United States Environmental Protection Agency
Research and Development

Risk Reduction Engineering Laboratory
Cincinnati, OH 45268

EPA/600/S-94/015 September 1994

EPA **ENVIRONMENTAL RESEARCH BRIEF**

Waste Minimization Assessment for a Manufacturer of Microelectronic Components

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Abstract

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. In an effort to assist these manufacturers, Waste Minimization Assessment Centers (WMACs) were established at selected universities, and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992). The WMAC team at Colorado State University performed an assessment at a plant that manufactures microelectronic components. Thin-film circuitry is generated on sheet-alumina substrates using photolithography for pattern generation and vacuum-chamber vapor deposition to form circuit components. Integrated circuits and other components are attached to the ceramic substrates. The team's report, detailing findings and recommendations, indicated that the waste streams generated in the greatest quantities are rinse water and waste developer and that significant cost savings could be realized by installing flow meters and flow reducers in certain production areas.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center, Philadelphia, PA.

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Introduction

The amount of waste generated by industrial plants has become an increasingly costly problem for manufacturers and an additional stress on the environment. One solution to the problem of waste generation is to reduce or eliminate the waste at its source.

University City Science Center has begun a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the in-house expertise to do so. Under agreement with EPA's Risk Reduction Engineering Laboratory, the Science Center has established three WMACs. This assessment was done by engineering faculty and students at Colorado State University's (Fort Collins) WMAC. The assessment teams have considerable direct experience with process operations in manufacturing plants and also have the knowledge and skills needed to minimize waste generation.

The waste minimization assessments are done for small and medium-size manufacturers at no out-of-pocket cost to the client. To qualify for the assessment, each client must fall within Standard Industrial Classification Code 20-39, have gross annual sales not exceeding $75 million, employ no more than 500 persons, and lack in-house expertise in waste minimization.

The potential benefits of the pilot project include minimization of the amount of waste generated by manufacturers and reduction of waste treatment and disposal costs for participating plants. In addition, the project provides valuable experience for graduate and undergraduate students who participate in the program and a cleaner environment without more regulations and higher costs for manufacturers.

Methodology of Assessments

The waste minimization assessments require several site visits to each client served. In general, the WMACs follow the procedures outlined in the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). The WMAC staff locate the sources of waste in the plant and identify the current disposal or treatment methods and their associated costs. They then identify and analyze a variety of ways to reduce or eliminate the waste. Specific measures to achieve that goal are recommended, and the essential supporting technological and economic information is developed. Finally, a confidential report that details the WMAC's findings and recommendations (including cost savings, implementation costs, and payback times) is prepared for each client.

Plant Background

This plant manufactures monolithic and hybrid amplifiers and integrated circuit assemblies. Over 100,000 assemblies are produced by the plant during approximately 5,000 hr/yr of operation.

Manufacturing Process

Thin-film circuitry is generated on sheet-alumina substrates using photolithography for pattern generation and vacuum-chamber vapor deposition to form circuit components. Photoresist is applied to the substrate, dried, exposed to ultra-violet light, and developed to leave polymerized material on areas to be protected during subsequent vapor deposition. Remaining photoresist is removed with a resist stripper. These process steps may be repeated several times to add circuit elements in a sequential manner. Resistors are trimmed to specifications using laser cutting machines.

Assembly of the products involves attaching integrated circuits and other components to the ceramic substrates. Much of the process is automated. The resulting products are tested, inspected, packaged, and shipped.

An abbreviated process flow diagram for this plant is shown in Figure 1.

Existing Waste Management Practices

This plant already has implemented the following techniques to manage and minimize its wastes:

- Waste acetone from the stagnant bath for photoresist removal is reused in the ultrasonic acid bath in the same line.
- Waste tri-iodide stripping solution is shipped offsite for gold recovery.
- Water-based solder fluxes are replacing solvent-based solder fluxes.
- A closed-loop rinse is used for the cleaning that follows stripping and etching.
- Acetone and isopropyl alcohol baths and waste drums are kept covered to reduce evaporation.

Waste Minimization Opportunities

The type of waste currently generated by the plant, the source of the waste, the waste management method, the quantity of the waste, and the annual waste management cost for each waste stream identified are given in Table 1.

Table 2 shows the opportunities for waste minimization that the WMAC team recommended for the plant. The minimization opportunity, the type of waste, the possible waste reduction and associated savings, and the implementation cost along with the simple payback time are given in the table. The quantities of waste currently generated by the plant and possible waste reduction depend on the production level of the plant. All values should be considered in that context.

It should be noted that the financial savings of the minimization opportunities result from the need for less raw material and from reduced present and future costs associated with waste management. Other savings not quantifiable by this study include a wide variety of possible future costs related to changing emissions standards, liability, and employee health. It also should be noted that the savings given for each opportunity reflect the savings achievable when implementing each waste minimization opportunity independently and do not reflect duplication of savings that would result when the opportunities are implemented in a package.

Additional Recommendations

In addition to the opportunities recommended and analyzed by the WMAC team, three additional measures were considered. These measures were not analyzed completely because of insufficient data, minimal savings, implementation difficulty, or a projected lengthy payback. Since one or more of these approaches to waste reduction may, however, increase in attractiveness with changing conditions in the plant, they were brought to the plant's attention for future consideration.

- Reuse the laser cooling water instead of sewering it after use.
- Use deionized water and a hot air dryer to replace acetone and isopropyl alcohol used for drying wafers after initial cleaning.
- Continue to use the tri-iodide gold stripper for a longer period of time before disposal.

This research brief summarizes a part of the work done under Cooperative Agreement No. CR-814903 by the University City Science Center under the sponsorship of the U.S. Environmental Protection Agency. The EPA Project Officer was **Emma Lou George**.

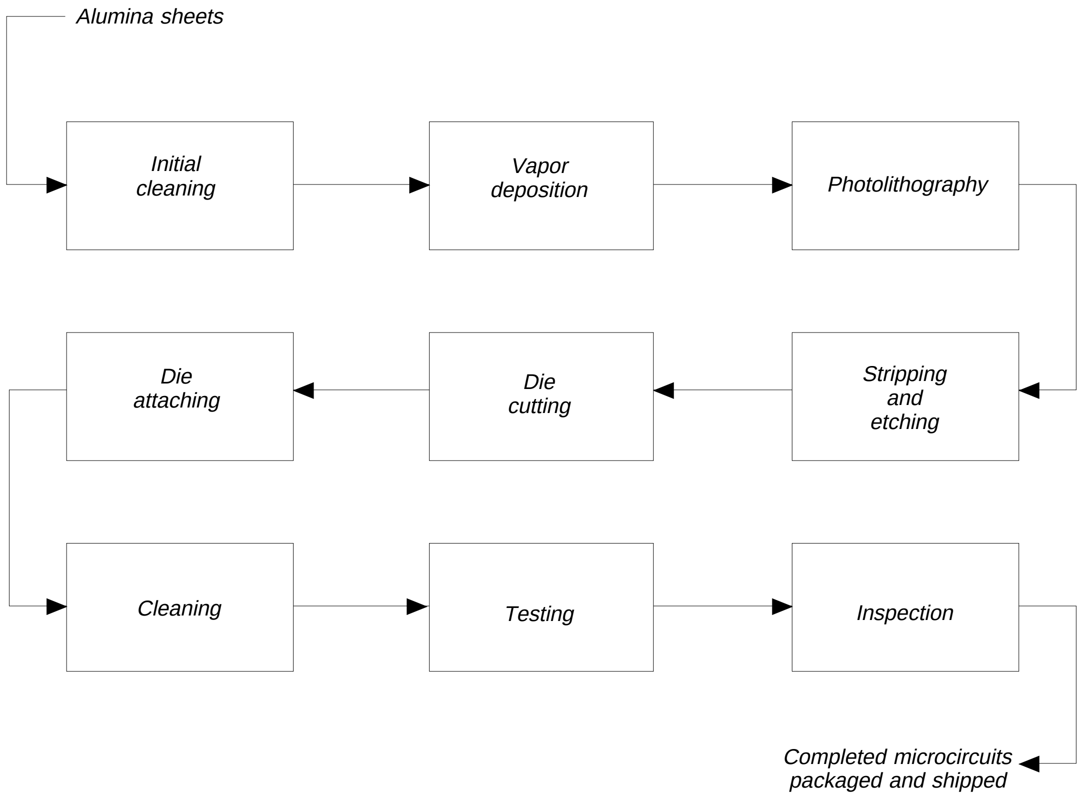

Figure 1. *Abbreviated process flow diagram.*

Table 1. *Summary of Current Waste Generation*

Waste Stream Generated	Source of Waste	Waste Management Method	Annual Quantity Generated (lb)	Annual Waste Management Cost*
Waste acetone	Initial cleaning of thin-film substrate	Shipped offsite for incineration	740	$720
Evaporated acetone	Initial cleaning of thin-film substrate	Evaporates to plant air	100	80
Waste isopropanol	Initial cleaning of thin-film substrate	Shipped offsite for incineration	380	460
Evaporated isopropanol	Initial cleaning of thin-film substrate	Evaporates to plant air	330	260
Waste developer (aqueous sodium hydroxide)	Photolithography	Shipped offsite for incineration	2,180	1,360
Waste photoresist	Stripping following photolithography	Shipped offsite for incineration	0[1]	0[1]
Waste acetone	Stripping following photolithography	Shipped offsite for incineration	370	420
Evaporated acetone	Stripping following photolithography	Evaporates to plant air	470	370
Waste hydrogen peroxide	Etching following photolithography	Shipped offsite for incineration	0[2]	0[2]
Tri-iodide stripper/gold	Stripping following photolithography	Shipped offsite for gold recovery	1,830	650
Rinse water	Various operations	Sewered	37,800,000	7,660

* Includes waste treatment, disposal and handling costs, and applicable raw material costs.
[1] No waste was shipped offsite during the previous yr; waste is accumulating onsite. No estimate of the quantity of accumulated waste was available.
[2] No waste was shipped offsite during the previous yr; waste is accumulating onsite. Fifty-five lb of waste had accumulated at the time of the assessment.

Table 2. *Summary of Recommended Waste Minimization Opportunities*

		Annual Waste Reduction				
Minimization Opportunity	Waste Stream Reduced	Quantity (lb)	Per cent	Net Annual Savings	Implementation Cost	Simple Payback (yr)
Neutralize waste developer and heat in an evaporator to reduce the water content of the waste shipped offsite.	Waste developer	—-[1]	—-	$940	$2,800	3.0
Install flow meters and flow reducers to reduce water usage in the production areas of the plant.	Rinse water	4,540,000	12	920	400	0.4
Extend the length of usage of the acetone and isopropanol in the initial cleaning baths and of the acetone in the baths of the photoresist removal process.	Waste acetone Waste isopropanol	500 250	45 66	850	0	Immediate
Replace acetone in the initial cleaning bath with a nonhazardous cleaner. Distill and reuse the replacement solvent cleaner. (A negligible amount of still bottoms will be generated.)	Waste acetone Evaporated acetone	190 50	26 50	225	90	0.4
Reuse acetone from the initial cleaning bath for photoresist removal.	Waste acetone	370	50	420	0	Immediate

[1] This opportunity does not reduce the quantity of waste generated, but it does offer a cost benefit to the manufacturer.

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