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BDX-613-1803

HMC SPRAY DEVELOPING, STRIPPING,
AND ETCHING

Final Report

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Published February 1978

Prepared for the United States Department of Energy
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**Kansas City
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BDX-613-1803, UNCLASSIFIED Final Report, Published February 1978

Prepared by P. L. Blessner, D/842

A small chamber spray processing system was designed for the developing and stripping of photoresist and the etching of thin films for hybrid microcircuits. A model chamber was fabricated and evaluated for uniformity of development of dry-film photoresist on 95 by 114 mm ceramic substrates. Line width variations obtained with this chamber were within the tolerances required for production HMCs.

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SUMMARY

A small chamber spray processing system for use in hybrid micro-circuit photolithographic processing was designed and a model chamber was fabricated and evaluated. The system was designed to provide economical photoresist developing and stripping and thin film etching in both laboratory and production environments. The smaller sump capacity of this system, compared to the present production spray equipment, would reduce solution losses and provide improved operator safety. Separate, identical chambers are used for each functional spray, providing interchangeability and simple economic replacement. The use of carriers for loading and removing up to 24 substrates at a time would minimize handling and reduce the operator attention required during processing.

The model chamber evaluation was based on the uniformity of development of dry-film photoresist across the surface of a 95 by 114 mm substrate. The best combination of spray head orientation, spray pressure, and spray times produced an average line width equal to the nominal value of 63.5 μm . The values ranged from 60.2 μm to 66.5 μm , producing a variation of 10 percent of the average. This deviation is only half the tolerance permitted on RF HMCs, for which the desired maximum line width variation is 6.4 μm .

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to determine the feasibility of a small chamber spray processing system designed specifically for economical photoresist developing and stripping and thin film etching for production of hybrid microcircuits (HMCs). The spray processing of HMC substrates is presently being done with equipment designed for printed circuit board fabrication. This equipment is inefficient in terms of operating costs, required floor space, and operator safety. Since spray processing equipment specially designed for HMC manufacturing was not commercially available, this project was initiated to design equipment which would better meet the technology requirements. This work was done between January 1975 and May 1976.

ACTIVITY

This spray processing system was designed with four goals in mind:

- To provide better control of the spray process;
- To provide improved safety for operators and maintenance personnel;
- To reduce the required floor space; and
- To reduce the operating costs.

System Design

To achieve the desired goals of the system, it was decided to base the design on the use of identical small chambers in which separate functional spray processes would be performed. The chamber concept would optimize system capacity by allowing the simultaneous operation of each chamber and would provide lower operating costs and improved safety by minimizing the spray area and sump capacity. Since the chambers would be identical and would function separately from the rest of the system, they could be replaced easily at a relatively low cost.

A simplified drawing of the system is shown in Figure 1. There is a separate chamber for each spray process: develop photoresist, strip photoresist, etch tantalum, etch chromium, and etch gold (twice). Since the final design employs three chambers per unit, two units are required for a complete HMC spray processing

Figure 1. System Configuration

system. The system would occupy approximately 35 square feet of factory floor space, which is less than one-fifth of the space required by the present spray equipment. The estimated capacity of the system is 40 to 60 substrates per hour per chamber.

Carriers would be used for loading and unloading up to 24 substrates at a time, which would eliminate the need to load substrates individually on a conveyor belt as is presently done. This would reduce the operator attention required--and thus the

processing cost per substrate--and would minimize the handling of substrates, thereby reducing the chance of damaging the substrates. The system control panel, designed to provide identical, but separately operational, controls for each chamber, is shown in Figure 2. The controls, some of which would be located inside the cabinet, include:

- Variable, functional spray duration (0 to 120 seconds);
- Variable rinse spray duration (0 to 60 seconds);
- Variable dry nitrogen spray duration;
- Variable conveyor speed control;
- Appropriate on-off controls;
- Appropriate pressure indicators;
- Automatic and manual-override operation;
- Temperature indicators and controls for the sump fluids; and
- Start and finish indicators.

Chamber Design

A conceptual sketch of the spray chamber is shown in Figure 3. The chamber is positioned between two conveyor belts which transfer substrates into and out of the chamber. The entrance and exit ports consist of rubber bladders which are held open by vacuum to permit the passage of substrates. During spraying, air pressure holds the ports closed to prevent fumes and liquids from escaping. A photoelectric switch is used to detect the presence of a substrate before allowing a spray cycle to begin. A set of chain-operated rollers inside the chamber permits the substrate to be cycled back-and-forth during spraying to compensate for variations in the spray pattern. After each functional spray, the chamber walls are rinsed with water to reduce chemical attack and thereby increase the useful life of the chamber. Air knives, located on the top and bottom of the exit port, dry the substrate as it leaves the chamber. The small chamber size permits small solution volumes to be maintained in the sumps, thereby reducing solution waste from evaporation, drag-out, and overspraying. This also provides improved safety, since smaller volumes of chemical solutions are handled during solution monitoring and replacement.

Spray Evaluation of Model Chamber

The spray pattern of a model chamber was evaluated for uniformity of development of photoresist across a 95 x 114 mm substrate. A

Figure 2. System Control Panel

Figure 3. Conceptual Design of Spray Chamber

total of 15 substrates were used, each of which had been laminated with dry-film photoresist and exposed with a 20-circuit pattern. The substrates were spray developed, using approximately 4 liters of solution, with various spray pressures, spray times, and spray angles. The line widths of a resistor were measured in six locations on each substrate: one in each corner and two in the center of the substrate. The measured pattern consisted of eight lines and spaces having a nominal width of $63.5\ \mu\text{m}$. The accuracy of the development process is determined by the difference between the actual and nominal line widths, and the uniformity of development is measured by the variation in line widths across a given substrate.

A plot of the summarized line width data is given in Figure 4, and the spray parameters used for each substrate are given in Table 1. The solution used first had previously been used for immersion etching. Increasing the amount of development, as a

Figure 4. Line Widths of Dry Film Photoresist For Various Spray Developing Parameters

result of a stronger solution or longer developing time, should cause a decrease in line width since developing removes the photoresist between conductor lines. This is evident on Substrates 4 and 8; for which a new lot of developing solution was used. Depletion of the solution is the cause of the general trend toward increasing line width for each subsequent use of the solution.

On all but a few of the substrates, the variation in line width would be acceptable for production HMC substrates; however, the average line width was less than the nominal value. A slight decrease in the spray times would have increased the average line width for these substrates, but should not have caused any significant increase in the variation of line widths across a substrate.

The best results were obtained on Substrate 2, on which the average line width was equal to the nominal value and the three-sigma limits varied less than 10 percent from the average. The closest line width tolerance currently required on production HMC substrates is that for MK 4 RF HMCs: a maximum variation of 6.4 μm . This variation is larger than the three-sigma limits of line width on all but four substrates: two of these were less

Table 1. Spray Developing Parameters

Substrate	Spray Pressure kPa (psi)	Spray Duration (s)	Spray Head Orientation*	Comments
1	138 (20)	60	Edge	
2	138 (20)	40	Center	
3	159 (23)	45	Center	
4	138 (20)	40	Center	New Solution
5	138 (20)	40	Center	
6	117 (17)	75	Center	
7	138 (20)	75	Center	Air Leak
8	138 (20)	30	Center	Air Leak
9	124 (18)	35	Center	New Solution
10	138 (20)	45	Center	
11	138 (20)	40	Center	
12	103 (15)	60	Edge	
13	165 (24)	35	Edge	
14	138 (20)	30	Edge	
15	138 (20)	35	Edge	

*Location on substrate where centers of spray patterns are directed.

than 13 percent higher, and the other two had air leaks occur in the spray system during developing.

This evaluation demonstrates that the spray chamber will provide a controlled spray process for uniform development of photoresist on HMC substrates. The uniform spray pattern obtained should also be capable of uniformly etching thin-film substrate metallization.

ACCOMPLISHMENTS

A small chamber spray processing system was designed for the spray developing and stripping of photoresist and the spray etching of thin-film metallization on HMC substrates in both laboratory and production environments. Compared to the present spray equipment, this system should

- Provide improved control of the spray process;
- Reduce operating costs;
- Improve operator and maintenance personnel safety; and
- Reduce the required floor space.

A model chamber was fabricated and evaluated for uniformity of development of dry-film photoresist across a substrate. The chamber produced photoresist line width variations within the tolerances required for production HMC substrates and is expected to provide similar uniformity in the etching of thin-film metallization. Complete system drawings were prepared and can be used to build a complete system if it is decided to pursue spray processing in the future.

FUTURE WORK

Further development work before production use of this spray processing system should include the following:

- Build a complete spray processing system for laboratory evaluation;
- Modify the design as required for proper mechanical operation;
- Establish the process parameters required for each HMC spray process; and
- Determine the process limits and solution control required for consistent production spray processing of HMCs.

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