A Cooperative Project between the U.S. Environmental Protection Agency and PWB Manufacturers Nationwide

design FOR THE ENVIRONMENT

EPA744-F-95-005

PRINTED WIRING BOARD CASE STUDY 2

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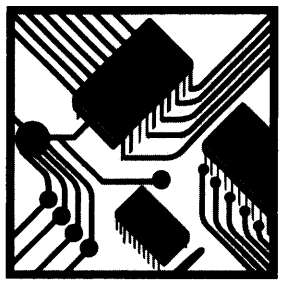


On-Site Etchant Regeneration

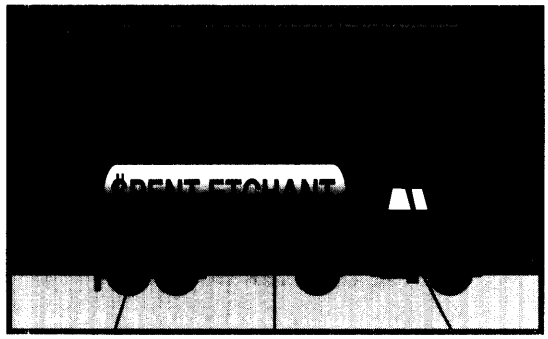
In business today, being responsive to the environment means learning new procedures and using new tools to do the same job with less environmental impact. Decisions about the purchase of equipment and products depend not only on cost, availability, and performance, but also on whether your environmental goals can be met. The manufacture of printed wiring boards (PWBs), the building blocks of the electronics industry, requires using substantial amounts of water and energy, and some hazardous chemicals that pose potential environmental and health risks. To facilitate the evaluation of alternative manufacturing technologies that reduce both environmental risks and production costs, EPA has entered into a partnership with the PWB industry through its Design for the Environment (DfE) Program. One of the goals of this cooperative effort (involving EPA, industry, trade associations, and public interest groups), is to generate and disseminate information on viable pollution prevention alternatives so that the industry can further explore cleaner manufacturing methods.

This is the second in a series of DfE case studies that illustrate the benefits of pollution prevention for PWB manufacturers. Specifically, this case study focuses on the benefits of etchant regeneration systems, and how they can reduce the impact of etching processes on the environment while reducing costs.

Why Etchant Regeneration?

In the process of making PWBs using the "subtractive" process, the circuit pattern is created by chemically etching copper from the unprotected (non-circuit) areas of the copper-coated panel, leaving circuit traces protected with photoresist. Etching can be accomplished with acids or bases, depending on the etch rate and the line width required. The ammoniacal etchants, either ammonium chloride or ammonium sulfate, are most commonly used. Cupric chloride is also used, even though it often requires chlorine gas, a significant health and environmental concern.

Approximately 60% of the copper on the board is removed in the typical etching process. As the copper content of the etchant increases, the etchant cannot effectively remove the copper from the board, and it is considered spent. The copper-saturated, spent etchant is stored in drums or a tank, and is ultimately shipped off-site for reclamation. Even in situations where the copper is recovered and the etchant is regenerated by the waste hauler, this waste stream may be an environmental hazard. Transportation of the spent etchant and its ultimate disposition may



Is Your Facility Shipping Revenue Off-site?

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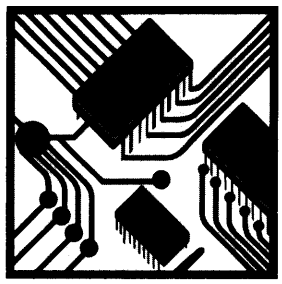

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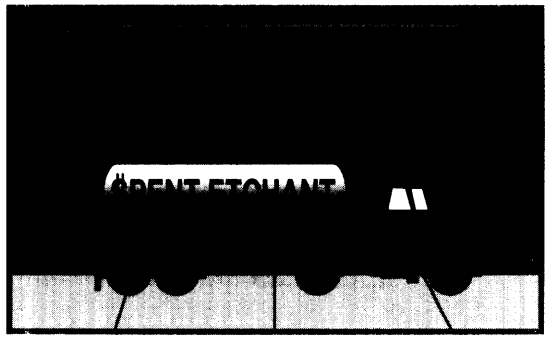


Is Your Facility Shipping Revenue Off-site?

pose environmental risks and result in increased liability for the PWB facility. In many plants, the spent etchant is the largest waste stream generated, making it a prime pollution prevention candidate. The costs of managing spent etchants and the danger they pose to the environment can be reduced dramatically with an on-site regeneration system.

On-site Etchant Regeneration Systems Offer Opportunities for Pollution Prevention through:

- ***Eliminating off-site shipments of spent etchant***
- ***Reducing chemical purchases of etchant***
- ***Recovering copper***
- ***Reducing water use***

The environmental and cost advantages of etchant regeneration and copper recovery can include:

- reducing the danger of polluting the environment by eliminating off-site shipments of spent etchant
- avoiding spills that can occur when transferring and transporting dangerous materials
- eliminating your company's liability associated with the off-site shipments of the spent etchant
- reducing or eliminating safety concerns associated with drum handling and storage for spent and fresh etchant
- saving labor hours spent on manifesting and regulatory reporting requirements associated with spent etchant (e.g., for some facilities, eliminating spent etchant can put them under the regulatory reporting threshold, or help them to maintain Small Quantity Generator status).
- reducing chemical purchases for fresh etchant
- generating revenue from the sale of recovered copper
- reducing the amount of water used and discharged

Although the technology may not be suitable for all operations, on-site etchant regeneration systems have successfully prevented pollution both in very small, prototype board shops, and in some of the highest volume PWB manufacturers in the country.

This case study provides an overview of the different types of systems currently in use in the U.S. and is based on product literature, and on interviews with both equipment manufacturers and PWB manufacturers using the systems. The information is offered only as an introduction and has not been independently validated by EPA. For more information on any of these systems, contact the manufacturers at the numbers listed throughout the text.

Ammoniacal Etchant Regeneration

Alkaline etchants (ammonium chloride or ammonium sulfate) are the most commonly used types of etchants in PWB manufacturing. Without an etchant regeneration system, an optimal copper concentration is maintained by replacing spent etchant with fresh etch solution and shipping of the spent etchant off-site.

MECER System,

manufactured by COGNIS, Inc., 707-576-6225

System description:

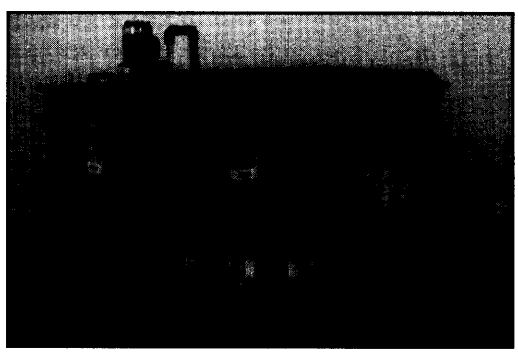
This system regenerates ammonium chloride, recycles rinse water, and recovers copper using a process of solvent extraction and electrowinning. The regeneration and recovery occurs in several stages: 1) a portion of the copper is removed from the spent etchant so that it can be used for further etching; 2) copper is removed from the rinse water so that it can also be reused; 3) copper is re-extracted and transferred to the electrolyte; and 4) in the electrowinning unit, copper is recovered from the now copper-enriched electrolyte to produce high quality, saleable copper metal.

Features:

- Eliminates spent etchant generation.
- Replenisher consumption is reduced by about 90%. After the copper is extracted, the alkaline etching solution is recycled and the only replenisher needed is to compensate for drag-out and evaporation losses.
- Copper is recovered from the spent etchant (where it is typically at a concentration of 16 to 21 ounces/gallon) and sold for approximately $1.00/lb (or about 90% of the COMEX copper price).
- Water consumption is greatly reduced (users estimate a 50 to 80% reduction in etching rinse water) and the copper concentration in the discharged rinse water is less than 5 ppm. Most of the copper content in the rinse water is recovered with a portion of the water being reused as rinse water in the etching machine. In addition to savings in water and sewer costs, savings are also realized in waste water treatment because fewer chemicals are needed for pH adjustment and metals recovery.
- Copper concentration in the etching solution can be maintained through the recovery system, and a precise pH is maintained using ammonia gas injection.

Availability

Units are sized based on the total throughput of the etching line, best estimated by your current consumption rate of replenisher. Ten different size systems are available depending on the facility's annual replenisher volume, ranging from 14,300 gal/year to 380,000 gal/year.



Mecer Electrowinning Unit

Costs/Savings:

Savings associated with the installation of this system include: savings associated with the elimination of off-site shipments of spent etchant, raw materials savings associated with a 90% reduction in replenisher purchased, revenue from sale of recovered copper, and savings associated with reduced water and sewer costs. Costs include the annual costs of copper starter sheets, replenisher makeup, solvent extractant, liquid ammonia, electricity, changes of anodes, spare parts, and other chemicals, and a one-time capital equipment cost. Users expect a payback of 2 years or less, but it depends on the specific costs and operating conditions of each facility. The manufacturer also offers the option to rent the equipment.

Elo-Chem System,

distributed by Atotech, 814-234-6543

System description:

Atotech supplies the Elo-chem Alkaline Regeneration Module and Copper Recovery System which regenerates ammonium sulfate and recovers copper in a closed-loop system. Although using ammonium sulfate allows direct electrolysis of the etchant, it also has a slower etch rate than ammonium chloride. The Elo-chem system consists of two separate regeneration circuits: an etchant recycling module and a copper recovery module. Etchant is regenerated utilizing atmospheric oxygen and ammonia to restore the copper in the spent etchant to the ionic form needed for etching. A portion of the solution is guided to the electrolytic cell, where copper is deposited on the cathodes. After electrolytic deposition of the copper is completed, the copper can be pulled off of the cathodes as a copper sheet.

Features:

Both large and small facilities have installed the Elo-chem system for etchant regeneration and recovery. The average copper recovery capacity of the system is 5.5 lb/hour, with a maximum hourly capacity of 6.6 lb. One customer who runs a prototype board shop (using fewer than 10,000 gallons of etchant/year), describes this as the "ideal" system for their operation. They expect the system can eliminate the time and resources associated with shipping spent etchant off-site, reduce the space required for storage of fresh and spent etchant, decrease chemical purchase costs, eliminate safety issues associated with handling drums, and improve etching process control. Ammonia gas, a proprietary rate accelerator (added at 0.25 liter/plating hour), and small quantities of ammonium sulfate crystals (from an industrial chemical supplier) are needed to operate the system; actual quantities required depend on the carry-over losses. This system does not recycle or remove copper from rinse water.

Availability:

The system works with a wide range of production capacities. The same equipment is used for all size facilities, and multiple plating cells are added to accommodate facilities with larger production capacities.

Costs/Savings:

Savings associated with the installation of this system include: annual savings associated with a 99% reduction in off-site shipments of spent etchant, savings associated with the elimination of replenisher purchases, and revenue from the sale of recovered copper. Costs include the annual costs of ammonia, electricity, spare parts, and other chemicals, and a one-time capital equipment cost. The manufacturer estimates a payback of 2.5 years or less, but this depends on the specific costs and operating conditions of each facility.

Cupric Chloride Regeneration

Many PWB manufacturers use a cupric chloride etchant to achieve fine line width etching, although it typically has a slower etch rate than ammonium chloride. Without an etchant regeneration system, manufacturers would typically purchase bulk chemicals to blend etchant and spent etchant would be shipped off-site. With etchant regeneration and recovery systems, saleable copper is recovered from the spent etchant and off-site shipments of spent etchant are eliminated. The types of regeneration equipment available include the FSL system, which recovers copper and regenerates etchant; and the Chemcut system, which regenerates etchant but does not recover copper.

FSL System,

distributed by Finishing Services Limited, 214-259-3326

System description:

The FSL Electrolytic Regeneration system is a closed-loop system that regenerates etchant and plates out the copper.

Features:

- Spent etchant is eliminated when the system is operated correctly within its maximum capacity according to the manufacturer. Customers have noted that they have reduced their volume of spent etchant by 95%.
- The pure copper byproduct that is electroplated out of the spent etchant solution is sold as scrap for about $0.75-$1.00/pound (a very high purity, but powdered-form copper is generated).
- The need for bulk chemical oxidizer is eliminated and the volume of hydrochloric acid needed is reduced by about 70 to 80%.
- Better control of the etching process (through maintaining constant copper concentration, HCl concentration, temperature and oxidation-reduction potential) can be obtained.

Availability:

The smallest FSL Regeneration system available is a module that removes 2.2 pounds of copper per hour; by joining these modules together, FSL can supply a system large enough to accommodate hundreds of pounds of copper per hour. As system capacity increases, however, so does the size of the system.