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Slicing of Single Crystal and Polycrystalline Silicon Ingots Using Multi-Blade Saws

FINAL REPORT

by

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JPL Contract No. 955563

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INTRODUCTION - STATEMENT OF WORK

This contract was issued by JPL to serve primarily as a feasibility study during which the capabilities of P. R. Hoffman Co., Division of Norlin Industries, Inc., could be evaluated with regard to our ability to satisfactorily provide the research and development effort which would lead to optimization of the Multi-Blade Slurry wafering technique as a contribution to the realization of the goals of the (DOE) Low-Cost Solar Array Project. In addition to making several wafering runs, we were to provide sufficient data necessary for a complete cost analysis of each of the three types of saw utilized.

The original requirements of this contract were to provide for a total of ten (10) wafering runs to be made on three (3) slurry saws as follows:

Varian 686 Saw

- One 4" diameter ingot (poly) to yield 18 to 20, 10 mil thick, wafers per centimeter of ingot length.
- Two 4" diameter ingots (single crystal) to yield 20, 10 mil thick, wafers per centimeter of ingot length.

Meyer and Berger GS-1 Saw

- One 4" diameter ingot (poly) to yield 18 to 20, 10 mil thick wafers per centimeter of ingot length.
- Two 4" diameter ingots (single crystal) to yield 20, 10 mil thick wafers per centimeter of ingot length.

Hoffman PL-4 Saw

- One 5.5" diameter ingot (poly) to yield 18 to 20, 10 mil thick wafers per centimeter of ingot length.

- Three 4" diameter ingots (single crystal) to yield 20, 22, and 25 wafers per centimeter of ingot length; wafer thickness to be greater than 8 mils.

All saw runs to be made using a standard abrasive oil vehicle and 400 grit SiC abrasive.

Upon completion of one run on each of the three types of saw, JPL requested a test run of a quartered ingot (referred to as the "quad" run elsewhere in this report). The results of these runs were reported at the technical review at JPL April 1, 1980. Subsequent to that review, JPL requested that all future saw runs be made with the primary goal of attaining 25 wafers per centimeter of ingot length or 1 meter^2/kg of silicon material.

DISCUSSION OF INDIVIDUAL SAW RUNS

Run # VAR 1(a)

A 10 cm diameter by 6" long polycrystalline ingot was prepared for wafering by mounting on a flat glass submount using an anaerobic adhesive. In an attempt to provide 18 wafers per centimeter of ingot length, at a thickness of .010", a blade pack containing 273 blades of .006" thickness and spacers of .016" thickness was utilized with an abrasive slurry of #400 Silicon Carbide. A Varian 686 Saw, which is normally used in daily production, was used for this run.

At approximately one-half inch depth of cut, the ingot broke free of the submount and the run was aborted. No data relating to wafer characteristics were available.

Run # VAR 1(b)

The partially sawn ingot from the previous run was ground flat and remounted with the flat surface to the glass submount. This trial essentially amounts to a continuation of the first run, enabling us to evaluate usage of consumables on the basis of a single complete run through a 10 cm diameter ingot. The run was successfully completed, although some blade breakage did occur as the blades entered the submount. A total of 241 complete wafers were produced, a yield of 88.3% of the potential. Thickness averaged .0094", vertical and horizontal taper was less than .0005" per inch, and approximately 18 wafers per centimeter of ingot length were provided.

Run # M&B 1

A 10 cm diameter by 7" long polycrystalline ingot was prepared for mounting by grinding a flat of less than one-half inch width along its length to preclude the break-away of the ingot from submount during slicing. This procedure was utilized in all subsequent wafering runs. Blade package and abrasive slurry parameters were essentially the same as in the Varian runs, except the higher tensioning capacity of the Meyer & Berger blade head allowed us to use 318 blades. This run was to provide a comparison to the Varian 686 saw based on the potential of this increased capacity as well as the built-in "bounce" feature of the Meyer & Berger GS-1 saw. The feed mechanism automatically provides a periodic movement of the workpiece away from the blades to theoretically allow flushing out of contaminants (silicon) and introduction of "fresh" abrasive. It is expected that this feature would result in reduced cycle time.

The full 4 inch depth of cut was traversed in approximately two-thirds the time required on the Varian saw, which tends to indicate this feature is an improvement. However, several other variables, some of which are difficult to control, effect cycle time. A further discussion of these appears elsewhere in this report.

The run was completed with a yield of 153 wafers (48.6%) having a vertical taper of slightly greater than .0005" per inch, negligible horizontal taper, and average thickness of .010". The low yield is the result of severe blade breakage after entry into the submount. Because of blade wear characteristics, it is necessary to cut some distance into the submount to insure complete cutting through the workpiece. Examination of the wafered ingot and submount assembly indicated that, had the run been stopped five minutes sooner, wafering would have been complete and (since blade breakage would not have occurred) a yield in excess of 95% would have been realized.

<u>Run # PL-4 1</u>

A 10 cm diameter by 8.8 inch long single crystal ingot was prepared as previously described and run on the Hoffman PL-4 saw. This is a production/prototype saw and had been run a total of less than 200 hours prior to its allocation to this project. Several design improvements over the Varian and Meyer & Berger saws were expected to provide substantial reductions in wafering cost. These include maximum speed of 200 strokes/minute (vs. 100 on Varian and Meyer & Berger), significantly higher blade head tensioning capacity, and increased depth-of-cut capacity.

The blade package contained 400 blades and the abrasive to oil ratio of the slurry was reduced as compared to previously discussed runs.

All other basic parameters were about the same.

Again, blade breakage occurred after entry into the submount. In spite of this, the saw was stopped in time to "save" the run, and 380 of the potential 400 slices provided a yield of 95%. Average wafer thickness was .011", vertical taper .0006" per inch, and horizontal taper averaged .0002" per inch.

Because of the higher stroke speed available on this saw, it was decided that a less concentrated abrasive slurry could be evaluated during this run with the probability of negative effects being minimal. This was not the case, as resulting wafers had a surface condition visibly different from that resulting from previous runs. In fact, at one point in the run cutting rate dropped to virtually zero and was only brought back up by the addition of abrasive to the slurry. Although various hand micrometer measurements of the wafers did not indicate a problem, there had been some degradation of wafer strength during this run. A total of 42 wafers fractured in handling during cleaning and packaging; this in spite of the .011" wafer thickness (as compared to .0095 to .010" thickness of wafers from previous runs). The use of the less concentrated slurry appears to have made worse the very condition it was expected to improve.

Run #PL-4 2

Per a request from the JPL Technical Manager, a special run (referred to as the "Quad Run") was attempted.

A 10 cm diameter by 6.8 inch long single crystal ingot was quartered on a conventional O.D. Diamond Blade Saw to yield quadrants which would provide the following conditions:

a. "work piece" cross-section more nearly representing a retangular block, thus providing a more desirable blade wear configuration.

b. three "quads" could be mounted in such a manner as to require a total depth of cut of 2 inches which could be negotiated in approximately half the run time required for a 4-inch diameter ingot (10 cm) resulting in an anticipated 50% increase in m^2 produced per unit of saw run time.

c. an equivalent effective increase in blade life could also be expected.

d. if results were favorable, this technique would enable us to wafer 15 cm diameter ingot on any of the three currently available saws.

The blade package for this run consisted of 310 blades, .006" thick with .016" spacers. Abrasive/oil ratio was 2 pounds #400 SIC per gallon. The trial proceeded very well until severe fracturing of the wafers occurred at approximately .250" from the completion of wafering, requiring us to abort the test. Had we completed the run, all of the expected benefits would have been realized. The failure resulted from two basic problems.

a. The ingot was not precisely quartered, resulting in a taper along the length of each quadrant. This caused variation in cutting force, which resulted in severe chipping and fracturing of wafers at the point of blade entry.

b. The center quadrant, mounted point down to the submount, required more support than was provided to resist drag forces during cutting, and began to fracture as the blades entered the minimum cross-section area.

Upon completion of all the tests described above, a technical review was held at JPL resulting in a redirection of our efforts during the balance of the contract period. Our goal was now specifically to make a complete saw run resulting in a high yield of wafers at 25 wafers per centimeter of ingot length or 1 m^2 of surface area per kilogram of silicon ingot. This would require slicing of thinner wafers than had ever been achieved at P. R. Hoffman. Blade thickness of .004 inch was dictated by the desired result, as were spacer thickness of .012" and abrasive grade #600. Our ability to control the many variables affecting the process became critical. Yet, we embarked on this endeavor confident that in one of the next five saw runs we would achieve 1 m^2 per kilogram of silicon ingot.

Run # PL-4 #3

A 10 cm diameter by 7 inches long single crystal ingot was run using 440 blades of .004" thickness and .012" spacers. The abrasive slurry utilized #600 SIC abrasive in the ratio of 2.33 pounds per gallon of oil. With blades of this thickness, we anticipated blade "buckling" or "wander" during the entry into the ingot. Chips and minor fracturing resulting from this condition had been noted in previous runs with .006" blades. The blades were preconditioned by running for 20 minutes into a piece of flat plate glass in an attempt to minimize this condition. Inspection of the wafers at the end of the run indicated improvement.

During the run, typical blade wear resulted in "bumping" or "bouncing" which can cause stresses leading to blade breakage, chipping and fracturing of the workpiece, and tapering of wafers. This condition can be overcome by periodically reducing the length of stroke of the saw.

For obvious reasons, this adjustment was made more frequently than usual during this run, resulting in no further adjustment available at 1.004" depth of cut. "Bumping" became increasingly severe. Wafers had begun to break out of the ingot at 0.606" depth of cut and continued to do so through the balance of the run. The pattern of this occurrence ideally matched the pattern of the slurry "puddle" on the blade pack, indicating that excessive slurry feed is detrimental. At 1.099" depth of cut "bumping" was severe enough to cause us to consider aborting the run. We decided to push the test to the limit. Gauges indicated a minimum "step" of .030" had developed in the blades. Approximately 5.5 hours later, blades began to break. Depth of cut was 1.194". At 1.242" depth of cut (3.5 hours later) the blade breakage was so frequent the run was aborted. Until this time, blades were cut out of the pack as they broke, and the run continued. The pattern of blade breakage appeared to follow that of wafer break-out previously discussed. This would indicate that slurry volume contributes to reduction of blade life. Examination of the remaining blades indicated they were worn to approximately one-eighth inch height at the center. Past experience with .008" blades has been to produce satisfactory wafers with blades worn to approximately one-sixteenth inch in height across a 5 to 6 inch length (cutting square cross sections). Since blade tensioning load is proportional to cross-sectional area of the new blade, it appears that breakage was the result of additional stresses from "bumping" and, possibly, drag forces.

Run # M&B-2

A 10 cm x 7.1 inches long polycrystalline ingot was mounted on the Meyer & Berger saw. Blade package contained 420 blades, .004" thick with .013" spacers. This would yield approximately 23 wafers per centimeter of ingot length. Slurry volume was reduced as much as practicable by clamping a rubber feed hose. Other significant parameter changes (from previous PL4 run) were less frequent stroke length reduction and no attempt to maintain a cutting rate of approximately .002"/minute. Except for minor break-out of a few wafers, the run proceeded very well. Wafer break-out occurred at the center of the ingot length (the point of highest slurry volume). At a cut depth of 2 inches, blades began to break and the run was aborted. At this point the decision was made to use one-half inch high blades in an attempt to complete a wafering run.

Run # M&B-3

While awaiting delivery of one-half inch blade packs, we found the Meyer & Berger blade head would not accommodate blades of this height. Since we had a blade pack on hand made up of .006" x .250 blades with .014" spacers, we decided to run with pressure and speed parameters used on .004" blade runs and use #400 SIC abrasive to reduce wafer thickness to approximately .0085". This would provide further data on the ability of the thinner wafer to stand up to drag forces, etc. The slower cutting rate would also provide information with regard to effect of cutting rate on taper. To insure complete through-cut, the remaining quadrant from the quartered ingot was used, thus requiring total cut depth of 2 inches. Total run time virtually equalled that of the 4 inch depth traversed in Run # M&B-1. Yield was 100%, but there was no improvement in the taper.

Run # PL4-4 and Run # VAR-2

It was our intention to use the one-half inch blade packs to run a 10 cm diameter ingot on the PL4 saw, followed by a run of 12.5 cm ingot with an identical pack. The saw had been used to run other materials since Run #3 and had developed a loud knock. Several attempts to identify the cause were unsuccessful. We decided to try one more run in spite of the questionable condition of the saw. A four inch length of the 12.5 cm diameter polycrystalline ingot was cut using an O.D. Diamond Blade. This was mounted on the Hoffman saw. A 250 blade package of .004 by ½" blades with .012" spacers was used. At a depth of cut of .105" the ingot broke free of the submount. We assume the integrity of the bond deteriorated during the diamond saw cut. There appeared to be no wafers (segments) on the ingot, but we could not be sure if this was due to the ingot breaking loose or other causes. The "damaged" area was surface-ground flat, the ingot inverted and remounted and the run continued. At this point, we decided to run the 10 cm diameter ingot on a Varian saw, since we had also experienced problems in alignment of the blades on the Hoffman saw, and run conditions were, indeed, questionable. Using an identical blade package, we were able to obtain excellent alignment on the Varian saw. All run parameters were set to match the Hoffman run as nearly as possible, and the two runs were made concurrently. A constant break-out of silicon slivers was noted on both saws. The condition became so severe that we stopped the PL4 run at a cut depth of .566" and the Varian run at a cut depth of .610". The ingot on the PL4 saw had one partially completed wafer which remained totally intact to this point. The Varian run yielded none. It appears that the ½ inch high blades cause sufficiently increased drag forces to tear away the thin wafer sections. Nothing appeared to justify continuation of either run. We had, apparently, reached the limits of the current state-of-the-art of multi-blade slurry slicing.

DISCUSSION OF RESULTS

As a result of several hundred thousand saw hours of production run at P. R. Hoffman prior to this contract, we were already aware of the many variables affecting the multi-blade wafering process. The state-of-the-art, however, was never pushed to the limits discussed above. The apparent effect of several variables has been noted in the discussion of each test run made. Several others, to this point, have not been mentioned. By tabulating all of these parameters and the saw runs in which they had an impact on failures, we can easily see the critical areas requiring considerable research to provide for optimization of the process and upgrading of the state-of-the-art. This information is presented in Table I which follows.

During the course of this effort, we attempted to maintain tightest possible control of the variables, consistent with our current knowledge of their effect on the process. We have not performed detailed studies of any of these variables. At this time, our data merely indicates trends which will serve as a basis for the direction of further research.

TABLE 1

VARIABLES AFFECTING THE RESULTS OF MULTI-BLADE WAFERING RUNS

X - Indicates runs in which the given parameter appears to have had a major effect on wafer yield.

PARAMETER / RUN #	VAR 1(a)	VAR 1(b)	M&B 1	PL 4 1	PL 4 2	PL 4 3	M&B 2	M&B 3	PL 4 4	VAR 2
Blade Wear		X	X	X		X	X		X	X
Blade Alignment									X	
Load (Feed Force Control)				X	X					
Stroke Speed									X	X
Slurry Volume					X				X	X
Drag Forces/Lubricity					X				X	X
Integrity of Mount	X								X	
De-mounting/Handling		X	X	X						
Wafer Support/"Tilting"		X	X	X	X					

CONCLUSIONS

As a result of the tests performed, we must conclude that current state-of-the-art of Multi-Blade Slurry Wafering is at a level which does not provide for successful wafering of 1 m^2 per kilogram of 10 cm diameter silicon ingot.

Optimization of the process to attain this goal does, however, appear possible. The major problems to be overcome are related directly to blade wear, feed force control, and abrasive slurry characteristics. We remain optimistic with regard to the probability of successfully wafering 1 m^2 per kilogram of ingot through optimization of the process.

Another major factor in accomplishing the goals of the Silicon Sheet Task, which has not yet been discussed, is cost of the wafering process. As will be seen in the economic analysis contained in this report, the cost of consumables used in the MBS process must be greatly reduced if the 1986 goals are to be attained. Therefore, process optimization must also include investigation of less expensive consumables and/or a practical system of reclamation.

Further, cleaning and handling of sawn wafers has not been of major concern in the course of our wafering tests. It is obvious that a wafer slicing facility would require an efficient wafer demounting, cleaning and packaging system. Such a system will probably have to be automated or, at least, highly mechanized to keep production costs in line with the goals of the Silicon Sheet Task. The development of these systems must begin at the point where completed wafers are still mounted on the MBS saw, since all handling of the wafers will be costly and must be kept to a minimum. This represents a new technology in a typical wafering facility such as P. R. Hoffman Co.

VARIAN SAW RUN DATA

Run #	VAR #1(a)	VAR #1(b)	VAR #2
Material	Si (Poly)	Si (Poly)	Si (Poly)
Size (mm)	100 mm	100 mm (Flated)	100 mm
Area/Slice (cm^2)	78.5	78.5	78.5
Blade Thickness (mm)	.15	.15	.10
Spacer Thickness (mm)	.41	.41	.30
Blade Height (mm)	6.35	6.35	12.7
Number of Blades	273	273	246
Load (psig) Balance	30	30	30
Load (psig) Start	36	35	30
Load (psig) Run	45	40	30
Speed (dial %) Start	50	50	10
Speed (dial %) Run	50	55	20
Abrasive	400 SIC	400 SIC	600 SIC
Oil Volume (qts)	8	8	12
Mix (lbs/gal)	2.5	2.5	2
Nom. Slice Thickness (in)	.011	.011	.0084
Nom. Kerf Loss (in)	.011	.011	.0076
Run Time (hrs)	4*	55.75	20.25*
AVG Cut Rate (in/min)	-	.001	.0005
AVG Taper Vertical (in/in)	-	.00047	-
AVG Taper Horizontal (in/in)	-	.00047	-
AVG Wafer Thickness (in)	-	.0094	-
Potential Yield (slices)	-	272	-
Actual Yield (slices)	-	241	-
Yield %	-	88.6	-

*Run Aborted.

MEYER & BERGER SAW RUN DATA

Run #	M&B #1	M&B #2	M&B #3
Material	Si (Poly)	Si (Poly)	Si 100
Size (mm)	100	100	50 (Quad)
Area/Slice (cm^2)	78.5	78.5	19.6
Blade Thickness (mm)	.15	.10	.15
Spacer Thickness (mm)	.41	.33	.35
Blade Height (mm)	6.35	6.35	6.35
Number of Blades	318	420	350
Load (bars) balance	10.5	10.5	10.5
Load (bars) start	13	11	10.5
Load (bars) run	14	11/11.75	11
Speed (dial %) start	40	40	40
Speed (dial %) run	60/80	60/800	60/70
Abrasive	400 SIC	600 SIC	400 SIC
O.1 Volume (qts)	12	12	12
Mix (lbs/gal)	2.67	2.33	2
Nom. Slice Thickness (in)	.011	.0092	.009
Nom. Kerf Loss (in)	.011	.0038	.011
Run Time (hrs)	44.72	65.83*	40.5
Avg Cut Rate (in/min)	.0015	.0005	.00078
Avg Vertical Taper (in/in)	.00056	-	.0006
Avg Horizontal Taper (in/in)	.00011	-	-
Avg Wafer Thickness (in)	.010	-	.0086
Potential Yield (slices)	317	-	349
Actual Yield (slices)	153	-	349
Yield %	48.3	-	100

*Run Aborted.

HOFFMAN SAW RUN DATA

Run #	PL-4 #1	PL-4 #2	PL-4 #3	PL-4 #4
Material	Si (100)	Si (100)	Si (100)	Si (Poly)
Size (mm)	100	(3) 50 (Quad)	100	125
Area/Slice (cm^2)	78.5	(3) 19.6	78.5	126.7
Blade Thickness (mm)	.15	.15	.10	.10
Spacer Thickness (mm)	.41	.41	.30	.30
Blade Height (mm)	6.35	6.35	6.35	12.7
Number of Blades	400	310	440	250
Load (psig) balance	66	69	67	68
Load (psig) start	70	71	67	68
Load (psig) run	70/73	70/74	68/70	68
Speed (strokes/min) start	50	50	50	50
Speed (strokes/min) run	80/125	70/100	80/130	70/90
Abrasive	400 SIC	400 SIC	600 SIC	600 SIC
Oil Volume (qts)	16/20	16	12	12
Mix (lbs/gal)	1.25/1.4	2	2.33	2
Nom. Slice Thickness (in)	.011	.011	.0084	.0084
Nom. Kerf Loss (in)	.011	.011	.0078	.0078
Run Time (hrs)	71.16	13.5*	29.1*	29.2*
Avg. Cut Rate (in/min)	.0009	.0022	.0007	.0006
Avg. Vertical Taper (in/in)	.00064	-	-	-
Avg. Horizontal Taper (in/in)	.00022	-	-	-
Avg. Wafer Thickness (in)	.0112	-	-	-
Potential Yield (slices)	399	-	-	-
Actual Yield (slices)	379	-	-	-
Yield %	95	-	-	-

*Run Aborted.

GENERAL COST DATA - SAMICS/IPEG, ANALYSIS INPUT

Blade Packages

Vendor: P. R. Hoffman Co., Machine Products Division

Cost of a blade pack may be determined by calculating the number of blades/pack and multiplying by "per blade" cost.

Example: 7" pack with .016" spacer and ¼" x .006" blade.

Spacer:	.016"
Blade:	.006"
Total:	.022"/blade

7" overall ÷ .022" = 318 blades

318 blades @ $0.23/blade = $73.14/pack

Per Blade Costs:

¼" x .006"	$0.23/blade
½" x .006"	0.25/blade
¼" x .004"	0.23/blade
½" x .004"	0.25/blade

P C Oil Vehicle

Vendor: Process Research Corporation, Pennington, New Jersey 08534

Cost: $5.08 per gallon

Silicon Carbide Abrasive

Vendor: Micro Abrasive Corporation, Westfield, Massachusetts 01086

#400 SIC	$4.38/Kg	or	$1.99/lb
#600 SIC	$7.24/Kg	or	$3.29/lb

Required Floor Area for Saw and Service Clearance

(Does not include allowance for aisles, this allowance will be factored in SAMICS/IPEG Analysis program.)

Hoffman PL-4 Saw	36 Square Feet
Varian 686 Saw	36 Square Feet
Meyer & Berger GS 1 Saw	30 Square Feet

Power Data for Energy Consumption Calculations

Varian 686 Saw	3/4 hp D.C. motor operating from 115 volt, 50/60 hertz, 1 ϕ source 1/8 hp A.C. pump motor 1/15 hp A.C. lubrication pump motor Min. 80 psi air source required (CFM consumption data unavailable)
Meyer & Berger GS-1 Saw	220 V 50/60 hertz 3 ϕ input Max. current draw operating 7 to 8 amp per leg No air requirement
Hoffman PL-4 Saw	2 hp D.C. (1.5 KW) 230 50/60 1 ϕ 1/6 hp A.C. pump (.12 KW) 115 50/60 1 ϕ Min. 80 psi air source required

Equipment Cost - Current Available Prices, May 1980

Varian 686 Saw (Not Available)	Model #7176	$27,500
Meyer & Berger GS-1 Saw		$35,000
Hoffman PL-4 Saw		$42,000 (1 saw and accessory items)

Man-Machine Ratio: Current estimate of one direct labor operator per 15 saws appears realistic.

ECONOMIC ANALYSIS

An economic analysis of the MBS process was presented at the Technical and Programmatic Review held at JPL April 1, 1980. This analysis was based on data from the first three "successful" wafering runs which had been completed. Since we have been unsuccessful in our attempts to provide 1 m^2 per kilogram of ingot, this same analysis represents costs of the MBS process at current state-of-the-art. The original presentation has been altered to correct an error made in the cost per square foot of factory floor area, and to reflect costs of equipment and consumables consistent with current (May 1980) data. The original calculation also assumed 25 wafers per cm of ingot. This revision is based on 20 wafers per cm which is the best yield demonstrated to date. Although we have reason to believe that the abrasive slurry can be utilized for more than one wafering run, the calculation does not assume this since it has not been demonstrated in the course of our contractual effort.

COST PROJECTIONS (1980 $) I P E G

Assumptions:

Projection is based on use of PL-4 saw due to largest capacity.

Equipment Cost: $42K/Machine

Floor Space: 36 sq ft/Machine

1 Operator/15 Units

Expendables/Run: $140.89 (Blade Pack, Oil, Abrasive)

455 Wafers/Run (20 Wafers/cm)

45 Hour Run Time

95% Yield

95% Duty Cycle

Interim standard price estimating equation:

$$\text{Price} = \frac{(.49 * \text{EQPT} + 135.8 * \text{SQFT} + 2.1 * \text{DLAB} + 1.3 * \text{MATS} + 1.3 * \text{UTIL})}{\text{QUAN}}$$

CALCULATION OF COSTS

QUAN is based on market share. We have assumed a facility which will supply 10% of the 1986 market or 133K m^2 annually.

QUAN = 133K

EQPT

45 hr/run @ 95% duty cycle = 47.37 hrs/run

95% yield x 455 wafers/run x .0079 m^2/wafer = 3.42 m^2/run

133K m^2 ÷ 3.42 m^2/run = 38.8 K runs required

Assuming a plant running 24 hrs/day, 365 days/year, available hr/saw = 8760

$$\frac{38.8\text{K runs x } 47.4 \text{ hrs/run}}{8760 \text{ hrs/saw}} = 210 \text{ saws required}$$

14 operators/shift

EQPT = \$42K x 210 saws = \$8820K

SQ FT = 36 sq ft/saw x 210 saws = 7.56K Sq Ft

DLAB = 14 operators x 8760 hrs x \$4.88/hr = \$598.5K

MATS

38.8K Blade Packs @ \$104.65	=	\$4060.4K
38.8K x 4 gals P C Oil @ \$5.08	=	788.4K
38.8K x 8 lbs abrasive @ \$1.99	=	617.7K
MATS	=	\$5466.5K

UTIL

210 Saws @ 1.5 KW = 315 KW

315 KW x 8760 hrs = 2759.4K KWH

2759.4K KWH @ $.035/KWH = $96.6K

UTIL = <u>$96.6K</u>

COST PROJECTION (1980 $)

$$\text{Price} = \frac{(0.49 * 8820K + 135.8 * 7.56K + 2.1 * 598.5K + 1.3 * 5466.5K + 1.3 * 96.6K)}{133K}$$

Price = $104.4/m^2

IPEG
1980 $