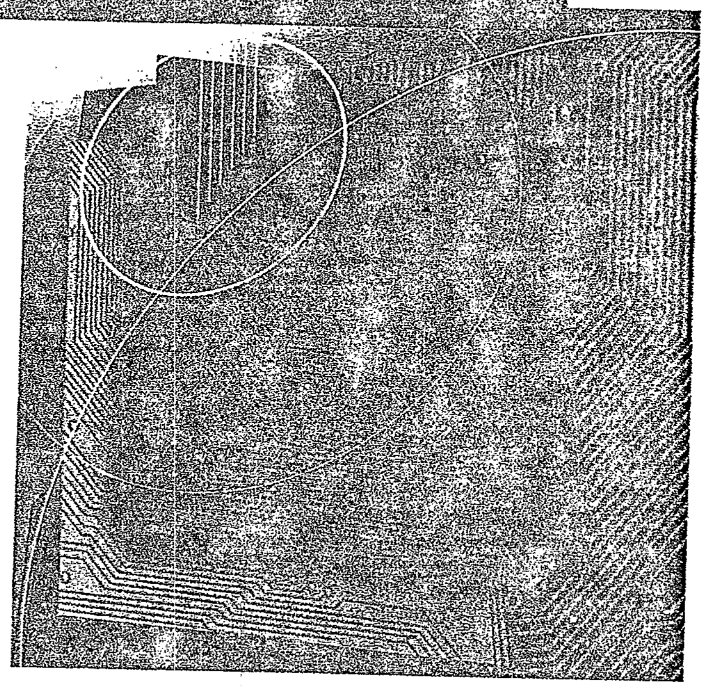
EPA 742/F-99/021

IPC/DfE

PRINTED WIRING BOARD PROJECT

Publishes Direct Metalization Results and Evaluates Alternative Surface Finishes



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Together, government, university, and industry work to protect our environment.

Reflecting a trend in environmental protection toward increased cooperation and collaboration between government and "regulated entities," the U.S. Environmental Protection Agency (EPA) Design for the Environment (DfE) program has been working closely with the IPC and its member companies, the University of Tennessee's Center for Clean Products and Clean Technologies, and other partners (academic, research, and public interest representatives) since 1994 on the DfE Printed Wiring Board (PWB) project. The primary goal of the DfE PWB project is to encourage PWB manufacturers to implement cleaner technologies that will improve the environmental performance and competitiveness of the PWB industry. The overall goal of the DfE program is to encourage businesses to incorporate environmental, as well as cost and performance considerations into the design and redesign of technologies, processes, and products.

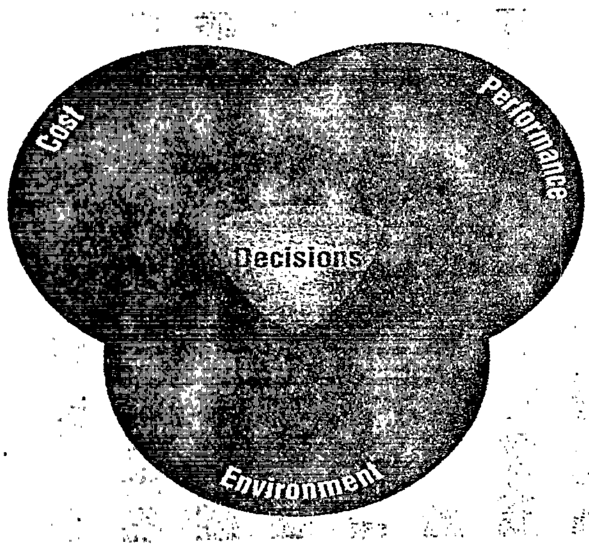

Figure 1. EPA's Design for the Environment program encourages businesses to consider environmental factors, as well as performance and cost, when making decisions.

Project partners have already completed and published a major comparative study of technologies used when making holes conductive (MHC) in PWB manufacturing (i.e., alternatives to the electroless copper process), and are now conducting a similar evaluation of technologies that may be used in the surface finishing step in place of hot air solder leveling. Results of the surface finishes study are expected to be published in a draft report later this year. A surface finishes project meeting will be held at IPC Printed Circuits Expo '99 (Long Beach, CA). The meeting is open to anyone who would like to learn more about, or participate in, the surface finishes project.

In addition to the MHC study, the DfE PWB project has produced several technical reports, including two on pollution prevention and control technologies used in the PWB industry, and produced and disseminated eight pollution prevention case studies.

Making Holes Conductive Study

The electroless copper plating process has long been the standard method of creating a conductive surface on the drilled through-hole walls of rigid, double-sided, or multilayer PWBs, required for electrolytic copper plating. Although the electroless copper process for making holes conductive is a mature technology that produces reliable interconnects, the typical process line is long (seventeen or more process tanks, depending on rinse configurations) and may have eight or more process baths. It is also a source of formaldehyde emissions and a major source of wastewater containing chelated, complex copper.

In the MHC study, project partners developed and analyzed technical information regarding the potential human health and environmental risks, performance, costs, and chemical and natural resource use of the electroless copper process and six "direct metalization" technologies (Table 1). These analyses were conducted by the University of Tennessee, and the results were compiled into a Cleaner Technologies Substitutes Assessment (CTSA) and CTSA summary document. A detailed description of the CTSA methodology may be found in Section 1.3 of the CTSA document. We believe that the CTSA results described below demonstrate that the direct metalization technologies make good economic and environmental sense for PWB manufacturers.

Table 2 lists the suppliers who participated in the MHC CTSA, and the technologies they submitted for evaluation. The suppliers provided publicly available chemistry data for their MHC chemical products, and were asked to provide the identities and concentrations of proprietary chemical ingredients.

Suppliers also completed a supplier data sheet describing their products, and nominated test sites for a performance demonstration. PWB manufacturers completed a workplace practices survey, which requested detailed information on their MHC processes as well as worker activities related to chemical exposure.

The data collected from the suppliers and through the workplace practices survey were aggregated to develop generic process steps and typical bath sequences for each technology category, while acknowledging that the types and sequence of baths in actual lines may vary, depending on facility-specific operating conditions.

There were a number of limitations to the study, due to the predefined scope of the project, the limit of the project's resources, and uncertainties inherent to risk characterization techniques. Those limitations are discussed in detail in the MHC CTSA.

Table 1. MHC Processes Evaluated in the CTSA*

MHC Technology	Equipment Configuration: Nonconveyorized	Equipment Configuration: Conveyorized
Electroless Copper (BASELINE)	X	X
Carbon		X
Conductive Polymer		X
Graphite		X
Nonformaldehyde Electroless Copper	X	
Organic-Palladium	X	X
Tin-Palladium	X	X

*The CTSA also presents chemical and process information for a conductive ink technology, which is applicable to double sided boards, but not multilayer boards. The risk, performance, and cost of this technology were not characterized.

The cost, energy, and resource use analyses determined the comparative costs and consumption rates of using an MHC technology in a model facility to produce 350,000 surface square feet (ssf) of PWBs. As with the risk characterization, this approach resulted in a comparative evaluation of cost or energy and natural resource consumption, not an absolute evaluation or determination.

Risk Characterization of MHC Technologies

Risk results suggest that alternatives to the nonconveyorized electroless copper process pose lower overall occupational risks. This is due to the reduced number of chemicals of concern in the alternative technologies for both inhalation and skin exposure, and to the level of cancer risk from inhalation exposure to formaldehyde in nonconveyorized electroless copper processes. Detailed information on potential occupational risk from inhalation and dermal contact for each technology may be found in the MHC CTSA. The indicators for public health risk (risk to residents near a facility), although limited to airborne releases, indicated low concern from all MHC technologies.

Performance Demonstration Results

In order to evaluate the relative performance of each technology category, a comparative performance demonstration was conducted. PWB panels designed to represent industry "middle of the road" technology were manufactured at one facility, run through individual MHC lines at 25 facilities, and then electroplated at one facility. The panels were electrically prescreened, followed by electrical stress (IST) testing and mechanical (microsection) testing, in order to distinguish variability in the performance of the MHC interconnect. The test methods used to evaluate performance were intended to indicate characteristics of a technology's performance, not to define parameters of performance or to substitute for thorough on-site testing; rather, the study was intended to be a "snapshot" of the technologies.

The microsection and IST tests were run independently, and had extremely good correlation of results. In terms of IST results, product performance was divided into two functions: plated through-hole (PTH) cycles-to-failure and the integrity of the bond between the internal lands (post) and PTH (referred to as "post separation"). The PTH cycles-to-failure observed in the study is a function of both electrolytic plating and the MHC process.

The mechanical testing and IST results indicate that each MHC technology has the capability to achieve comparable (or superior) levels of performance to electroless copper, if operated properly. Post separation results indicated percentages of post separation that were unexpected by many members of the industry. It was apparent that all MHC technologies, including electroless copper, are susceptible to this type of failure. A copy of the complete technical paper may be obtained by contacting Star Summerfield at IPC (847-790-5347).

Cost Analysis Results

The results of the cost analysis indicated that all of the MHC alternatives are more economical than the nonconveyorized electroless copper process. The average cost for most MHC technologies ranged from 57–82 percent less than the baseline technology (the cost for non-formaldehyde electroless copper, nonconveyorized, was 22 percent less). Chemical cost was the single largest component cost for nine of the ten technologies and equipment configurations evaluated. Equipment cost was the largest cost for the nonconveyorized electroless copper process. Three separate sensitivity analyses of the results indicated that chemical cost, production

Table 2: MHC Technologies Supplied by Chemical Suppliers

	MHC Technology:							
Chemical Supplier	Electroless Copper	Carbon	Conductive Ink	Conductive Polymer	Graphite	Nonformaldehyde Electroless Copper	Organic-Palladium	Tin-Palladium
Atotech U.S.A. Inc.	✕			✕			✕	
Electrochemicals Inc.	✕				✕			
Enthone-OMI Inc.	✕							✕
W.R. Grace and Co.			✕					
LeaRonal Inc.								✕
MacDermid Inc.	✕	✕				✕		
Shipley Company	✕				✕			✕
Solution Technology Systems								✕

labor cost, and equipment costs have the greatest effect on the overall cost results.

Energy and Resource Use Results

The energy and water consumption rates of MHC technologies were estimated, based on data supplied by PWB manufacturers and their suppliers, and through direct observation during performance demonstration site visits. All of the technologies consumed significantly less water and energy than the baseline, nonconveyorized electroless copper technology. The water use savings for most technologies ranged from 85–96 percent on a ssf basis, and energy savings ranged from 63–99 percent. Nonformaldehyde electroless, nonconveyorized, used 68 percent less water and 53 percent less energy per ssf.

Surface Finishes Study

DfE PWB project partners are now evaluating lead-free alternatives to the hot air solder leveling (HASL) process in order to identify those surface finish technology alternatives that perform competitively, are cost-effective, and pose fewer potential environmental and health risks. The most commonly used PWB finishing technologies are HASL and electroplated tin-lead. These technologies may pose potential health and environmental risks due to their use of lead, and the HASL process also generates significant quantities of excess solder that must be recycled. In addition to the HASL process, which will be tested as the baseline technology, the alternatives being evaluated include: thick organic solder protectorate, immersion tin, immersion silver, electroless nickel/immersion gold, and electroless nickel/electroless palladium/immersion silver. The alternative technologies are expected to generate substantially less hazardous waste and may be more cost effective than the baseline technology.

Performance data for some of the technologies have been developed by the Circuit Card Assembly and Materials Task Force (CCAMTF) and the National Center for Manufacturing Sciences (NCMS). However, performance data for other technologies, and information on the relative health and environmental risks and costs of all technologies, have not been generated. The DfE PWB Surface Finishes Project will supplement the work done by the CCAMTF, and is expected to provide valuable information to both the PWB manufacturing and assembly industries.

To evaluate the performance of each surface finish technology, a number of functional test boards were fabricated (a modified version of the IPC-B-24 board). The test boards contain a variety of circuitry (including high voltage/low current, high current/low voltage, high frequency, and high-speed digital), and can be subjected to multiple processing steps (wave, reflow, and hand soldering). The boards were fabricated at one facility and then shipped to the volunteer demonstration sites, where the surface finishes were applied.

The boards were shipped to a common location for assembly, including both through-hole and surface mount components. Assembly was completed in November 1998. Half of the boards for each surface finish are being processed using a halide-free, low-residue flux; a halide-containing, water-soluble flux is being used on the other half. The circuit performance will be assessed under applicable environmental stresses, with the HASL process serving as a baseline. The functional boards will be evaluated through a series of reliability tests, including thermal shock and mechanical shock. C

For More Information

For more information about the DfE program or the DfE PWB project, or to obtain copies of the CTSA or other documents produced by the project, contact the Pollution Prevention Information Clearinghouse, U.S. EPA, 401 M St., SW (7409), Washington, D.C., 20460 (Telephone: 202-260-1023, Fax: 202-260-4659, or e-mail <PPIC@epa.gov>). You may also view or order the project documents, including the CTSA, and obtain additional project information by visiting the DfE program Web site <www.epa.gov/dfe> or visit the IPC Web site <www.ipc.org/html/ehstypes.htm#design>.

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