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CONTAMINATION CONTROL IN HYBRID MICROELECTRONIC MODULES

SPECIFICATIONS FOR COATING MATERIAL AND PROCESS CONTROLS
FINAL REPORT – PART 3 OF THREE PARTS

APRIL 1975

AEROSPACE GROUPS

HUGHES

HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

PREFACE

This report was prepared by Hughes Aircraft Company, Culver City, Calif. under NASA Contract NAS8-30876 entitled "Contamination Control in Hybrid Microelectronic Modules." The work was sponsored and administered by the George C. Marshall Space Flight Center, Alabama with Mr. S. V. Caruso serving as the MSFC Technical Manager. The Hughes Program Manager was Mr. R. Y. Scapple, Manager of the Microcircuit Department. The Hughes Principal Investigator was Mr. R. P. Himmel, Head of the Microcircuit Technology Section. This report was prepared by Mr. A. R. Mastro and Mr. F. Z. Keister.

This report is Part 3 of a three-part Final Report and covers the work described in Task IV of the Statement of Work. Task IV had two objectives. One of the objectives of Task IV was to prepare a specification for hybrid coating materials which could be used as a source control document for procurement. The other objective of Task IV was to prepare a process control specification for hybrid contamination control.

Parts 1 and 2 of the Final Report are under separate cover. Part 1 identifies the process steps, handling procedures, and other critical parameters that could contribute to internal contamination of hybrid microcircuit packages. Part 2 documents work involved in the selection, testing, and evaluation of electrically and thermally stable coating materials for contamination control of hybrid microcircuits.

This report covers work performed from May 1974 through April 1975. There have been no inventions, discoveries, improvements, or innovations made under this contract.

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INTRODUCTION

This third part of the Final Report on Contamination Control in Hybrid Microelectronic Modules basically consists of two separate specifications. The first specification fulfills the requirements of Task IVA of the Statement of Work and is entitled "Coating Compound for Contamination Control Applicable to Hybrid Microcircuits." It covers two basic resin systems for coating hybrids prior to hermetic sealing. The two resin systems are a flexible silicone junction resin system and a flexible cycloaliphatic epoxy resin system. These two coatings were the two best coatings as determined by the tests and evaluations conducted in Tasks II and III of this program. The coatings are intended for application to the hybrid after all the chips have been assembled and wire bonded, but prior to hermetic sealing of the package. The purpose of the coating is to control particulate contamination by immobilizing particles and by passivating the hybrid.

The second specification fulfills the requirements of Task IVB of the Statement of Work and is entitled "Contamination Control for Hybrid Microcircuits." It establishes recommended process controls for the purpose of minimizing contamination in hybrid microcircuit packages. Emphasis has been placed on those critical hybrid processing steps in which contamination is most likely to occur. These critical steps have been determined to be:

1. Parts mounting
2. Interconnect bonding
3. Package sealing
4. Rework

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Much of the information in this process control specification is based on the data collected and documented in Part 1 of the Final Report.

TASK IV A

COATING MATERIALS SPECIFICATION

"COATING COMPOUND FOR CONTAMINATION CONTROL APPLICABLE TO HYBRID MICROCIRCUITS"

COATING COMPOUND FOR CONTAMINATION CONTROL APPLICABLE TO HYBRID MICROCIRCUITS

1. SCOPE

1.1 Scope. This specification covers resin systems for coating of hybrid microcircuits prior to hermetic sealing for the purpose of controlling particulate contamination.

1.2 Classification

1.2.1 Types. The material shall be of the following types as specified (see 6.2):

Type I - Flexible, silicone junction resin systems.

Type II - Flexible, cycloaliphatic epoxy resin systems.

2. APPLICABLE DOCUMENTS

2.1 The following document of the latest issue in effect forms a part of this specification to the extent specified herein:

Standards

Fed. Test Method Standard No. 151	Metals; Test Methods
MIL-STD-883	Test Methods and Procedures for Microelectronics

2.2 Other Publications. The following documents of the latest issue in effect, form a part of this specification to the extent specified herein:

American Society for Testing and Materials

D 149	Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies, Tests for
D 150	A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials, Tests for
D 257	D-C Resistance or Conductance of Insulating Materials, Tests for
D 445	Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities) Test for

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103).

3. REQUIREMENTS

3.1 Qualification. The material furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein. Qualified products are listed in Section 7 of this specification.

3.2 Material Properties

3.2.1 Storage Life. The materials as furnished by the manufacturer shall be capable of meeting all the requirements specified herein after storage in the original unopened containers at temperatures between 4 and 32°C (40 and 90°F) for not less than 6 months.

3.2.2 Condition in container. The material shall be clear, colorless to light amber in color, free of lumps, gel articles, dirt or any other visible contaminates that would adversely affect the material's properties.

3.2.3 Purity. The purity of the material shall be as follows:

Parts Per Million, Maximum	
Potassium	2
Sodium	2
Any other metal	1
Chlorine	5
Any other halogen	5

3.2.4 Viscosity. The viscosity of the material shall be such that it is suitable for spraying after dilution with solvent.

3.3 Performance Properties

3.3.1 Film Thickness. The thickness of the cured film shall be 0.4 to 1.5 mils.

3.3.2 Color. The cured material shall be colorless to amber in color.

3.3.3 Electrical Properties. The electrical properties of the cured material shall be in accordance with Table I.

TABLE I. ELECTRICAL PROPERTIES

Electrical Property	Requirement
Surface resistivity	$\geq 1 \times 10^{15}$ ohms (1,000 teraohms)
Volume resistivity	$\geq 1.8 \times 10^{15}$ ohms-centimeter (190 teraohms-millimeter)
Dielectric strength	≥350 volts per mil (13.8 kV per mm)
Dielectric constant	≤2.70 (Type I) and 3.50 (Type II)

3.3.4 Solvent Resistance. The material shall not soften, crack, craze or discolor when tested for solvent resistance.

3.3.5 Thermal-Vacuum Exposure. The material shall have the following maximum percentages of weight loss (WL) at specified exposures (see Table II):

TABLE II. THERMAL VACUUM PROPERTIES

Exposure	Percent Weight Loss
A	1.50
B	1.75

3.3.5 Thick and Thin Film Resistor Compatability. Coated thick and thin film resistors shall not change in resistance value more than 0.50 percent greater than that of the uncoated control resistors.

3.3.6 Thermal Shock Resistance. Coated thick and thin film interconnections shall not crack or rupture.

3.4 Workmanship. The workmanship shall be such as to ensure a product which is compatible with hybrid microcircuits, uniform in composition, and free of any contamination and other defects that would affect either the material's properties or the hybrid microcircuits upon which it is applied.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of Tests. The inspection and testing of the material is classified as (a) qualification tests and (b) quality conformance inspection.

4.2 Qualification Tests. Qualification tests are those tests performed on samples submitted for approval as qualified products. They shall consist of all the examinations and tests contained in this specification.

4.3 Quality Conformance Inspection. Quality conformance inspection comprises the tests performed on individual lots which have been submitted for acceptance. The tests are described in the following subparagraphs.

4.3.1 Sampling for Quality Conformance Inspection. A sample consisting of one kit or package shall be selected at random from each lot of material for quality conformance inspection.

4.3.2 Lot Formation. A lot shall consist of all the material manufactured in one operation by the same process, by the same manufacturer in accordance with this specification and submitted for inspection at one time.

4.3.3 Inspection. Inspection of the sample specified in 4.3.1, to determine compliance with the characteristics specified in Table III, shall be conducted in accordance with the corresponding test and inspection paragraph.

TABLE III. QUALITY CONFORMANCE INSPECTION

Characteristic	Requirement Source	Test and Inspection Paragraph
Condition in container	3.2.2	4.5.2.2
Purity	3.2.3	4.5.2.3
Viscosity	3.2.4	4.5.2.4
Film thickness	3.3.1	4.5.2.5
Color	3.3.2	4.6
Workmanship	3.4	4.6
Packaging and packing	5.1	4.6
Marking	5.2	4.6

4.4 Inspection Equipment. The inspection equipment for conducting examination and tests shall be as specified in the applicable test methods and procedures paragraphs.

4.5 Test Methods and Procedures

4.5.1 Test Specimen Preparation. Test specimen size and configuration shall be as specified in the applicable test methods paragraphs and shall be mixed where applicable. Curing temperature and time shall be per the manufacturer's recommendation but shall not exceed 150°C or 16 hours.

4.5.2 Tests

4.5.2.1 Storage Life. A sufficient amount of materials in the original unopened containers shall be stored under the conditions specified in 3.2.1. At the end of the storage period, the materials shall meet all the requirements specified herein. The supplier's certification of compliance to the storage life requirements (see 3.2.1) may be accepted during the storage testing period.

4.5.2.2 Condition in Container. The material shall be visually examined for the condition in the container for conformance to 3.2.2.

4.5.2.3 Purity. The purity of the material shall be determined by Federal Test Method Standard 151, Method 111.2 or other acceptable test procedures for conformance to 3.2.3. The supplier's certification of compliance with 3.2.3 may be accepted in lieu of testing.

4.5.2.4 Viscosity. Viscosity shall be measured in accordance with ASTM D 445 to establish conformance to 3.2.4 and 3.3.1.

4.5.2.5 Color. The cured material shall be visually examined for conformance to 3.3.1.

4.5.2.6 Surface Resistivity. The surface resistance of the cured material shall be tested in accordance with ASTM D 150 for conformance to 3.3.3.

4.5.2.7 Volume Resistivity. The volume resistivity of the cured material shall be determined in accordance with ASTM D 257 to establish conformance to 3.3.3.

4.5.2.8 Dielectric Strength. The dielectric strength of the cured material shall be tested in accordance with ASTM D 149 to determine conformance to 3.3.3.

4.5.2.9 Dielectric Constant. The dielectric constant shall be tested in accordance with ASTM D150 to determine conformance to 3.3.3.

4.5.2.10 Solvent Resistance. The solvent resistance of the cured material shall be tested by coating a flat ceramic specimen, size 25.4 mm x 50.8 mm x 1.59 mm (1 by 2 by 0.062 inches) and cured in accordance with 4.5.1. The cured test specimens shall be immersed in ethanol for 1 minute (60 seconds) minimum, followed by immersion in Freon TF for 1 minute (60 seconds) minimum and examined for conformance to 3.3.4.

4.5.11 Thermal-Vacuum Exposure. The material shall be deposited on an inert substrate such as glass, cured in accordance with 4.5.1, and exposed to the following conditions, using separate specimens for each exposure:

Exposure A = 200°C, 10 minutes at less than 10^{-6} torr
(133×10^{-11} bar)

Exposure B = 175°C, 30 minutes at less than 10^{-6} torr
(133×10^{-11} bar)

4.5.12 Thick and Thin Film Resistor Compatibility. Thick and thin film resistor specimens shall be prepared incorporating all representative usable ranges of ohms-per-square. Test specimens shall be overcoated with the coating compound. Control specimens shall have no coating.

Specimens shall be exposed to 150° ± 10°C for 500 hours minimum.

4.5.13 Thermal Shock Resistance. Thick and thin film hybrid microcircuit assemblies incorporating thermocompression or ultrasonically bonded semiconductor devices shall be coated with the coating compound, cured in accordance with 4.5.1, thermally cycled per MIL-STD-883, Method 1010, Condition C, for 200 cycles, and visually examined (10X to 20X magnification) for conformance to 3.3.6.

5. PREPARATION FOR DELIVERY

5.1 Packaging and Packing. The material shall be packaged and packed in accordance with the standard commercial practice to assure safe delivery by common carrier.

5.2 Marking. Interior and exterior containers shall be permanently and legibly marked in accordance with standard commercial practice. Marking shall include, but not be limited to, the following information:

(a) Manufacturer's name and address.
(b) Manufacturer's designation.
(c) Lot number or batch number.
(d) Date of manufacturer.
(e) Number of this specification and type, class, grade.
(f) Net weight of contents in container.

6. NOTES

6.1 Intended Use. The coating compound in conformance with this specification is used as a coating to provide protection to high reliability hermetically sealed hybrid microcircuit assemblies against particulate contamination.

6.2 Ordering Data. Procurement documents should specify the following:

- (a) Title, number and date of this specification.
- (b) Requirement for certification of the storage life (see 4.5.2.1).
- (c) Requirement for certification of purity (see 4.5.2.3).
- (d) Type

7. QUALIFIED PRODUCTS

7.1 Procurement under this specification is limited to the products listed below:

Type	Manufacturer's Designation	Manufacturer's Name and Address
1	DC 90-711 R 6101	Dow Corning Corporation Electronic Products Div. S. Saginaw Road Midland, Michigan
2	ERL 6289 plus dimer acid.	Resins Union Carbide Corp. Bound Brook, N. J. Dimer Acid Emergy Ind., Inc. Cincinnati, Ohio
	ERL 4221 plus dimer acid.	

TASK IV B

PROCESS CONTROL SPECIFICATION

"CONTAMINATION CONTROL
FOR
HYBRID MICROCIRCUITS"

CONTAMINATION CONTROL FOR HYBRID MICROCIRCUITS

1.0 SCOPE

This publication establishes recommended process controls for the purpose of minimizing contamination in hybrid microcircuit packages. Emphasis has been placed on those critical hybrid processing steps in which contamination is most likely to occur. These critical process steps have been determined to be:

1. Parts mounting
2. Interconnect bonding
3. Package sealing
4. Rework.

Also included are general contamination guidelines and suggested controls for the work area, personnel, equipment, materials, and cleaning processes.

Contamination can occur in other processing steps as well, such as in thick film or thin film substrate fabrication (e. g., vacuum deposition, screen printing, photoresist processing, chemical etching, resistor trimming, etc.). However, contaminants occurring in such processes can ordinarily be detected by an adequate visual inspection and can be removed by a thorough cleaning. Thus these processing steps are not considered as "critical" as the subsequent assembly steps. Once chip components are added to the substrate and wire bonding is done, both the inspection and the cleaning processes have been made more difficult.

The contamination types of particular interest are those which potentially can cause reduced reliability and reduced lifetime in hybrids. Tables 1, 2, and 3 list certain types of contamination of which the manufacturer of hybrid microcircuits should be aware.

No attempt has been made to recommend controls for processes, materials, or parts over which the hybrid microcircuit fabricator has no control. Examples of these types of processes would include those processes used by manufacturers in producing semiconductor chips, high purity bonding wire, alumina material for substrates, or hybrid packages. The hybrid manufacturer purchases and uses these parts, but has little direct control over their processing.

TABLE 1. CONTAMINANTS THAT ARISE FROM THE VARIOUS PARTS USED IN HYBRID FABRICATION

Part and Process	Type of Contamination
1. **Thin Film Substrates**	
a. Substrate cleaning	- Residual surface contaminants from shipping, packaging, inspection, handling. - Bake-out environment - Solvent contaminants
b. Film deposition	- Residual chamber contaminants - Gas contaminants - Metal impurities - Outgassing - Oxidation - Backstreaming - Leakage
c. Film build-up plating	- Bath impurities - Deposit impurities - Anode impurities - Rinse impurities - Drying contaminants
d. Photomask	- Mask contamination, imperfections - Resist impurities - Resist drying contamination - Developer impurities - Rinse impurities - Bake/dry oven contamination
e. Etching	- Etchant impurities - Rinse impurities
f. Resist removal	- Residual resist - Stripper impurities - Rinsing and drying impurities
g. Film stabilization	- Chamber residuals
h. Resistor trimming	- Splatter, flaking - Oxidation
i. Substrate cutting	- Sawing contaminants - Scribe and break or Laser cutting ceramic chips, flakes, dust
i. Final cleaning, packaging, storing	- Cleaning contaminants - Package contaminants - Identification materials - Storage environment
2. Thick Film Substrates	
a. Substrate cleaning	- Same as for thin film
b. Paste preparation	- Paste contaminants - Thinner impurities - Mixing/blending tool and container contaminants
c. Printing	- Printer lubricants - Squeegee contaminants, residual pastes - Screen contaminants, residual pastes - Pneumatic air system contaminants
d. Drying	- Oven residual contaminants
e. Firing	- Furnace contamination, adjacent paste poisoning, belt contamination - Environmental gas impurities
f. Resistor trimming	- Splatter, dust, flaking, static damage
g. Final cleaning, packaging, storing	- Same as for thin films
3. Active Devices Dice, beam leads, flip chips, LIDs packaged (plastic or hermetic) diodes, transistors, ICs, FETs, MOS chips, etc.	- Surface contaminants (organic and inorganic) - Packaging material contaminants - Shipment damage - Inspection (shipping and receiving) contaminants - Solvent residues, flux residues, absorbed gases - Plating residues, flaking, outgassing, peeling, oxides - Marking paints
4. Passive Devices Capacitors, resistors, inductors, transformers	
5. Hybrid Packages Kovar, glass, and ceramic bases and covers	

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TABLE 2. CONTAMINANTS THAT CAN RESULT FROM THE VARIOUS HYBRID ASSEMBLY PROCESSING STEPS

Assembly Processing Step	Type of Contamination
Substrate attachment to package	– Package residuals – Flux residues, solder splatter – Adhesive particles, void entrapment
Attachment of chips to substrate	– Epoxy or eutectic alloy contaminants – Tool and equipment contaminants – Chip contaminants, chip fragments – Adhesive migration, adhesive fragments – Eutectic flakes or balls
Interconnect bonding	– Wire contaminants – Wire fragments – Oxidation, water condensation – Chip fragments
Pre-seal electrical testing and rework	– Probe contaminants – Wire fragments, chip fragments – Adhesive and eutectic solder fragments
Hermetic sealing	– Bake chamber residuals and backstreaming – Sealing chamber residuals – Purge gas impurities – Sealing material contaminants – Solder balls – Flux – Moisture – Weld splatter

TABLE 3. CONTAMINANTS THAT ORIGINATE WITH THE ENVIRONMENT OR THE OPERATOR

Source	Type of Contamination	
Atmospheric	Dust	Dessicator contaminants
	Lint	Sulfur dioxide
	Moisture	Solvent volatiles
	Smog	Miscellaneous airborne particles
	Smoke	Outgassing products
Operator	Perspiration	Skin flakes
	Hair	Food particles
	Sputum	Clothing particles
	Makeup	Finger prints
Equipment	Grease	Fumes
	Oil	Loose particles

2.0 APPLICABILITY

This publication is intended for use with all types of hybrid microcircuits. Typical examples of such intended usage would be thin film and thick film hybrids (including multilayer types). It includes hybrids packaged in TO-type headers, ceramic flatpacks, metal platform packages, or other enclosures. Figure 1 shows a process flow chart for the assembly of a typical hybrid microcircuit. Different hybrid manufacturers may use different materials, equipment, and processes. Thus a flow chart for their special processes would appear slightly different. However, the end product is a hybrid microcircuit, whether beam lead chips are used instead of face-up chips with flying wires or whether chips are attached to the substrate with a conductive adhesive or a gold/tin eutectic.

In Figure 1 emphasis has been placed on visual inspection and cleaning processes at critical locations in the fabrication sequence. In particular, the manufacturer of hybrids should inspect for loose particles at all stages of processing. The manufacturer should also take special precautions to control the amount of moisture inside the hybrid package. Moisture and loose particles have been determined to be two of the worst contaminants.

3.0 APPLICABLE DOCUMENTS

The following documents form a part of this publication to the extent specified herein.

<u>Military</u>

MIL-STD-883	Test Methods and Procedures for Microcircuits

<u>Federal</u>

Federal-STD-209	Clean Room and Work Station Requirements Controlled Environment

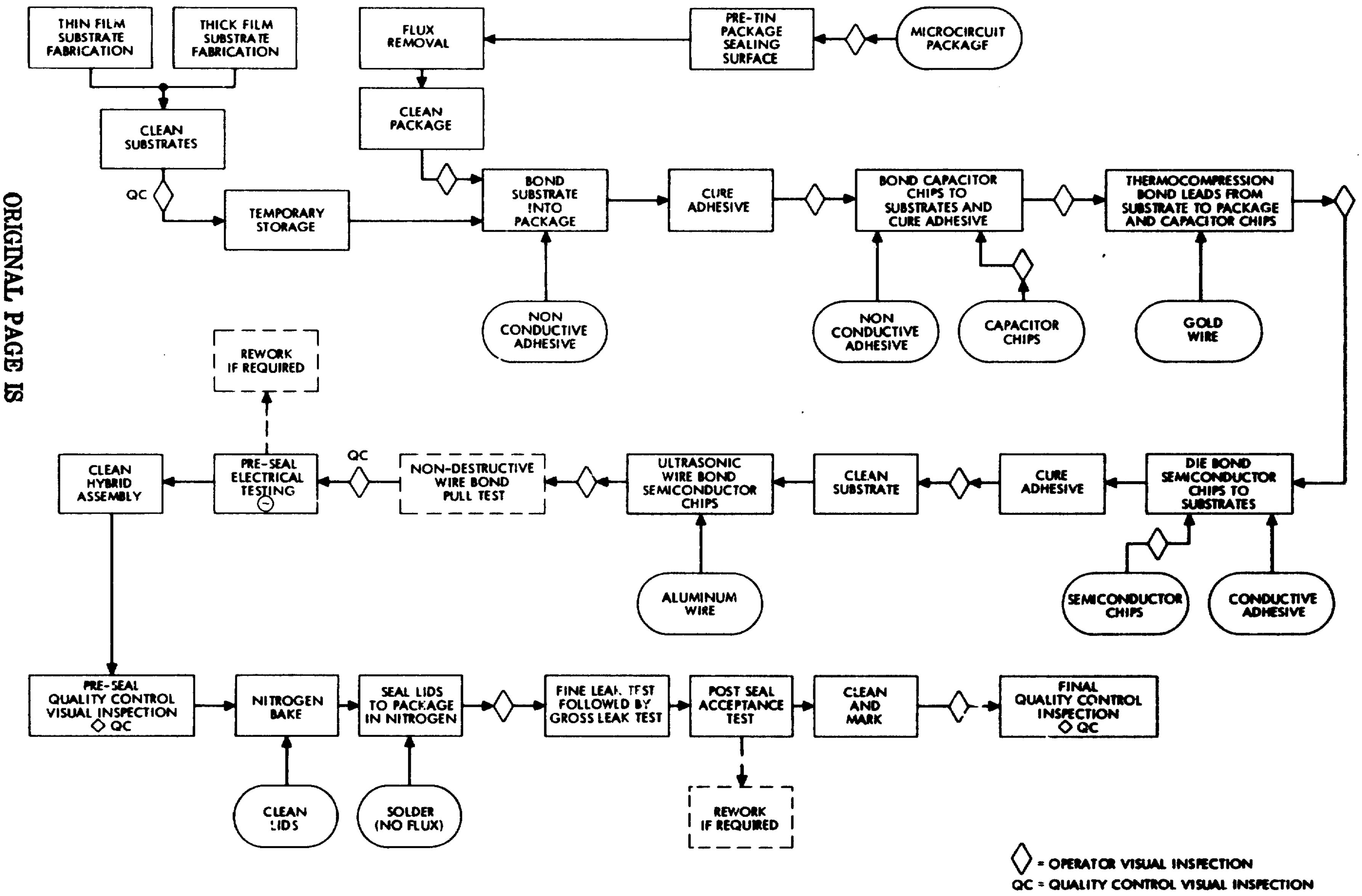

Figure 1. Process flow for hybrid microcircuit fabrication showing manufacturing and quality-control inspection and test operations.

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4.0 GENERAL CONTAMINATION CONTROL GUIDELINES

4.1 Work Area Guidelines and Controls

4.1.1 Guidelines. The work areas where hybrid microcircuits are fabricated and assembled should be free from dust, dirt, lint, grease, smoke, excessive moisture, solvent volatiles, outgassing products, large airborne particles, oil fumes, and similar contaminants. It is not necessary that the work area be a particular class of clean room per Federal-STD-209. However, the work area should be "controlled" to a certain extent. Airlocks, air showers, a special dressing room or anteroom, shoe cleaners, floormats at the entrance, and similar precautions all help to control contamination.

At the very least, the hybrid manufacturer should have controls for temperature, relative humidity, and for the size and number of the airborne particles entering the work area.

4.1.2 Suggested Controls. The hybrid manufacturer may use special work stations, such as laminar flow benches, to protect special individual operations. Humidity of the work area may be controlled by air conditioning via refrigeration, by desiccants and dehumidifiers, or by other means. A recommended moisture level is a relative humidity of 30 to 45 percent. The temperature should be thermostatically or otherwise controlled. A recommended temperature is 75°F ±5°F. A particle count should be taken periodically of the work area. Filtration of the incoming atmosphere can be done by HEPA filters, carbon filters, or other basic filter and prefilter elements designed for clean room design.

Housekeeping controls of the work area should include periodically scheduled floor mopping (dry and wet), vacuuming, washing, work surface wiping, wall washing and wiping, vacuuming of air ducts, ceilings, and fixtures, and similar precautions. An example of a typical microelectronic production area maintenance schedule is given in Table 4.

TABLE 4. TYPICAL MAINTENANCE SCHEDULE FOR A MICROELECTRONIC PRODUCTION AREA.

Location	Method	Frequency
All floor areas	Dry mop (use freshly treated mop)	Daily
	Wet mop[1]	Weekly
	Vacuum	Every two weeks
Footmats, fiber	Vacuum	Daily
Footmats, gelatin	Alcohol wipe	Daily
Waste baskets	Empty	Daily
Windows	Wash	Monthly
Drinking fountains	Wash	Daily
Air ducts, inlets and exhausts	Wipe-vacuum	Monthly

[1] In screem rooms or where wet mopping may cause electrical hazards, vacuuming shall be performed weekly.

4.2 Personnel Guidelines and Controls

4.2.1 Guidelines. The working area should be kept free from contaminants which can be introduced by operator personnel within the working area or by visitors. Contaminants which can be introduced by personnel include hair, skin, lint, starch, clothing fibers, cosmetics, fingerprints, droplets of moisture (breathing, coughing, perspiring), fingernail polish, eye shadow, hair spray, powders, and dandruff.

4.2.2 Suggested Controls. Smoking, drinking, and eating in any hybrid microcircuit fabrication, inspection, or test area should be forbidden. Personnel should wear special garments such as knee length smocks of a lint-free synthetic material (e.g., nylon, Dacron, etc.) in the clean areas. These garmets should not be worn outside of the clean area dressing room and should be specially laundered at regular intervals. Additional protective garments which could be used include special caps and shoe covers.

Personnel actually handling the microcircuits should either use tweezers or vacuum pick-up tools or wear clean gloves or clean finger cots of surgical rubber.

4.3 Equipment Guidelines and Controls

4.3.1 Guidelines. The equipment used to fabricate, assemble, and test hybrid microcircuits must be kept clean and free from grease, oils, dust, dirt, metallic burrs, etc. It should not be a source of undesirable fumes, gases, or other airborne or liquid-borne particles which could possibly come into contact with the hybrid microcircuit. Examples of such equipment are vacuum pumps, wire bonders, ovens, and firing furnaces. Cleanliness requirements should also be imposed on small tools which come into contact with the hybrid microcircuits, chips, or packages. Examples of such tools would be tweezers and holding fixtures.

Special attention should be paid to gas lines which are used to blow off hybrid microcircuits as part of a final drying cycle.

4.3.2 Suggested Controls. All equipment and tools used in hybrid microcircuit production or in the same work area should be cleaned and vacuumed periodically. Compressed air, nitrogen, or other gas lines or hoses should have adequate filters for moisture, oils, and particles. Vacuum pumps or other devices that produce hydrocarbons or fumes should either be vented outside the work area or equipped with adequate exhaust filters. Air abrasive trimming, substrate sizing by sawing, or similar operations which are inherently dirty should be done in special rooms or have special shields or exhausts. Only closed top waste containers with disposable plastic bags should be permitted in the hybrid production area. Ovens where hybrids are baked or dried should be kept clean. Ultrasonic, beam lead, and thermocompression bonding tips should be kept clean by wiping the tips with lens tissue moistened in methyl alcohol or other means.

Special containers, such as a plastic box flushed with nitrogen, are recommended for storing chips, bonding wire, and partially-assembled hybrid microcircuits when not being used. In addition, when transferring hybrids between areas, it is recommended that clean, covered "tote" boxes be used as protection against contaminants.

Although not a contaminant, static electrical charges can damage certain semiconductor devices (such as CMOS integrated circuits) and certain thick film resistors. It is therefore recommended that precautions should be taken to avoid such damage. Examples of such precautions would include grounded table tops, grounded wrist straps for operators, and anti-static carriers.

4.4 Materials Guidelines and Controls

4.4.1 Guidelines. All materials used in hybrid microcircuit production should be kept clean and pure. Examples of such materials are cleaning solvents, etching chemicals, bonding wire, solder, photoresists, thick film inks, etc. Rinse water, in particular, should be maintained at a high purity level. Chemicals and water should not be a source of particles, algae, bacteria, unwanted organic and inorganic salts, or other contaminants. Waste water, waste chemicals and their by-products should be disposed of by proper drain systems or waste storage containers.

Common solvents and cleaners used in hybrid microcircuit production include methyl alcohol, trichloroethylene, acetone, methylene chloride, isopropyl alcohol, and trichlorotrifluoroethane. It is recommended that only the highest attainable grades of these chemicals should be used.

Water should be of a maximum resistivity, have a minimum solids content, and have a minimum organic impurity count. Water treatment may include filtration, deionization, demineralization, and reverse osmosis.

4.4.2 Suggested Controls. Special filtering should be used for chemicals which are suspected of containing particulate matter. Where the use of chemicals can emit fumes, exhaust hoods should be used. Containers used to store chemicals should be clean, particle-free, and kept covered. The user should verify that materials such as solder and bonding wire are of the proper composition and purity.

The resistivity of high purity deionized water for hybrid usage may be controlled by measuring its resistivity or conductivity using a suitable bridge. A suggested resistivity control level would be a resistivity greater than 12 megohms. Water solids and organic impurities can be monitored by a periodic particle count. This will determine the effectiveness of the filters. The acid-alkali balance can be monitored by a pH reading.

4.5 General Cleaning Guidelines and Controls

4.5.1 Guidelines. Cleaning of the hybrid and its component parts is done at several critical places throughout the fabrication and assembly process as shown previously in Figure 1. The method of cleaning selected should be related to the identified contaminant which it is desired to remove. Any suitable cleaning method may be used, such as solvent immersion, vapor degreasing, ultrasonic cleaning, swabbing, wiping, brushing, etc. The type of cleaning chemical used should remove the unwanted contaminant without leaving any residue or redepositing particles.

As the hybrid progresses through the various assembly processes, the cleaning procedures necessarily change. Bare substrates can be subjected to stronger chemicals than can hybrids with chips mounted and wire bonds intact. Cleaning is usually followed by a thorough rinsing and drying. Drying may be done by means such as a dry nitrogen blow-off, oven heating, infrared, hot air, or other means. However, care should be taken that the drying process itself does not redeposit any contaminants on the hybrid or that the temperature is not harmful to sensitive parts.

4.5.2 Suggested Controls. There are certain controls which can be used to determine the effectiveness of the cleaning process. For example, a water break test or a contact angle test can be used to determine adequate wetting. However, the best control is a thorough 100% visual inspection after the cleaning process for any evidence of residues, corrosion, foreign matter, or loose particles. The visual inspection should be at a minimum magnification of 30X. The lighting should be adjusted to reveal contamination. If any contaminants are still present, the hybrid should be recleaned. It is equally important that the person inspecting the hybrid for contamination knows what to look for. Both operators and inspection personnel must learn to recognize the various contaminants. Figures 2, 3, 4, and 5 show contaminants of the type which inspection should reject.

5.0 CONTAMINATION CONTROLS FOR THE PROCESS OF PARTS MOUNTING

5.1 Scope

The process of parts mounting involves mounting of semiconductor chips, resistor chips, capacitor chips, and other component types to the thin film or thick film substrate or to the package. It also includes mounting or attachment of the substrate within the package enclosure. This process includes all types of mounting methods, such as conductive adhesives, nonconductive adhesives, soldering, and eutectic die bonding. Refer to Figure 6 for typical examples of parts mounting.

Figure 2. Foreign particle on transistor chip.

Figure 3. Loose particles on top of capacitor chip.

Figure 4. Stain on thin film resistor.

Figure 5. Stain on bonding pad area.

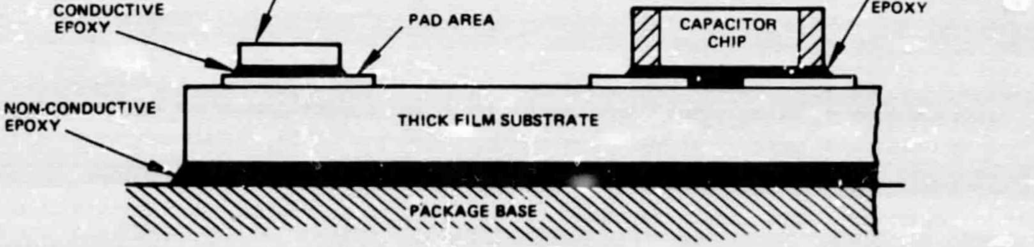


Figure 6. Illustration of materials used in mounting parts and substrates.

5.2 Requirements.

After parts mounting there should be no evidence of any loose particles on the substrate, on any of the chips, or inside the package. Examples of such loose particles might be small pieces of silicon which had broken off a semiconductor chip, solder balls, fragments of conductive silver epoxy, or pieces of gold/tin eutectic alloy. If flux has been used in parts mounting, all traces of flux residue must be removed. If adhesives are used to mount chips or to mount the substrate, there should be no evidence of the adhesive spreading to unwanted areas. There should be no adhesive on the surface of semiconductor chips, on bonding pads, or on the sealing surface of the package.

There should be no evidence of excessive solder or excessive adhesive which could subsequently break off and become a free particle.

Refer to Figure 7 for examples of typical rejectable conditions involving contamination resulting from parts mounting.

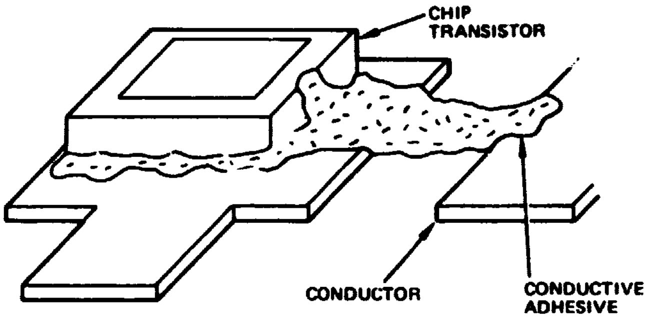
5.3 Equipment Controls.

Parts mounting may be done manually or by a machine. If done manually, the tools used to handle the chips or substrates should be clean and free of dust, dirt, or foreign contaminants so they will not be transferred to the chips. If done by a machine (e.g., epoxy die bonder, eutectic die bonder, solder reflow machine, etc.), the machine should be properly calibrated and the proper bonding schedules should be used. If not mounted securely, the chip or substrate may eventually come loose. If the chip is misoriented or if the adhesive or solder spreads to adjacent conductors or resistors, electrical short circuits can result.

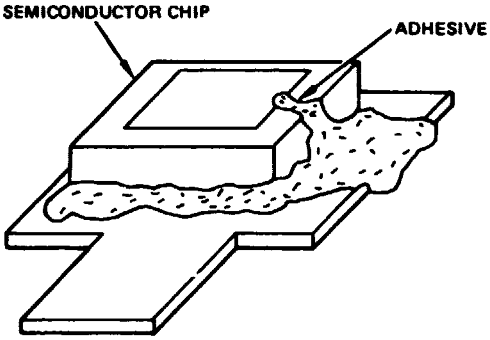
Equipment temperature controls are especially critical. If the adhesive or solder alloy is not properly heated or cured, pieces may loosen or flake off later becoming loose particles.

5.4 Materials Controls

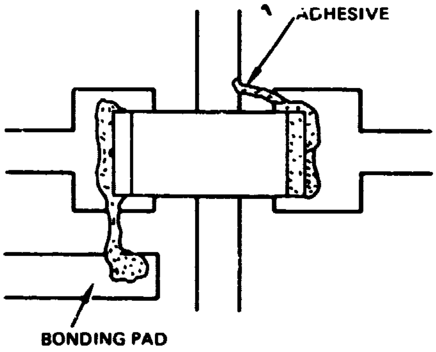
The materials used to mount the active and passive components on the substrate should be controlled as to applicable properties, such as purity, composition, electrical resistivity, shear strength, tensile strength, and similar properties. Control may be done by incoming inspection tests on the purchased materials, by purchasing to adequate specification requirements, by having the vendor furnish a certificate of compliance, or other suitable means.



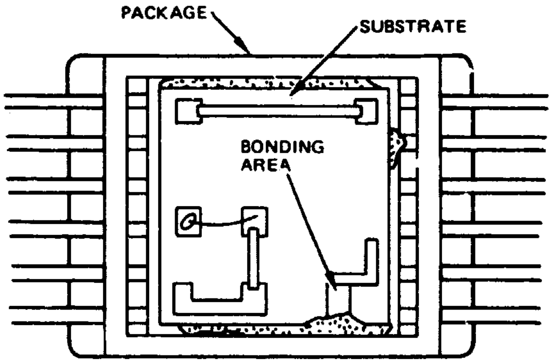
CONDUCTIVE ADHESIVE BRIDGES TO ADJACENT METALLIZATION



ADHESIVE ON CHIP METALLIZATION



NONCONDUCTIVE ADHESIVE BRIDGES TO ADJACENT BONDING PAD



SUBSTRATE ADHESIVE FLOWS ON TOP OF BONDING AREA OF SUBSTRATE AND ON BONDING AREA ON PACKAGE

Figure 7. Typical rejectable contaminants resulting from parts mounting.

Frozen adhesive premixes must be kept at the proper temperatures. Solder pastes and adhesives should not be used beyond their shelf life. Once the hybrid manufacturer determines that a particular material is optimum for that application, this same material should continue to be used. One of the best material controls is proper identification and labeling of the material.

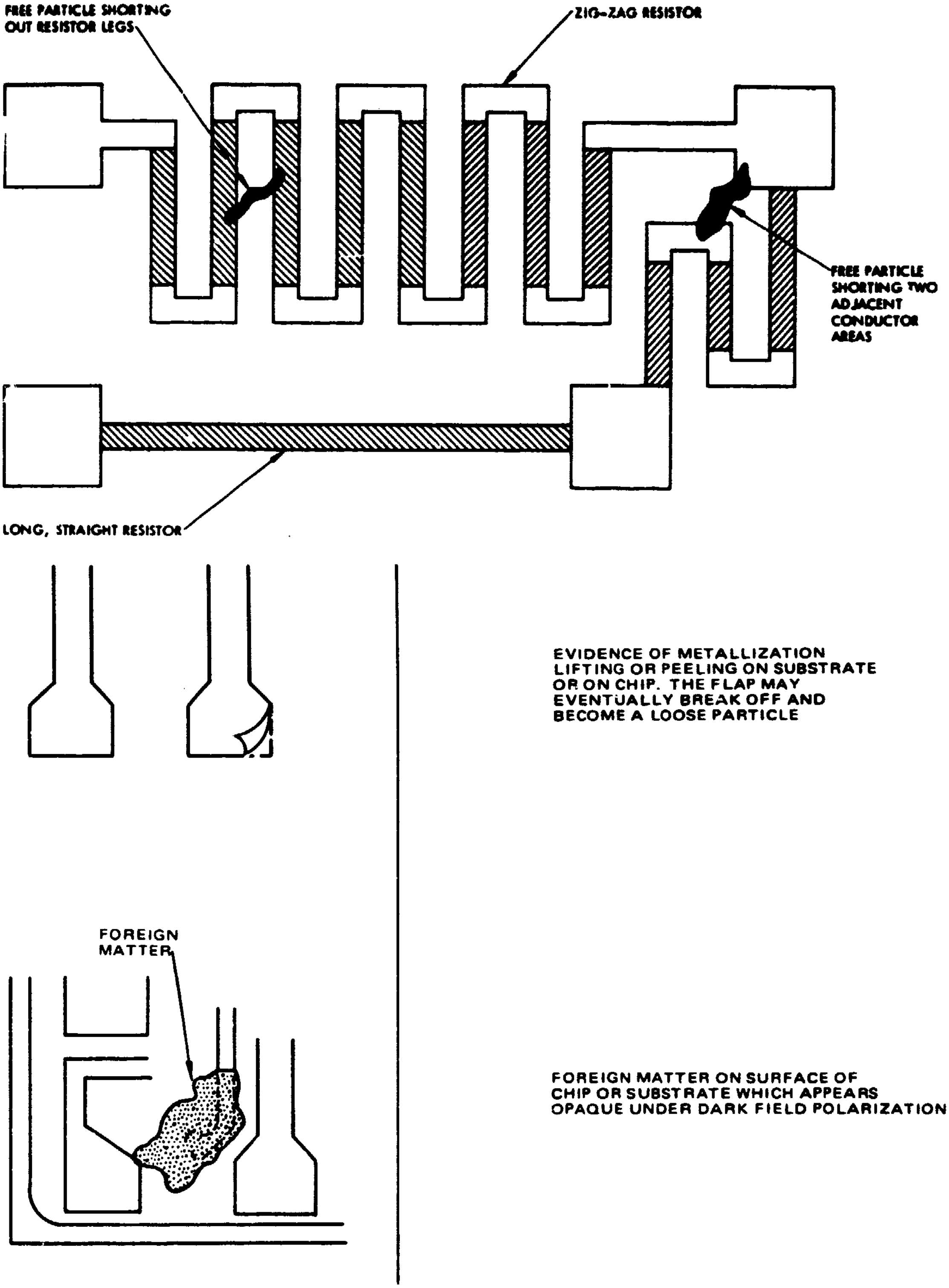
If the material is the two-component type, the two parts should be mixed in their proper ratios. If the material has a pot life, it should be mixed and used before it sets up and is no longer workable.

It is especially important to initially select a material which has a minimum amount of outgassing and which will maintain its strength at the maximum anticipated storage temperature of the hybrid.

5.5 Process Controls.

The parts to be mounted (e. g., active chips, passive chips, substrates, etc.) should be 100% visually inspected and, if necessary, cleaned immediately prior to use. In particular, the semiconductor chips should be visually inspected before mounting to avoid using contaminated chips. Cleaning of chip components is difficult and can cause damage to the chips so care is necessary. Chips should be inspected at magnifications of at least 30X. Magnifications of 60X or greater are recommended for semiconductor chips. Chips and substrates should not show any evidence of foreign matter, corrosion, dust, dirt, lint, and lifting or peeling metallization. In short, the parts should be free of all contamination <u>before</u> mounting. See Figure 8.

Where adhesives are involved in parts mounting, the adhesives must be properly cured (i. e., proper temperature for the proper time). Incomplete curing can result in poor adhesion or subsequent outgassing. Poor adhesion can be monitored after mounting by "push-off" tests, by impact shock tests, by a nitrogen blow-off, or by a centrifuge test. All of these tests are designed to apply a force sufficient to loosen an inadequately mounted chip or substrate. Incomplete curing can result in reduced electrical conductivity for conductive adhesives. Improper soldering temperatures can result in cold solder joints with the subsequent danger of solder flakes breaking loose and becoming free conductive particles within the package.



EVIDENCE OF METALLIZATION LIFTING OR PEELING ON SUBSTRATE OR ON CHIP. THE FLAP MAY EVENTUALLY BREAK OFF AND BECOME A LOOSE PARTICLE

FOREIGN MATTER ON SURFACE OF CHIP OR SUBSTRATE WHICH APPEARS OPAQUE UNDER DARK FIELD POLARIZATION

Figure 8. Typical examples of contaminants on chips and substrates.

After parts mounting and adhesive curing, a thorough 100 percent visual inspection is probably the best control possible. If the hybrid must be stored prior to the next step, it is recommended that storage be done in a dry box flushed with nitrogen. The hybrid should be kept in a closed container during transportation from one operation to the next.

6.0 CONTAMINATION CONTROLS FOR THE PROCESS OF INTERCONNECT BONDING

6.1 Scope.

The process of interconnect bonding is the electrical interconnection of active and passive components to the substrate, to the package, and to other components. It includes thermocompression bonding, ultrasonic bonding, beam lead bonding, reflow soldering, flip-chip handling, conductive adhesives, and similar processes. Refer to Figure 9 for typical examples of interconnect bonding.

6.2 Requirements.

After interconnect bonding, there should be no evidence of any loose particles, wire ends, chip fragments, solder balls, flux residue, corrosion of any bonding wire, long wire tails which could possibly break off later, or other potential contaminants. Figure 10 shows some examples of rejectable contaminants resulting from interconnect bonding.

6.3 Equipment Controls.

All equipment used in the interconnection process must itself be clean and free of contaminants, such as dust, dirt, and oils. All equipment used to electrically test the interconnected hybrid should be clean and free of contamination. Examples of such equipment would include test fixtures and probes.

It is important that machine bonding be done using the proper bond schedules (e.g., pressure, time, power, temperature, etc.). Bond schedules should be determined for each wire size, wire type, and substrate/chip material combination. Bonders should be calibrated prior to use each day and after any new setup.

Refer to Section 5.3 for other equipment controls.

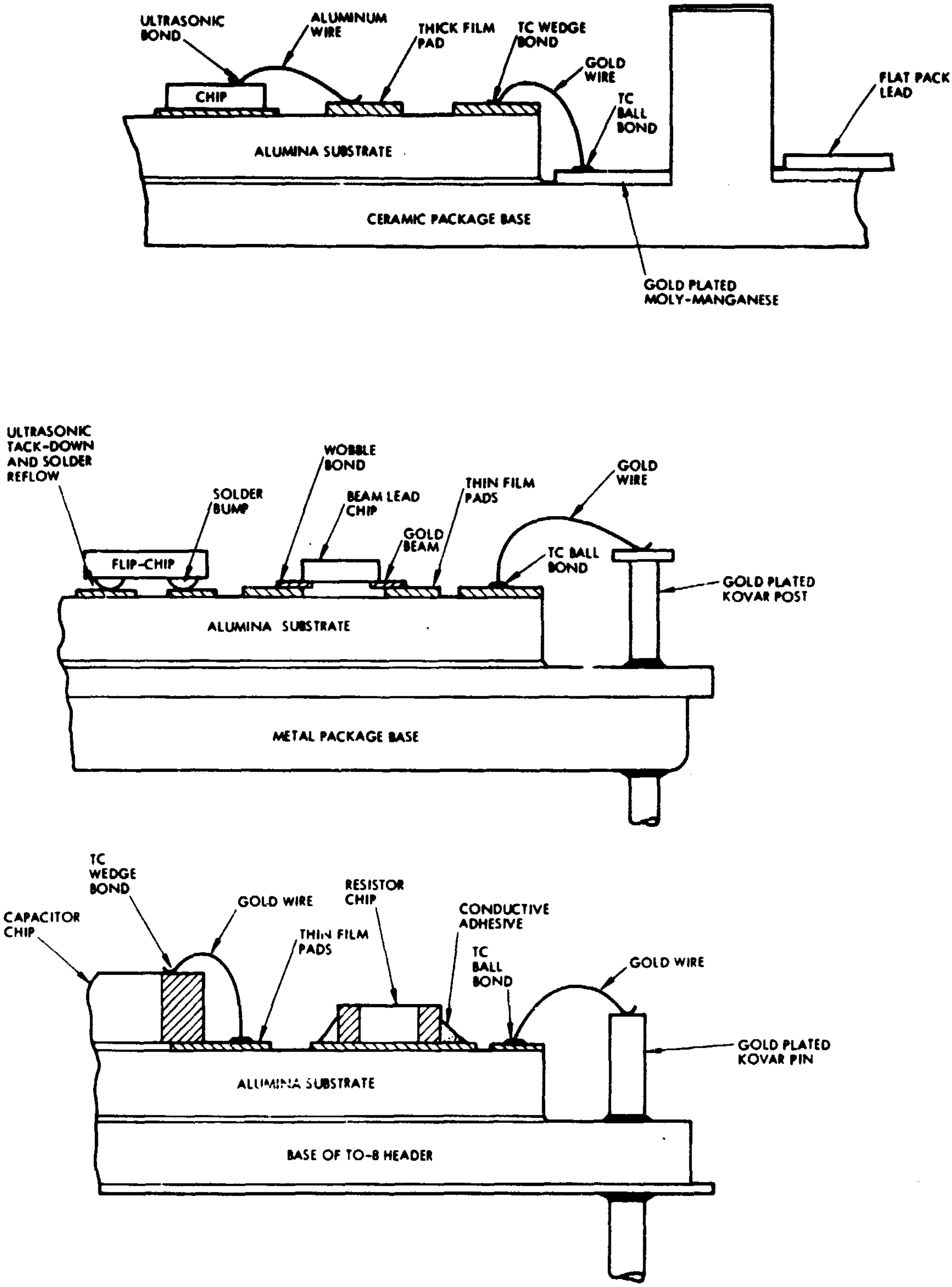
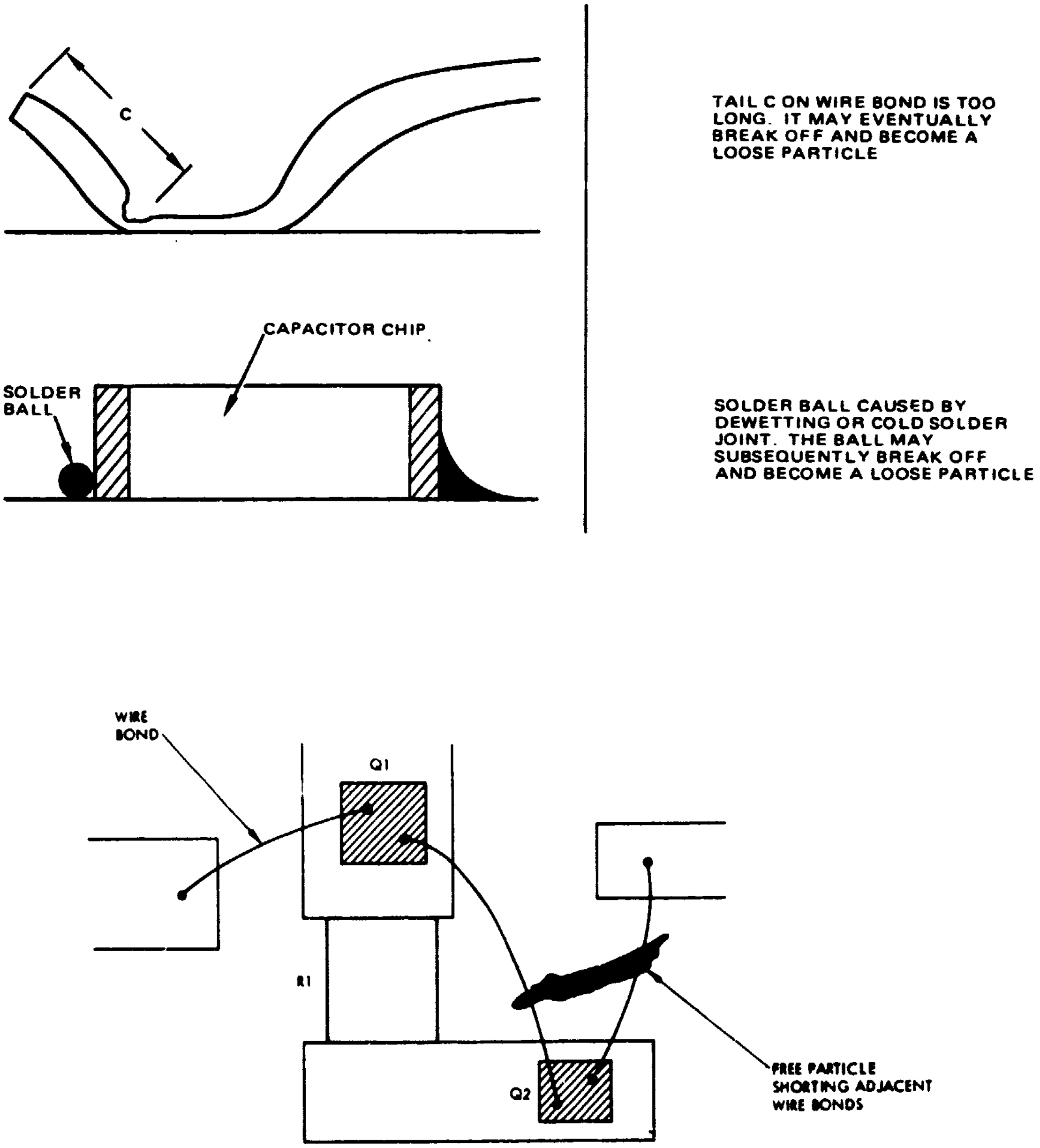


Figure 9. Sketches showing typical bond types, materials, and techniques which might be used in the interconnection of hybrid microcircuit components.



TAIL C ON WIRE BOND IS TOO LONG. IT MAY EVENTUALLY BREAK OFF AND BECOME A LOOSE PARTICLE

SOLDER BALL CAUSED BY DEWETTING OR COLD SOLDER JOINT. THE BALL MAY SUBSEQUENTLY BREAK OFF AND BECOME A LOOSE PARTICLE

Figure 10. Particle contaminants introduced during interconnect bonding.

6.4 Material Controls.

The materials used to interconnect the parts must be kept clean and free of any corrosion, foreign materials, greases, or other contaminants. This is particularly true of aluminum and gold bonding wire. The wire should never be handled with bare fingers. The spools of wire should be kept stored in a clean cabinet flushed with nitrogen or with a dessicant to prevent contamination prior to installation of the spool on the bonder.

The materials should be controlled as to the proper purity, composition, wire size, conductivity, breaking strength, and similar applicable properties. If solder or conductive adhesive is used for interconnect bonding, the controls previously mentioned in Section 5.4 apply.

6.5 Process Controls.

Prior to any interconnect bonding operation, the substrate and chips should be cleaned. It is recommended that cleaning be done immediately prior to interconnect bonding rather than after parts mounting. This is because there may be a delay of several days between the two operations. The essential thing is that the pads on the substrate, on the package, and on the chips should be contaminant-free prior to wire bonding, soldering, or other means of interconnection.

For operations such as beam-lead bonding and flip-chip bonding, the parts mounting and interconnect bonding processes are done simultaneously. Thus the chips must be 100 percent inspected prior to bonding, not only to be sure they are contaminant-free, but to be sure that the beams or bumps are contaminant-free and undamaged. Once bonded, the chip is inverted and can no longer be visually inspected.

Controls over the interconnect bonding process include pull strength tests on sample wire bonds prior to each shift. See Figure 11. For beam-lead or flip-chip components, push-off tests on sample chips would normally be used to determine that the bonding process is within the predetermined control limits.

Weak bonds may be detected by nondestructive tests, such as a nitrogen blow-off test, impact shock testing, centrifuge, or by 100 percent nondestructive wire bond pull testing at load levels of only 1 to 3 grams.

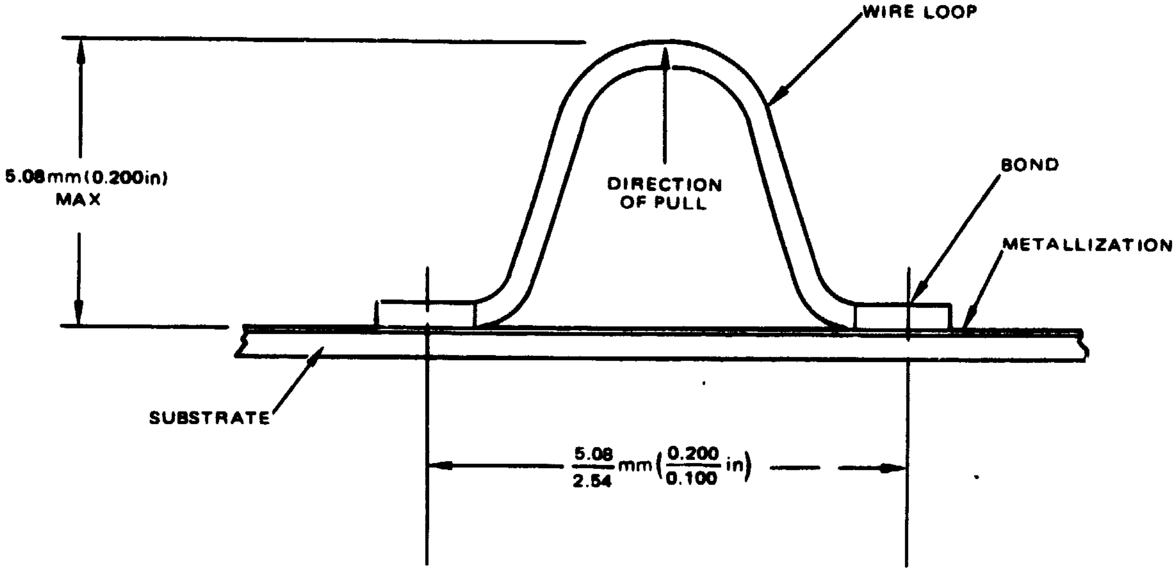


Figure 11. Wire loop used for pull testing as a control measure for the interconnect bonding process.

A 100 percent visual inspection under high magnification is probably one of the best controls possible for interconnect bonding. After interconnect bonding, the hybrid microcircuit is normally electrically tested to make sure that it functions properly prior to sealing the package. Electrical testing is a process control in itself as it frequently reveals loose bonds, bad chips, undetected loose particles, and other defects. During electrical testing the hybrid should be kept covered, except when necessary to remove the cover for test probing, for active trimming of resistors, or other purposes.

Since the interconnect bonding process and the pre-seal electrical testing process can introduce contaminants into the package, the hybrid microcircuit should always be cleaned afterwards. Solvent cleaning followed by a nitrogen forced air drying and a short bake out in an oven would be a typical cleaning procedure.

7.0 CONTAMINATION CONTROLS FOR THE PROCESS OF PACKAGE SEALING

7.1 Scope.

The process of package sealing involves sealing lids to all types and sizes of hybrid packages and the subsequent leak testing of the packages to determine hermeticity. Sealing includes methods such as parallel seam welding, hand soldering, peripheral sealing with gold/tin preforms, epoxy preforms, and others. Package types include ceramic, metal, butterfly, platform, dual in-line, TO-type headers, and others. See Figure 12 for examples of typical hybrid package types.

7.2 Requirements

All hybrid microcircuit packages shall be hermetic in accordance with Method 1014 of MIL-STD-883. The sealing process shall be controlled in such a manner that it does not introduce contaminants into the package. Examples of such contaminants are moisture, solder balls, weld splatters, solder splashes, flux gases, or loose particles of any type. Moisture inside the package should be kept to a minimum. A suggested maximum moisture level is 500 ppm. The atmosphere inside the package should essentially be inert with unwanted gases, such as oxygen and sulfur dioxide, kept to a minimum. Pure nitrogen is commonly used as the sealing atmosphere.

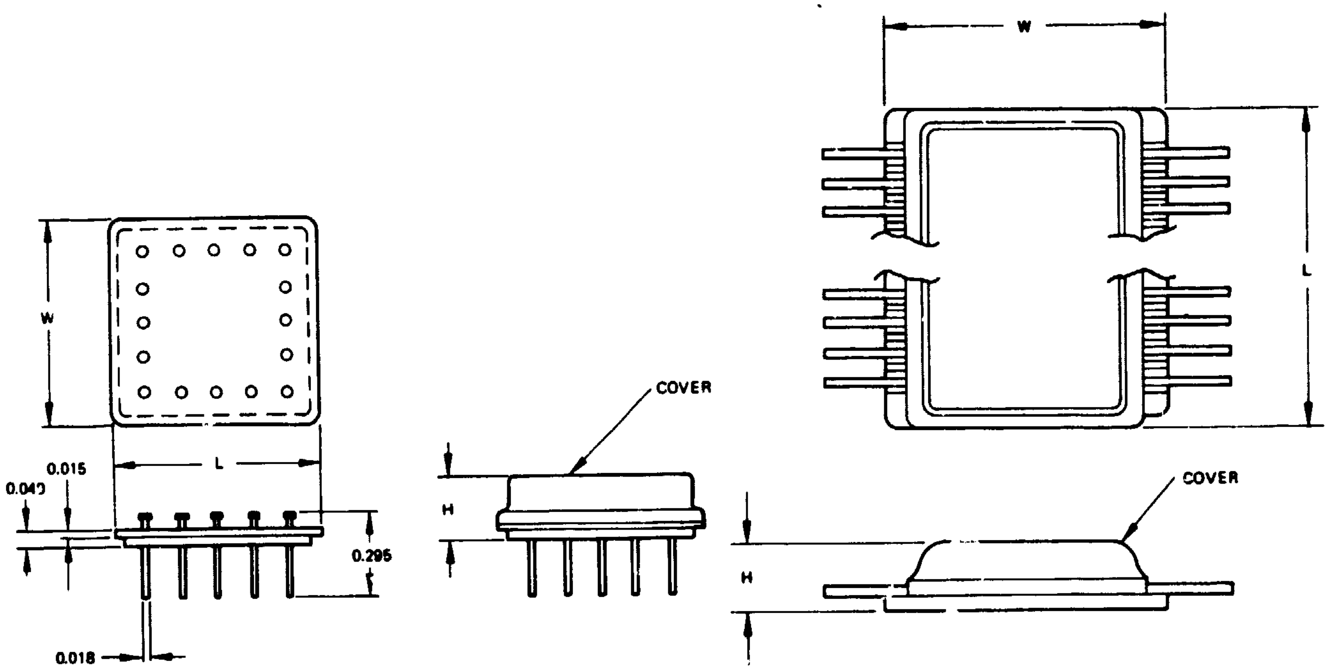


Figure 12. Typical hybrid microcircuit package types. Metal platform package on the left. Ceramic butterfly package on the right.

7.3 Equipment Controls

The sealing equipment should be kept clean and free from contaminants which could enter the package. For example, welding electrodes must be kept clean. Proper sealing schedules should be determined for the different package types, materials and sizes to be sealed. Sealing should be done in a dry box or with sealing equipment which furnishes its own inert sealing atmosphere.

The moisture content of the dry box should be monitored using instruments such as the Alnor Dew-Pointer, Panametrics Moisture Monitor, DuPont Moisture Analyzer, or the equivalent. If, for example, the moisture inside the hybrid package is to be kept to a level not exceeding 500 ppm, then the moisture level inside the dry box must be at a much lower level, such as 10 to 100 ppm. Thus the moisture monitoring method used must be capable of measuring levels at least this low.

If sealing is done by soft soldering (either machine or manual), fluxes should never be used because of the danger of the flux getting sealed into the package. Temperature controls for the sealing equipment are especially critical. Too high or too low a temperature could result in a non-hermetic package or in excessive splatters, solder balls, or similar defects which could eventually lead to loose particles within the package.

7.4 Material Controls

The nitrogen or other inert atmosphere used in the sealing process should be pure and dry. It is recommended that, for example, the nitrogen should be at least 99.99 percent pure with a dew point of at least -40°F. The flow rate of nitrogen into the dry box or sealing chamber should be sufficient to maintain an adequate supply of clean, dry nitrogen at all times.

Pre-forms or solders used to seal hybrid packages must be of the proper purity and composition.

7.5 Process Controls

A pre-seal visual inspection should be done prior to sealing. This is the last opportunity to inspect for loose particles, stains, dust, lint, and similar contaminants before the lid is sealed to the package.

The lid, pre-form, and the package to be sealed should be clean and dry. There should be no evidence of tarnish, corrosion, organics, loose electroplating, or other contaminants on the lid or on the sealing surface of the package. A bake-out in an inert atmosphere or in a vacuum for 1 or 2 hours at +125°C to +150°C is recommended just before sealing. This can be done in an oven attached to the dry box or in a separate oven.

The hermeticity of the seal is measured afterwards. Ordinarily, both fine and gross leak testing is done. Fine leak testing can be done by using a commercially-available helium leak detector or radioisotope leak detector. Gross leak testing may be done by a fluorocarbon bubble test, a penetrant die test, or a weight gain test.

Two methods for detecting loose particles inside the sealed package are by radiography or by a particle impact noise test (PIN test). The PIN test will detect both metallic and non-metallic particles and will detect smaller particles than x-rays.

If the package is hermetic and if there are no loose particles inside, the primary contaminant remaining is moisture which had been sealed into the package. Once the package is sealed, any moisture inside is difficult to detect. Cavity gas analysis may be done on a sample basis to evaluate the sealing process. However, this process is destructive, as it requires puncturing the package. Another possible approach is to seal a small moisture detector inside the package.

Post-seal electrical and acceptance testing may reveal contaminants such as loose particles and moisture, providing these contaminants have caused an electrical malfunction.

If the package leaks, or if the hybrid fails electrically, or if loose particles are found inside the package, then the lid may have to be removed and replaced. In some cases, if hermeticity is the only problem, it may be possible to touch up the seal without lid removal. For example, if solder sealing has been used, reflowing of the solder may seal the leak and make the package hermetic. Such a resealing operation should always be preceded, however, by vacuum baking and back flushing of dry nitrogen to insure replacement of any alien atmosphere introduced into the package during leak testing or subsequent atmosphere exposure.

8.0 CONTAMINATION CONTROLS FOR THE PROCESS OF REWORK

8.1 Scope.

Rework may be necessary either before or after the lid has been sealed to the package. It includes such tasks as removing and replacing chip components on the substrate, replacing wire bonds, and possibly removing the lid and resealing a new lid to the package. Thus, the rework process can encompass parts mounting, interconnect bonding, and package sealing.

8.2 Requirements.

Pre-seal and post-seal rework requirements are identical to those requirements previously stated in Sections 5.2, 6.2 and 7.2. Briefly summing up these requirements, the hybrid should be free of loose particles or other contaminants. The package should be hermetic. The atmosphere inside the package should be inert and moisture-free.

8.3 Equipment Controls

The equipment controls for the rework process are identical to those controls previously stated in Sections 5.3, 6.3, and 7.3. In addition, any new equipment used in chip component removal or in lid removal must be clean, contaminant-free, properly calibrated, and operated by qualified personnel. For example, special desoldering equipment (e.g., vacuum, hot air jets, Solder-Wick, etc.) may be required to remove a lid or clean up a bonding pad.

8.4 Material Controls

The material controls for the rework process are identical to those controls previously stated in Sections 5.4, 6.4, and 7.4.

8.5 Process Controls

Where applicable, the same process controls previously discussed in Sections 5.5, 6.5 and 7.5 will apply to the pre-seal and post-seal rework process. However, rework introduces new contamination hazards not normally experienced. Rework should either be done in a clean or controlled area or under a laminar flow hood to reduce airborne contaminants. A thorough visual inspection and cleaning operation should always follow rework to make sure no chip fragments, wire bonds, or similar particles have been left in the hybrid. Chip fragments may be generated when the operator removes the old chip, since the removal operation may require chiseling away the old chip. The old wire bonds must also be removed. Care must be taken not to leave bits of the old wire bond, such as a foot or ball, still attached to the substrate or lying loose inside the package.

When the old chip or bond is removed, the operator may need to scrape the pad clean to prepare for the new chip or wire. These scrapings must be blown off or cleaned off prior to sealing the package.

Lid removal can be particularly hazardous, especially if the lid has been welded on or sealed on with 80 Au/20 Sn eutectic and has to be removed by grinding or machining. The fine particles created by grinding or other methods of lid removal can easily find their way inside the package. There are some methods of removing a lid which minimize the entrance of particles. These include: 1) remove the lid with the package inverted; 2) if machining is used to remove the lid, position a vacuum nozzle adjacent to the tool bit to suck up the particles as they are generated; 3) lift up a corner of the lid with a sharp edged instrument and then peel off the lid with pliers, similar to opening a can of sardines. None of these methods is guaranteed to keep out all the particles. Therefore, the inside of the package should always be blown out with dry nitrogen and the package recleaned.

Special controls may be required when resealing a new lid to the old package. The sealing surface on the package must be contamination-free. However, because it has already been sealed once before, the plating or metallization on the package sealing surface may be degraded so that it can no longer be wetted properly by the pre-form. For a welded package, the new lid may have to be welded to a bare steel, nickel, or Kovar surface instead of a gold plated surface. This may require a different welding schedule to attain hermeticity. Where preforms are involved, the package sealing surface may no longer be as smooth or flat as with a new package. The sealing surface may also be metallurgically different, as it may still retain traces of the previous solder alloy. These conditions may indicate the need for a change in the package sealing schedule.