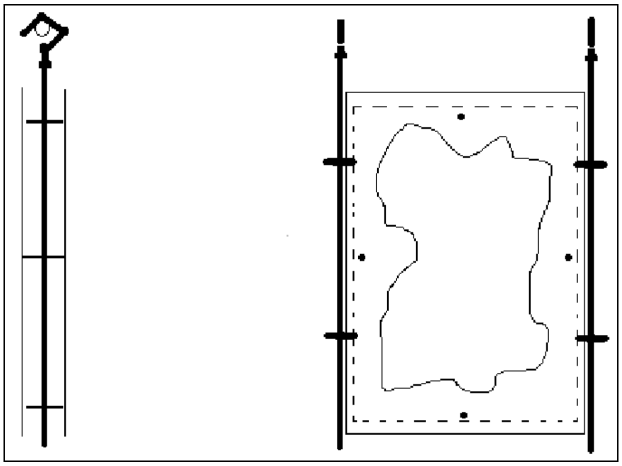


Figure 11

Numerous field tests and production applications have proven the accuracy of PlatingMaster simulation software. On average, it has been found that simulated results have been 95% accurate in modeling thickness and plating deposit uniformity.

The implications of these kinds of sophisticated plating simulation tests are considerable for:

- Electroplating R&D
- Technical Service
- Customer Electroplating Engineering.

Uniform plating deposit thicknesses can now be more easily achieved while simultaneously reducing metal and chemical consumption and increasing production. Higher quality and more reliable products produce even longer-term advantages.

Plating technology should no longer be considered an "art" as much as a science. Thorough analysis, coupled with accurate simulations, can produce a highly successful plating operation.

Elsyca PlatingMaster

MINIMUM SYSTEM REQUIREMENTS

- Performance PC Pentium 4, 3.2 GHz, 1 MB Cache
- 4 GB RAM (4 X1024 modules)
- CD/DVD Read/Write
- Hard disk: 100 GB
- Video Card: New PC NVidia Quadro FX and Quadro 4 Recommended
- Video Card for a current PC, please check: www.solidworks.com/pages/services/videocardtesting.html
- Operating System – Windows 2000, NT, XP

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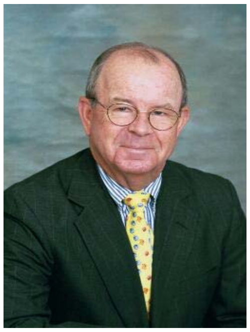

Roger Mouton founded EIMC, focusing on Advanced Plating Technologies and electroplating process development. He has experience in product and business development, sales, marketing and technical service in the electronics manufacturing and metal finishing industries. He has authored articles in Printed Circuit Fabrication, CircuiTree Magazine and The Board Authority, Metal Finishing Magazine and Plating and Surface Finishing Magazine. He holds a B.A. in Economics from Loyola University.
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