AWP Group/Sigma-Mecer acid etch recycling system under construction in Poland.

Equipment/Process Selection:

Case Study of a DMADV Approach to PCB FAB Process Design

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Background

In 2014, Whelen Engineering Company, the OEM market leader in the emergency warning industry, developed the world's first green smart PCB fab factory as a captive operation servicing internal demand. Due to the success of this venture, in 2016, a decision was made to explore building an upgraded factory which would serve the merchant market. This article outlines the approach we took to designing this new phase of our commercial existence, which has now been spun off as a separate business unit known as Greensource Fabrication. This new business unit is expected to go live in 2018.

Summary Approach

In our experience, a holistic DMADV approach to complex process design is not commonly used in the PCB industry. This approach requires a commitment to dedicated R&D resources, extensive travel by the technical team, a great deal of hands-on experience, as well as significant investment capital. Since very few PCB fabs perform R&D, we believe that there is a currently a very high ROI to this approach with low risk, since it is easy to design and secure strong competitive advantages when everyone else is just copying each other.

Stage 1: Define

When designing any factory or process, the first step is to define the market needs. In our case, since we were just coming to the market

DMADV APPROACH HIGH LEVEL OUTLINE

Define	**Define** the goals of the design activity.
Measure	**Measure** customer input and compare roadmaps with your suppliers. Your suppliers often have great ideas on how to achieve your customer goals. What problems can/should we try to solve to develop advantages?
Analyze	**Analyze** innovative concepts for products and services to create value for the customer. Determine performance of similar best-in-class designs.
Design	**Design** new processes, products, and services to deliver customer value. Use predictive models, simulation, prototypes, pilot runs, etc., to validate the design concept's effectiveness in meeting goals.
Verify	**Verify** the new systems perform as expected. Create mechanisms to ensure continued optional performance.

for the first time, we spent six months traveling the world, and visited scores of PCB shops and equipment suppliers in 20 different countries. We also researched customer roadmaps and had conversations with key OEM technologists. What we quickly found was that most of the best equipment/processes in the world were not even available in North America. We also found that our potential customers had to often procure PCBs offshore to meet their advanced technical needs. In the cases where offshore manufacturing was not an option due to IP export restrictions/legal constraints, design limits had often been restricted by our regional capability limits. This should come as no surprise since North America has not been a major center for PCB fab for almost 20 years now.

We also found that if, as a board shop, you rely on local reps for guidance, then you may be significantly limiting your capabilities. If you work directly with overseas principals, you often find that there are much better solutions available than what your local reps tell you. This is especially true in North America due to its small share of worldwide PCB production, and even smaller share of PCB fab capex investment, resulting in it not being a focus market for the major equipment suppliers.

Our conclusion from this stage was that, if we were to procure world class processes and place them together in a North American shop, we would have a good likelihood of developing a strong competitive advantage with a good ROI. It was subsequently decided that we would design the factory to focus on advanced HDI, tight registration tolerances (X, Y, and Z axis), high aspect ratios, and thin dielectrics (including flex, ABF, etc.) across a wide overall thickness range of 0.050 - 6.20mm; we would do this with no significant environmental footprint, and with the highest level of automation possible.

Stage 2: Measure

Once we identified the key equipment suppliers, we began having meetings to benchmark individual companies to determine their technical and commercial capabilities as potential partners. We then vetted their prior project performance by auditing multiple installations, and contacting our industry contacts to sift through the marketing pitch and hearsay. The more reference data points collected, the closer to the truth of the matter we came. We quickly found that there was a high ROI for this research, and we had some surprises with what were previously perceived as top worldwide suppliers failing to qualify, and smaller regional suppliers excelling.

After completing the measurement stage, we found that 80% of the suppliers we selected as partners were from Europe and Japan, with the balance from the U.S., Taiwan, and PRC. This regional distribution was driven in large part by the need for highly reliable processes, and a low total cost of quality, given our highly automated/low-labor approach.

Atotech thin core flex electroless and flash plate line under construction in Germany.

Stage 3: Analyze

Once we had our key supplier partners selected, we sat down with them and began discussing the specifics of the project. Only at this point did we begin to discuss details and introduce our own IP to the project under controlled conditions. Our IP was associated with having already developed the world's first green smart factory[1] for captive work. The challenge now was to do the same thing economically in a shop that would service the merchant market with more conventional processes (i.e., dry film, electroless copper, OSP, etc.) compared to our previous captive operation.

The good news was that our chosen suppliers were very excited by our project approach and had a tremendous amount of good ideas to both automate and make green even the most high-tech processes in the world market.

Stage 4: Design

The design phase was the most time-consuming part of the project and required hundreds of hours of face-to-face discussions—mostly at supplier sites overseas—between our own engineering team, and our suppliers' technical departments. This was done to sort out the details of the tool designs we would procure, to ensure that we engineered out any risk, and to maximize the design performance.

This phase yielded the greatest number of positive surprises since we spent so much time together with our partners, and could combine the experience of some of the most talented engineers in our industry on a worldwide scale. For instance, the automation level we have now targeted is at half the labor level we originally estimated, and the wastewater balancing we did within the wet process equipment has resulted in no waste rinse-water ever leaving the actual wet process lines, while reducing chemical cost by over 50% through engineering of balanced systems with full drag-out recovery built in.

We were also able to design the world's first full traceability system for PCB fab production,

AWP Group's zero-liquid discharge, single-piece flow DES line under construction in Poland.

Ludy's zero liquid discharge specialized SAP and high aspect ratio plating line under construction in Germany.

with embedded 2D codes and RFID tracking down to every individual CCL, allowing for true single piece flow and elimination of paper and manual traveler transactions, along with the use of some AGV transport. These are just a few of the initial design innovations achieved with our partners.

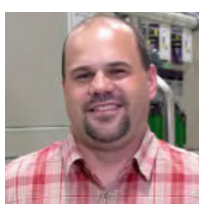
Stage 5: Verify

We are currently in the process of start-up and verification with 50% of the equipment set already installed and qualified. To date, we have met all our milestone targets, and the ownership has been pleased with our progress. We attribute the performance to date to our diligent supplier selection, coupled with a tremendous amount of hard work and travel by both ourselves and our supplier partners, and we believe it gives some credence to our chosen DMADV approach.

We hope that the market will agree, and that smart green factories with zero discharge/emissions and high levels of automation and consistency become the industry norm in the not-too-distant future. Based on our experiences, we feel that this transformation is long overdue in our industry, and it is truly time to proceed to the 21st century in this regard, especially given the high ROI for the change-over. **PCB007**

Reference

1. "Whelen Engineering Reduces Cycle Time by Building a New Automated PCB Factory," *The PCB Magazine,* October 2015.



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