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# A New Millennium Vision Based on Electric Field Process Control

In his recent book *Clock Speed*, Professor Charles Fine of the Sloan School of Management at M.I.T. states that all competitive advantage is temporary.[1] Furthermore, analogous to biological organisms, which must evolve in the face of environmental adversity, business organizations must continually anticipate and cultivate the appropriate competencies to maintain profitability under changing economic conditions.

## What Do Fruit Flies Have to Do With the Metal Finishing Industry?

In order to study the forces of evolution, biologists study fruit flies (*Drosophila*), whose generational time-scale is less than two weeks. By considering the *Drosophilas* of business, companies in industries with very fast product/process technology lifecycles, *i.e.*, clock speed, insights on the relationship between competitive advantage and industry structure are possible.

In the vertical industry structure with integral products, companies attain profitability by maximum control of their supply chain. In the horizontal industry structure with modular products, companies attain profitability by supplying a critical part of the supply chain. Prof. Fine's studies identify the basic forces that cause the continual evolution between vertical and horizontal industry structures. His model is depicted in Fig. 1.

Niche competitors, bureaucratic inefficiencies, and managing the diverse aspects of their technology and markets eventually force a vertical/integral industry to disintegrate into a horizontal/modular structure.

Conversely, market- driven technological innovations provide an opportunity for the innovator to capture more components of the supply chain and eventually cause a horizontal/modular industry to disintegrate into a vertical/integral industry structure. This process of flip-flopping between vertical/integral and horizontal/modular is a continual process, it just happens at different clock-speeds for different industries.

The metal finishing industry is a classic horizontal/modular structure, schematically depicted in Fig. 2. The general components of the supply chain include process chemistry, process equipment, waste treatment, and fabricating facilities. Interestingly, the metal finishing industry serves and is consequently influenced by the electronics, automotive and aerospace industries. As discussed by Prof. Fine, these are fast, medium, and slow clock-speed industries, respectively.

The metal finishing industry is also termed a "gatekeeper industry" in that the number of participants along the supply chain is grossly unequal, *i.e.*, less than a few dozen process chemistry suppliers compared to approximately 10,000 metal finishing facilities. Because of their strong position in the supply chain, gatekeepers resist technological innovation that threatens their standing.

Based on the above discussion, evidence of the forces of change in the metal finishing industry should first come from a sector such as the electronics industry, a fast clock-speed industry. As evident in the

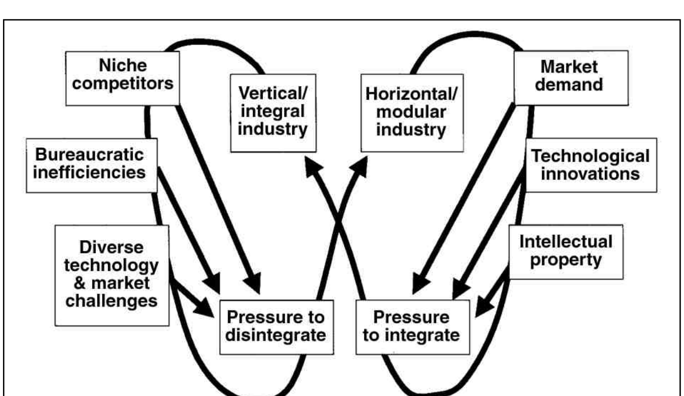


*Fig. 1—Pressures influencing the continual evolution of industries.*

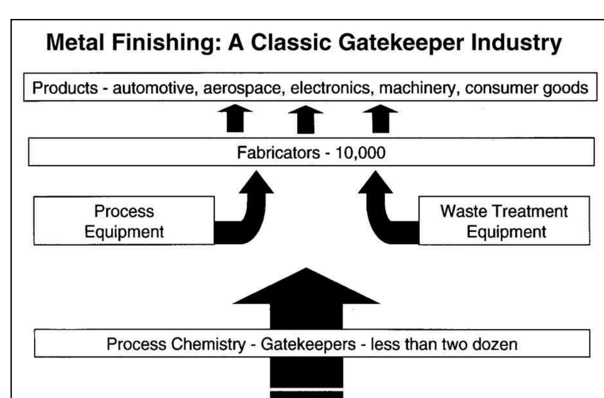


*Fig. 2—Schematic representation of the metal finishing industry.*

merger of Flextronics International and the Dii Group,[2] the electronics industry sector is currently consolidating into large vertically integrated companies or strategic alliances to control all sectors of the supply chain.

The March issue of *P&SF* focused on "Finishing for Electronics." In the case of the electronics industry, the forces of change are the process technologies required for new high-margin products.

The demand for smaller and faster electronics products has driven Motorola and IBM to change from aluminum to copper metallization for integrated circuits (IC).[3] In addition to the challenges associated with sub-0.25 µm IC interconnects, this market demand has created technical challenges to incorporate these advanced devices with high-density interconnects.

At the Fifth International Pulse Plating Symposium (June 29-30, Chicago, Navy Pier), seven of the 20 papers dealt with copper deposition process technology for electronics applications. A side effect of these forces of change is evident in recent publications as the industry struggles with terminology to describe the new business paradigm.

In a recent paper dealing from a process chemistry supplier, Milad and Morrissey[4] suggest acid copper plating is quickly becoming the limiting factor, *i.e.*, force of change, in fabricating high-density interconnects. The challenge is to control the throwing power in order to achieve good metal distribution in microvias less than 150 µm, specifically plating inside the microvia with minimal over-plate. These authors review the old paradigm for controlling throwing power with carriers/suppressors, additives/brighteners, and levelers. This approach is termed the chemically mediated approach. However, an approach based on a plating system "engineered to respond to a periodically pulsed reverse current" is also described. This approach is termed "the electrically mediated process."

In a recent *P&SF* article, Rehrig and Mandich[5] explained that "The apparent advantage of pulse deposition is … simple electronic manipulation of the pulse waveform, rather than by involved chemical variations, the more traditional approach to tuning electrodeposition."

Finally, in a paper selected for the Pulse Plating Symposium,[6] my colleagues and I make a point of optimizing the copper plating process using a simple plating bath that does not contain difficult-to-control additives. Rather than use the moniker "pulse plating," we also struggle for appropriate terminology and suggest that the process is more aptly referred to as "charge modulated electrodeposition." Significantly, we were able to plate through-holes (325 µm) and microvias (100 µm) by using the waveform sequence depicted in Fig. 3 to plate the microvias and the through-holes in a single process step. We were able to electrically mediate the plating process by simply tuning the waveform parameters using a simple, additive-free plating bath.

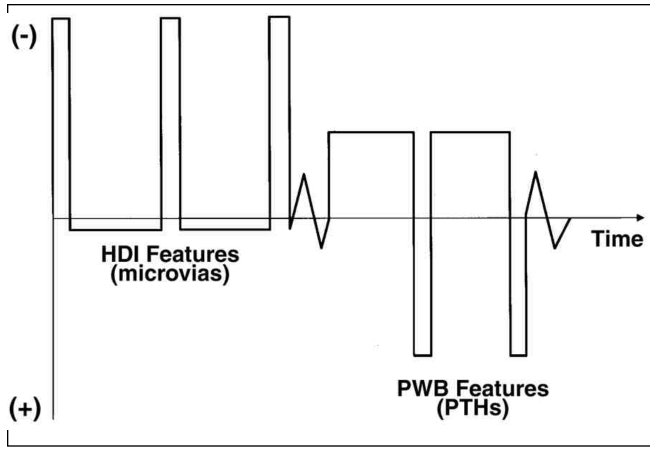

*Fig. 3—Waveform sequence used to plate microvias and through-holes.*

Although the above discussion has been focused on process technology specifically addressing the needs of the electronics industry, are there implications to some of the slower clock-speed industries served by metal finishers? I think shifting the paradigm for plating process control from chemical mediation to electric field mediation has enormous implications for the metal finishing industry in general. Electric field mediation of nickel, gold, chromium and alloy plating, as well as anodizing, polishing and deburring processes were included in the Fifth Pulse Plating Symposium. Apparently the knowledge diffusion of the electric field mediation approach to slower clock-speed applications has already begun.

Finally, as a horizontal/modular industry disintegrates into a vertical/integral structure, competitive advantage is exploited in the form of proprietary systems based on intellectual property, such as patents. But surely Prof. Fine's analysis must not be applicable to electric field mediation. After all, pulse plating processes were described and patented over a hundred years ago. To paraphrase a Commissioner of Patents and Trademarks, all pulse plating inventions have already been patented! Or have they?

In next month's column, I'll discuss and review some of this patent literature and its potential implications to the future metal finishing industry. P&SF

## References


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