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RTG THERMOPILE GLASS BONDING
PROCESS DESCRIPTION (1D-W)

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RTG THERMOPILE GLASS BONDING PROCESS DESCRIPTION (1D-W)

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ABSTRACT

This report was written to provide a detailed description of the current glass bonding and associated processes that have been developed at Sandia Laboratories for the fabrication of one-dimensional, high-resistivity tungsten interconnect thermopiles (1D-W). It also provides the necessary information for transferring technology to the selected production agency. It describes operator techniques, material and equipment, documentation procedures, and methods of process and quality control, and includes drawings of tools and fixturing.

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GLOSSARY OF TERMS

(As Applied to the 1D-W Glass Bonding Process)

1. p-type SiGe Material - A semiconducting material (boron doped) whose conductivity is controlled by holes (positive charges).
2. n-type SiGe Material - A semiconducting material (phosphorous doped) whose conductivity is controlled by electrons (negative charges).
3. 1D-W - An abbreviation for one-dimensional tungsten interconnect.
4. Slug - A hot-pressed body of SiGe material (p or n) from which wafers are sliced.
5. Wafer - One slice of material from a p or n SiGe slug. (Drawing Nos. AY254232-35)
6. Oxidized Wafer - A SiGe wafer that has been thermally treated in an oxygen atmosphere to produce a thin oxide coating on its surface.
7. Wafer Batch - All the wafers sliced from a common slug.
8. Wafer Stack - A glass-bonded assembly consisting of 44 alternately stacked n and p wafers (Drawing No. AY294252).
9. Channel - One of the four sections obtained by slicing a wafer stack (Drawing No. AY294253).
10. Element - One of the 44 SiGe (n or p) components of a channel.
11. Thermopile - A glass-bonded assembly consisting of two channels. (Drawing No. AY254254)
12. Slurry - A paste composed of glass frit particles suspended in a liquid organic vehicle.
13. Glass Transfer Tape - A material used for depositing a uniform and controlled amount of glass frit on wafers. It is composed of four layers: plastic carrier layer, glass layer, adhesive film, and opaque backing.
14. Binder - The organic adhesive component of glass transfer tape and screen printing slurry which is used to bond glass frit to the wafers or channels during glass deposition operations.
15. Glass Frit - Small ($< 20\mu$) particles of glass.
16. First Bonds - The 43 CGW Code 7059 1-mil solid-glass layers that electrically insulate and bond the wafer stack.
17. Second Bond - The 4-mil solid-glass (CGW Code 7052) layer that joins and electrically insulates the channels.
18. Mil Equivalent of Glass - The theoretical thickness of a solid-glass layer that can be formed by the amount of glass frit deposited on the wafer.
19. Vacuum Hot Pressing - The technique used to thermally bond, under pressure, wafer stack and thermopile channels in a vacuum atmosphere.
20. Mica Shims - Cut and/or formed mica paper used to prevent extruded glass from adhering to alumina hot-pressing fixturing.
21. Clean Room - A temperature-controlled, air-filtered work area which meets Class 10,000 clean-room specifications (Fed-Std-209A).
22. Shorts - Any glass bond with a resistance less than 10 kilohms.
23. Voids - Holes in the glass bond.

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RTG THERMOPILE GLASS BONDING PROCESS DESCRIPTION (1D-W)

Wafer Stack and 1D-W Thermopile Glass Bonding Process

Forward

The objective of the 1D-W glass bonding development program was to develop a procedure for fabricating RTG thermopiles by bonding together SiGe thermopile elements and channels with mechanically strong, void-free, high-electrical-resistance and uniformly thick glass bonds.

Briefly, the 1D-W glass bonding process consists of the following steps. First, a uniform and controlled amount of glass frit (Code 7059 CGW) is deposited on one surface of cleaned and oxidized 80-20 SiGe, n and p wafers. A total of 44 n and p wafers (43 glass frit coated) are stacked alternately in an alumina fixture and then bonded into a wafer stack assembly by vacuum hot pressing. Next, the stack ends are ground to facilitate mounting of the stack for slicing. A Navian Automatic I.D. Slicer saw is used to slice the wafer stack into four thermopile channels. The one-dimensional thermopile is fabricating by bonding two thermopile channels together with Code 7052 CGW glass, using a vacuum hot-pressing technique. A schematic diagram and detailed process flow sheet are presented in Figures 1 and 2.

Figure 1. Schematic of glass bonding process

Figure 2. Wafer stack and thermopile glass bonding process flow sheet

Preparation of Wafers for Glass Frit Deposition

Introduction

Before sawing, SiGe (80-20) slugs are mounted on a lava-block sawing fixture with an epoxy cement. The slugs are then sliced into 0.007-inch and/or 0.014-inch-thick wafers.¹ A water-soluble blade lubricant is used in the sawing operation. If the lubricant is allowed to dry, a very adherent residue of lubricant and sawing debris remains on the surface of the wafer. Consequently, immediately after slicing, the mounted wafers are submerged in water until they can be thoroughly cleaned to remove sawing-operation contaminants. The cleaning and handling operations presented in this section are designed to remove organic and inorganic contaminants from parts and equipment and to reduce the possibility of contamination due to handling.

After cleaning, selected wafers are inspected for thickness, flatness, and defects such as cracks, chips or lips.² Following the inspection operation, selected wafers are weighed, thermally oxidized in an atmosphere of oxygen, and then weighed again. Repeated weighing was instituted to generate process control data. The cleaned wafer weight is used to obtain a close estimate of wafer thickness.³ The oxidized weight is used for oxidation and glass-frit-deposition process control. The oxidizing procedure was incorporated to reduce glass insulating bond defects, primarily shorts and voids.

1. "Wafer Slicing," Procedure 30.30.

2. "Wafer Inspection," Procedure IP101.

3. Memo R. L. Snodgrass, 1644, to R. D. Snidow, 7121-4, "Study of Relationships between Wafer Thickness and Weight," dated 12/22/72.

Cleaning and Handling -
Tools, Equipment and SiGe Wafers

Preliminary Information

1. Perform assembly and weighing operations in a class 10,000 clean room. Where size, equipment and conditions permit, perform cleaning, assembly and inspection operations on a Class 100 clean bench.
2. Unauthorized personnel shall not be allowed in the vicinity of critical areas (absolute filter, clean rooms, or laminar-flow workbench) at any time.
3. Prohibit smoking in the immediate vicinity of areas designated as critical.
4. Wrap cleaned parts in lint-free paper and/or store in clean plastic containers lined with lint-free paper and covered with protective lids.
5. Use monofilament nylon, rubber or approved plastic gloves during all processing steps.
6. All handling and adjusting tools within the dust-controlled enclosures shall be polished stainless steel, chrome-plated steel, anodized aluminum, or electroless nickel-plated steel. Ultrasonically clean all small adjusting tools and handling equipment used in critical areas in isopropyl alcohol. After tools have been ultrasonically cleaned, transport them to their respective dust-controlled enclosures in sealed plastic storage containers. Clean tools and fixtures too large for ultrasonic cleaning with lint-free paper, cloth, or plastic sponge, wet with reagent-grade isopropyl alcohol. Wipe the dust-controlled enclosures clean with a slightly moist plastic sponge.
7. Require all personnel assigned to the vicinity of the critical area to wear lint-free smocks and head coverings.
8. Use clean, dry nitrogen in the drying operations where specified. When the tank pressure drops below 500 psig, replace with a fresh tank.
9. Post the required processing instructions at all work stations.
10. Stress the vital importance of cleanliness and proper handling of components, since even minute contamination can seriously affect the electrical properties of the thermopile.
11. Maintain wafer, channel and thermopile identification throughout the entire cleaning and handling operations.
12. Perform all cleaning operations using acid solutions in a vented hood workbench.
13. Use wafer-handling tools with broad contact areas to reduce high stress concentrations at wafer-tool contact points.

Procedure

A. Cleaning of Trays, Glassware, Equipment

1. Process

- a. Prepare alcohol-water solution (see Appendix B).
- b. Wash the parts in liquid detergent and hot water. Use approximately 1/2 cup of liquid detergent (Joy, Wisk, or Ivory) per 10 gallons of water. This amount should be such that suds are kept to a minimum.
- c. Rinse the parts under hot running water.
- d. Place the parts in a clean stainless-steel pan with the alcohol-water solution and agitate, rinsing entire surface.
- e. After draining, blow the parts dry with dry nitrogen and place them upside down on clean surface.

B. Ultrasonic Cleaning

1. General

- a. Perform ultrasonic cleaning in the vented hood workbench.
- b. Maintain coupling fluid at a level equal to or slightly above the liquid level in the actual cleaning or rinsing container.
- c. Use glass beakers for cleaning containers.
- d. Completely cover parts being cleaned with at least one inch of the specified solvent during ultrasonic cleaning and rinsing.
- e. Remove parts or units from the cleaning solution while cavitation is occurring.
- f. Change the cleaning fluids in the cleaning containers after each load of parts has been cleaned, except as noted.
- g. Do not touch parts, cleaning baskets or fixtures with hands or gloves which come in contact with the outside of cleaning containers.
- h. When beakers containing different cleaning solvents are mounted in the same ultrasonic cleaner tank, take adequate measures to avoid the possibility of the cleaning solutions being mixed.
- i. Rinse the beaker in 25 to 30 milliliters of cleaning agent to be used, and discard, before using the beaker. Do not use beakers in which one type of cleaning agent has been used for a different type of cleaning agent before all residues of the first cleaning agent have been removed. Washing is the preferred cleaning process (Procedure A).
- j. For maximum efficiency, operate the ultrasonic cleaner 10 to 15 minutes before beginning cleaning each day.

2. Operation of Ultrasonic Cleaner

Tune the ultrasonic cleaner for maximum cavitation by setting the power control knob for maximum power output as indicated by the milliammeter. If

part damage is observed (chipping, cracking, etc), reduce the power setting as required.

3. Monitoring of Ultrasonic Cleaner (Aluminum Foil Test)

- a. Materials. Unquilted aluminum foil, approximately 0.001 inch thick (most household aluminum foil is the proper thickness), approximately 12 inches long by 4 inches wide.
- b. Procedure. Lower foil into the coupling liquid, not touching the sides of the tank. Within 1 minute (properly operating unit), the immersed portion of the foil should show work hardening, and small holes should appear.

C. Cascade Cleaning

1. Operation

- a. Adjust the reservoir water level to 1 inch below the top of the sight glass by adding distilled water.
- b. Turn on the circulating pump and adjust the flow rate to 25 gph.
- c. Turn on the immersion heaters. (Immersion heaters are preset to hold temperature of $160 \pm 5^{\circ}\text{F.}$)
- d. Allow 30 minutes for warmup.

2. Monitoring Cascade Cleaner

Proper functioning of the cleaning system is indicated by measurement of the resistance across the inlet and outlet of the unit. Resistance readings should be from 14 to 17 megohms.

3. Procedure

- a. Transfer the loaded teflon fixture into a stainless-steel wire basket.
- b. Check to see that the cascade cleaner water temperature is 160°F.
- c. Read the resistance at the water inlet and outlet on the monitor gage. (The acceptable reading range is 14-17 megohms.)
- d. If the water temperature and resistance are acceptable, place the wire basket containing the fixture in the tank compartment having the lowest level of water.
- e. At the end of 1 minute, provided the resistance is within acceptable range (14-17 megohms) and water temperature is 160°F. , move the fixture to the next tank compartment for one minute.
- f. Continue this process through all five tank compartments. If at any time an unacceptable water resistance or temperature reading is obtained, check the cascade cleaner for malfunction. If it is functioning properly, repeat all cleaning procedures.

D. Cleaning of n and p Wafers

1. General

- a. Transfer the glass jar containing the water-covered, sliced and mounted wafers to the cleaning area.
- b. Forward the attached traveler covering chill casting, hot pressing, and slicing to the responsible engineering organization.
- c. Place a labeled, clean, covered, plastic container lined with lint-free paper in the cascade cleaner clean bench.
- d. Wafers are received and kept in glass containers, completely submerged in water, until they are cleaned. Cleaning is normally performed within 24 hours of the sawing operation. Wafers may be physically identified as shown in Figure 3.

2. Procedure

- a. Remove the lava-block sawing fixture and wafers from the storage jar and place them in a 600-ml glass beaker.

- b. Cover the wafers with clean distilled water and ultrasonically clean for 3 minutes. Drain off the water and repeat this procedure 2 more times (3 total).
- c. Load the teflon cleaning fixture (Figure 4) with wafers sliced from a common slug.

Figure 4. Loading wafer cleaning fixture

- d. Place the fixture containing the wafers into a 600-cc glass beaker.
- e. Make a solution of 1:1 (by volume) glacial acetic acid and distilled water (add the acid to the water).
- f. Cover the wafers with the acetic acid solution and place the beaker in the ultrasonic cleaner for 5 minutes.
NOTE: Clean 0.014-inch-thick wafers for 15 minutes.
- g. Transfer the loaded fixture to another clean beaker.
- h. Rinse the wafers three times with clean distilled water.
- i. Cover the wafers with clean distilled water, and ultrasonically clean for 1 minute.
- j. Drain off the distilled water, cover the wafers with ethyl alcohol, and ultrasonically clean for 1 minute.
- k. Remove the loaded fixture from the ultrasonic cleaner and transfer it to a clean beaker.

- l. Make a solution of 1:1 (by volume) hydrochloric acid and distilled water (add acid to water).
- m. Pour the solution into the beaker to cover all the wafers and allow them to soak for 10 minutes.

CAUTION: DO NOT ULTRASONICALLY CLEAN WITH THIS SOLUTION.

- n. Place the loaded fixture in a clean beaker and rinse 3 times with clean distilled water.
- o. Cover the wafers with clean distilled water and ultrasonically rinse for one minute.
- p. Cascade clean per Procedure C.
- q. Place the fixture containing the clean wafers under the infrared heaters until dry (about 10-15 minutes).
- r. Transfer the wafers into a clean (Procedure A) plastic container lined with lint-free paper, and seal the container with its plastic cover.

NOTE: Limit 30 wafers per container; place in 3 rows of 10 each.

- s. Using a ballpoint pen, mark the slug number and wafer type on the container and cover labels.
- t. Transfer the container of wafers to the clean room and place it on the clean bench for inspection.*

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Ultrasonic Cleaner	(A-1)
2. Acid Sink and Fume Hood	(A-2)
3. Cascade Cleaner	(A-3)
4. Water Still	(A-4)
5. Teflon Fixtures	(A-5)
6. 600-cc Glass Beakers	(A-6)
7. Plastic Containers	(A-7)
8. Rubber-covered Tweezers (Sandia)	(A-8)
9. Stainless-steel Wire Basket	(A-9)
10. Plastic Gloves	(A-10)
11. Wide-mouth Glass Jar	(A-11)
12. Stainless-steel Trays	(A-69)

*"Wafer Inspection, " Procedure IP101.

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Distilled Water	(B-1)
2. Glacial Acetic Acid	(B-2)
3. Hydrochloric Acid	(B-3)
4. Ethyl Alcohol	(B-4)
5. Lint-free Paper	(B-5)
6. Isopropyl Alcohol	(B-23)
7. Alcohol-water Solution	(B-24)
8. Nitrogen	(B-25)
9. Coupling Fluid	(B-26)

Drawings

NOTE: See Appendix C for complete drawing.

1. Cleaning Fixtures, Drawing No. SK203
2. Wire Basket, Drawing No. SK210
3. Wafers, Drawing Nos AY294232, 294233, 294234, 294235.

Weighing and Oxidizing of n and p Wafers

A. Weighing of Clean Wafers

Preliminary Information

1. All operations are performed in the clean room. In addition to normal clean room attire, the technician wears disposable plastic gloves during wafer and fixture handling operations.
2. Individual wafer identity must be maintained through the wafer stack assembly procedure; therefore, care must be taken to maintain the assigned numerical order for the wafers.
3. Obtain a new Glass Deposition Data Sheet with attached "Quartz Boat Map" and place them on the balance table. (See Appendix D, Figures D-2 a-b and D-3.)

Procedure

1. Check and zero the balance as follows:
 - a. Dust the balance pan with a soft bristle brush and/or a rubber dusting bulb.
 - b. Set all balance weight dials to zero and then release the balance pan. Allow the balance to warm up for a minimum of 15 minutes with the pan hanging free.
 - c. Lock the balance pan. Using tweezers, place the master weight on the pan. Release the pan and weigh the master weight.
 - d. If necessary, use the zeroing knob to adjust the balance to read the certified master weight.
 - e. Lock the pan, remove the master weight and then proceed with the weighing of specimens.
 - f. Repeat steps c through e after a maximum of every 10 weighings. Dust after each weighing.
2. Enter the date and slug number in the appropriate locations on the Glass Deposition Data Sheet.
3. Before weighing, all wafers from a common slug (p or n) are arranged in their container(s) in sequence as shown in Figure 5. Write the wafer number in ink on the lint-free paper adjacent to the wafer.

Figure 5. Wafer layout in container

4. During the weighing operation, all wafers are handled with a vacuum pickup tool. Under normal operating conditions, the first five wafers and every fifth wafer thereafter will be weighed. Starting with wafer number 1:
 - a. Remove the wafer and place it on the balance pan.
 - b. Close the balance door and weigh the wafer to the nearest 0.01 milligram (5th decimal place).
 - c. Record the clean wafer weight in the appropriate column and position on the Glass Deposition Data Sheet.
 - d. Return the wafer to its initial location in the container. The operation is continued until all the designated wafers from a common slug are weighed.
5. After the weighing operation is completed, the oxidizing procedure may be initiated or the wafers may be stored in their closed containers.

B. Wafer Oxidizing Process

Preliminary Information

1. The fused quartz boat and alumina oxidizing fixtures are cleaned before the oxidizing operation if necessary. The cleaning operation need not be performed

each time if the fixturing and boat are handled with gloved hands and if precautions are taken to prevent particles from contaminating the inside faces of the boat cover, boats, and the fixturing. Clean per 40:01-01, Procedure A.

2. Locate the plastic box(es) containing the clean weighed wafers and their associated Glass Deposition Data Sheet(s) and Quartz Boat Map form(s) on the clean bench. Also, place a fused-quartz boat and the required oxidizing fixtures on the bench.

Procedure

1. With rubber-coated tweezers, the wafers from the preceding operation are removed sequentially from their plastic container(s) and mounted in marked alumina fixtures as shown in Figure 6.

Figure 6. Loaded oxidizing fixture

Wafer number 1 is placed in the slot closest to the marked end of the fixture. The remaining wafers are mounted sequentially in the remaining slots. If the number of wafers (from the same slug) exceeds the number of fixture slots, sequential loading continues in additional fixtures starting at the marked ends.

CAUTION: Since the loading procedure is designed to maintain the identity of the slug number, type, and the wafer number, use caution during the sequential loading and unloading process. Place only one type of wafer (p or n) sliced from a common slug in the fixtures.

2. Place the loaded alumina fixtures in the fused-quartz boat. Wafers from more than one slug can be oxidized at one time. Fixtures are loaded into the boat and mapped as shown in Figure 7.

NO. _____		NO. _____
SLUG NO. _____		SLUG NO. _____
NO. _____		NO. _____
NO. _____		NO. _____
SLUG NO. _____		SLUG NO. _____
NO. _____		NO. _____
NO. _____		NO. _____
SLUG NO. _____		SLUG NO. _____
NO. _____		NO. _____

Figure 7. Loaded quartz boat - Quartz boat map

3. Slide the covered, loaded boat into the oxidizing furnace. Mate the quartz boat oxygen manifold opening with the quartz oxygen supply tube.
4. Close the furnace door and then turn on and adjust the flow meter to a flow rate of 10 ± 1 CFH of oxygen.
5. Turn on the furnace and activate the cam-operated recorder-controller. The furnace is programmed for the following temperature cycle
 - a. 0 to 950°C at $300^{\circ} \pm 25^{\circ}$ per hour
 - b. Hold at $950^{\circ}\text{C} \pm 15^{\circ}$ for 2 hours.
 - c. Furnace shut off after 2 hours ± 15 minutes at 950°C .
6. Allow the furnace to cool to below 75°C . Remove the covered boat and transfer it to the balance table for the next weighing operation.

C. Weighing of Oxidized Wafers

Preliminary Information

1. The vacuum pickup tool or rubber-coated tweezers are used during all wafer handling operations.
2. Obtain the Glass Deposition Data Sheet(s) and labeled plastic container(s) that match the slug number(s) listed on the Quartz Boat Map and place them on the balance table.

Procedure

1. Repeat the balance check procedure as prescribed in Section A, "Weighing of Clean Wafers."
2. In accordance with the Quartz Boat Map for orientation, the wafers are sequentially removed from the oxidizing fixtures and
 - a. are weighed and returned to their original positions in the plastic containers before oxidation, or
 - b. are returned directly to their original position in the container before oxidation.
3. Using the Glass Deposition Data Sheet for identification, reweigh the wafers that were weighed before the oxidizing procedure. The following procedure is used
 - a. Remove the wafer from the fixture and place it on the balance pan.
 - b. Close the balance door and weigh the wafer to the nearest 0.01 milligram (5th decimal place).
 - c. Record the oxidized wafer weight on the Deposition Data Sheet adjacent to the clean wafer weight of the wafer being processed.
 - d. Transfer the weighed oxidized wafer to its previously designated position in the container.

4. Upon completion of the weighing and transferring operation, the plastic containers are closed and then stored until they are needed for the next operation, glass deposition.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Plastic Gloves (disposable)	(A-10)
2. Balance	(A-12)
3. Vacuum Pickup Tool	(A-13)
4. Fused-quartz Boat	(A-14)
5. Alumina Fixtures (Sandia)	(A-15)
6. Rubber-coated Tweezers	(A-8)
7. High-temperature Furnace	(A-16)
8. Cam-operated Controller-recorder	(A-17)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Detergent	(B-6)
2. Distilled Water	(B-1)
3. Ethyl Alcohol	(B-4)
4. Oxygen	(B-7)

Drawings

NOTE: See Appendix C for complete drawings.

1. Oxidizing fixture, Drawing No. SK207
2. Wafers, Drawing Nos. AY294232, 294233, 294234, 294235
3. Quartz Boat and Cover, Drawing No. SK208

Glass-Frit Deposition Techniques

Introduction

Two processes have been developed for depositing a reproducible, uniform and measured coating of glass frit on SiGe wafers.

The primary procedure is the screen printing process. Screen printing is used to deposit a slurry containing glass frit onto one side of cleaned and oxidized SiGe wafers. This method was selected for the glass bonding development program because it is commonly used for depositing coatings of this nature on various substrates. It was selected as the primary production procedure because it was found that, after initial setup and adjustment, it was a rapid procedure for applying a uniform coating of glass frit. In addition, the amount of glass deposited can be controlled within a narrow tolerance range with minor equipment adjustments.

The use of glass transfer tape for depositing a coating of glass frit was also found to be a feasible production method. Although screen printing is potentially a much faster coating method, the tape technique is simple, requires no expensive tooling, and has the desirable feature of built-in control over the amount of frit deposited. The glass-transfer-tape technique is still being evaluated as an alternate approach for frit deposition.

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Screen Printing

A. Preliminary Information1. Screen Printer

The important parts of the printer are shown in Figure 8. Before operation, the printer must be checked for parallelism between the substrate carriage (1), vacuum chuck (2), the machined surfaces of the screen (3), and the frame and slides of the squeegee mechanism (4). Suitable shims or readjustments should be used to maintain parallelism within 0.001 inch.

Figure 8. Presco Model 100 screen printer

This printer is air actuated. Filtered compressed air at 60 psi is used for the horizontal movement and at 15 psi for the vertical movement of the squeegee (5). The horizontal travel rate of the squeegee is adjusted by means of the valves (6) provided at the back, which are set to allow the squeegee to travel at a rate of about

2 inches per second for printing and return. The timer (D) is adjusted to allow the squeegee full travel of the screen mask opening with some pre- and post-contact of the screen. The printer should be operated in a Class 100 laminar flow clean bench. The Presco printer control box is shown in Figure 9.

Figure 9. Presco printer control box

2 Screens

The printer uses 3- x 5-inch screens of 105 mesh. This mesh size has been found to be proper for printing the required amount of glass coating in the present application. Other mesh sizes also are available for glass slurries of differing composition and viscosity. A screen mask is required and is applied by a photochemical process using Ulanocron, Red RX200 direct emulsion.

NOTE Masks are prepared by the Sandia Photofabricated Components Lab in accordance with Process No. 131 (see Appendix C).

The screen mask opening, as shown in Figure 10, is made slightly smaller (e.g., 0.008 inch smaller) than the wafer dimension so that slurry is not printed on the edge of the wafer. Randomly deposited excess slurry causes less precise coating weights and contaminates the surface of the vacuum chuck, making wafer removal more difficult. When the mask wears sufficiently around the edge of the opening to cause excess slurry to be deposited on and around the wafer edge, the resist should be removed and a new mask prepared. Similarly, if the screen tension becomes too low, the screen should be discarded.

Figure 10. Screen with mask

3. Screen Tension Meter

A screen tension meter suitable for monitoring screen tension is shown in Figure 11. As the screen tension decreases, printing quality is lowered because the screen does not snap back from the wafer after printing. When the resiliency of the screen becomes too sluggish, the surface of the slurry coating is degraded.

Figure 11. Screen tension meter

The tension meter may be used for predicting when the screen should be replaced before poor quality is obtained. The meter reading must be calibrated against printing quality. For operation, the meter is placed above the screen while mounted in the printer. The foot is placed on the screen surface at the mask opening. The 500-gram weight is placed on top of the dial indicator and the foot is lowered, depressing the screen until the dial reading is zero. This is accomplished by rotating the height-adjusting screw counterclockwise. The weight is then removed and the dial reading noted. The difference in dial readings in mils is a measure of the screen deflection caused by a load of 500 grams. The screen deflection under this same load will increase as the screen loses its tension during use. A typical life curve is shown in Appendix D, Figure D-4.

4. Squeegee

The squeegee is made of Viton plastic. This material swells only negligibly from the chemicals in the glass slurry and is therefore preferred to polyurethane squeegees. The squeegee edge must be straight and parallel to the wafer substrate when mounted in the squeegee holder. The squeegee edge should be monitored periodically for wear, and the piece either rotated to a new edge or replaced with a new piece when the edge shows wear such as to affect printing quality.

5. Vacuum Chucks

The construction of the vacuum chuck for holding wafers for printing is described in Appendix C, Drawing No. SK202. AISI-01 ground-flat stock was used for the chuck rather than stainless-steel, since grinding tolerances could be held more closely. It may be necessary occasionally to wipe the chuck with an oily cloth to prevent rusting. Wipe the chuck clean before printing wafers.

6. Viscometer

A Brookfield Synchro-Electric Viscometer, Model HBT, with SC4-14 spindle running at 10 rpm has been found suitable for use. Since the glass slurry used is so thick, care must be taken that the slurry does not separate and form a gap between the slurry on the rotating spindle and that on the inner periphery of the sample container. Low and nonreproducible readings will be obtained if this happens.

7. Analytical Balances

A suitable balance is the Mettler No. 54 Analytical Balance for weighing to 5 decimal places (nearest 0.01 milligram).

8. Glass Slurry

The glass slurry must be compounded as to glass content and viscosity so that the desired amount of glass can be deposited, using machine settings within the range of adjustments of the machine to be used. In the present application, the slurry consists of about 63.8 weight percent Corning No. 7059 glass powder (5-micron average particle size) in Texanol vehicle. (Texanol is reported to be 2, 2, 4 trimethyl pentane diol mono isobutyrate.) The viscosity of this material as received and without the addition of thinner was measured as 2600 stokes at 23°C using the viscometer described above.

9. Wafers, Forms and Fixtures

Transfer the plastic container(s) previously loaded with oxidized and weighed SiGe wafers and the associated Glass Deposition Data Sheet(s) from storage to the clean bench (Appendix D, Figure D-2, a and b.) Locate clean binder burnout fixtures (quartz plate and ceramic spacers) on the balance table.

B. Determination of Printing Parameters

1. Introduction

The amount of glass slurry printed onto the wafer depends upon the screen mesh size, slurry viscosity, the squeegee pressure, and the breakaway distance. For a particular batch of glass slurry, whose viscosity may be considered constant if the containers are kept tightly closed, the machine parameters, once established, can normally be used for printing all of this batch of slurry. As discussed below, only minor adjustments in squeegee pressure will then be required. Typical parameters for printing glass slurry coatings in the range of 67.3 to 73.0 mg as required for the present application are as follows:

Glass slurry 63.8 o/w, Corning No. 7059 glass

Viscosity (10 rpm) 2600 stokes, 23°C

Screen mesh size 105

Breakaway distance 0.024 inch

Squeegee pressure 0.000 inch to 0.005 inch

NOTE: Enter preliminary screen printing information as shown in Appendix D, Figure D-2a.

The weight of printed glass slurry varies as follows:

	<u>Coating Weight</u>
Breakaway distance increases	Increases
Squeegee pressure increases	Decreases
Screen mesh size increases (lower number)	Increases

The coating weight printed is very sensitive to changes in squeegee pressure; this variable is easiest to change while printing, since the graduated, pressure-adjusting

knob on the squeegee mechanism may be quickly turned to produce an increase or decrease in squeegee pressure.

2. Calculation of Required Glass Slurry Coating Weight

The required weight of glass slurry coating on the wafer may be calculated with sufficient accuracy from the following general formula. This formula gives the weight of slurry coating to provide a one-mil thickness of pure glass on a given size of wafer and for a particular Corning glass composition. The coating weight per mil is multiplied by the required glass thickness in mils to obtain the desired slurry coating weight to be printed.

Wt. slurry/mil glass, mg

$$\frac{(L \text{ in.} \times W \text{ in.} \times 0.001 \text{ in.} \times 16.39 \text{ cc/cu. in.}) (\text{glass density g/cc}) \times 10^5}{\text{Wt. \% glass in slurry}}$$

The weight percent glass in the slurry is determined on the coated wafers by burning out the binder and determining the weight loss of the glass coating

Example (present application)

For a mask opening size of 1.167 inches x 0.692 inches, glass density 2.75 g/cc and 63.8 Wt. % glass in the slurry, the required glass-slurry coating weight range to yield glass bonds in the range of 1.18 to 1.28 mils thick is 67.3 to 73.0 mg.

NOTE The equivalent glass-thickness range of 1.18 to 1.28 mils has been found optimum to allow some extrusion of glass during hot pressing of the wafer stack and to ensure that a void-free, 1-mil glass bond is obtained.

3. Setting the Breakaway Distance

The breakaway distance is the spacing between the top of the wafer and the bottom of the screen before printing. Typical distances are 0.020 inches to 0.030 inches. The breakaway distance can be set accurately by means of a shim which is the same size as the wafer and of a thickness equal to the wafer thickness plus the desired breakaway distance. The shim is placed on the vacuum chuck and the screen is brought within about 0.0005 inch of the shim surface by means of the rear vertical adjustment screw (9), which is located behind and below the screen frame, and the two vertical adjustment screws (7) at the front. Care must be taken to adjust the screen parallel to the wafer. The spacing can be observed from the side by viewing against an illuminated white background. Covering the screen top surface with a lint-free cloth to shut out the light aids in viewing the spacing. At this point, the front and rear vertical adjustment

screws are moved only a minimum distance so the shim and screen are just touching. The adjustment screws are then locked in place.

4. Setting the Squeegee Pressure (Figure 12)

Figure 12. Squeegee pressure adjusting assembly

The squeegee pressure is determined by the vertical travel of the squeegee after it depresses the screen and the screen just touches the wafer (this is defined as zero pressure). The vertical travel is adjusted (relieve compressed air pressure during this operation) by loosening the locking nut and, while applying slight hand pressure on the knob of the adjusting screw, turning the graduated dial until the squeegee depresses the screen sufficiently so that it just touches the wafer. The locking nut is then tightened. The setting should then be verified by raising the squeegee mechanism and snapping it down against the stop with slight hand pressure while watching the contact at the wafer surface. This action simulates that occurring when the squeegee mechanism is actuated by air pressure. Turning the graduated dial one division down from the zero position, as measured on the graduated dial, increases the vertical travel 0.001 inch and hence the squeegee pressure (since the squeegee is slightly compressed). Since the vertical travel distance (0.001 inch per division) is related to the squeegee pressure, this travel distance from the zero position has been used to represent pressure values for reference purposes. Always tighten the locking nut after making pressure adjustments.

NOTE The squeegee mechanism was modified by replacing the squeegee pressure-adjusting knob with a 50-division graduated dial (see Appendix C, Drawing No. SK214). For ease of reading, every tenth graduation was numbered and the graduation mark made longer than the others. Each graduation mark represents 0.001-inch vertical travel, since the screw has 20 threads per inch and the dial is divided into 50 equal divisions. A clear piece of plastic with a reference line inscribed was bonded to the front of the mechanism for use in setting the pressure accurately.

5. Determining the Proper Machine Settings

The proper machine settings are determined by printing weighed wafers and determining the printed-coating weight at each of several machine settings. Once the screen size, squeegee pressure, and breakaway distance have been determined for a given slurry batch, small changes in the printed-slurry weight can be obtained by changing the squeegee pressure. Normally the squeegee pressure should be no greater than 0.005 inch. Negative pressures up to 0.005 inch may sometimes be helpful in obtaining the proper slurry-coating weight, but the reproducibility of printing may be reduced.

NOTE Printed wafers used for setting machine operating parameters may be reused for setup purposes after cleaning in alcohol and drying.

In the above procedure it is assumed that the viscosity of the glass slurry does not change appreciably. The viscosity should be checked periodically, such as once

a week; it also should be checked if the proper coating weight cannot be printed within the limit of the machine settings.

C. Wafer Printing Procedure

1. Turn on the electrical switch on the printer control box (Figure 9), and adjust the air pressure to 60 psi on the input air gauge (C). Exercise the squeegee mechanism several times with the squeegee set off the screen and verify that the control valves are set properly as described above. Turn on the pump to the vacuum chuck.
2. Wearing plastic gloves and using the rubber-coated tweezers or vacuum pick-up tool, place a set-up wafer on the vacuum chuck. Position the wafer accurately against the stops, then turn on the vacuum valve (Figure 8, #8).
3. With the compressed air valve (C) temporarily closed, push the substrate carriage (1) under the screen. Set the squeegee pressure to zero as discussed above, and then adjust the graduated dial to give the estimated proper squeegee pressure value. The breakaway distance is assumed to be set properly from a previous run. If not, it may also have to be reset as discussed above. Retract the carriage and turn on the compressed-air valve.
4. Place about 1cc of slurry just back of the screen mask opening, using a teflon spatula. Close the squeegee holder and lock the latch (10).
5. Push the substrate carriage under the screen to print the wafer. Repeat Steps 4 and 5 with at least 5 set-up wafers to saturate the screen with slurry and to verify that the slurry coating completely covers the top surface of the wafer and is uniform. Adjust the wafer position with the X-Y micrometer adjusting screws (11), if necessary, to better align the wafer with the screen mask. After each printing, scrape the slurry from around the screen mask opening and the squeegee with the spatula, and reapply it just behind the back edge of the opening in the screen as before. Fresh slurry should be added as needed, but only a minimum should be applied.

NOTE: Do not scrape the slurry from the screen mask opening between prints or otherwise disturb it because the coating weight printed will be adversely affected. If removal of slurry from the mask opening is necessary for some reason, Step 5 will have to be repeated to saturate the screen with slurry before reproducible prints can be obtained.

NOTE: Since the slurry dries out in the air of the clean bench, the bulk of the slurry on the screen and squeegee (not in the mask opening) should be removed with the spatula and replaced with fresh slurry every 5 to 10 wafers printed. Excess slurry and dried slurry should not be allowed to accumulate on the apparatus or tools.

NOTE Partial drying of the slurry in the screen mask opening affects the weight of slurry printed on the next wafer. Hence it is advisable not to interrupt the printing operation between wafers by more than a minute, preferably less. If delay is necessary, resaturation of the screen as in Step 5 above will be required. It is recommended that one operator print and another operator weigh for most efficiency in screen printing.

NOTE The surface of the vacuum chuck must be kept clean and free of dried slurry. Wipe with a clean lint-free cloth and alcohol.

6. Position an oxidized and weighed set-up wafer in the vacuum chuck, using the vacuum pickup tool or rubber-coated tweezers, and print as above. Remove the wafer with a teflon or nylon spatula or the tweezers.

NOTE Zero and check the balance as described in 40 01-02,
"Weighing and Oxidizing of n and p Wafers."

Weigh the slurry-coated wafer to verify by calculation that the proper coating weight (weight difference between printed and unprinted wafer) has been printed. If the coating weight is proper, place the coated set-up wafer aside for cleaning and reuse. If the weight is not correct, clean the wafer and reprint, or print at least two more weighed set-up wafers to verify proper coating weight. If the coating weight is low after printing three wafers, lower the squeegee pressure by 0.001 inch and print again. If the coating weight is too high, increase the squeegee pressure by 0.001 inch and reprint. Repeat this process until the proper coating weight is obtained on three wafers.

NOTE At the start of printing it is not advisable to adjust the squeegee pressure too soon if the coating on the first wafer printed does not have the proper weight. Print at least three wafers to obtain an average coating weight or to see a trend upward or downward in the coating weight as the machine stabilizes.

7. When the machine is printing properly, proceed to print oxidized production wafers.

NOTE Once the machine has stabilized, only small changes of 0.0005 inch or 0.001 inch in squeegee pressure are normally required to bring the printed-coating weight within the set limits should the slurry weight drift to these limits.

NOTE Individual wafer identity must be maintained through the binder burnout procedure, therefore, care should be taken to maintain existing numerical order for identifying wafers.

8. The oxidized production wafers are removed, one at a time, in numerical order from their container and:
 - a. are printed, weighed and then transferred to the binder burnout fixture, or
 - b. are printed and transferred directly to the burnout fixture.
9. Only those wafers that are weighed after cleaning and oxidation are reweighed after printing. The following procedure is used:
 - a. Remove the wafer from the vacuum chuck and place it on the balance pan.
 - b. Close the balance-pan door and weigh the printed wafer to the nearest 0.01 milligram (5th decimal place).
 - c. Enter the weight in the appropriate column and position of the Glass Deposition Data Sheet.
 - d. Transfer the printed wafer to its prescribed location on the quartz plate.
10. The binder burnout fixture loading and stacking operation is shown in Figure 13.

Figure 13. Loading of binder burnout fixture (wafers)

- a. Using a high-temperature grease pencil, label each quartz plate, as shown, with the following:
 - (1). Slug number at the top of the plate.
 - (2). Wafer number in the extreme lower left corner of the plate.
- b. Arrange the wafers in three rows, as shown for a total of 15 wafers per plate.

- c. Place only one type of wafer (sliced from one slug) on each plate.
 - d. After the first quartz plate is filled with wafers, place the loaded quartz plate into the fused-quartz boat. Place a 3/16-inch-high alumina spacer at each corner of the quartz plate.
 - e. Repeat operations a through d until all wafers have been processed.
11. A total of six filled quartz plates can be stacked in the quartz boat. The seventh plate (cover plate) is an empty quartz plate. When the stacking operation is completed, place the fused-quartz lid on the boat.
 12. When all wafers of a batch (e.g., p wafers) have been printed, proceed immediately to the next group (e.g., n wafers).
 13. When all wafers have been printed, scrape the slurry from the screen, screen opening, squeegee and tools, and wash them with ethyl alcohol and a clean lint-free cloth.
 14. For reference and screen-control purposes, measure the screen tension with the tension meter while the screen is in place on the printer. Record the total number of wafers printed on that screen to date and the tension meter reading on the graph as shown in Appendix D, Figure D-4.
 15. Place empty plastic containers with associated Glass Deposition Data Sheets in storage until required for the post-burnout weighing operations.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Screen Printer	(A-24)
2. Screens for Presco Model 100 Printer	(A-25)
3. Screen Tension Meter	(A-26)
4. Vacuum Chuck	(A-27)
5. Viscometer	(A-28)
6. Analytical Balance	(A-12)
7. Rubber-coated Tweezers	(A-8)
8. Teflon or Nylon Spatulas	(A-29)
9. Polyethylene Squeeze Bottle	(A-30)
10. 4-inch-diameter Petri Dish	(A-31)
11. Plastic Boxes	(A-7)
12. Quartz Plates	(A-22)
13. Aluminum Spacers	(A-23)
14. Clean Plastic Throw-away Gloves	(A-10)
15. Quartz Boat	(A-14)
16. Quartz Cover	(A-33)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Glass Slurry	(B-8)
2. Thinner for Glass Slurry	(B-9)
3. Lint-free Cloths	(B-10)
4. Lint-free Paper	(B-5)
5. Ethyl Alcohol	(B-4)
6. Screen Mask Emulsion	(B-11)
7. Viton Squeegee Material	(B-12)

Drawings

NOTE: See Appendix C for complete drawings.

1. Vacuum Chuck, Dwg. No. SK202
2. Tension Meter, Dwg. No. SK201
3. Squeegee Adjustment Knob, Dwg. No. SK214
4. Screen and Mask, Dwg. No. SK205
Process Sheet PC-131 Attached
5. Spatula, Dwg. No. SK206
6. Spacers - Breakaway Adjustment, Dwg. No. SK209
7. Quartz Boat and Cover, Dwg. No. SK208
8. Binder Burnout Fixture, Dwg. No. SK213

Glass Tape Application Process

Preliminary Information

1. In addition to normal clean room attire, the technician wears disposable plastic gloves and uses rubber-coated tweezers or the vacuum pickup tool during all wafer- and fixture-handling operations.
2. Prepare an 8-1/2- x 11-inch paper place mat for the tape-cutting operation. Poster board or manila folder paper is adequate.
3. All wafer-taping operations are performed in a Class 100 laminar-flow clean bench.
4. Transfer the plastic container(s) previously loaded with oxidized and weighed SiGe wafers and the associated Glass Deposition Data Sheet(s) from storage to the clean bench.
5. Remove the glass-tape container from storage and locate it on the clean bench. The glass tape should be stored in a dust-proof container when not in use.
6. Locate clean binder burnout fixtures (quartz plates and ceramic spacers) on the balance table. After initial cleaning, quartz plates need not undergo the full cleaning process before each binder burnout operation. An ethyl-alcohol wipe before loading is sufficient.

Procedure

1. The width of the glass tape roll is 8 inches. Unroll a short length (~ 6 inches) of tape onto the paper mat. Using a razor blade and straight edge, cut a 1-1/2-inch-wide strip of tape across the width of the roll.

NOTE The surface under the place mat should be flat and clean.

2. Remove the opaque backing from the tape to expose the adhesive surface of the tape and a portion of the clear carrier layer (edges). Figure 14 shows a cross section of the glass transfer tape.

Figure 14. Cross section of glass transfer tape

3. CAUTION: Individual wafer identity must be maintained through the binder burn-out procedure; therefore care should be taken to maintain existing numerical order for identifying wafers. With this in mind, sequentially transfer 8 wafers (starting with wafer number 1) to the adhesive portion of the tape strip. Using a ballpoint pen, write the number 1 on the clear carrier layer adjacent to wafer number 1. Figure 15 shows the layout of wafers on the tape strip.

Figure 15. Layout of wafers on tape strip

4. Gently press each wafer against the glass tape with a gloved finger. Use enough pressure to insure that a good bond is formed between the wafer and the adhesive layer.
- Starting with the first wafer, use a razor blade to cut through the glass tape along the four edges of the wafer.
 - Pick up the wafer with the tweezers and place it between the thumb and forefinger of the free hand. Grip the wafer edges with the thumb and forefinger.
 - Using the tweezers, peel off the clear carrier layer as shown in Figure 16.
 - Return the wafer, tape side up, to its proper location in the plastic container.
 - Repeat Steps a through d for all 8 wafers.

Figure 16. Removal of carrier layer

5. Continue the taping procedure, as described in Steps 1 through 4, until all the wafers have been taped and replaced in their container(s). Return the glass tape roll to its dust-proof container.
6. Transfer the loaded container(s) to the balance table for the weighing and fixture-loading operations.
7. Enter the necessary glass-taping data in the proper locations on the Glass Deposition Data Sheet forms.

8. Locate a clean quartz plate on the balance table in preparation for the wafer weighing and transferring operation.
9. Zero and check the balance as described in 40:01-02, "Weighing and Oxidizing of n and p Wafers."
10. The wafers are removed, one at a time, in numerical order from the container and:
 - a. are weighed and then transferred to the quartz plate, or
 - b. are transferred directly to the quartz plate.
11. Only those wafers that were weighed after cleaning and oxidation are reweighed after taping. The following procedure is used:
 - a. Using rubber-coated tweezers or the vacuum pickup tool, transfer the wafers from the container to the balance pan.
 - b. Close the balance door and weigh the wafer to the nearest 0.01 milligram (5th decimal place).
 - c. Enter the weight in the appropriate column and position on the Glass Deposition Data Sheet.
 - d. Transfer the wafer to its prescribed location on the quartz plate.

NOTE: Refer to Steps 10, 11, and 15 in "Screen Printing," Operation 40:02-01 for a detailed description of the wafer loading procedure for binder burnout fixtures.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Laminar-flow Clean Bench	(A-18)
2. Clean Plastic Gloves	(A-10)
3. Rubber-coated Tweezers	(A-8)
4. High-temperature Grease Pencil	(A-19)
5. Razor Blade	(A-20)
6. Steel Straight Edge	(A-21)
7. Quartz Plates	(A-22)
8. Alumina Spacers	(A-23)
9. Quartz Boat	(A-14)
10. Vacuum Pickup Tool	(A-13)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Glass Transfer Tape (2 mil)	(B-13a)

Drawings

NOTE: See Appendix C for complete drawings.

1. Binder Burnout Fixture, Dwg. No. SK213
2. Quartz Boat, Dwg. No. SK208

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Preparation of Coated Wafers for Vacuum Hot
Pressing Into Wafer Stacks

Introduction

After the glass-frit deposition operation is completed, the Texanol vehicle in the screen printing slurry and the adhesive layer on the glass frit must be removed. The coated wafers are placed in a covered fused-quartz boat and then heated in an oxygen atmosphere to burn out the organic binders. Complete combustion of these materials reduces the probability of voids and, possibly, low-resistance shorts in the glass bonds. Weighing of wafers was instituted to generate process-control data. Pre- and post-binder burnout weights are used to calculate the percent glass and percent binder of the glass slurry or transfer tape and the amount of frit deposited on the wafer.

Following the post-binder burnout weighing, the required data are transferred from the Glass Deposition Data Sheet to computer paper tape. The data is then entered into the computer for analysis. If the analysis shows that the coated wafers are within prescribed tolerance limits, they are released for production use.

Before assembling a wafer stack, all the alumina hot-pressing fixtures and spacers are cleaned, if necessary, to remove any foreign material and/or stains. Next the coated wafers are stacked in a wafer-stack hot-pressing fixture. Subsequently, the assembled wafers are bonded together with a vacuum hot-pressing technique.

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Binder Burnout and Weighing - Wafers

Preliminary Information

1. All operations are performed in the clean room. In addition to normal clean room attire, the technician wears disposable plastic gloves during wafer and fixture handling operations.
2. Transfer empty, labeled plastic containers with the associated Glass Deposition Data Sheet(s) from storage to the balance bench (Appendix D, Figure D-2, a and b).
3. For wafer handling, use the vacuum pick-up tool on all screen-printed wafers. For all taped wafers, use the rubber-coated tweezers.
4. The binder burnout operation is normally done overnight because of the odors involved. For normal workday operation, a hooded furnace is required.

Procedure

1. Transfer the quartz boat loaded with screen-printed or taped SiGe wafers into the furnace used for binder burnout.
2. Mate the quartz boat oxygen manifold opening with the quartz oxygen supply tube.
3. Close the furnace door and then turn on and adjust the flow meter to a flow rate of 10 $\pm$ 1 CFH of oxygen.
4. Turn on the furnace and activate the cam-operated recorder-controller.
5. The furnace is programmed for the following temperature cycle:
 - a. 0 deg to 550°C at 275° $\pm$ 20° per hour.
 - b. Hold at 550°C $\pm$ 20° for 4 hours.
 - c. Furnace shutoff after 4 hours $\pm$ 15 minutes at 550°C.
6. Allow the furnace to cool to below 75°C. Remove the covered boat and transfer it to the balance table for the next weighing operation.
7. Repeat the balance-check procedure as described in section A of "Weighing and Oxidizing of n and p Wafers," Procedure 40:01-02.
8. Using the binder burnout fixture markings for orientation, the wafers are removed in reverse order to the loading procedure used for the binder burnout fixture and:
 - a. are weighed and returned to their original position in the plastic container before binder burnout, or
 - b. are returned directly to their original position in the containers before binder burnout.
9. Using the Glass Deposition Data Sheet for identification, reweigh the wafers that were weighed after glass application (screened or taped).

10. The following procedure is used:

- a. Remove the wafer from the fixture and place it on the balance pan.
 - b. Close the balance door and weigh the wafer to the nearest 0.01 milligram (5th decimal place).
 - c. Record the weight of the wafer after burnout on the Glass Deposition Data Sheet in its proper location under the column heading "Wt. Oxidized Wafer & Glass."
11. Transfer the weighed glass-coated wafer to its previously designated position in the plastic container.
12. Upon completion of the weighing and transferring operation, the plastic containers are sealed with covers and stored until they are needed for the next assembly operation.*

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. High-temperature Furnace	(A-16)
2. Cam-operated Recorder-controller	(A-17)
3. Plastic Gloves	(A-10)
4. Oxygen Flow Meter	(A-32)
5. Rubber-coated Tweezers	(A-8)
6. Vacuum Pickup Tool	(A-13)
7. Balance	(A-12)
8. Oxygen Line Filter	(A-36)
9. Fused-quartz Boat	(A-14)
10. Quartz Plate	(A-22)
11. Alumina Spacer	(A-23)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Oxygen	(B-7)

Drawings

NOTE: See Appendix C for complete drawings.

1. Oxidizing Fixture, Dwg. No. SK207
2. Quartz Boat, Dwg. No. SK208

*"Wafer Stack Assembly Procedure for 1D-W Wafer Stacks," Procedure 40:03-04.

Computerized Data Analysis

Preliminary Information

Many of the preceding sections of this report contain instructions for making weight measurements and recording data that can be used for glass bonding process quality control.

In addition to controlled-vacuum hot-pressing parameters, close control of the following is necessary

1. the glass and binder content of the screening slurry,
2. wafer thickness, and
3. the amount of glass deposited on the SiGe wafers.

Moderate variations of any of the factors listed could cause problems in producing a well-bonded thermopile of the required dimensions. Increased wafer thickness and above-nominal deposition of glass frit requires additional extrusion of glass. If the excess glass is not extruded, the stack and pile may not meet dimensional requirements. Below-nominal glass deposition can result in voids in the glass bond. Knowledge of the glass and binder content of the slurry is required to maintain control over the screen frit deposition process.

A FORTRAN program, GLASSF, was written to facilitate the analysis of glass bonding processing data. The program is set up for use on the PDP-10 for the convenience of the user.

GLASSF is used to compute the percent glass and percent binder of the screening paste or tape, the weight of deposited glass, the approximate weight of the oxide coating, and the calculated wafer thickness. Averages of the preceding, their high, low, range, variance, and standard deviation also are computed. In addition, the weight of deposited glass frit, oxide coating, and the calculated wafer thickness for each specimen are plotted about their selected nominal values.

The general procedure for use of the program is as follows

1. Create a FORTRAN data file for input data. Most of the required input data is obtained from a wafer-batch Glass Deposition Data Sheet.
2. Correct the data file, if necessary, using TECO (Test Editor and Corrector).
3. Execute GLASSF.
4. Review the computer output and make a decision regarding the use of the batch of wafers.
5. Take corrective processing measures, if necessary.

ProcedureA. Data Input

1. Input data are punched on paper tape at a PDP-10 teletype terminal using the following procedure
 - a. Set the terminal switch in the local mode and then depress the CONTROL and TAPE keys simultaneously.

- b. Punch a series of rubouts at the beginning of the tape by depressing the RUBOUT and REPEAT keys simultaneously.

- c. Punch the required data by using the following typing format:

A, B, C, D, E, C/R

LINE FEED

where

A = slug identification number (i. e. , N1234)

B = code for glass-deposition method (i. e. ,

T = taped, S = screened)

C = NN = number of wafers in this data set

D = theoretical density of the bonding glass (gms/cu. in.), i.e.,

Code 7059 CGW = 45.230

Code 7052 CGW = 37.363

E = area of substrate (sq. in.),

i.e., SiGe wafer = 0.823

SiGe channel = 0.411

C/R = CARRIAGE RETURN

EX. = N1234, s, 14, 45.23, 0.823C/R

LINE FEED

- d. For the next NN lines, the user punches in the required wafer weight data using the following format:

F G H I J C/R

LINE FEED

where

F = wafer number

G = cleaned-wafer weight (mgms)

H = oxidized-wafer weight (mgms)

I = oxidized weight + slurry or tape weight (mgms)

J = oxidized weight + glass-frit weight (binder burned off) (mgms)

C/R = CARRIAGE RETURN

NOTE: Be sure to use a space between each entry; i. e. ,

01 279.74 279.58 348.84 324.12C/R

LINE FEED

NOTE: Type a series of rubouts after the last line of data has been punched, then depress the CONTROL and ~~TAPE~~ keys simultaneously.

2. The paper tape is now ready to be used to create a data file in the user's disc area.

Proceed as follows:

- a. Follow the standard log-in procedure at a PDP-10 terminal.

- b. The computer will respond with a period (.) after the log-in procedure is completed. The user then types in

._SET TTY TAPEC/R

._R PIPC/R

NOTE Underlining will be used to indicate computer's response.

- c. After the computer responds with an asterisk, the user depresses the CONTROL and Q keys simultaneously followed by a CARRIAGE RETURN and then a LINE FEED.

._↑QC/R

LINE FEED

Then type file name ← TTY C/R, i. e.,

._N1234.DAT ← TTY C/R

LINE FEED

NOTE Data files are named after the wafer batch being processed

i. e., N1234.DAT, P1227.DAT, etc.

- d. The computer will not respond with an asterisk after the line feed. At this point, with the tape reader switch in the free position, position the opening rubout section of the tape in the tape reader. Place the switch in the start position. When the tape has been read, place the reader switch back in the free position.

- e. Depress the CONTROL and Z keys simultaneously.

._↑Z

Then CONTROL and S

._↑SC/R

Then CONTROL and C

._↑C

- f. Type

._SET TTY NO TAPEC/R

3. The next step is the use of TECO to check the data file and to make corrections, if necessary. Proceed as follows

- a. ._TECO N1234.DATC/R

- b. The computer will respond with an asterisk. The user types

._JZT\$\$

This command will cause the computer to type out the entire data file.

NOTE The \$ is the ALT mode or ESC key, not the \$ above the number 4.

- c. If the file contains errors, correct the errors as shown in the following statements.

- d. To correct a data line, type

._JNLT\$\$

where N = 0 to NN (first data line - zero, last data line = NN).

The data line will be typed out.

- e. If this is the data line that requires correction, type

_KI(insert corrected line)C/R

\$_LT\$\$

The computer will type out the corrected data line.

To remove an entire line, type

_K\$\$

- f. If the line typed in step d is not the line requiring correction, type

_LT\$\$ (to go forward one line at a time until the line requiring correction is reached) or

_-LT\$\$ (to go backward one line at a time until the line requiring correction is reached).

Follow step e when the sought-after line has been typed.

- g. Continue using steps d through f until all corrections have been made.

When all corrections have been made, type

_JZT\$\$

Check the file for errors.

- h. If the file is correct, type

__\$

_EX\$\$

._R PIPC/R

_N1234.DAT/A=N1234.DATC/R

Then CONTROL and C

_↑C

The data file is now ready to be used with GLASSF to make the necessary computations.

4. The command to start execution of the program is typed

_.EX GLASSFC/R.

- a. The first user response required is the data file name i.e.,

ENTER FILE NAME - A5N1234C/R.

- b. Next, the computer types out the tolerance limits for the amount of frit, oxide thickness, and wafer thickness. The user has the option of changing these limits for this execution of the program. The computer will provide the instructions for making changes. When all the limits have been corrected and the user responds by typing YC/R to the question "ARE ALL LIMITS CORRECT," the computer prints out the corrected tolerance limits. If there are no errors in limits, the user types YC/R.

- c. The user is given the option of having the computer output typed out on the teletype (TTY) or printed out on the line printer (LPT). In most cases, the line printer is preferred because of the rapid printout. In addition, the PDP-10 terminal is not tied up for long periods. The printout is sent to the user's box within a few hours after execution of the program.

- d. When GLASSF is executed, including the printing or typing of output, the computer will ask for a new data file: i.e.,

ENTER FILE NAME - A5.....

If the user does not have any more data files to be processed, he types in

EXIT: i.e., ENTER FILE NAME - A5.....EXITC/R.

5. Before or during the PDP-10 sign-off procedure, the user deletes undesired files from his disc area: e.g., unwanted files ending with .DAT, .BAK, .REL.

B. Data Output

Program output for a typical wafer batch and a listing of the program are given in Appendix E.

The computerized analysis procedure can be used to regularly or occasionally monitor the status of the wafer slicing, oxidizing, and glass-frit deposition operations. After reviewing the computer output, the user must decide on a course of action. If the output indicates that processing is in control, the coated wafers are accepted for production purposes. If tolerance requirements are not being met, wafers may be rejected or reprocessed. If a batch-to-batch trend, such as an increase in wafer thickness, is observed, production personnel should be notified to make tooling adjustments to reverse the trend.

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Cleaning Process for New and Used Alumina
Vacuum-Hot Pressing Fixtures and Spacers

Preliminary Information

Perform operations 2 through 5 of section A in the acid sink of the fume hood.

Procedure

A. New Fixtures and Spacers

1. Place the fixture and spacers in a clean 600-cc polyethylene beaker.
2. Make a solution of 1:1 by volume, hydrofluoric acid and distilled water.
NOTE: Solution is made starting with a 48% hydrofluoric acid solution.
3. Pour the solution into the beaker to cover all parts of the fixture and spacers, and allow them to soak for 5 minutes.
4. Pour off and discard the solution, and rinse the fixture and spacers thoroughly 3 times with distilled water.
5. Pour off the distilled water, cover the beaker with a watch glass cover and transfer it to the clean room.
6. Using clean plastic gloves, transfer the fixture(s) and spacers into a covered, clean fused-quartz boat.
7. Place the covered boat containing the fixture(s) and spacers in an air furnace and heat to 1050°C at a rate not to exceed 12°C per minute. Hold the furnace at $1050^{\circ}\text{C} \pm 25^{\circ}$ for 30 ± 5 minutes.
8. Shut the furnace off and allow it to cool to room temperature before removing the boat and parts.
9. Using clean plastic gloves, remove the fixture(s) and spacers from the boat and place them in the clean bench.

B. Used Fixtures and Spacers

1. When foreign material exists on fixture(s) or spacers, remove this residue using 600 grit carborundum paper.
CAUTION: Removal of residue with carborundum paper must not be performed in the clean room.
2. After residue is removed, proceed with the same cleaning process used for new fixtures.

NOTE: If in the process of vacuum hot pressing and bonding, no perceptible foreign matter has adhered to or stained the fixture(s) or spacers, cleaning is not necessary for subsequent use of the fixture(s) and spacers in the vacuum hot-pressing and bonding operations. Clean all fixtures at least once each month.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. High-temperature Furnace	(A-16)
2. Acid Sink and Fume Hood	(A-2)
3. Quartz Boat	(A-14)
4. Quartz Cover	(A-33)
5. 600-cc Polyethylene Beakers	(A-57)
6. Plastic Gloves (disposable)	(A-10)
7. Polyethylene Graduated Cylinder	(A-34)
8. Rubber Gloves (for working with hydrofluoric acid)	(A-35)

Material

NOTE: See Appendix B as noted below for pertinent information.

1. Distilled Water	(B-1)
2. Hydrofluoric Acid	(B-15)

Drawings

1. Hot-pressing Fixture (Pile), Dwg. No. SK211
2. Hot-pressing Fixture (Stack), Dwg. No. SK212
3. Upper and Middle Spacers, Dwg. No. SK215
4. Quartz Boat and Cover, Dwg. No. SK208

Wafer Stack Assembly Procedure

Preliminary Information

1. Coated (Code 7059 CGW glass frit) wafers are available in sealed plastic boxes located in the storage cabinet above the assembly clean bench.
2. The necessary clean hot-pressing fixturing, monitor thermocouple, and mica paper shims are stored in the assembly clean bench. The split fixture and the three spacers (upper, lower, and middle) are identified by an engraved code letter and/or number. In addition, the spacers have an engraved arrow used to orient the spacers in the hot press.

CAUTION: Middle and lower spacers are matched and used in pairs and are marked accordingly.

3. All assembly work is done in a Class 100 laminar-flow clean bench which is located in the clean room. In addition to normal clean-room attire, the technician wears disposable plastic gloves during the wafer assembly operation.
4. A wafer layout sheet (Figure 17) should be firmly attached to the clean bench table with two-sided adhesive tape. Always brush off the top of the layout sheet to remove any foreign matter which may be on it.

Figure 17. Wafer layout sheet

NOTE: The purpose of the layout sheet is to reduce the possibility of accidentally stacking two n or two p wafers together.

5. Using rubber-coated tweezers, transfer the wafers from their container onto the layout sheet. Only the wafer sides should be touched with the tweezers, as shown in Figure 18. Wafers are to be transferred according to type: that is, all n wafers first, and then all p wafers next. Transfer the exact number and type of wafers required to fill out the layout sheet.

NOTE: For 1D-W stacks:

21 - 0.007-inch-thick n	1 - 0.014-inch-thick n
21 - 0.007-inch-thick p	1 - 0.014-inch-thick p (not glassed)

Figure 18. Wafer handling

6. After transferring the n wafers to the layout sheet and before transferring the p wafers, enter the following in the 7121-4 "Wafer Stack Log" as follows:
 - a. Stack number (newly assigned - next number in sequence).
 - b. The slug number associated with the 0.014-inch-thick n wafer.
 - c. The slug number(s) corresponding to the 0.007-inch-thick n wafers used to make up one stack.
 - d. Finally, the number of wafers used from each slug adjacent to the slug number.

NOTE: See Appendix D, Figure D-7.

7. Transfer the required number of p wafers to the layout sheet. Orient the wafers as shown in Figure 17.
8. After transferring the required number of p wafers to the layout sheet, enter the same type of information for the p wafers as was entered in 6a-d for n wafers.
9. Pick out a set of fixturing (split fixture, spacers, ring assembly, and cap) that will be used in the stack assembly process and record the letters and/or numbers associated with the fixturing in the "Wafer Stack Log."

10. Disposal of plastic containers:

- a. If empty, remove all labels and lint-free paper and place the box in storage for cleaning (Procedure 40:01-01, Section A).
- b. If the boxes contain unused wafers, return them to the storage cabinet on top of the laminar-flow clean bench.

Procedure

1. Start with the lower spacer. Locate the spacer in a convenient place on the clean-bench table top. The reduced diameter end is placed in the up position. The arrow on the spacer should be facing the left end of the clean bench (Figure 19).

Figure 19. Assembled wafer stack and fixture

2. Next, place the 0.030-inch-thick rectangular spacer at the approximate center of the lower spacer end face.
3. A total of 44 wafers will be stacked on top of the rectangular spacer in the following manner and sequence:
 - a. All wafers are assembled with glassed side up.
 - b. The 0.014-inch-thick n wafer (No. 1 in Figure 17) is the first to be placed on the rectangular spacer.
 - c. Beginning with a 0.007-inch-thick p wafer (No. 2 in Figure 17), 0.007-inch-thick p and n wafers are stacked alternately until a total of 43 have been stacked.
 - d. The final wafer is an unglassed 0.014-inch-thick p wafer. It is stacked with the identification groove exposed.

NOTES:

- (1) In the course of the stacking procedure, individual wafers are inspected for contamination and wafer defects. A headloop 4X magnifier is used. Loose particles are brushed off with a camel's hair brush. A wafer is rejected if:
 - a. Contamination cannot be brushed off.
 - b. The wafer is cracked or badly chipped.
 - c. The glass coating is unusually discolored.
 - d. The glass coating is damaged (i.e., holes, bumps, scratches, etc.).
 - (2) All p-wafer identification notches must be located on the same end of the stack.
4. When all the wafers are stacked, place the alumina cap on top of the wafer stack and use two alumina caps to align wafer edges on all four sides of the stack (Figure 20).

Figure 20. Procedure for aligning stack edges

5. Using a camel's-hair brush, remove any existing loose particles from around the stack and the lower spacer.
6. Place both halves of the split fixture loosely around the wafer stack. The slotted half of the fixture is placed, with the slotted side up, on the left side of the stacked wafers.
7. Two mica paper strips are cut and formed around the ends of the stack (Figure 21).

Figure 21. Location of mica-paper stack shims

8. Place a mica-paper shim around each end of the stack, between the stack and the fixture. The shims are used to prevent the extruded glass from adhering to the alumina fixturing.

CAUTION: Do not reuse mica-paper shims. The mica paper becomes flakey and could cause bond contamination problems if reused.

NOTE: Rotate the lower spacer so that the alignment arrow faces the front of the clean bench.

9. At this point, obtain a new or used prefabricated Chromel-Alumel thermocouple (Figure 22). Measure 0.375 inch back from the junction (ball tip) and make a right-angle bend in the wire. The 0.375-inch bend length will place the monitor couple junction approximately in the center of the furnace hot zone and near the top of the wafer stack. It is important to have the thermocouple junction located in approximately the same position for each wafer-stack hot-pressing operation to insure reproducibility of monitor-thermocouple strip-chart recorder traces.

Figure 22. Monitor thermocouple

10. Assemble the monitor thermocouple-wafer stack fixture assembly (Figure 23) as follows:

- a. Slide the split fixturing into position around the stack. Hold in place.
- b. Place the bent end of the thermocouple between the stack and the slotted half of the split fixture and locate the wires (long end) in the slots on top of the fixture.
- c. Hold the wire down in the slots with one finger and bend the long end wires at right angles into the slots running down the side of the split fixture. With one hand, place a light tension on the long end of the wire to hold it in position in the slots.
- d. Place the alumina ring assembly over the split fixture and thermocouple wires. Orient the ring assembly so that the two thermocouple wires will exit through the slot on the bottom of the ring.

IMPORTANT: Ring must slip over the reduced diameter of the lower spacer and seat squarely on the large diameter.

- e. Align the screw on the ring assembly so that it is perpendicular to the fixture jaws. Tighten the screw on the ring assembly to finger tightness. This will provide enough pressure to hold the wafer-stack assembly and fixturing in position for the hot-pressing operation. (See Figure 23.)

11. The wafer-stack assembly is now ready to be placed in the vacuum hot press for bonding. Store the assembly in the clean bench if the hot-pressing operation is delayed for some reason.

Figure 23. Lower spacer, wafer stack and fixture assembly

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Laminar-flow Clean Bench (A-18)
2. Alumina Hot-pressing Fixtures (A-37)
3. Headloop 4X Magnifier (A-38)
4. Chromel-Alumel Thermocouple (A-39)
5. Plastic Gloves (disposable) (A-10)
6. Rubber-covered Tweezers (A-8)
7. Camel's-hair Brush (A-40)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Mica paper sheet (B-14)

Drawings

NOTE: See Appendix C for complete drawing.

1. Hot-pressing Fixture (stack), Dwg. No. SK212
2. Upper and Middle Spacer, Dwg. No. SK215

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Vacuum Hot Pressing of Wafer Stacks

Introduction

The vacuum hot-pressing procedure presented in this section is used to produce a stack of SiGe wafers bonded together with mechanically strong, high-electrical-resistance, low-void-content solid-glass bonds. After bonding, the wafer stack is cut into four sections (thermopile channels).*

Preliminary Information

1. The basic components of the vacuum hot press shown in Figure 24 are:
 - a. A platinum-wire-wound ceramic heater tube (12).
 - b. A water-cooled (27) vacuum chamber (9) suitably insulated from the heater with Fiberfrax insulation (31).
 - c. A mechanical vacuum pump (mounted outside the clean room) suitably trapped with liquid nitrogen to prevent back streaming of organic and other vapors. The pump should be capable of maintaining less than 50 microns pressure on the vacuum chamber.
 - d. A hydraulic ram (18) for applying force to the steel ram (21), complete with a 0-300 divisions pressure gauge (2) mounted on the unit.
 - e. Advac electrical feedthroughs (24) to supply power to the heater and to allow thermocouple controls to be brought out to the instrumentation.

Figure 24. Vacuum hot press

*"Slicing Thermopile Channels," Procedure 30:00.

2. The basic components of the temperature control console shown in Figure 25 are:

- a. Power is supplied by a motor-driven Variac (A) designed to maintain a current of approximately 25 amps during the hot-pressing cycle.
- b. A Honeywell controller-recorder (B) is used for on-off control of power. This unit controls and records the temperature of the furnace over a temperature range of 0-1200°C.
- c. A Honeywell overtemp control (C) is used to prevent overheating.
- d. Three Chromel-Alumel thermocouples are used to control and monitor the temperature (Figure 24):
 - (1) The control (30) and overtemp (28) are located at the furnace core wall.
 - (2) The monitor thermocouple (29) is located at the stack.

Figure 25. Temperature control console

NOTE: Although these controls appear to be adequate, it would be desirable to have a saturable core reactor power supply controlled by a cam-operated or programmable recorder-controller to insure reproducibility and reduce the possibility of equipment and operator error.

3. Required Documentation Forms

- a. "Wafer Stack Log" (Appendix D, Figure D-7).
- b. "1-DW Stack Bonding Data" traveler (Appendix D, Figure D-1, a-f)
- c. "Glass Deposition Data Sheet" (Appendix D, Figure D-2, a and b).

4. Significant Notes

- a. All operations are performed in the clean room. The technician wears disposable plastic gloves during all fixture-handling operations.
- b. For convenience, post a graph showing the hot-pressing cycle (Figure 27) and graph (Appendix D, Figure D-5) showing the conversion of the hydraulic-gauge reading to actual pressure (psi) applied.
- c. The loaded wafer stack fixture - lower spacer assembly (Figure 23) is stored on the assembly clean bench until used.
- d. Before initial use, after major repair operations (furnace-core replacement, insulation replacement), and/or if the vacuum chamber has been exposed to atmospheric conditions for long periods (lid off or chamber vent open), bake out the furnace for a minimum of 4 hours under vacuum at temperatures of 150 to 200°C hotter than vacuum hot-pressing temperatures to desorb gases and moisture from the vacuum chamber components.
- e. After the hot-pressing unloading procedures have been completed, and while the liquid-nitrogen trap is still in operation, replace the vacuum chamber lid (Figure 24, 6) close the vent valve (25), and pull a vacuum on the chamber. When the chamber pressure is reduced to 50 microns or below, close the chamber evacuation valve (22). The chamber should remain vacuum sealed when not in use.

Procedure

- 1. Check to see that the chamber evacuation valve is closed. Start the mechanical vacuum forepump and then fill the liquid-nitrogen cold trap. Both are located outside the clean room.
- 2. Open the vacuum-chamber vent to allow the chamber to come to atmospheric pressure and then raise the lid of the chamber to permit loading of the wafer stack fixture - lower spacer assembly.
- 3. Raise the fixture support pedestal (Figure 24, 14) to a level which is most convenient for loading the wafer stack fixture - lower spacer assembly into the furnace. Dust off the elevator pedestal if necessary.
- 4. Place the wafer stack fixture - lower spacer assembly on top of the elevator pedestal with the lower spacer engraved arrow facing the front of the unit. The pedestal is recessed to accept and locate the lower spacer - wafer stack assembly.

5. Connect the wafer stack monitor thermocouple to the proper connections in the furnace chamber.

CAUTION: The thermocouple connections are not symmetrical; care must therefore be exercised in mating the thermocouple plugs with their connections.

6. Since the spacers are heavy, they can damage the assembled wafers if not handled with care during the loading procedure. Gently place the middle spacer (11) (engraved arrow facing the front of the unit) on top of, and concentric with, the top of the wafer stack fixture assembly.

Figure 26. Loaded wafer stack fixture - spacer assembly

7. Next, gently place the upper spacer (10) (engraved arrow toward the front of the unit) on top of and concentric with the middle spacer.
8. Carefully lower the fixture support elevator to its lower limit. While lowering the elevator, observe that the assembly and thermocouple maintain their concentricity, orientation and clearance.
9. Before lowering the vacuum-chamber lid, check to see that the steel ram-lock screw (4) is fully extended to insure that the steel ram is in the UP position. If the ram is in the DOWN position, fixture and spacer alignment can be destroyed and wafers can be fractured.
10. Lower the vacuum chamber lid over the guide pins (7) with the dial indicator (5) facing the front of the unit. (See Figure 24.)

11. Remove the turnbuckle assembly (17) from the vacuum chamber lid and from the cable hook (16). Place the turnbuckle assembly aside until needed for removal of the vacuum-chamber lid.
12. Close the vacuum-chamber vent valve and then open the chamber evacuation valve.
13. Evacuate the chamber to a pressure of 50 microns or less as indicated on the Hastings thermocouple vacuum gauge (1).
14. Upon attaining a pressure of 50 microns or lower, close the chamber evacuation valve and open the oxygen supply valve (23). Backfill with 1/10 atmosphere of oxygen as indicated on the Bourdon type vacuum-pressure gauge (26). Upon attaining the required pressure, close the oxygen supply valve.
15. The wafer stack hot-pressing profile of temperature, pressure and atmosphere versus time is illustrated in Figure 27.

Figure 27. Profile 1D-W (Stack)

16. Start the furnace heating cycle as follows (Figure 25):
 - a. Adjust controller set point (D) to 650°C; check to see that the controller mode switch (M) is in the automatic position.
 - b. Before proceeding to the next step, check to see if the Variac has been set to its lower stop. This precaution is necessary to prevent a 25-amp or greater current surge from damaging the furnace coil or power connections.
 - c. Turn on main power switch (E).
 - d. Turn on the power switch (F) to the Variac motor drive (G).
 - e. Reset the overtemp control by depressing the reset button (H).
 - f. Start the heating cycle by supplying a current of 25 amps to the furnace coil. This is achieved by disengaging the manual gear lever (I) on the motor-driven Variac and manipulating the Variac handle (J) to the required setting while monitoring the current reading on the ampmeter (K).

g. Record the stack number and date on the strip chart recorder paper (L) adjacent to the temperature trace for the run.

17. Enter the start time, control temperature setting, control-couple temperature reading (red trace), and monitor-couple temperature reading (blue trace) in the "Wafer Stack Log". A typical strip-chart record of the vacuum hot-pressing temperature profiles for the monitor and control thermocouples is shown in Appendix D, Figure D-6.

NOTE: From this point on, enter vacuum hot-pressing cycle records as illustrated in Appendix D, Figure D-7.

18. When the monitor thermocouple registers 600°C on the strip chart, open the chamber evacuation valve and allow the wafer stack to soak at this temperature in vacuum for 30 minutes.

19. After the 30-minute soak, adjust the temperature controller set point to 910°C .

NOTE: With the controller set at 910°C , the monitor thermocouple will read 860°C . This temperature, $\pm 10^{\circ}\text{C}$, is the established bonding temperature for screen-printed and taped Code 7059 glassed wafer stacks.

20. When the monitor thermocouple temperature reaches 860°C , allow the wafer stack to soak at this temperature for 10 minutes before applying pressure. This soak allows the wafer stack to approach equilibrium temperature.

21. After the 10-minute soak, slowly release the ram-lock-screw to allow the steel ram to make contact with the upper spacer. When the dial indicator pointer stops rotating (indicating contact with the spacer), rapidly unscrew the ram-lock-screw until the bottom of the screw is flush with the ram-stop-clamp (20). Record the dial indicator reading at ram contact in the Wafer Stack Log.

22. Slide the hydraulic ram into position over the steel ram and hardened steel ball (19).

23. After positioning the hydraulic ram, close the pressure release valve (8) on the hydraulic hand pump (3) and start hand pumping. While holding the hydraulic ram approximately concentric to the steel ram, continue pumping until a reading of 50 is attained on the hydraulic pressure gauge. Record the gauge reading and dial indicator reading.

NOTE: Apply pressure slowly. The time interval from ram contact to a reading of 50 on the hydraulic gauge is 2 minutes.

24. Increase the hydraulic-pressure-gauge reading in increments of 10 dial units over 1-minute intervals until a reading of 100 is attained. From 100 to 170 dial units, increase the pressure 20 dial units over 2-minute intervals with a

final pressure increment of 10 dial units over 2 minutes. (See Figure 28.)

Elapsed Time (minutes)	Dial Gauge Reading	Pressure (psi on stack)
Ram contact	0	Approx. 20
2	50	160
3	60	220
4	70	275
5	80	335
6	90	400
7	100	460
9	120	580
11	140	700
13	160	825
15	170	885

All times ± 10 seconds. All pressure ± 15 psi.

Figure 28. Gauge reading to psi conversion chart (stack)

Enter the appropriate data in the wafer stack log after each pressure application step. After reaching 170 dial units on the hydraulic gauge, maintain this gauge pressure reading for 10 minutes.

25. Upon completion of the 10-minute post-pressing soak, do the following:
 - a. Close the chamber evacuation valve.
 - b. Open the chamber vent valve to allow the chamber to come to room atmospheric pressure.
 - c. Shut off the main power switch.
 - d. Shut off the Variac motor power switch.
 - e. Disengage the manual gear lever on the motor-driven Variac and turn the Variac to its lower stop.
 - f. Reset the controller set point to 650°C .
 - g. Turn on the main power switch to provide power to the strip-chart recorder (ammeter should read 0 amps). This is done so that the dropping temperature readings can be monitored.
26. When the monitor thermocouple indicates a temperature of 750°C , open the pressure release valve on the hydraulic pump and allow the hydraulic ram to retract completely. Slide the hydraulic unit back to its original position.
27. Turn the ram-locking-screw clockwise until the head of the screw bottoms out on the ram-stop-clamp.
28. Attach the turnbuckle assembly to the vacuum-chamber lid and cable hook. When the stack temperature, as indicated by the monitor couple, reaches 200°C , remove the lid of the vacuum chamber.

29. Raise the fixture support elevator to a convenient height for removing the spacer-wafer stack fixture assembly.
30. Disconnect the monitor thermocouple.
31. Using tongs, individually remove the top and middle spacers and the lower spacer-wafer stack assembly and place them on a metal plate to cool.
32. When the fixturing has cooled to approximately room temperature, place it on the clean bench, disassemble it and remove the bonded wafer stack.
33. Remove loosely adhered mica from the stack with an adhesive tape.
34. Using a 1-inch micrometer, measure the stack height in five places as shown in Figure 29. Record the measurements and other observations (appearance, etc.) in the Wafer Stack Log. Transfer the necessary data to the 1D-W Stack Bonding Data traveler.

Figure 29. Measurement location on stack

NOTE: A stereo microscope with a minimum of 30X magnification is used to inspect the bonded wafer stack for the following:

- a. Extrusion of 7059 glass (first bond).
 - b. Bubbles in the extruded glass.
 - c. Proper order: starting with the top notched and grooved p wafer, check to see that every other wafer is a notched p wafer.
 - d. Any cracks or chips on all surfaces of the wafer stack.
35. Wrap the stack in lint-free paper and place it in a plastic box. Attach a label to cover and side of the box. Mark the stack number on the labels.
 36. The wafer stack is now ready for grinding and slicing.
 37. Check the fixturing and spacers for contamination. If clean, place the wafer stack fixturing in a clean plastic box for storage. The spacers are placed on the clean bench. Chemically clean^{*} all contaminated items, except the monitor thermocouple.

^{*}"Cleaning Process for New and Used Alumina Vacuum Hot-Pressing Fixtures and Spacers," Procedure 40:03-03.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Vacuum Hot Press	(A-41)
2. Temperature Control Console	(A-42)
3. Mechanical Vacuum Pump	(A-43)
4. Liquid N ₂ Cold Trap	(A-44)
5. Hydraulic Ram	(A-45)
6. Hastings Thermocouple Gauge	(A-46)
7. Alumina Hot-pressing Fixtures	(A-37)
8. Plastic Gloves	(A-10)
9. Chromel-Alumel Thermocouples	(A-39)
10. Micrometer	(A-47)
11. Microscope	(A-48)
12. Tongs	(A-59)
13. Plastic Boxes	(A-58)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1. Mica Paper	(B-14)
2. Oxygen	(B-7)
3. Liquid Nitrogen	(B-16)
4. Adhesive Tape	(B-17)
5. Furnace Core	(B-18)
6. Alundum Cement	(B-19)
7. Pt Wire	(B-20)
8. Adhesive Labels	(B-21)

Drawings

NOTE: See Appendix C for complete drawing.

1. Vacuum Hot Press, Dwg. No. SK200
2. Hot-pressing Fixture (Stack), Dwg. No. SK212

BLANK

Preparation of Thermopile Channels for Vacuum Hot Pressing

Introduction

Thermopile channels are chemically cleaned after the wafer-stack-grinding,¹ sawing,² and channel-mechanical-inspection³ operations have been completed. The objective of the cleaning procedure is to remove any sawing-operation contaminants and conductive materials from the machined channel surfaces. Conductive contaminants can bridge the 1-mil first glass bond and cause inter-element shorts.

Upon completion of the channel-electrical-inspection operation,⁴ a coating of Corning Code 7052 glass frit is deposited on the cleaned and weighed channels with glass-transfer tape. The taped and weighed channels are then placed in a muffle furnace and heated in an oxygen atmosphere to obtain complete combustion and removal of the transfer-tape organic components.

Following the binder burnout and weighing operations, two selected thermopile channels are loaded into a thermopile vacuum hot-pressing fixture for the next (second bond) glass bonding operation.

1 "Wafer Stack Grinding," Procedure 50:00

2 "Wafer Stack Slicing," Procedure 30:00

3 "Mechanical Inspection," Procedure IP103

4 "Electrical Testing and Shorts Burnout Procedure for Thermopile Channels,"
Procedure 40:08

BLANK

Chemical Cleaning - Channels and Thermopiles

Preliminary Information

1. Thermopile channels are received from mechanical inspection in separate plastic boxes labeled with the stack number and the channel identification letters A, B, C, or D. The identification sketch in Figure 30 shows the location and orientation of thermopile channels.

Figure 30. Thermopile channel identification

2. Obtain new 1D-W Pile Bonding traveler forms and enter the preliminary information as shown in Appendix D, Figure D-8a. Thermopiles are fabricated using adjacent channels sliced from a common wafer stack. Two channels are used to fabricate a thermopile. Therefore, assign adjacent channels to the same traveler. For example, assign channels A and B to the first traveler and C and D to the second traveler.
3. Thermopile channel identity should be maintained through all subsequent processing and assembly operations. Consequently, care should be taken to maintain the assigned numerical and alphabetical identification.

Procedure

1. Insert the A, B, C, and D thermopile channels, from a common stack, into the Teflon cleaning fixture as shown in Figure 31.

Figure 31. Loaded channel cleaning fixture

2. Follow the cleaning procedure as described in Procedure 40:01-01, Section D, steps d through o, with the addition of the following steps between o and p.
 - a. Prepare the following solution in a clean 600-cc polyethylene beaker: 90-pbv glacial acetic acid, 6-pbv concentrated nitric acid, and 4-pbv 48 percent hydrofluoric acid.
 - b. Place the loaded Teflon fixture into the acid solution. The channels are kept submerged in the solution for 3 minutes.
 - c. Place the loaded fixture in a clean polyethylene beaker and rinse 3 times with clean distilled water.

3. Wrap the clean thermopile channels with clean, lint-free paper and return them to their original containers.

NOTE: Thermopile channels are now ready for electrical inspection.

Procedure 40:08.

4. When this inspection is completed, the thermopile channels are cleaned in ethyl alcohol, wrapped in lint-free paper, and placed in their marked plastic containers.
5. Transfer the plastic containers with the thermopile channels to the clean room for the next operation, Procedure 40:05-02.
6. Certify that this operation has been performed by signing and dating the pile traveler in the appropriate location on page 2.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Ultrasonic Cleaner	(A-1)
2. Acid Sink and Fume Hood	(A-2)
3. Cascade Cleaner	(A-3)
4. Water Still	(A-4)
5. Teflon Fixtures	(A-5)
6. 600-cc Glass Beakers	(A-6)
7. Plastic Boxes	(A-58)
8. Rubber-covered Tweezers	(A-8)
9. Stainless-steel Wire Basket	(A-9)
10. Plastic Gloves	(A-10)
11. 600-cc Polyethylene Beakers	(A-57)

Material

NOTE: See Appendix B as noted below for pertinent information.

1. Distilled Water	(B-1)
2. Glacial Acetic Acid	(B-2)
3. Hydrochloric Acid	(B-3)
4. Hydrofluoric Acid	(B-15)
5. Nitric Acid	(B-22)
6. Ethyl Alcohol	(B-4)
7. Lint-free Paper	(B-5)

Drawings

NOTE: See Appendix C for complete drawings.

1. Cleaning Fixtures, Drawing No. SK203
2. Channel, Drawing No. AY294253

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Weighing, Glass Application, and Binder Burnout -
Thermopile ChannelsPreliminary Information

1. All operations are performed in the clean room. In addition to normal clean room attire, the technician wears disposable plastic gloves and uses rubber-coated tweezers or gloved fingers during all thermopile channel handling operations.
2. All thermopile channel taping operations are performed in a Class 100 laminar-flow clean bench.
3. Locate clean binder burnout fixture (quartz plates and ceramic spacers) on the clean bench. After initial cleaning, quartz plates need not undergo the full cleaning process before each binder burnout operation. An ethyl-alcohol wipe before loading is sufficient. Clean per Procedure 40 01-01 at least once each month.
4. The binder burnout operation is normally done overnight because of the odors involved. For normal work-day operation, a vented or hooded furnace is required.
5. Transfer the plastic boxes containing the cleaned, electrically tested channels and the associated 1D-W Pile Bonding travelers to the balance table. A 1D-W Pile Bonding traveler containing sample data is shown in Appendix D, Figure D-8, a-f.
6. Remove the Code 7052 glass-tape containers from storage and locate them on the clean bench.

NOTE Two thicknesses of glass tape are used to bond thermopile channels, 3-mil glass tape is applied to the A and C channels and 8-mil tape is applied to the B and D channels.

NOTE If the code 7052 CGW 8-mil Vitta glass tape has enough glass (0.177 ± 0.009 gm/sq. in.) to form a void-free second bond, this tape is applied to only one channel of the thermopile. Weigh, tape and burnout the binder, using the A and C channels, The B and D channels are cleaned and then set aside until needed for thermopile assembly. Assemble the thermopiles, using A-B and C-D channel combinations.

7. Transfer a clean fused-quartz boat and cover to the balance table.
8. Thermopile channel identity should be maintained through all the subsequent processing and assembly operations. Therefore, care should be taken to maintain the assigned numerical and alphabetical identification.

"Cleaning and Handling - Tools, Equipment and Side Wafers," Procedure 40 01-01.

Procedure

A. Weighing of Cleaned Channels:

1. Zero and check the balance as described in Procedure 40:01-02, Section A.
2. Starting with the four channels sliced from a common wafer stack (Channels A through D) proceed as follows:
 - a. Remove channel A from its container and place it on the balance pan.
 - b. Close the door and weigh the channel to the nearest 0.01 milligram (5th decimal place).
 - c. Record the clean-channel weight in the appropriate column and position on page 2 of the 1D-W Pile Bonding traveler that is associated with the channel being weighed.
 - d. Return the channel to its labeled plastic container.
 - e. Continue the operation until all channels have been weighed.
 - f. Transfer the plastic containers with the weighed channels to the clean bench for the glass-transfer-tape operation.

B. Glass Tape Application

1. Using a high-temperature grease pencil, label each quartz plate as follows:
 - a. Stack number at the top center of the plate.
 - b. Channel identification letters. Only channels cut from a common stack are placed on one quartz plate. Prepare as many quartz plates as needed for the current taping operation. (See Figure 32.)

Figure 32. Loading of binder burnout fixture (channels) (1 of 2)

Figure 32. Loading of binder burnout fixtures (channels) (2 of 2)

2. Starting with the 3-mil glass tape, unroll a short length of tape onto the paper mat.
3. Using a razor blade and straight edge, cut off enough material to tape the A and C thermopile channels currently available for taping.
4. Remove the opaque backing from the tape to expose the adhesive surface of the tape.
5. Transfer the A and C channels to the adhesive surface of the 3-mil tape.

CAUTION: Exercise care in placing the channel on the adhesive surface to insure that the proper surface (relative to the identification notch) is facing the tape. (See Figure 33.)

Figure 33. Positioning of channels on tape

6. Gently press each channel against the glass tape with a gloved finger. Use enough pressure to insure that a good bond is formed between the channel and the adhesive layer.
 - a. Using a razor blade, cut through the glass tape and clear backing along the four edges of the channel.
 - b. Pick up the channel with the gloved fingers of one hand. Using a pair of tweezers, peel off the clear carrier layer.
 - c. Transfer the taped channel to its proper location on a labeled, clean quartz plate.
 - d. Repeat operations a through c for the second channel.
7. Continue the 3-mil-tape application procedure until all the A and C channels have been taped and placed in their designated locations on the clean, labeled quartz plate(s).
8. Return the 3-mil glass tape to its container.
9. Remove the 8-mil Corning Code 7052 glass-transfer tape from its container.
10. Repeat the taping operations 2 through 8, using the 8-mil tape and channels identified with the letters B and D.
11. One at a time, transfer the loaded quartz plates to the balance table for the next weighing operation.

C. Weighing of Taped Channels

1. Follow the same weighing and recording procedure described in Section A except for the following:
 - a. Return the weighed channel to its original location on the quartz plate.
 - b. When all four channels on the quartz plate have been weighed and returned to their locations, place the loaded quartz plate into the fused-quartz boat.
 - c. Place two ceramic spacers on each corner of the plate.
 - d. Continue the weighing operation until all taped channels have been weighed and loaded into the fused-quartz boat. A maximum of four loaded quartz plates and one clean cover plate will fit into the quartz boat.
2. Cover the loaded quartz boat and transfer it to the clean bench.

D. Binder Burnout - Taped Channels

1. Transfer the boatload of taped channels into the binder burnout furnace. Mate the quartz boat oxygen manifold opening with the quartz oxygen supply tube.
2. Close the furnace door and then turn on and adjust the oxygen flow meter to a flow rate of 10 ± 1 CFH.

3. Turn on the furnace and activate the cam-operated record-controller. The furnace is programmed for the following temperature cycle:
 - a. 0-550°C at 275°C $\pm$ 25° per hour.
 - b. Hold at 550°C $\pm$ 20° for 4 hours.
 - c. Furnace shut off after 4 hours ($\pm$ 15 minutes) at 550°C.
4. Allow the furnace to cool to below 75°C.
5. Remove the covered boat and transfer it to the balance table for the next weighing operation.

E. Post-Burnout Channel Weighing

1. Remove the boat cover and the clear quartz cover plate.
2. Remove the loaded top quartz plate and ceramic spacers and place them next to the balance
3. Follow the same weighing and recording procedure described in Section A except for the following:
 - a. Return the weighed channel to its original position on the quartz plate.
 - b. When all four channels have been weighed, transfer the loaded quartz plate and ceramic spacers to the assembly clean bench.
4. Continue the weighing operation until all channels have been weighed and the loaded quartz plate(s) have been transferred and stacked on the assembly clean bench.
5. The stacked channels remain on the clean bench. The next operation is the thermo-pile fixture assembly operation.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Plastic Gloves	(A-10)
2. Rubber-coated Tweezers	(A-8)
3. Laminar-flow Clean Bench	(A-18)
4. Quartz Plate	(A-22)
5. Alumina Spacers	(A-23)
6. High-temperature Furnace	(A-16)
7. Cam-operated Recorder-controller	(A-17)
8. Balance	(A-12)
9. Plastic Boxes	(A-58)
10. Fused-quartz Boat	(A-14)

11. Quartz Boat Cover	(A-33)
12. Razor Blade	(A-20)
13. High-temperature Grease Pencil	(A-19)
14. Steel Straight Edge	(A-21)

Material

NOTE: See Appendix B as noted below for pertinent information.

1. Code 7052 8-mil Tape	(B-13-c)
2. Code 7052 3-mil Tape	(B-13-b)
3. Oxygen	(B-7)

Drawings

NOTE: See Appendix C for complete drawings.

1. Binder Burnout Fixture, Drawing No. SK213
2. Quartz Boat, Drawing No. SK208
3. Channel, Drawing No. AY294253

Thermopile Assembly Procedure 1D-W

Preliminary Information

1. Coated (Code 7052 CGW glass frit) channels are located on quartz plates which are stacked in the assembly clean bench.
2. The necessary clean hot-pressing fixturing, monitor thermocouple, and mica paper are stored in the laminar-flow assembly clean bench. The split fixture and the three spacers (upper, lower, and middle) are identified by an engraved code letter and/or number. In addition, the spacers have an engraved arrow that is used to orient the spacers in the hot press.
3. All assembly work is done in a Class 100 laminar-flow clean bench which is located in the clean room.
4. In addition to normal clean-room attire, the technician wears disposable plastic gloves and/or uses rubber-coated tweezers during all thermopile-channel handling operations.
5. Obtain the 1D-W Pile Bonding traveler associated with the channels to be processed and a new Thermopile Assembly Log sheet (Appendix D, Figure D-9).

Procedure

1. Enter the pile number (newly assigned - next in sequence) on the traveler and log sheet associated with the channels to be processed.
2. Locate the lower spacer in a convenient place on the clean-bench table top. The reduced diameter end is placed in the UP position. The arrow on the spacer should be facing the left end of the clean bench.
3. Place a mica-paper disc, slightly smaller than the reduced end diameter, on top of the lower spacer.
4. Remove the quartz cover plate from the stored thermopile channels.
5. Pick up and visually inspect the A channel for contamination. A head-loop 4X magnifier is used. Loose particles are lightly brushed off with a camel's-hair brush. A channel is reprocessed if
 - a. contamination cannot be brushed off,
 - b. the glass coating is unusually discolored, or
 - c. the glass coating is damaged i.e., holes, bumps, scratches, etc.
6. Place the A channel at the approximate center of the mica-covered lower spacer, taped side up, oriented as shown in Figure 34.
7. Pickup the B channel and inspect it as described in Step 5 above.
8. Place the B channel, taped side down, squarely on top of the A channel oriented as shown in Figure 34.

9. Rotate the lower spacer so that the alignment arrow faces the front of the clean bench. (See Figure 34.)

Figure 34. Thermopile channel orientation

10. Place the precut 1-mil-thick mica cover on top of the B channel.

CAUTION: Do not reuse mica-paper disc and cover. The mica paper becomes flaky and could cause bond contamination and/or alignment problems if reused.

11. Place the alumina cap squarely on top of the mica cover sheet.
12. Using a camel's-hair brush, remove any loose particles from around the stacked channels and lower spacer.
13. Place both halves of the thermopile split fixture (Figure 35) loosely around the stacked channels. The slotted half of the fixture is placed, with the slotted side up, on the left side of the stacked channels.
14. To assemble the remaining fixture and monitor thermocouple components, refer to Steps 10 and 11, "Wafer Stack Assembly", Procedure 40:03-04.
15. Repeat Steps 1 through 14 of this procedure for fixture loading of C and D thermopile channels.

Figure 35. Lower spacer - Thermopile-fixture assembly

16. The loaded thermopile pressing fixture is now ready to be placed in the vacuum hot press for bonding. Store the assembly in the clean bench if the hot pressing operation is delayed for any reason. (See Figure 36.)

Figure 36. Loaded thermopile pressing fixture

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Laminar-flow Clean Bench (A-18)
2. Quartz Plate (A-22)
3. Alumina Spacers (A-23)
4. Alumina Hot-pressing Fixture (thermopile) (A-49)
5. Rubber-coated Tweezers (A-8)
6. Head-loop 4X Magnifier (A-38)
7. Chromel-Alumel Thermocouple (A-39)
8. Camel's-hair Brush (A-40)
9. Plastic Gloves (A-10)

Material

NOTE: See Appendix B as noted below for pertinent information.

1. Mica Paper (B-14)

Drawings

NOTE: See Appendix C for complete drawings.

1. Hot-pressing Fixture (Pile), Drawing No. SK211
2. Binder Burnout Fixture, Drawing No. SK213
3. Channel, Drawing No. AY294253

Vacuum Hot Pressing of Thermopiles 1D-W

Introduction

The vacuum hot-pressing procedure described in this section is used to bond together two thermopile channels with a mechanically strong, high-electrical-resistance, low-void-content, solid-glass bond. The fabrication of this second glass bond completes the required thermopile glass bonding operations. The bonded channels form a 1D-W thermopile.

Preliminary Information

1. An assembly drawing of the vacuum hot press is shown in Figure 37. The basic components are:
 - a. A platinum-wire-wound ceramic heater tube (12).
 - b. A water-cooled (27) vacuum chamber (9) suitably insulated from the heater with Fiberfrax insulation (31).
 - c. A mechanical vacuum pump (mounted outside the clean room) suitably trapped with liquid nitrogen to prevent back streaming of organic and other vapors. The pump should be capable of maintaining less than 50 microns pressure on the vacuum chamber.
 - d. A hydraulic ram (18) for applying force to the steel ram (21), complete with an 0-300 divisions pressure gauge (2) mounted on the unit.
 - e. Advac electrical feedthroughs (24) are provided to supply power to the heater and to allow thermocouple controls to be brought out to the instrumentation.

Figure 37. Vacuum hot press

2. The basic components of the temperature control console (Figure 38) are:
 - a. Power is supplied by a motor-driven Variac (A) designed to maintain a current of approximately 25 amps during the hot-pressing cycle.
 - b. A Honeywell controller-recorder (B) is used for on-off control of power. This unit controls and records the temperature of the furnace over a temperature range of 0-1200°C.
 - c. A Honeywell overtemp control (C) is used to prevent overheating.
 - d. Three Chromel-Alumel thermocouples are used to control and monitor the temperature (Figure 37). The control (30) and overtemp (28) couples are located at the furnace core wall. The monitor thermocouple (29) is located at the stack.

Figure 38. Temperature control console

NOTE: Although these controls appear to be adequate, it would be desirable to have a saturable-core-reactor power supply controlled by a cam-operated or programmable recorder-controller to insure reproducibility and reduce the possibility of equipment and operator error.

3. Required Documentation
 - a. Thermopile Assembly Log (Appendix D, Figure D-9).
 - b. 1D-W Pile Bonding traveler (Appendix D, Figure D-8, a-f).

4. Significant Notes

- a. All operations are performed in the clean room. The technician wears disposable plastic gloves during all fixture-handling operations.
- b. For convenience, post a graph showing the thermopile hot-pressing cycle (Figure 40) and a graph (Appendix D, Figure D-5) showing the conversion of the hydraulic-gauge reading to actual pressure (psi) applied.
- c. The loaded thermopile fixture - lower spacer assembly (Figure 37, 13) is stored on the assembly clean bench until used.
- d. Before initial use, after major repair operations (furnace core replacement, insulation replacement), and/or if the vacuum chamber has been exposed to atmospheric conditions for long periods (lid off or chamber vent open), bake out the furnace for a minimum of 4 hours under vacuum at temperatures of 150 to 200°C hotter than vacuum hot-pressing temperatures to desorb gases and moisture from the vacuum-chamber components.
- e. After the hot-pressing unloading procedures have been completed, and while the liquid-nitrogen trap is still in operation, replace the vacuum-chamber lid (6), close the vent valve (25) and pull a vacuum on the chamber. When the chamber pressure is reduced to 50 microns or below, close the chamber evacuation valve (22). The chamber should remain vacuum sealed when not in use.

Procedure

1. Check to see that the chamber evacuation valve is closed. Start the mechanical vacuum forepump and then fill the liquid-nitrogen cold trap. Both are located outside the clean room.
2. Open the vacuum-chamber vent to allow the chamber to come to atmospheric pressure and then raise the lid of the chamber to permit loading of the thermopile fixture - lower spacer assembly.
3. Raise the fixture support elevator (14) to a level which is most convenient for loading the thermopile fixture - lower spacer assembly into the furnace. Dust off the elevator pedestal if necessary.
4. Place the thermopile fixture - lower spacer assembly on top of the elevator pedestal with the arrow on the lower spacer facing the front of the unit. The pedestal is recessed to accept and locate the lower spacer - thermopile fixture assembly.
5. Connect the thermopile fixture monitor thermocouple to the proper connections in the furnace chamber.

CAUTION: The thermocouple connections are not symmetrical; care therefore must be exercised in mating the thermocouple plugs with their connections.

6. The spacers are heavy and therefore can damage the thermopile channels if not handled with care during the loading procedure. Gently place the middle spacer (11) (arrow facing the front of the unit) on top of, and concentric with, the top of the thermopile fixture assembly.
7. Next, gently place the upper spacer (10) (arrow toward the front of the unit) on top of and concentric with the middle spacer.
8. Carefully lower the fixture support elevator to its lower limit. While lowering the elevator, observe that the assembly and thermocouple maintain their concentricity, orientation and clearance (Figure 39).
9. Before lowering the vacuum-chamber lid, check to see that the steel-ram-lock screw (4) is fully extended to insure that the steel ram is in the UP position. If the ram is in the DOWN position, fixture and spacer alignment can be destroyed and channels can be damaged.

Figure 39. Loaded thermopile-fixture-spacer assembly

10. Lower the vacuum-chamber lid over the guide pins (7) with the dial indicator facing the front of the unit.
11. Remove the turnbuckle assembly (17) from the vacuum chamber lid and from the cable hook (16). Place the turnbuckle assembly aside until needed for removal of the vacuum-chamber lid.
12. Close the vacuum chamber vent valve and then open the chamber evacuation valve.
13. Evacuate the chamber to a pressure of 50 microns or less as indicated on the Hastings thermocouple vacuum gauge (1).
14. Upon attaining a pressure of 50 microns or lower, close the chamber evacuation valve and open the oxygen supply valve (23). Backfill with oxygen to a pressure of 20 inches of vacuum as indicated on the Bourdon type vacuum-pressure gauge (26). Upon attaining the required pressure, close the oxygen supply valve.
15. The thermopile hot pressing profile of temperature, pressure, and atmosphere vs. time is illustrated.

Figure 40. Profile for 1D-W (Thermopile)

16. Start the furnace heating cycle as follows:
 - a. Adjust controller set point (Figure 38 (D)) to 650°C. Check to see that controller mode switch (M) is in the automatic position.
 - b. Before proceeding to the next step, check to see that the Variac has been set to its lower stop. This precaution is necessary to prevent a 25-amp or greater current surge from damaging the furnace coil or power connections.
 - c. Turn on the main power switch.
 - d. Turn on the power switch to the Variac motor drive (G).
 - e. Reset the overtemp control by depressing the reset button (H).
 - f. Start the heating cycle by supplying a current of 25 amps to the furnace coil.

This is achieved by disengaging the manual gear lever (I) on the motor-driven Variac and manipulating the Variac handle (J) to the required setting while monitoring the current reading on the ampmeter (K).

- g. Record the thermopile number and date on the strip-chart recorder paper (L) adjacent to the temperature trace for the run.

17. Enter the start time, control temperature setting, control-couple temperature reading (red trace), and monitor-couple temperature reading (blue trace) in the Thermopile Assembly Log. A typical strip-chart record of the vacuum hot-pressing temperature profiles for the monitor and control thermocouples is shown in Appendix D, Figure D-6.

NOTE: From this point on, enter vacuum hot-pressing cycle records as illustrated in Appendix D, Figure D-9.

18. When the monitor thermocouple registers 600°C on the strip chart, open the chamber evacuation valve and allow the thermopile to soak at this temperature in vacuum for 30 minutes.
19. After the 30-minute soak, adjust the temperature controller set point to 760°C .

NOTE: With the controller set at 760°C , the monitor thermocouple will read 720°C . This temperature, $\pm 10^{\circ}\text{C}$, is the established bonding temperature for (Code 7052) tape glassed thermopiles.

20. When the monitor thermocouple temperature reaches 720°C , allow the thermopile to soak at this temperature for 10 minutes before applying pressure. The soak allows the thermopile to approach equilibrium temperature.
21. After the 10-minute soak, slowly release the ram-lock-screw to allow the steel ram to make contact with the upper spacer. When the dial indicator pointer stops rotating (indicating contact with the spacer), rapidly unscrew the ram-lock-screw until the bottom of the screw is flush with the ram-stop-clamp (Figure 37, 20). Record the dial indicator reading at ram contact in the Thermopile Assembly Log.
22. Slide the hydraulic ram into position over the steel ram and hardened-steel ball (28).
23. After positioning the hydraulic ram, close the pressure release valve (19) on the hydraulic hand pump (3) and start hand pumping. While holding the hydraulic ram approximately concentric to the steel ram, continue pumping until a reading of 50 is attained on the hydraulic pressure gauge. Record the gauge reading and dial indicator reading.

NOTE: Apply pressure slowly. The time interval from ram contact to a reading of 50 on the hydraulic gauge is 2 minutes.

24. Increase the hydraulic-pressure-gauge reading in increments of 10 dial units over 1-minute intervals until a reading of 100 is attained (Figure 41).

<u>Elapsed Time (min.)</u>	<u>Dial Gauge Reading</u>	<u>Pressure on Thermopile (psi)</u>
0	0	Approx 10
2	50	300
3	60	430
4	70	555
5	80	675
6	90	795
7	100	915

Figure 41. Gauge reading to PSI conversion chart (thermopile)

Enter the appropriate data in the Thermopile Assembly Log after each pressure application step. After reaching 100 dial units on the hydraulic gauge, maintain this gauge pressure reading for 10 minutes.

25. Upon completion of the 10-minute post-pressing soak, do the following
 - a. Close the chamber evacuation valve.
 - b. Open the chamber vent valve to allow the chamber to come to room atmospheric pressure.
 - c. Shut off the main power switch.
 - d. Shut off the Variac motor power switch.
 - e. Disengage the manual gear lever on the motor-driven Variac and turn the Variac to its lower stop.
 - f. Reset the controller set point to 650°C.
 - g. Turn on the main power switch to provide power to the strip-chart recorder (ampmeter should read 0 amps). This is done so that the dropping temperature readings can be monitored.
26. When the monitor thermocouple indicates a temperature of 650°C, open the pressure release valve on the hydraulic pump and allow the hydraulic ram to retract completely. Slide the hydraulic unit back to its original position.
27. Turn the ram-locking-screw clockwise until the head of the screw bottoms out on the ram-stop clamp.
28. Attach the turnbuckle assembly to the vacuum-chamber lid and cable hook. When the pile temperature, as indicated by the monitor couple, reaches 200°C, remove the lid of the vacuum chamber.
29. Raise the fixture support elevator to a convenient height for removing the spacer-thermopile fixture assembly.
30. Disconnect the monitor thermocouple.
31. Using tongs, remove the top and middle spacers and the lower spacer-thermopile fixture assembly separately and place them on a metal plate to cool.

32. When the fixturing has cooled to approximately room temperature, place it on the clean bench, disassemble it and remove the bonded thermopile.
33. Remove loosely adhered mica from the stack with an adhesive tape.
34. Using a 1-inch micrometer, measure the thermopile height in two places as shown in Figure 42.

Figure 42. Measurement of bonded pile

Record the measurements and other observations (appearance, etc) in the Thermopile Assembly Log. Transfer the necessary data to the 1D-W Pile Bonding traveler.

NOTE: A stereo microscope with a minimum magnification of 30X is used to inspect the bonded thermopile for the following:

- a. extrusion of 7052 glass (second bond),
 - b. bubbles in the extruded glass,
 - c. alignment of thermopile elements on both end faces,
 - d. any cracks or chips on all surfaces of the bonded thermopile.
35. Wrap the thermopile in lint-free paper and place it in a plastic box. Attach a label to the cover and side of the box. Mark the thermopile number on the labels.
 36. The thermopile is now ready for grinding and lapping.¹
 37. Check the fixturing and spacers for contamination. If clean, place the thermopile fixturing in a clean plastic box for storage. The spacers are placed on the clean bench. Chemically clean² all contaminated items, except the monitor thermocouple.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Vacuum Hot Press	(A-41)
2. Temperature Control Console	(A-42)
3. Mechanical Vacuum Pump	(A-43)

¹ "Grinding and Lapping", Procedure 60:00

² "Cleaning Process for New and Used Alumina Vacuum Hot Pressing Fixtures and Spacers", Procedure 40:03-03.

4.	Liquid N ₂ Cold Trap	(A-44)
5.	Hydraulic Ram	(A-45)
6.	Hastings Thermocouple Gauge	(A-46)
7.	Alumina Hot-pressing Fixtures	(A-49)
8.	Plastic Gloves	(A-10)
9.	Chromel-Alumel Thermocouples	(A-39)
10.	Micrometer	(A-47)
11.	Microscope	(A-48)
12.	Tongs	(A-59)
13.	Plastic Boxes	(A-58)

Materials

NOTE: See Appendix B as noted below for pertinent information.

1.	Mica Paper	(B-14)
2.	Oxygen	(B-7)
3.	Liquid Nitrogen	(B-16)
4.	Adhesive Tape	(B-17)
5.	Furnace Core	(B-18)
6.	Alundum Cement	(B-19)
7.	Pt Wire	(B-20)
8.	Adhesive Labels	(B-21)

Drawings

NOTE: See Appendix C for complete drawings.

1.	Vacuum Hot Press, Dwg. No. SK200
2.	Hot-pressing Fixture (Pile), Dwg. No. SK211
3.	Pile, Dwg. No. AY294254

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Thermopile Glass Bonding Process Evaluation

Introduction

Bonded thermopiles are returned to the Glass Laboratory after they have been ground, lapped,¹ and mechanically inspected.² Upon return, the thermopiles are visually inspected at low and then high magnification to evaluate the quality of the glass bonds in respect to voids and element alignment. The objectives of this inspection procedure are to monitor thermopile quality and to correlate thermopile quality with current processing parameters. Following the quality evaluation procedure, the thermopiles are chemically cleaned³ and transferred to Organization 1334 for element isolation tests and final visual evaluation before electroding.

Preliminary Information

1. All identification grooves and notches that were used to identify wafers and channels have been removed as a result of the preceding grinding and lapping operation. Check to see that the top and bottom elements of the channels have been tested and marked, in pencil, to identify the p and n elements.
2. CAUTION: Handle the machined thermopiles very carefully because defects such as chips and cracks introduced at this stage cannot be removed by further machining. Use soft mats and cushioned fixtures when examining the pile.
3. Keep the unmarked thermopile in its labeled container when it is not being processed, to insure maintenance of pile identity.
4. Fill in the required preliminary information on page 6 (End Face Void Chart) of the 1D-W Pile Bonding traveler that is associated with the pile being processed. (Appendix D, Figure D-8).

Procedure

1. Wipe the end faces of the machined thermopile with an ethyl alcohol-saturated lint-free wipe.
2. Examine all surfaces of the thermopile under low-power (30-60X) magnification for the following:
 - a. chipped or cracked pile edges, corners, and elements;
 - b. the uniformity of the second-bond thickness; and
 - c. defects in end-face-element alignment.

1 "Lap and Grind Thermopile", Procedure 60:00.

2 "Inspection Instructions for Thermopile Assembly", Procedure IP-104.

3 "Chemical Cleaning - Channels and Thermopile", Procedure 40:05-01

3. Record any comments and observed defects on page 4 or 5 of the 1D-W Pile Bonding traveler.
4. Next, examine the first and second glass bonds at both end faces, using dark field lighting and 100X magnification. Approximately six first bonds can be scanned at one time. Record observations and comments on page 6 of the 1D-W Pile Bonding traveler. Proceed as follows
 - a. Arbitrarily select and designate the first end face to be examined as end face one.
 - b. Using the microscope stage, scan and raster (six bonds at a time) until all side-one bonds have been examined and voids, if any, have been mapped.

NOTE If a large number of end-face voids are encountered, make an estimate of the number of voids or just count the number of bonds containing voids.
 - c. Estimate and record the degree of element misalignment, if any, across the second bond.
 - d. Rotate the thermopile to the left to view end face two. Repeat steps b and c for end face two.
5. Clean the pile, using Procedure 40 05-01, and then transfer the pile to Organization 1334 for electrical-element isolation tests and visual examination.

NOTE The compiled data can be used in an attempt to correlate any observed significant defects with the recorded glass-deposition, wafer-stack, and thermopile-processing information.

Equipment

NOTE See Appendix A as noted below for pertinent information.

1. B&L Metallograph Microscope (A-60)
2. Stereo Microscope (A-48)

Materials

NOTE See Appendix B as noted below for pertinent information.

1. Ethyl Alcohol (B-4)
2. Lint-free Paper (B-5)

Electrical Testing and Shorts Burnout Procedure for Thermopile Channels

Introduction

The objectives of this procedure are to increase the production yield and improve the electrical quality of 1D-W thermopiles. An electrical testing procedure is used to detect (1) low-resistance (less than 10 kilohms) glass insulating bonds between adjacent channel elements and (2) broken elements. Upon detection of a low-resistance bond, an attempt is made to "burnout" the material causing the low resistance (short), using a dc current-pulse treatment. A liquid crystal panel is used to locate shorts that do not clear.

Figure 43. Electrical test apparatus

Preliminary Information

1. All power supplies and test instruments are allowed a 15-minute warmup period before testing begins.
2. Handle channels with gloved hands. Dust off the specimen holder to remove possible conductive contaminants. If possible, perform this electrical testing and treatment operation in a Class 100 laminar-flow clean bench.
3. Channels are not marked; therefore, do not remove more than one channel from its marked container at any time. Channel identity must be maintained through the thermopile hot-pressing procedure.
4. Place the associated 1D-W Stack Bonding traveler on the test bench. Record the required test data on page 6 (Electrical Inspection-Thermopile Channels) of the traveler, Appendix D, Figure D-1f.

Procedure (See Figure 44.)

A. Resistance Measurements

1. Insert a channel into holder H1 with the P groove on the left top side.
2. Arrange the probes as shown. Adjust the probes so that they almost make contact with the designated channel elements. Position microprobe P1 and P2 near the end of element number 1 as close to the glass insulating bond between element number 1 and 2 as possible. The probes must contact the SiGe and not the glass.
3. Close switch S1 to operate solenoid SO1. The solenoid raises the holder to permit the channel to make contact with the probes. Observe this operation to insure that the probes are making contact with the SiGe element. The probes should skid slightly in order to scratch through any surface oxide. If good contact is not observed, repeat steps 2 and 3.
4. Position and adjust probes P3 and P4 on element number 1 and P5 on element number 2, using the procedure outlined in steps 2 and 3 above.
5. When probes P1 through P5 have been positioned and adjusted, depress switch S1 to make contact between the probes and the channel elements being tested. The resistance of the element is read from the milliohm meter (M1) with the meter set on the 3-ohm scale. A reading of 0, full scale, or an erratic reading indicates that one of the probes is not making good contact and should be readjusted by repeating steps 2 and 3, above.

NOTE: If, after readjusting the probe, the milliohm meter continues to read full scale, set the meter to the 100-ohm scale. A full-scale reading on this scale would indicate a broken element.

6. The resistance of the glass insulating bond is measured at the same time as the element resistance measurement is being made. Probes P4 and P5 are used to mea-

sure the glass bond resistance. Probe P4 is connected in common with the milliohm meter and the multimeter (M2). The bond resistance is read from the multimeter with the meter set on the R x 100 scale.

Figure 44. Schematic of electrical testing and burnout apparatus

7. Record element resistance greater than 10 ohms and glass insulating bond resistances less than 100,000 ohms as shown in Appendix D, Figure D-1f.

B. Shorts Burnout Procedure

1. Many of the interelement shorts may be cleared (burned out) by applying a 20-volt dc pulse across the shorted bond, using power supply PS2. This is accomplished by depressing switch S3. When S3 is depressed, meters M1 and M2 are disconnected from the circuit and the power from PS2 is applied across probes P4 and P5.

NOTE: The initial pulses are approximately a half second in duration.

If the short does not "burnout" within five pulses, check to see that the probes are located and seated properly. Adjust the microprobes (P4 and P5) to insure good contact, thus minimize arcing at the tips. Next, try pulses of 1, 2, and then 3 seconds if necessary. If the short fails to clear, proceed to step 2.

2. The post-burnout insulating bond resistance value is entered on the test data sheet under the appropriate column heading. If the resistance of the bond is below 500 ohms, after the dc pulse treatment, the location of the shorted area of the bond is determined as described in the following procedure.

C. Short Location Procedure (See Figure 45.)

Figure 45. Short location

1. Lay a heat-sensitive liquid crystal panel on top of the channel.
2. Apply a minimum of 10 volts for a short duration across the shorted bond using the same setup and procedure as described in Section B. A blue spot should appear on the liquid crystal panel over the shorted area as the current flows through the shorted area between the elements.

3. Position P6, the marking microprobe, above the center of the blue spot on the liquid crystal panel.
4. Remove the liquid crystal panel and place an ink dot on the channel directly under the tip of the marking microprobe.
5. Mark the location of the short on the drawing of the shorted channel (Appendix D, Figure D-1f).

D. Scanning Procedure

1. After completing procedure A and, if necessary, B and C for element number 1 and the glass bond between element number 1 and 2, continue as follows:
 - a. Using the linear positioner (Figure 43), position probes P1 through P4 on the next element (number 2) and P5 on the adjacent element (number 3).
 - b. Repeat the element and bond resistance measurement procedure A and, if necessary, the shorts burnout B and location C procedures.
 - c. Repeat steps a and b until all elements and bonds have been tested.

NOTE: A digital counter advances one digit each time switch S1 is depressed. It can be reset by operating switch S2.

Equipment

NOTE: See Appendix A as noted below for pertinent information.

1. Milliohmeter	(A-61)
2. Power Supplies	(A-62)
3. Power Supply	(A-63)
4. Volt-Ohm-Milliohmeter	(A-64)
5. Microscope	(A-65)
6. Prober Assembly	(A-66)
7. Encapsulated Liquid Crystal Panels	(A-67)
8. Microprobes	(A-68)

Drawings

1. Channel, Dwg. No. AY294253

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APPENDIX A
Catalog of Equipment

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APPENDIX A

Catalog of Equipment

<u>Item</u>		<u>Source</u>
A-1	Ultrasonic Cleaner	Branson Instruments Co. Progress Drive Stanford, Conn. 06904
	Description	Model AP-50, Mounted in a Class 100 Laminar Flow Clean Bench
A-2	Acid Sink and Fume Hood	Typical Laboratory Installation
A-3	Cascade Cleaner	Dexon, Inc. 3440 Belt Line, Blvd. Minneapolis, Minn. 55416
	Description	Model VT53E-870 - 3-Ft. Clean Bench Modified with a Barnstead Model 60 Cascade Cleaner
A-4	Water Still	Barnstead Still and Sterilizer Co. 2 Lanesville Terrace Boston, Mass. 02131
	Description	Model CE-1, 10 Gal/Day
A-5	Teflon Fixtures	Sandia Designed and Fabricated
	Description	Dwg. No. SK203
A-6	Glass Beakers	Any Laboratory Supply House
	Description	600cc Griffin Style
A-7	Plastic Containers	Sandia General Stores Item
	Description	Chemical Catalog #675619 Size - 10-5/8 in. Long x 7-3/4 in. Wide x 2-3/4 in Deep With Cover
A-8	Tweezers (Rubber Covered)	Local Purchase - Rio Grande Wholesale Jewelers
	Description	Right Angle Bend - Modified by Filing a Notch in Each Gripping Face to Hold Wafers. The Rubber Coating is a Light Spray Coating of 10% Dow Corning DC 92-009 Silicon in Naphtha. The Coating is Air Dried Overnight and Baked at 150°F for One Hour.
A-9	Wire Basket	Sandia Designed and Fabricated
	Description	Made From 12 Mesh Woven 304SS Wire Size - 12 in. Long x 3 in. Wide x 5 in. High With a Handle

<u>Item</u>		<u>Source</u>
A-10	Plastic Gloves (Disposable)	Davids Gloves, Inc. 3612 Byers Avenue Fort Worth, Tex. 76107
	Description: Gloves, Vinyl, Seamless, Sciberling Disposable Talc-Free, Style 3004 (Sealed 100 Per Bag)	
A-11	Wide Mouth Glass Jar	Sandia General Stores Item
	Description: Squat Form, Wide Mouth w/Molded Screw Cap Volume - 8 oz., Stk. #675147	
A-12	Balance	Any Lab Supply House
	Description: Mettler Model H54, Single Pan Style Precision ± 0.01 mg Readability 0.01 mg	
A-13	Vacuum Pick-Up Tool	Any Lab Supply House
	Description: Peer Vacuum Tool #47-805	
A-14	Fused Quartz Boat	Thermal American Fused Quartz Co. Rt. 202 & Change Bridge Rd. Montville, N. J. 07045
	Description: Trays, Plain, 10-1/4 in Long x 6 in. Wide x 4 in. High	
A-15	Alumina Oxidizing Fixtures	Sandia Fabricated
	Description: See Dwg. SK207	
A-16	High-Temperature Furnace	Blue M Electric Co. Blue Island, Ill. 60406
	Description: Model 8600F-2, Comp. With Over-Temperature Protection	
A-17	Cam Operated Controller-Recorder	Honeywell, Inc. 1885 Douglas Dr., N. Minneapolis, Minn. 55422
	Description: Honeywell, Model 152015-P-239-E-101	
A-18	Laminar Flow Clean Bench	Any Source Which Meets Spec.
	Description: Standard Class 100 Type	
A-19	High Temp. Grease Pencil	Blaisdell, Inc. Huntingdon Valley, Pa. 19006
	Description: Hi Temp. Markers - Green 1371T	
A-20	Single-Edge Razor Blade	Any Source
A-21	Steel Straight Edge	Any Source
	Description: 12 in. Rule	
A-22	Quartz Plate	Amersil, Inc. 685 Ramsey Ave. Hillside, N. J.
	Description: 0.250 in. Thick x 4 in. x 6 in.	

<u>Item</u>		<u>Source</u>
A-23	Alumina Spacers Description: Dwg. No. SK213	Sandia Fabricated (from 1/2 dia. Al_2O_3 rod)
A-24	Screen Printer Description: Presco Model 100 - Modified by Sandia. See Dwg. SK214 NOTE: Currently Evaluating a New Screen Printer, Weltek Model 1200, for Reproducibility, Ease of Setup, and Operation	Precision Systems Co., Inc. Bound Brook, N.J.
A-25	Screens for Printer Description: Screen No. 700, 5 in. x 5 in., Parallel Machined, Stainless Steel, Mesh Size 105	Industrial Reproduction Industries 100 N. Eastern Blvd. Nashua, N. H.
A-26	Screen Tension Meter Description: See Dwg. SK201	Sandia Fabricated
A-27	Vacuum Chuck Description: See Dwg. SK202	Sandia Fabricated
A-28	Viscometer Description: Brookfield Synchro-Electric Viscometer, Model H BT with SC4-14 Spindle	Any Laboratory Supply House
A-29	Teflon or Nylon Spatulas Description: See Dwg. No. SK206	Sandia Fabricated
A-30	Polyethylene Squeeze Bottle	Any Source
A-31	Petri Dishes Description: 4 in. Dia.	Any Laboratory Supply House
A-32	Oxygen Flow Meter Description: 0-25 CFH. of Oxygen	Any Source
A-33	Quartz Boat Cover Description 5-1/4 in. x 11 in. x 1/4 in. Thick	Any Source
A-34	Polyethylene Graduated Cylinder Description: Vol - 250 cc	Any Laboratory Supply House
A-35	Rubber Gloves Description: For Use with HF	Sandia General Stores Item
A-36	Oxygen Line Filters Description: Type A Oil and Moisture Filter Type C Particle Filter (5 to 12 microns)	The Matheson Co. A Division of Will Ross, Inc. Morrow, Ga.

<u>Item</u>		<u>Source</u>
A-37	Alumina Hot Pressing Fixture (stack) Description: See Dwg SK212	Sandia Designed and Fabricated
A-38	Head Loop 4X Magnifier Description: Typical	Any Source
A-39	Chromel Alumel Thermocouple Description: See Dwg. SK212	Sandia Fabricated
A-40	Camel's Hair Brush Description: Small Artist's Brush	Any Source
A-41	Vacuum Hot Press Description: See Dwg. SK200	Sandia Designed and Fabricated
A-42	Temperature Control Console Description: See Figure No. 25	Sandia Assembled
A-43	Mechanical Vac. Pump Description: Kinney Model - 1397	Any Laboratory Supply House
A-44	Cold Trap	Sandia Fabricated
A-45	Hydraulic Ram Description: Black Hawk Model RG-251	Black Hawk Industrial Products Co. Butler, Wis.
A-46	Vacuum Gauge Description: Thermocouple Type (Typical) Hastings Thermocouple	Any Source
A-47	Micrometer Description: 1 in. Standard, Read to 0.0001 in.	Any Source
A-48	Microscope Description: Stereo 30X, 90X Preferred	Any Source
A-49	Alumina Hot Pressing Fixture (Thermopile) Description: See Dwg SK211	Sandia Designed and Fabricated
A-50	Temperature Recorder Controller Description: Model #11130213-5302-4301-00-10001-106-02-OPT151 NOTE: A New Recorder Controller with a Silicon-Controlled Rectifier has been Ordered to Provide More Control Over the Furnace Heating Cycle.	Honeywell
A-51	Over-Temperature Controller Description: Type R-7371	Honeywell
A-52	Variable Transformer Description: 110 V - 30 Amp AC	Any Source

<u>Item</u>		<u>Source</u>
A-53	Motor Drive Unit (Variac)	Sandia Designed and Fabricated
A-54	Voltmeter Description: 0-110 V AC	Any Source
A-55	Ammeter Description: 0-50 Amps AC	Any Source
A-56	Clean Room Description: Filtered Air and Temperature Controlled - Meets Class 10,000 Clean Room Requirements	
A-57	Polyethylene Beakers Description: 600 cc	Any Source
A-58	Plastic Boxes for Subassemblies and Piles Description: Stock #677099	Sandia General Stores
A-59	Tongs	Any Source
A-60	Metallograph Microscope Description: Bausch and Lomb Balphot Metallograph	Any Supply House
A-61	Milliohmmeter Description: Model 4328	Hewlett Packard
A-62	Power Supply, DC Description: Model 6200B	Hewlett Packard
A-63	Power Supply, DC Description: Model 721A	Hewlett Packard
A-64	Voll-Ohm-Milliammeter Description: Model 250L	Simpson
A-65	Microscope Description: Binocular	Bausch and Lomb
A-66	Prober Assembly	Sandia Fabricated
A-67	Liquid Crystal Panels	Edmond Scientific
A-68	Microprobes Description: PR-0150	Wentworth Lab., Inc.
A-69	Stainless Steel Trays Description: Typically 6 in. x 10 in. x 1/2 in.	Any Source

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APPENDIX B
Catalog of Materials

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APPENDIX B
Catalog of Materials

<u>No.</u>	<u>Item</u>	<u>Source</u>
B-1	Distilled Water Specification - ACS	Laboratory Still
B-2	Acetic Acid Grade - Reagent Specification - ACS	Any Source
B-3	Hydrochloric Acid Grade - Reagent Specification - ACS	Any Source
B-4	Ethyl Alcohol Grade - Reagent Specification - ACS	Any Source
B-5	Lint-free Paper Grade - Lens Paper, Size 16 in. x 16 in. Specification - None	Reeve Angle Co., Inc. 9 Bidwell Place Clifton, N. J.
B-6	Liquid Detergent Grade - Joy, Wisk, Ivory	Any Source
B-7	Oxygen Specification - BB-0-925A	Any Source
B-8	Glass Slurry Specification - SS 298455	Electro Science Lab., Inc. 1133 Arch Street Philadelphia, Pa. 19107
B-9	Glass Slurry Thinner Grade - As Supplied by Manufacturer	Same as above
B-10	Lint-free Cloths	Texwipe Co. Box 278 Hillsdale, N. J. 07642
B-11	Screen Mask Emulsion Grade - Ulanocron, Red, RX 200	Ernst W. Dorn Co., Inc. 15905 S. Broadway Cardena, Calif. 90247

<u>No.</u>	<u>Item</u>	<u>Source</u>
B-12	Viton Squeegee	Precision Systems Co., Inc. P. O. Box 148 Somerville, N.J. 08876
B-13	Glass Transfer Tape Specification - SS298457 (A) Grade - 7059 (CGW)1 Weight of 0.056 Grams/sq in. $\pm$ 0.002 Grams/ sq. in. Using Binder System - 004 (B) Grade - 7052 (CGW) (0.003 in.) Weight of 0.065 Grams/sq. in. $\pm$ 0.002 Grams/sq. in. Using Binder System - 004 (C) Grade - 7052 (CGW) (0.008 in.) Weight of 0.139 Grams/sq. in. Using Binder System - 004	Vitta Corp. 382 Danbury Road Wilton, Conn. 06897
B-14	Mica Paper Grade - As Supplied by Manufacturer Cat. #4100-0009	Minesota Mining Mfg. Co. 2121 Santa Ana Dallas, Texas 45238
B-15	Hydrofluoric Acid Grade - Reagent Specification - ACS	Any Source
B-16	Liquid Nitrogen Type II Specification - BB-N-411	Any Source
B-17	Adhesive Tape	Any Source
B-18	Furnace Core Grade - Alundum Core RA-4098 Norton Part No. L2620034A 3 in. Bore x 18 in. Long x 1/4 in. Wall Groove Depth 1/16 in. x 1/16 in. Wide	Norton Co. 1 New Bond Street Norchester, Mass. 01606
B-19	Core Cement Grade - Alundum RA-1162 for use with Platinum Windings and RA-4098 Core	Same as Above
B-20	Platinum Heater Wire Grade - Hi Purity 0.050 in. Dia.	Any Source
B-21	Adhesive Labels	Any Source

<u>No.</u>	<u>Item</u>	<u>Source</u>
B-22	Nitric Acid Grade - Reagent Specification - ACS	Any Source
B-23	Isopropyl Alcohol Grade - Reagent Specification - ACS	Any Source
B-24	Alcohol Water Solution 80 pbv Isopropyl alcohol 20 pbv distilled water 2 cc/liter Surfactent Per 4702403 0.5 cc/liter Surfactent Per 4702401 Prepare the alcohol-water solution and then mix in the detergent and wetting agent. There should be no turbidity after final mixing.	Sandia Prepared
B-25	Nitrogen Grade A, Class 1 Specification - BB-N-411	Any Source
B-26	Coupling Fluid 0.25 cc Liquid Detergent (typical - Igepal) per liter of distilled water.	Sandia Prepared

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APPENDIX C

Formal Drawings for RTG Glass Bonding
Fixtures and Equipment Modifications

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1. MARK PART NUMBER PER 9919100, CLASS H-1.
2. MAKE FROM STACK, PART NO. 294252.
3. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS, SEE 9900000-05.

DESIGN AGENCY CONTROL NO		REV & DMS		PREPARED BY		DATE	CHG	APP
AY294226-000		A	C DUVAL, 7613/T HARRISON, 1334	1/11/72				F
		B	1125 WAS 1150, ADDED DATUMS B C, D DUVAL, 7613/HARRISON, 1334	10/1/72				F
		C	ADDED GRIND DIRECT, 1125±001 WAS 1125±003 DUVAL, 7613/HARRISON, 1334	1/2				F
		D	DELETED MILLIMETERS, 698 WAS 699 MIN DUVAL, 7613/HARRISON, 1334	1/4/73				F
		E	REMOVED B C, & D DATUMS C DUVAL, 7613/T HARRISON, 1334	2/27/73				F
		F	REVISED SCRIBE LINE FROM VERT TO 125 C DUVAL, 7613/T HARRISON, 1334	7/8/73				F

AGENCY APPROVAL		SHEET	1	OF	1
DATE	1/11/72	BY	C	CHKD	
PAR C ASS CA UN		UNCLASSIFIED			
DA		UNCLASSIFIED			
14213		AY294226			
SCALE		SHEET			

TIE SL/GEND

STACK, SIZED
(1-D W INTERCONNECT)

1. MARK PART NUMBER PER 9919100, CLASS H-1.
2. MAKE FROM BLOCK, PART NO. 294229.
3. SLICED WAFERS TO BE IMMEDIATELY PLACED AND STORED IN DE-IONIZED WATER UNTIL CLEANED.
4. .015 DEEP X .050 WIDE CHIPS PERMITTED ON THIS END. TWO POINTS ON THIS END MUST REMAIN TO ESTABLISH THE ORIGINAL LINE AT THE END.
5. THE WAFER MUST HAVE THREE CORNERS.
6. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS, SEE 9900000-05.

DESIGN AGENCY CONTROL NO.		REVISIONS				
ISSUE	DESCRIPTION	PREPARED BY	DATE	CHGR	ENGR.	
AY294232-000	A	C. DUVALL, 7613 / T. HARRISON, 1334	6/14/72			F
	B	ADDED FLATNESS CALLOUTS. C. DUVALL, 7613 / T. HARRISON, 1334	3/23/72			F
	C	ADDED NOTE 3, DELETED MILLIMETER C. DUVALL, 7613 / T. HARRISON, 1334.	1-23-73			F
	D	ADDED NOTE 4, PARALLEL CALLOUT, .0070 TOL WAS .0006, FLATNESS WAS .001 C. DUVALL, 7613 / T. HARRISON, 1334.	2/12/73			F
	E	REVISED NOTE 4, ADDED NOTE 5. C. DUVALL, 7613 / T. HARRISON, 1334	5/2/73			F

AGENCY APPROVALS			SHEET	TITLE	
ORG	DATE	INITIALS	ISSUE	WAFFER, P TYPE (1-D)	
1334			E		
			SHEET INDEX		
			PART CLASSIFICATION		
			UNCLASSIFIED		
			DWG CLASSIFICATION LEVEL		
			UNCLASSIFIED		
7613					
			SIZE	CODE IDENT NO	DWG NUMBER
			B	14213	AY294232
			SCALE	2 / 1	SHEET 1 OF 1

1. MARK PART NUMBER PER 9919100, CLASS H-1.
2. MAKE FROM BLOCK, PART NO. 294229.
3. SLICED .WAFERS TO BE IMMEDIATELY PLACED AND STORED IN DE-IONIZED WATER UNTIL CLEANED.
4. .015 DEEP X .050 WIDE CHIPS PERMITTED ON THIS END. TWO POINTS ON THIS END MUST REMAIN TO ESTABLISH THE ORIGINAL LINE AT THE END.
5. THE WAFER MUST HAVE THREE CORNERS.
6. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS, SEE 9900000-05.

DESIGN AGENCY CONTROL NO.		REVISIONS				
ISSUE	DESCRIPTION	PREPARED BY	DATE	CHKD	ENGR.	
AY294233-000	A	C. DUVAL, 7613 / T. HARRISON, 1334	6/14/72			F
	B	ADDED FLATNESS CALLOUT. C. DUVAL, 7613 / T. HARRISON, 1334	9/23/72			F
	C	DELETED MILLIMETERS, ADDED NOTE 3 C. DUVAL, 7613 / T. HARRISON, 1334	1-23-73			F
	D	ADDED NOTE 4, PARALLEL CALLOUT. C. DUVAL, 7613 / T. HARRISON, 1334	2/27/73			F
	E	REVISED NOTE 4, ADDED NOTE 5, REVISED SCRIBED LINE FROM VERT. TO 15°. C. DUVAL, 7613 / T. HARRISON, 1334	5/2/73			F

AGENCY APPROVALS			SHEET 1	TITLE	
ORG	DATE	INITIALS	ISSUE	END WAFER, P TYPE (I-D)	
1334			E		
PART CLASSIFICATION			SHEET INDEX		
UNCLASSIFIED			UNCLASSIFIED		
DWG CLASSIFICATION LEVEL			DWG NUMBER		
UNCLASSIFIED			AY294233		
7613			SCALE 2/1	SHEET 1	OF 1

- 4.

F
F
F
F
F

TIE SL/GEND

- 1 MARK PART NUMBER PER 9919100, CLASS H-1
- 2 NOTCHES IN ENDS OF ITEMS 1 & 2 TO BE AT THIS END.
3. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS, SEE 9900000-05.
- 4 MATERIALS & PROCESSING PER 55298454, 55298455 & 55298436.

QMS OR AGENCY DRAWING CODE NO. AND	SHEET DESCRIPTION	REV 1 ONE	PREPARED BY	DATE	CHKD	ENGR
AY294252-000	A C DUVALL, 7613/T HARRISON, 1334			1/14/72		F
	B ± 003 TOL WAS ± 0056, DELETED PARALLEL TO 005 FROM [A] C DUVALL, 7613/T HARRISON, 1334			2/1/72		F
	C 362± 003 WAS 365± 003, 001 WAS 0036 GLASS THK, ADDED [111] 002 C DUVALL, 7613/T HARRISON, 1334			3/1/72		F
	D DELETED WAFER DIMS, ADDED NO REQD C DUVALL, 7613/T HARRISON, 1334			1/1/72		F
	E DELETED MILLIMETERS C DUVALL, 7613/T HARRISON, 1334			1/4/73		F
	F ADDED NOTE 2, FLATNESS & PARALLEL CALLOUT WAS 002, ADDED GLASS THK C DUVALL, 7613/T HARRISON, 1334			2/6/72		F
	G ADDED NOTE 3, SHOWED DIAGONAL SLOT C DUVALL, 7613/T HARRISON, 1334			3/1/73		F

TIE SL/GEND

A TNCY APPR. A S		SHEET	1	TITLE	
DRG	DATE	REV	AS	DATE	STACK
7/1/72					(I-D W INTERCONNECT)
PART C ASL		A ON		UNCLASSIFIED	
NO C ASL		A ON E I		UNCLASSIFIED	
7/1/72		3/1		AY294252	

1. MARK PART NUMBER PER 9919100, CLASS H-1.
2. MAKE FROM SIZED STACK, PART NO. 294226.
3. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS, SEE 9900000-05.

DESIGN AGENCY NUMBER OR NO. NO.	REV	DESCRIPTION	PREPARED BY	DATE	CHKD	ENGR
AY294253-000	A	C DUVALL, 7613/T HARRISON, 1334		4/4/72		F
	B	1125 WAS 1150, NOTE 2 294226 WAS 294252 DUVALL, 7613/HARRISON, 1334		1/11/72		F
	C	362 WAS .365 C DUVALL 7613/T HARRISON, 1334		11/17/72		F
	D	ADDED TABLE & GRIND DIRECT C DUVALL, 7613/T HARRISON, 1334		1/5/72		F
	E	DELETED MILLIMETERS, ADDED E83 C DUVALL, 7613/T HARRISON, 1334		1/4/73		F
	F	REMOVED THERMOPILE FROM TITLE, SAW LAP TABLE, ADDED WIDTH DIM C DUVALL, 7613/T HARRISON, 1334		2/6/73		F
	G	ADDED NOTE 3 SHOWED SAW CUT 15° C DUVALL, 7613/T HARRISON, 1334				F

AGENCY APPROVALS		SHEET		TITLE	
DATE	BY	DATE	BY	CHANNEL	
1324				(I D W INTERCONNECT)	
UNCLASSIFIED				C 14213 AY294253	
UNCLASSIFIED				d/1	

AGENCY APPROVALS			SHEET 1		14	
DATE	DATE	INITIALS	NAME	GRADE	THERMOPILE, LAPPED
(I-D W INTERCONNECT)	
7/3/84						
			PART CLASSIFICATION			
			CLASSIFIED			
			ORIG CLASSIFICATION			
			UNCLASSIFIED			
76/13			F 28 CODE IDENT NO		ORIG NUMBER	
			C 14 213		AY294254	
			SC-A	4 / 1	SHEET OF 1	

DESIGN AGENCY TAMM'S CONTROL NO.		REVISE ONE.						
	SUOT	DES	#	IN	PREPARED BY	DATE	CHECK	ENG
AY294254-000	A	C DUVAL	7613	/T HARRISON	1334	1-14/72		F
		.006 ± .005	WAS .007 ± .003	348 ± .003				
	B	WAS 351 ± .002	✓ WAS 348	ADDED		1-14/72		F
		[1114] [002]	DUVAL	7613/HARRISON	1334			
	C	REMOVED PHANTOM LINES.						
		C DUVAL	7613	/T HARRISON	1334	1-17/72		F
	D	ADDED DETAIL-S & LAP DIRECTION						
		C DUVAL	7613	/T HARRISON	1334	1-1/72		F
	E	DELETED MILLIMETERS, ADDED NOTE 3						
		C DUVAL	7613	/T HARRISON	1334	1-14/72		F
	F	.284 WAS .254 ± .002, ADDED DETAIL, NOTE 4.						
		.0040 TAPE WAS .0038				1-17/72		F
		C DUVAL	7613	/T HARRISON	1334			
	G	REVISED MISALIGNMENT NOTE						
		C DUVAL	7613	/T HARRISON	1334	1-17/72		F

—ITEM 3—

- ITEM 1 -

— ITEM 5 —
MATERIAL 206 24142-5

A-A

— ITEM 2 —

TIE SL/GEND
VACUUM HOT PRESS

GROUP	A								
GROUP CLASSIFICATION LEVEL									
UNCLASSIFIED									
DATE	GROUP REVIEW FOR				GROUP REVISION				
E	14213				M 712 SK20				
SCALE	1/2				SHEET		OF 4

ITEM 13
SIMILAR TO ITEM 3
EXCEPT AS SHOWN

ITEM 9

ITEM 16

ITEM 14

ITEM 15
MATERIAL - 304 STAINLESS

ITEM 17

TIE SL/SEND
VACUUM HOT PRESS

ISSUE	A								
DOW CLASSIFICATION LEVEL									
UNCLASSIFIED									
DOW AGENCY NUMBER									
SITE		DOW NUMBER							
E		MC 720 SK200							
SCALE		1				2

GROUP 1
 AND CLASSIFICATION IS
UNCLASSIFIED
 DATE 04/29/2008
 BY 60322 JAL/STP
 SCALE 1 SHEET 1

1

DESIGN AGENCY		REVISIONS			
PART DESIGNATION NO.	ISSUE	DESCRIPTION	PREPARED BY	DATE	CHKD
MC2730-SK202	A	C DUVAL, 7613/C.W.S. R. SNIDOW, 7121/G GUIST		2/11/75

TIE SL/GEND .

AGENCY APPROVALS				SHEET	1	TITLE
ORD	DATE	INITIALS	SIGN	A		VACUUM CHUCK, F.R. PRESCO
				SHEET INDEX		
				PART CLASSIFICATION		
				UNCLASSIFIED		
				OWN CLASSIFICATION		
				UNCLASSIFIED		
				SIZE	CODE IDENT NO	DWG NUMBER
				C	14213	MC 2730-SK202
				SCALE	SHEET 1	OF 1

WASH-OFF FILM

56202

SP 9300 C 12-90

MC2730-SK203

15K203

MATERIAL: TEFLON (ALL ITEMS)

COMMON END VIEW
FOR ITEMS 8 AND 9

TIE SL/GENO
CLEANING FIXTURE

ISSUE [A]	
SUG CLASSIFICATION LEVEL	
UNCLASSIFIED	
14213	
D/MC2730-SK203	
SHEET 3 OF 3	

MC2730-SK203

15A202

WASH OFF FILM

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.
3. USED ON NEWSCREED WELTEK 1200.
4. NICKLE PLATE .0002 THK.

 DESIGN AGENCY
 PART-NO-REQUIRED NO
 MC2730-SK204

REVISIONS		DATE	CHG	ENG
ISSUE	DESCRIPTION	PREPARED BY		
A	C. DUVALL, 7613/C.S.W. R. SNIDOW, 7121/G. GUIST	5/1/5

AGENCY APPROVALS			SHEET		TITLE	
ORG	DATE	INITIALS	ISSUE	NO.	VACUUM CHUCK, FOR WELTEK	
			PART CLASSIFICATION			
			UNCLASSIFIED			
			DWG ASSOCIATION LEVEL			
			UNCLASSIFIED			
			C 14 C 13		MC2730-SK204	
			SHEET 1 OF 1			

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.

DESIGN AGENCY PART OR STANDARD NO.		REVISIONS			
ISSUE	DESCRIPTION	PREPARED BY	DATE	CHECK	ENGL.
MC2730-SK205	A	C. DUVAL, 7613/G. GUIST R. SNIDOW, 7121	5/21/73

SCREEN 5 X 5 FOR PRESCO
SCREEN 8.5 X 5.75 FOR WELTEC

MASK OPENING $1.167 \pm .002$
 $X.692 \pm .002$ (FOR 1.175 X .700 WAFERS.
OPENING CENTERED IN SCREEN $\pm .19$

TIE SL/GEND

AGENCY APPROVALS			SHEET 1	TITLE	
ORG	DATE	INITIALS	ISSUE A	SCREEN AND MASK	
			SHEET INDEX		
			PART CLASSIFICATION		
			UNCLASSIFIED		
			DWG CLASSIFICATION LEVEL		
			UNCLASSIFIED		
			SIZE B	CODE 14-213	DWG NUMBER MC2730-SK205
			SCALE NONE	SHEET 1	OF 1

PHOTOCHEMICAL PROCESSES LABORATORY

PROCESS SHEET

PC 131

Page 1 of 1

(date) 6-13-72

R.T.G. SCREEN PRINTING MASKS - IMAGE APPLICATION

- 1.0 Strip and clean screen in J-44 Stripper
- 2.0 Degrease in hot vapor degreaser
- 3.0 Expose on the Scanex II (PC 211)
 - 3.1 Lay circuit master on glass emulsion side up
 - 3.2 Lay Ulano Fotofilm on top of CM with mylar side down
 - 3.3 Lay plastic bag on top of Fotofilm
 - 3.4 Lay black crepe paper on top of sandwich (expose bottom side only)
 - 3.5 Printing speed - "0" on dial
- 4.0 Develop in 1½% Hydrogen Peroxide (H_2O_2) for 1½ minutes
 - 4.1 Mix 20ml 35% H_2O_2 and 580ml H_2O
- 5.0 Hold Ulano Fotofilm in hand with mylar side down and wash out pattern with 95 - 100 F water
- 6.0 Center pattern on screen with mylar side up
- 7.0 Press emulsion through screen with linen napkin
- 8.0 Dry at room temperature - 3 hours
- 9.0 Peel off mylar

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.
3. TEFLON ROUND PER MIL-P-19468.

DESIGN AGENCY PART OR DRAWING NO		REVISIONS			
		ISSUE	DESCRIPTION	PREPARED BY	DATE
MC2730-SK206		A	C. DUVALL, 7613/G. GUIST R. SNIDOW, 7121		1/21/73

TIE SL/GEND

AGENCY APPROVALS			SHEET	1		TITLE	
ORG	DATE	INITIALS	ISSUE	A		SPATULA	
			SHEET INDEX				
			PART CLASSIFICATION				
			UNCLASSIFIED				
			UNCLASSIFIED				
			SIZE	CODE IDENT NO	TR. NUMBER		
			B	14213	MC2730-SK206		
			SHEET	1	OF 1		

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.
3. QUARTZ BOAT A PRODUCT OF THERMAL AMERICAN FUSED QUARTZ CO. ROUTE 202 & CHANCEBRIDGE RD, MONTVILLE, N.J., 07045.

DESIGN OFFICE	REV	DATE	BY	CHKD	QTRD
MC2730-SK208	A	7/1/75	C DUVALL, 7613/ C GUIST R SNIDOW, 7121

AGENCY APPROVALS			SHEET		TIE SL/GEND	
ORG	DATE	INITIALS	SHEET	NO	QUARTZ BOAT AND COVER	
			ALL	1		
			UNCLASSIFIED			
			UNCLASSIFIED			
			CODE	DATE	NO	NUMBER
			C	14213		MC2730-SK208
			3	4	1	2
			BY 2002 C 1447			

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.
3. 32/ ALL OVER UNLESS OTHERWISE SPECIFIED.
4. STAINLESS STEEL, 302, COND A, NO. 2 BRIGHT FINISH PER QQ-S-766.

DESIGN AGENCY
PART OR-000000 NO.MC2730-SK209
SEE TABULATION

REVISIONS

ISSUE	DESCRIPTION	PREPARED BY	DATE	CHKR	ENGR.
A	C. DUVALL, 7613/ R. SNIDOW, 7121	G. GUIST	5/21/73		

PART NO.	DIM A
-001	.027
-002	.031
-003	.034
-004	.038
-005	.041

DIM A $\pm .0005$
SEE TABLE

TIE SL/GEND

AGENCY APPROVALS			SHEET	1		TITLE	
ORG	DATE	INITIALS	ISSUE	A		SPACERS, BREAKAWAY ADJUSTMENT	
			SHEET INDEX				
			RT CLAC				
			UNCLASSIFIED				
			JWG CLASSIFICATION LEVEL				
			UNCLASSIFIED				
			SIZE		CODE IDENT NO	DWG A	
			B		14213	MC2730-SK209	
			SCALE		2 / 1	SHEET 1	OF 1

3. THIS DWG WAS SK 154.

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL EQUIPMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.

REGION AGENCY PART 00-00000000 NO		REV VISIONS				
MC	ISSUE	DESCRIPTION	PREPARED BY	DATE	CNBS	SP
MC2730-3K211	A	C DUVALL, 7613 / R. SNIDOW, 7121	NCR	5/11/85

5/32 SPHER R

5/16-18 NC2 FULL LENGTH

ITEM 8 (MAKE 3)

Technical drawing of a mechanical part. The drawing shows a side view and a cross-sectional view. The side view shows a cylindrical part with a diameter of $.625 \pm .010$ and a length of $.050^{+.010}_{-.000}$. A spherical feature is indicated by a callout "5/32 SPHER R". The cross-sectional view shows a hole with a diameter of $.040^{+.010}_{-.000}$ and a note ".040^{+.010}_{-.000} ON ϕ WITHIN .010".

SSU	A								
UNCLASSIFIED									
C	14213	MC2730-SK211

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 9900000.
3. $\frac{63}{100}$ ALL OVER UNLESS OTHERWISE SPECIFIED.
4. SIMILAR TO DWG BY A. REPETTI.

DESIGN AGENCY
PART OR DRAWING NO
MC 2730 -
SEE VIEWS

REV	DESCRIPTION	PREPARED BY	DATE	CHECK	DATE
A	C. DUVAL, 7613 / G GUIST/AR. R. SNIDOW, 7121		7/1/73

PRINTED IN U.S.A. BETWEEN AREAS ONLY

NOTES :

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. GENERAL REQUIREMENTS & DRAWING INTERPRETATIONS ARE DEFINED IN 9900000-05.
3. ALUMINA.

DESIGN AGENCY PART 00-00000000 NO		REV & CDS			
DATE	DESCRIPTION	PREPARED BY	DATE	CHNG	FW
MC2730-5K215	A C DUVAL, 7613 / 6 GUIST R. SNIDOW, 7121		2/4/73

UPPER SPACER
WHITE ALUMINA

MIDDLE SPACER
PINK ALUMINA

AGENCY APPROVALS			SHEET	TITLE
ORG.	DATE	INITIALS	SUBJ	SPACERS UPPER AND MIDDLE
			PAGE NUMBER	
PAR 1 CLASS ON			UNCLASSIFIED	FBI CODED EVENT NO
				DNC NUMBER
RECLASS ACTION			UNCLASSIFIED	C 14213 MC2790-SK215
				SCALE 1 / 1 SHEET 1 OF 1

APPENDIX D
Forms and Graphs
for
RTG Glass Bonding

BLANK

ID-W STACK BONDING

Date of Form: 3/5/73

Page 1

MC2730 DEVELOPMENT TRAVELER

Stack No. W-161-5

Wafer to Thermopile Channel

STEP #	OPERATION	ORG.	BLDG.	W.O.	OPERATORS INITIALS	DATE
8a	Prepare Traveler	7121-4	839	F-308453	<u>CT</u>	<u>1-5-73</u>
9	Hot Press Stack	7121-4	839	F-308453	<u>CT</u>	<u>1-5-73</u>
9a	Tap Stack for Shcing	7145-2	840	F-308453	<u>MN</u>	<u>1-9-73</u>
10	Dimensional Inspection	7113-1	840	F-308453	<u>CL</u>	<u>1-10-73</u>
11	Slice Stack	7122-1	840	F-308453	<u>DA</u>	<u>1-11-73</u>
11a	Inspect T. P. Channel	7113-1	840	F-308453	<u>CL</u>	<u>1-16-73</u>
11b	Clean T. P. Channel	7121-4	839	F-308453	<u>DA</u>	<u>1-16-73</u>
12	Elec. Test T. P. Channel	7113-3	894	F-308453	<u>DA</u>	<u>1-17-73</u>

- OTLS: 1. See following sheet for identification of stack and also required data.
2. After last operation, usually 12, send traveler to T. D. Harrison, 1334, 892/200

STACK Good ✓ Bad _____ Maybe _____

REMARKS: Minor chipping of channels

INITIAL CT

Figure D-1. 1D-W Stack Bonding Data Traveler

Figure D-1a

Date of Form: 3/5/73

ID-W STACK BONDING

Page 3

Stack No. W-161-5

DATE 12-19-72

BINDER BURNOUT:

Tape _____, Screen Printed ✓

Refer to: Procedure 40:03-01

Temperature 550°C Time 4 hrs.

Atmosphere Oxygen Flow Rate 10 CFH

Technician HAWK

FIXTURE CLEANING: Yes _____ No ✓

Date 1-4-73

Refer to: Procedure 40:03-03

Fixtures Nos. 1D-Ws-1 C3 X X

Modifications _____

Technician _____

STACK HOT PRESSING:

Date 1-4-73

Refer to: Procedure 40:04

For hot pressing parameters (this stack), see: "WAFER STACK LOG"

Modifications and Comments _____

Appearance (Note chips and fractures on attached sheet)

Extrusion good Glass-Clear good Bubbles No

Technician C.T.

STACK GRINDING:

Date 1-5-73

Refer to: Procedure 50:00

Technician _____

DIMENSIONAL INSPECTION:

Date 1-5-73

Refer to: IP102 and AY294252

Wafer Stack Dimensions

A .3664 B .3665 C .3658 D .3656 E .3662

Comments _____

Technician C.L.

Figure D-1c

Date of Form: 3/5/73

ID-W STACK BONDING

Page 4

Stack No. W-161-5

Date 1-8-73

STACK SLICING:

Refer to: Procedure 30:00

No. of cuts on blade 348

Certification of mounting by C.L.

Thermopile Subassembly Thickness:

Stack Sliced By D. J.

SLICED THERMOPILE CHANNELS

Date 1-10-73

Refer to: IP103 and AY 294253

Thermopile Channel Dimensions

T. P. C.

	A	B	C	D
Thickness	<u>0.1398</u>	<u>0.1402</u>	<u>0.1395</u>	<u>0.1397</u>

Microscopic Evaluation of Thermopile Channels:

End Alignment Good

Broken Elements — Type — Location —

Damage to SiGe: Chips - Yes ☒ No ☐

Comments: Slight chipping on A + C channels

Technician C.L.

THERMOPILE CHANNEL CLEANING:

Date 1-11-73

Refer to: Procedure 40:05-01

Modifications —

Technician Hawk

Figure D-1d

Date of Form: 3/5/73

RECORD OF STACK AND THERMOPILE CHANNEL FRACTURE AND CHIPS

Page 5

Stack No. W-161-5

Indicate observed damage on drawing with initial		Org.	Init.	Date
<p>STACK</p>	7121-4	CT	1-5-73	
	7145-2	mh	1-9-73	
	7113-1	CL	1-10-73	
	7122-1	DA	1-11-73
<p>THERMOPILE CHANNELS</p> <p>GL-101072</p>	7122-1	DA	1-11-73	
	7113-1	CL	1-16-73	
	7121-4	CT	1-16-73	
	7113-3	NS	1-17-73	
	7121-4	CT	1-18-73	

Figure D-1e

ELECTRICAL INSPECTION - THERMOPILE CHANNELS

Date of Form: 3/5/73

Date 1-17-73

Page 6

Thermopile Channel No. <i>W-161-s</i>	Shorted Elements Nos.	Resistance of Short Ohms	Cleared <u>20</u> Volts		Resistance Uncleared Shorts Ohms	Shorts Location and Comments
			Yes	No		
<i>A</i>						<i>ALL > 14,000</i>
<i>B</i>	<i>43-44</i>	<i>1800</i>	<i>✓</i>		<i>—</i>	<i>ALL others > 50,000</i>
<i>C</i>						<i>ALL > 60,000</i>
<i>D</i>						<i>ALL > 10,000</i>

Additional Comments: _____

No BROKEN ELEMENTS

Technician *Dick SPARKS*

Short Locations

A
B
C
D

Figure D-1f

Date of Form: 3/5/73

GLASS DEPOSITION DATA SHEET

Sheet 1 of 2

Slug No. P-1231Wafer Thickness .007Glass Type 7059

SCREENING DATA

Glass Paste Lot No. 266-28Screen Mesh 105Viscosity (10) 2620 Poise, at 21 °CScreen Tension 93 milsBreakaway Distance .024 inchSqueegee Pressure 4-7 milsScreen No. 1Squeegee Speed 2 in/sec

TAPE DATA

Wt. of Glass gm./in²Thickness milsDate Mfgd. Quantity Recd

No.	A Wt. Wafer Clean, mg	B Wt. Oxidized Wafer, mg	C Wt. Oxidized Wafer + Glass and Binder, mg	C-B Binder and Glass Wt., mg	D Wt. Oxidized Wafer + Glass, mg	D-B Glass Wt., mg	Eddy Test
1	<u>27910</u>	<u>27935</u>	<u>34869</u>	<u> </u>	<u>32356</u>	<u> </u>	<u> </u>
2	<u>27928</u>	<u>27951</u>	<u>34946</u>	<u> </u>	<u>32425</u>	<u> </u>	<u> </u>
3	<u>27972</u>	<u>28000</u>	<u>34962</u>	<u> </u>	<u>32420</u>	<u> </u>	<u> </u>
4	<u>27834</u>	<u>27853</u>	<u>34777</u>	<u> </u>	<u>32236</u>	<u> </u>	<u> </u>
5	<u>28029</u>	<u>28051</u>	<u>34971</u>	<u> </u>	<u>32438</u>	<u> </u>	<u> </u>
6	<u>28060</u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
7	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
8	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
9	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
10	<u>28060</u>	<u>28080</u>	<u>35002</u>	<u> </u>	<u>32464</u>	<u> </u>	<u> </u>
11	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
12	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
13	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
14	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
15	<u>28061</u>	<u>28090</u>	<u>34986</u>	<u> </u>	<u>32448</u>	<u> </u>	<u> </u>
16	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
17	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
18	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
19	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
20	<u>28020</u>	<u>28045</u>	<u>34934</u>	<u> </u>	<u>32404</u>	<u> </u>	<u> </u>
21	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
22	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
23	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
24	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
25	<u>28026</u>	<u>28045</u>	<u>34887</u>	<u> </u>	<u>32376</u>	<u> </u>	<u> </u>
26	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
27	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
28	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
29	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
30	<u>28022</u>	<u>28045</u>	<u>34890</u>	<u> </u>	<u>32374</u>	<u> </u>	<u> </u>

Figure D-2. Glass Deposition Data Sheet

Figure D-2a

Date of Form: 3/5/73

GLASS DEPOSITION DATA SHEET (CONT.)

Sheet 2 of 2

Slug No. P-1231Wafer Thickness .007 Glass Type 7059

N	A	B	C	C-R	D	
	Wt Wafer Clean, mg	Wt Oxidized Wafer	Wt Oxidized Wafer + Glass + Binder, mg	Binder and Glass Wt, mg	Wt	Wt
31						
32						
33						
34						
35	<u>28012</u>	<u>28036</u>	<u>34877</u>		<u>32364</u>	
36						
37						
38						
39						
40	<u>27995</u>	<u>28021</u>	<u>34850</u>		<u>32360</u>	
41						
42						
43						
44						
45	<u>28096</u>	<u>28132</u>	<u>34935</u>		<u>32457</u>	
46						
47						
48						
49						
50	<u>28066</u>	<u>28092</u>	<u>34926</u>		<u>32446</u>	
51						
52						
53						
54						
55						
56						
57						
58						
59						
60						

Figure D-2b

NO. <u>21</u>		NO. <u>35</u>
SLUG NO. <u>N-1263</u>		SLUG NO. <u>N-1263</u>
NO. <u>1</u>		NO. <u>22</u>
NO. <u>23</u>		NO. <u>52</u>
SLUG NO. <u>N-1245</u>		SLUG NO. <u>N-1245</u>
NO. <u>1</u>		NO. <u>24</u>
NO. <u>23</u>		NO. <u>50</u>
SLUG NO. <u>N-1244</u>		SLUG NO. <u>N-1244</u>
NO. <u>1</u>		NO. <u>24</u>

Figure D-3. Quartz Boat Map

SCREEN TENSION

SCREEN NO. 3
SCREEN MESH 105

Figure D-4. Screen Tension

PRESSURE VS GAUGE READING; 0-1000 PSI GAUGE

Figure D-5. Pressure conversion graph (stack and pile)

Figure D-6. Typical control and monitor thermocouple traces (stack and pile)

STACK NO. W-161-5

WAFER STACK LOG

DATE 1-4-73

No. Used
 N .014 1220
 N .007 1213 21
 N .007 _____
 N .007 _____

No. Used
 P .014 1212
 P .007 1193 11
 P .007 1203 10
 P .007 _____

STACK ASSEMBLY FIXTURE AND SPACER IDENTIFICATION

 Fixture 10-W5-1 Upper Spacer C3 Middle Spacer X Lower Spacer X

VACUUM HOT PRESSING CYCLE

Time	Controller Temp. °C		Monitor °C	Dial Indicator Inches	Ram Travel Inches	Hydraulic Pressure Gauge	Vacuum Gauge Microns
	Set	Reading					
8:25	650	Rt	Rt				—
9:30	650	655	600	Start	30	MIN. Soak	10
10:00	900	655	630				"
11:05	900	905	860	Start	10	MIN. Soak	"
11:15	900	905	863	.142	Ram	Contact	10
11:17	900	905	863	.149	.007	50	"
11:18	900	905	860	.150	.008	60	"
11:19	900	905	860	.151	.009	70	"
11:20	900	905	860	.152	.010	80	10
11:21	900	900	860	.152	.010	90	"
11:22	900	900	860	.153	.011	100	"
11:24	900	900	860	.154	.012	120	"
11:26	900	898	860	.155	.013	140	10
11:28	900	895	862	.156	.014	160	"
11:30	900	900	865	.157	.015	170	"
11:40	900	900	870	.158	.016	170	Vac. Off
Power off		640	750		Ram released		Atm

OBSERVATIONS AND COMMENTS

 Dimensions A. 3664 B. 3665 C. 3658 D. 3656 E. 3662

General Appearance (Voids, Extrusion, Cracks) _____

Looks good - Extrusion - No bubbles

Deviations from Normal Pressing or Heating Cycle _____

Instrumentation, Equipment or Fixture Modifications or Changes _____

CONTINUE ON BACK IF NECESSARY

Figure D-7. Wafer Stack Log sheet

Date of Form: 3/5/73

ID-W PILE BONDING

Page 1

Thermopile No. W-218P

MC2730 DEVELOPMENT TRAVELER

Pile Serial No. W-218P

Thermopile Channels to RTG

RTG Serial No. _____

Tungsten Interconnect

First Thermopile Channel W-161-S-C

0.007" Wafers from Slugs

0.014" End Wafer

N Slugs 1213P Slugs 1193120312201212Second Thermopile Channel W-161-S-DN Slugs 1213P Slugs 1193120312201212

OP #	OPERATION	ORG.	BLDG.	W. O.	INIT.	DATE
13	Prepare Traveler	7121-4	839	F-308453	<u>C.T.</u>	<u>1-25-73</u>
14	Hot Press Thermopile	7121-4	839	F-308453	<u>C.T.</u>	<u>1-25-73</u>
15	Lapping & Grinding	7145-2	840	F-308453	<u>M.H.</u>	<u>1-31-73</u>
16	Mechanical Inspection (photograph ends)	7113-1	840	F-308453	<u>C.L.</u>	<u>2-1-73</u>
16a	Glass Bond Quality Check	5334	808		<u>J.M.</u>	<u>2-5-73</u>
17	Clean Thermopiles	7121-4	839	F-308453	<u>G.H.</u>	<u>2-7-73</u>
18	Electrical Test T. P.	1334	643			
19	Polish T. P.	7145-2	840	F-308453		
20	Interconnect	7121-1	828	F-308454		
21	Bond Leads	1435	643	F-308454		
22	Test Bonds, Electrical	1334	643	F0312514		
23	Radiation Safety	3311	643	F-308457		
24	RTG Assembly	1334	643	F-308459		
25	Final Test, Mechanical	1334	643	F-308459		
26	Final Test, Electrical	1334	643	F-312514		

Thermopile

Good ☒Bad ☐Maybe ☐

COMMENTS _____

INITIAL _____

Figure D-8. 1D-W Pile Bonding traveler

Figure D-8a

Date of Form: 3/5/73

ID-W PILE BONDING

Page 2

Thermopile No. W-218-p

RAW MATERIAL:

Thermopile Channels from Stack No. W-161-5

NOTE: ALL PROCESSING ORGANIZATIONS RECORD ANY SILICON
GERMANIUM OR GLASS DAMAGE ON ATTACHED "RECORD
OF PILE FRACTURE AND CHIPS" WORK SHEET (PAGE 5).

Thermopile Channel Cleaning:

Date 1-19-73

Refer to: Procedure 40:05-01

Modifications: _____

Technician Hawk

Glass Application:

Date 1-19-73

Refer to: Procedure 40:05-02

Glass Tape 7052 Thickness 358 Mils _____ GMS/in²

Date Mfgd. _____ Quantity Received _____

Binder System - 004

Technician Hawk

A	B	B-A	C	C-A
T. P. C.	Wt. T. P. C. & Glass & Binder	Wt. Glass + Binder	Wt. T. P. C. + Glass	Glass Wt.
<u>161-C</u> .280754 Mg	<u>.287436</u> Mg	<u>66.82</u> Mg	<u>.286586</u> Mg	<u>58.32</u> Mg
<u>161-D</u> .280386 Mg	<u>.284019</u> Mg	<u>36.33</u> Mg	<u>.283076</u> Mg	<u>26.90</u> Mg

Tape Binder Burnout:

Refer to: Procedure 40:05-02

Date 1-19-73

Temperature 550°C Time 4 hrs.

Atmosphere Oxy. Flow Rate 10 CFH

Technician Hawk

Figure D-8b

Date of Form: 3/5/73

ID-W PILE BONDING

Page 3

Thermopile No. W-218-p

Date 1-24-73

Fixture Cleaning: Yes ☐ No ☒

Refer to: Procedure 40:03-03

Fixture Nos. 1D-Wp-2 B3 Z Z _____

Modifications _____

Technician Tuthill

Pile Hot Pressing:

Date 1-24-73

Refer to: Procedure 40:06

For hot pressing parameters (this pile) see: "Thermopile Assembly Log" Sheet

Modifications and Comments: _____

Pile Data:

Alignment good Extrusion good

Comments: _____

Dimensions: A- .2844 B- .2853

Technician Tuthill

Grinding and Lapping:

Refer to: Procedure 60.00

Date 1-31-73

Comments: _____

Technician mn

Figure D-8c

Date of Form: 3/5/73

ID-W PILE BONDING

Page 4

Date 2-1-73

Thermopile No. W-218-p

Mechanical Inspection:

Refer to: Procedure 1P104

Photos: Yes ☒ No ☐

Comments: Element Alignment Good Squareness Good

Photos of end faces - no chips

Technician C.L.

Thermopile Glass Bonding Process Evaluation

Refer to: Procedure 40:07

See Pg. 6 This Traveler

Pile Cleaning:

Date 2-7-73

Refer to: Procedure 40:05-01

Comments:

Technician Hawk

Figure D-8d

Date of Form: 3/5/73

Thermopile No. W-218-p

RECORD OF PILE FRACTURE AND CHIPS

Indicate observed damage on drawing with initials

	Org.	Init.	Date
7121-4	C.T.	1-25-73
	7145-2	mh	1-31-73
	7113-1	C.L.	2-1-73
	5334	Jh.	2-5-73
	7121-4	A.H.	2-7-73
	1334		
	7145		
	1334		

Page 5

Figure D-8e

THERMOPILE GLASS BONDING PROCESS EVALUATION

Refer to: Procedure 40:07

END FACE VOID CHART

MICROSCOPIC EXAM - B&I, METALLOGRAPHIC

EXAMINED BY: MATSKO

Date: 2-5-73

Thermopile No. W-218-p

CHANNELS

W- 161 -S-A B C D

W- 161 -S-A B C D

VISUAL

LIGHTING = DARK FIELD

OBJECTIVE = 10X D.F.

EYE PIECE = 10x

MAGNIFICATION = $\sim 100\times$

PHOTOS

YES _____ NO ☒

END FACE

BELLWS = _____

OBJECTIVE = _____

CAM LENS = _____

TIME = SEC

P

○ - VOID END FACE 1 ● = VOID END FACE 2

END FACE 1: TOTAL VOIDS = 4 TOTAL BONDS WITH VOIDS = 4

END FACE 2: TOTAL VOIDS = 1 TOTAL BONDS WITH VOIDS = 1

ELEMENT ALIGNMENT

END FACE 1

END FACE 2

EXCELLENT = < 0.0005" OFF

GOOD = 0.0010" OFF

FAIR $\approx \sim 0.0015''$ OFF

POOR = $>0.0015''$ OFF

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1. *Journal of the American Medical Association*, 1997; 278: 1023-1028.

COMMENTS: _____

Figure D-8f

PILE NO. W-218-p **THERMOPILE ASSEMBLY LOG** DATE 1-24-73

THERMOPILE CHANNELS W-161-C & W-161-D

THERMOPILE ASSEMBLY FIXTURE AND SPACER IDENTIFICATION

Fixture 1D-Wp-2 Upper Spacer B 3 Middle Spacer Z Lower Spacer Z

VACUUM HOT PRESSING CYCLE

Time	Controller Temp. °C Set	Reading	Monitor °C	Dial Indicator Inches	Ram Travel Inches	Hydraulic Pressure Gauge	Vacuum Gauge Microns
1:05	650	R.T.	R.T.	start			
2:10	650	650	600	start 30 min. soak			12
2:40	750	650	620				12
3:35	750	750	705	start 10 min. soak			12
3:45	750	750	705	.169	Ram contact		12
3:47	750	750	705	.175	.006	50	"
3:48	750	750	705	.176	.007	60	"
3:49	750	750	710	.177	.008	70	"
3:50	750	750	710	.178	.009	80	12
3:51	750	750	710	.179	.010	90	"
3:52	750	750	710	.179	.010	100	"
4:07	750	750	710	.181	.012	100	VAC. off Atm.
	Power off		650				

OBSERVATIONS AND COMMENTS

Dimensions A. .2848 B. .2853

General Appearance (Voids, Extrusion, Cracks) _____

Looks good - Adequate extrusion - No bubbles

Deviations from Normal Pressing or Heating Cycle _____

Instrumentation, Equipment or Fixture Modifications or Changes _____

CONTINUE ON BACK IF NECESSARY

Figure D-9. Thermopile Assembly Log sheet

Figure D-10. Temperature-viscosity curves for CGW 7059 and 7052 glasses

APPENDIX E

Computer Program GLASSF
for
Process Evaluation of RTG Glass Bond

BLANK


```

C DIMENSION KINO(2,2),Y(100,12),IDD(100),DD(2),FLM(3,3),O(7,12)
C   ARRAY HAS N MEAN, S, VAR, MAX, MIN, RANGE
C DIMENSION LAR(7), KYND(2,2)
C   DIMENSION HEAD (3)
C DATA KY/1HY/,HEAD/4HERIT,4HUXID,4HJINK/,KEXIT/4HEXIT/
C DATA KINO/5HSCREE,THNEI,5HTAPE0,1H /,KYND/5HSLURR,1HY,5H TAPE,1H /
C DATA FLM/44,54,46,56,42,78,0.3',1.50,0.10,7.0,7.30,5.7 /
C   DEVICE FOR OUTPUT ---- NEEDED IN PLTR SUBROUTINE
C   COMMON /DEV/LD
C   REGRESSION COEFFICIENT SUPPLIED BY L.SNOODGRASS 2-23-73
C   BASED ON 96 PAIRS OF VALUES
C   REGCOI=.250923
C   USED TO COMPUTE Y(11)
C   MAX NUMBER OF OBS
C   MAX=100
C LAR(1)=1HA
C LAR(2)=4HMF4.
C LAR(3)=5HS OFV
C LAR(4)=5HVAR
C LAR(5)=5HMAX X
C LAR(6)=5HMIN X
C LAR(7)=5HRANGE
51   TYPE 205
2050   FORMAT(/' ENTER FILE NAME - A5 .....')
C   ACCEPT 2 51,FILE
C   IF(FILE.EQ.KEXIT)STOP
2051   FORMAT(A5)
C   CALL IFILL (1,FILE)
C   TYPE 2039
2039   FORMAT(/' WANT TO CHANGE TOL LIMITS?... Y OR N.. '1)
C   ACCEPT 2 23,MK
C   IF(MK.NE.KY) GO TO 652
51   TYPE 204
2040   FORMAT(/'X, 'TOLERANCE LIMITS')
C   TYPE 2040
2040   FORMAT(/X, 'INDEX NOMINAL INDEX UPPER INDEX LOWER')
C   O 600 I=1,3
C   TYPE 2010 ,HEAD(1),(J,I,FLM(J,I),J=1,3)
2010   FORMAT(1H A4,3X,2I2,F8.3,5X,2I2,F8.3,3X,2I2,F8.3)
2010   CONTINUE
C   ICOR=0
51   TYPE 2020
2020   FORMAT(' ALL LIMITS CORRECT? Y OR N..... '3)
C   ACCEPT 2 25,MK
2020   FORMAT(A1)
C   IF(MK.EQ.KY) GO TO 654
C   ICOR=1
C   TYPE 2030
2030   FORMAT(' ENTER INDEX AND CORRECT VALUE')
C   ACCEPT 2 35,J,I,FLM(J,I)
2035   FORMAT(2I,F)
C   GO TO 605
605   IF(ICOR.EQ.0) GO TO 652
C   ICOR=0
C   GO TO 51
652   TYPE 7780
7780   FORMAT(/' OUTPUT ON TTY OR LPT? .. TYPE ALL 3 CHARACTERS..'5)
C   ACCEPT 778,IDEV
7780   FORMAT(A3)
C   DEFAULT OPTION TTY (-1)
C   LD=-1

```



```

      IF (IDEV.EQ.3HLEPT) LD=-3
      IF (IDEV.EQ.3HLEPT) WRITE(LD,779A)
270  FORMAT(11)
      CALL DATE (DD)
      READ (1,41',END=999)ISLUG,KD,NN,CON1,CON2
410  FORMAT(A5,1X,A1,1X,1,2F)
      IF (NN.GT.1AX) GO TO 540
      IS = 1
      IF (KD.EQ.1HS) IS=1
      IF (KD.EQ.1HT) IS=2
      IF (ISW.LT.1.OR.ISW.GT.2) GO TO 496
      WRITE(LD,232),ISLUG,KD,(KIND(JJ,ISV),JJ=1,2),CON1,CON2,NN,PE,CON
      WRITE(LD,231),(FLM(1,J),J=1,3),(FLM(3,J),J=1,3),(FLN(2,J),J=1,3)
231  FORMAT(/1X,'TOLERANCE LIMITS FOR GLASS FRIT OXIDE WGT
      1  CALC WAFER THICK'//
      2 1X,5X,'NOMINAL' 14X,F17.3,2X,F10.3,5X,F10.3/
      3 1X,5X,'LOWER LIMIT'2X,F17.3,2X,F10.3,5X,F10.3/
      4 1X,5X,'UPPER LIMIT'2X,F17.3,2X,F10.3,5X,F10.3/)
23  FORMAT(/25X,12(2H- )/1X,'DATA IDEN. ---',A5,30X,'DATE',2X,2A5/
      1 1X,2A5/1X,'DENSITY OF CODE 7059 GLASS CGW=',F7.3,' GMS/CM.IN.'//
      2 18X,'AREA OF WAFER='F7.3,' SQ.IN.'/20X,'NO. OF ORS.='13/
      3/1X,'CALC. WAFER THICKNESS = CLEANED WGT. X',F17.7/)
      READ (1,254) (IDD(I),(Y(I,J),J=1,4),I=1,NN)
      1 THINK NEW DATA WILL BE ENTERED XXX.XX

      DO 60 I=1, 4
      Y(I,5)=Y(I,4)-Y(I,2)
      Y(I,6)=Y(I,5)-FLM(1,1)
      Y(I,9)=Y(I,2)-Y(I,1)
      Y(I,10)=Y(I,9)-FLM(1,2)
      Y(I,7)=(Y(I,5)/(Y(I,3)-Y(I,2)))*107,
      Y(I,8)=100,-Y(I,7)
      Y(I,11)=Y(I,1)*RFGCON
      Y(I,12)=Y(I,11)-FLM(1,3)
60  CONTINUE
      DO 60 J=1,12
      G(1,J)=NN
      CALL MINID (Y(1,J),NN,G(2,J),G(3,J),G(4,J),G(5,J),G(6,J),G(7,J))
80  CONTINUE
      10TX=0
311  FORMAT(/1X,'WAFER'10X,'CLEANED',8X,'OXIDIZED',8X,'OXIDIZED',
      1 6X,'OXID. '+/1X,'IDEN.'10X,'WEIGHT',9X,'WEIGHT',9X,'+ '
      2 A5,A1,6X,'GLASS FRIT'/1X,' NO.',11X,'M GMS'11X,'M GMS',
      3 11X,'M GMS',9X,'M GMS'//)
312  FORMAT(/1X,'WAFER',12X,'GLASS',9X,'GLASS -',8X,
      1 'GLASS IN',7X,'BINDER IN'/1X,'IDEN.',12X,'FRIT',9X,
      2 'NOMINAL',9X,A5,A1,1X,9X,A5,A1/1X,' NO. ',13X,'MGMS',12X,'M GMS'
      3,12X,'%',15X,'%'//)
313  FORMAT(/1X,'WAFER',12X,'OXIDE',4X,'OXIDE WEIGHT',5X,
      1 'CALC. WAFER',7X,'C.THICK.'/1X,'IDEN.'12X,'WGT.',5X,
      2 'NOMINAL',9X,'THICKNESS',7X,'NOMINAL'//
      3 1X,'NO. ',13X,'MGMS',9X,'MGMS',13X,'MILS ',13X,
      4 'MILS' //)
      DO 82 K=1,9,4
      IF (K.EQ.1) WRITE(LD,311),(KYND(LL,ISW),LL=1,2)
      IF (K.EQ.5) WRITE(LD,312),(KYND(LL,ISW),LL=1,2),PAY=1,2)
      IF (K.EQ.9) WRITE(LD,313)
      JS=K+3
      DO 83 JJ=1,NN
      WRITE(LD,260), IDD(JJ),(Y(JJ,MM),MM=K,IS)

```

```

83      CONTINUE
      WRITE(LD,241)
241     FORMAT( )
      DO 84 L=1,7
      WRITE(LD,240),LAR(L),(L(L,MM),MM=K,IS)
      CONTINUE
82      CONTINUE
      DO 120 KK=1,3
      GO TO (1,1,1,2,1,3),KK
121     X=5
      WRITE(LD,302)
302     FORMAT(//3,X,'GLASS FRIT DEPOSITED MGMS'/)
      GO TO 104
122     X=9
      WRITE(LD,301)
301     FORMAT(//3,X,'OXIDE HEIGHT MGMS'/)
      GO TO 104
123     X=11
      WRITE(LD,302)
302     FORMAT(//3,X,'CALC. WAFER THICKNESS - MILS'/)
      WRITE(LD,303)
303     FNUM=FLM(1,KK)
124     CALL PLYR(1,Y(1,X),IND(1),FNUM,FLM(3,KK),FLM(2,KK))
125     CONTINUE
      WRITE(LD,304)
304     GO TO 50
999     TYPE 100
1000    FORMAT(///1X,'END OF DATA FILE'/)
      STOP
496     TYPE 497
497     FORMAT(//1X,'CODE NEITHER T NOR S'//)
      GO TO 51
501     TYPE 501,IN,MAX
501     FORMAT(//1X,'THIS WAFER HAS ',I,' ABS MAX DIMENSIONS'//)
517     STOP
      C
160     FORMAT (A1)
190     FORMAT (/ ' ANY CHANGES      TYPE Y OR N... 'b)
250     FORMAT (I,4F)
260     FORMAT (I6,1X,4F16.5)
230     FORMAT(1X,A5,1X,4F16.5)
330     FORMAT (/)
      END
      SUBROUTINE MIXID (A, I, XB, S, VAR, MAX, MIN, R)
      DIMENSION A(1)
      REAL MIN, MAX
      XB=1,
      S=' ',
      VAR=0,
      MAX=0,
      MIN=0,
      R=' ',
      IF (N.LT.1) RETURN
      SUM=0
      SG=1
      MAX=-1.E25
      MIN=1.E25
      DO 10 K=1,
      SUM=SUM+A(K)

```

```

      IF (MAX.LT.A(K)) MAX=A(K)
      IF (MIN.GT.A(K)) MIN=A(K)
10  CONTINUE
      R=MAX-MIN
      XB=SUM/N
      DO 20 K=1,
      TEMP=A(K)-XB
20  SQ=SQ+TEMP*TEMP
      IF (N.EQ.1) RETURN
      VAR=SQ/(N-1)
      S=SQRT(VAR)
      RETURN
      END
      SUBROUTINE PLTH (N,X,IN,XB,LO,HI)
      DIMENSION X(1),IN(1),TYPL(51),TOPL(51),IRAY(51)
      INTEGER TOPL,TYPL,AST,COLN,DOT,RLNK,AYE
      REAL LO,MI,MAX
      DATA AST,COLN,DOT,RLNK/1F*,1H:,1H.,1H /,AYE/1HI/
      C      DEVICE FOR OUTPUT
      COMMON / EV/LO
      INK=51
      CON=INK-1
      DO 10 N=1,INK
      TYPL(N)=3L'A
10  TOPL(N)=DOT
      DO 20 I=1,INK,5
20  TOPL(I)=COLN
      MI=LO
      MAX=HI
      DO 30 K=1,
      IF (X(K).GT.MAX) MAX=X(K)
      IF (X(K).LT.MIN) MIN=X(K)
30  CONTINUE
      C      JUST A SAFEGUARD
      IF (XB.LT.MIN) MIN=XB
      IF (XB.GT.MAX) MAX=XB
      RNG=MAX-MI
      IF (RNG.EQ.0) GO TO 60
      UNIT=RNG/CON
      WRITE(LO,7'), AYE,XB,COLN,LO,COLN,HI,UNIT
      WRITE(LO,8'), MIN,MAX
      WRITE(LO,9'), TOPL
      L=((LO-MIN)/RNG)*CON+1.5
      TYPL(L)=COLN
      L=((HI-MIN)/RNG)*CON+1.5
      TYPL(L)=COLN
      L=((XB-MIN)/RNG)*CON+1.5
      TYPL(L)=AYE
      DO 50 J=1,
      WRITE(LO,9C), TYPL
      DO 40 I=1,INK
40  IRAY(I)=TYPL(I)
      L=((X(J)-MIN)/RNG)*CON+1.5
      IRAY(L)=AST
      WRITE(LO,10'), I(J),X(J),IRAY
50  CONTINUE
      WRITE(LO,9'), TOPL
      RETURN
      TYPE 110
      RETURN

```

```

C
70  FORMAT (1X,'LEGEND: '/1X,A1,1X,'NOMINAL='9XF10.3/1X,A1,1X'LOWER
1   TOL. LIMIT='F11.3,15X,'PLOT SCALE'/1X,A1,1X,'UPPER TOL.
2   LIMIT='F10.3,15X,'ONE SPACE='E11.4/)
80  FORMAT (18X,E12.5,28X,E12.5)
90  FORMAT (20X,51A1)
100 FORMAT (15,E13.4,2X,51A1)
110 FORMAT (' NO VARIATION IN DATA -- NO PLOTS'//)
     F V)

```

DATA FILE : ----P1231

DATE 11-MAY-73

SCREENED

DENSITY OF CODE 7759 GLASS CON= 45,236 GMS/CM³, IN.

AREA OF WAFER= 7.823 SQ. IN.

U. OF OBS.= 14

CALC. WAFER THICKNESS = CLEARED WGT. X 0.025423

TOLERANCE LIMITS FOR GLASS FRIT	OXIDE WGT	CALC WAFER THICK
NOMINAL	44.64%	7.80%
LOWER LIMIT	42.78%	6.76%
UPPER LIMIT	46.51%	7.36%

WAFER IDEN. NO.	CLEARED WEIGHT M GMS	OXIDIZED WEIGHT M GMS	OXIDIZED + SLURRY M GMS	OXID. + GLASS FRIT M GMS
1	279,14200	279,35000	348,69000	323,56000
2	279,21100	279,51700	349,46000	324,25000
3	279,72200	279,00000	349,62000	324,27000
4	278,34200	278,53000	347,77000	322,36000
5	280,29100	280,51000	349,71000	324,38000
1	280,62200	279,40000	350,02000	324,64000
1	280,61000	279,90000	349,86000	324,48000
2	280,20000	279,45000	349,34000	324,04000
2	280,26000	279,45000	348,87000	323,76000
3	280,22000	279,45000	348,90000	323,74000
3	280,12000	279,36000	348,77000	323,64000
4	279,25000	279,21000	348,58000	323,60000
4	280,96000	281,32000	349,35000	324,57000
5	280,66000	279,92000	349,26000	324,46000
MEAN	14,800000	14,800000	14,800000	14,800000
STDEV	280,02214	280,26856	349,15714	323,97715
VAR	2,77721	0,72821	0,60162	0,62228
MAX	2,50014	0,53029	0,36194	0,36274
MIN	280,96000	279,32000	350,02000	324,64000
RANGE	278,34000	278,53000	347,77000	322,36000
	2,62000	2,79000	2,25000	2,28000

WAFER IDEN. NO.	GLASS FRIT M GMS	GLASS - NOMINAL M GMS	GLASS IN SLURRY %	BINDER IN SLURRY %
1	44,21000	-0,43000	63,75830	36,24170
2	44,74000	-0,10000	63,95997	36,04003
3	44,27000	-0,44000	63,48751	36,51249
4	43,83000	-0,31000	63,30156	36,69844
5	43,87000	-0,77000	63,39596	36,60404
1	43,84000	-0,80000	63,33430	36,66570
1	43,58000	-1,06000	63,19625	36,80375
2	43,59000	-1,05000	63,27479	36,72521
2	43,31000	-1,33000	63,30020	36,69980
3	43,29000	-1,35000	63,24324	36,75676
3	43,28000	-1,36000	63,26560	36,73440

4	43.3400	-1.25000	63.46350	36.53650
45	43.75000	-1.39000	63.57489	36.42511
5	43.54000	-1.10000	63.71086	36.28914
MEAN	14.00000	14.00000	14.00000	14.00000
S DEV	0.43803	0.43803	0.22753	0.22753
VAR	0.19257	0.19257	0.05177	0.05177
MAX V	44.74000	0.10000	63.95997	36.00395
MIN	43.25000	-1.39000	63.19675	36.04013
RANGE	1.49000	1.49000	0.76322	0.76382
WAFER THICK.	WAFER THICK.	WAFER THICK.	WAFER THICK.	WAFER THICK.
10.	10.	10.	10.	10.
1	0.25000	-0.05000	7.00326	0.00326
2	0.23000	-0.07000	7.00178	0.00178
3	0.28000	-0.02000	7.01882	0.01882
4	0.19000	-0.11000	6.98419	-0.01581
5	0.22000	-0.08000	7.03312	0.03312
15	0.20000	-0.10000	7.04090	0.04090
25	0.29000	-0.01000	7.04115	0.04115
35	0.25000	-0.05000	7.03086	0.03086
45	0.19000	-0.11000	7.03237	0.03237
55	0.23000	-0.07000	7.03136	0.03136
65	0.24000	-0.06000	7.02085	0.02085
75	0.26000	-0.04000	7.02459	0.02459
85	0.36000	0.06000	7.04993	0.04993
95	0.24000	-0.04000	7.04240	0.04240
MEAN	14.00000	14.00000	14.00000	14.00000
S DEV	0.24643	0.24643	0.02640	0.02640
VAR	0.04403	0.04403	0.001775	0.001775
MAX X	0.36000	0.06000	7.04993	0.04993
MIN X	0.19000	-0.11000	6.98419	-0.01581
RANGE	0.17000	0.17000	0.26574	0.06574

GLASS FRIT DEPOSITED M GMS

LEGEND:

I NOMINAL= 44.64
 : LOWER TOL. LIMIT= 42.75
 : UPPER TOL. LIMIT= 46.50

PLOT SCALE
 ONE SPACE= 0.744E-01

	0.42787E+02		0.46504E+02
1	0.4421E+02	*	I
2	0.4474E+02		I*
3	0.4420E+02	*	I
4	0.4383E+02	*	I
5	0.4387E+02	*	I

10	0.4364E+02	:	*	:
15	0.4358E+02	:	*	:
20	0.4359E+02	:	*	:
25	0.4331E+02	:	*	:
30	0.4329E+02	:	*	:
35	0.4328E+02	:	*	:
40	0.4339E+02	:	*	:
45	0.4325E+02	:	*	:
50	0.4354E+02	:	*	:

OXIDE WEIGHT MG/IN

LEGEND:

I NOMINAL= 0.300
 : LOWER TOL. LIMIT= 0.100
 : UPPER TOL. LIMIT= 0.500

PLOT SCALE
 ONE SPACE= 0.8701E-02

			0.1000E+00		0.5000E+00
1	0.2500E+00	:	*	:	
2	0.2300E+00	:	*	:	
3	0.2800E+00	:	*	:	
4	0.1900E+00	:	*	:	
5	0.2200E+00	:	*	:	
10	0.2000E+00	:	*	:	
15	0.2900E+00	:	*	:	
20	0.2500E+00	:	*	:	
25	0.1900E+00	:	*	:	
30	0.2300E+00	:	*	:	
35	0.2400E+00	:	*	:	
40	0.2600E+00	:	*	:	
45	0.3600E+00	:	*	:	
50	0.2600E+00	:	*	:	

CALC. WAFER THICKNESS - MILS

LEGEND:

I NOMINAL = 7.000
 : LOWER TOL. LIMIT = 6.700
 : UPPER TOL. LIMIT = 7.300

PLOT SCALE
 ONE SPACE = 0.1200E-01

APPENDIX F
Photographs of Equipment
for
RTG Glass Bonding

BLANK

Figure F-1. Ultrasonic Cleaner

Figure F-2. Cascade Cleaner

Figure F-3. Balance and table

Figure F-4. Presco screen printer

Figure F-5. Oxidizing and burnout furnaces

Figure F-6. Vacuum hot press and controls

Figure F-7. Electrical test (channel) apparatus

Figure F-8. Electrical test (channel) specimen holder and probe assembly

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