DESTRUCTIVE TESTING OF HYBRID MICROCIRCUITS CONTAINING THERMOCOMPRESSION BONDED DEVICES AND LEAD-INDIUM SOLDERED CAPACITORS

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ABSTRACT

In-house hybrid microcircuits are manufactured at Bendix, Kansas City Division, for DOE weapons systems. This paper reports on the results of destructive testing two development electronic systems on a new manufacturing program which contains thermocompression bonded devices and lead-indium soldered capacitors. The destructive testing program was used to determine the reliability of the development assemblies and to develop base-line data for a destructive testing program for utilization during the production phase of the program.

BACKGROUND

Hybrid microcircuits (HMC's) manufactured by the Bendix Corporation, Kansas City Division, for the Department of Energy (DOE) are designed by Sandia Laboratories, Albuquerque, New Mexico. The technology used is thin film chrome-gold conductors evaporated over sputtered tantalum-nitride resistive material. The substrate material is alumina .027 inch (.686 mm) thick.

A new manufacturing program utilizing HMC's requiring high reliability and long life was placed into development fabrication at Bendix approximately five years ago and was concluded in mid-1977. HMC design information on the project includes 50/50 lead-indium soldered capacitors, inductors and power transistors and thermocompression bonded ribbons, lead frames, fine wires and beam lead devices. Thickness of gold conductors which the above devices are bonded and soldered to is 6 to 9 microns. Later designs on the project also use 3 micron gold.

During the latter portion of the development phase of the project, an environmental test sequence and D-test evaluation program was developed by Sandia and Bendix. This program was developed to provide a periodic check upon the thin film technology being used within the HMC's. It is now planned every two months during the production phase of the program an assembly will be selected and submitted to the D-test program.

This periodic check on the technology is the final check in a series of receiving inspection, in-process tests and equipment verification tests that are conducted at our facility on HMC's and their components. A list of the various tests is contained in Table 1.

D-TEST SCHEDULE

HMC's are assembled, inspected, sealed with ceramic covers and soldered to printed wiring assemblies which are fabricated into a final assembly and the final assembly is electrically and mechanically accepted. The D-test schedule developed is as follows:

1. Temperature cycle - three cycles (sinusoidal) -37°C to +85°C, 4 hours at each temperature.
2. Electrical test assembly.
3. Humidity exposure for 72 hours per temperature profile in Figure 1.
4. Vacuum bake - 60 mm Hg (abs) maximum, 71°C for 72 hours.
5. Electrical test assembly.
6. Life cycle - 960 on-off cycles (5 minutes on, 1 minute off) at 71°C.*
7. Electrical test assembly.
8. Encapsulate assembly with polystyrene bead foam.
9. Electrical test assembly.
10. Temperature shock - 10 cycles, -37°C to +71°C, 1 hour at each extreme with 3 minutes maximum between extremes.
11. Electrical test assembly.
12. Random vibration 20 minutes each axis (3), non-operating.

Frequency	Power Spectral Density (G^2/Hz)
20 to 180	0.0067
180 to 2000	0.02

13. Electrical test assembly

14. Random vibration operating, 40 seconds each axis (3)

Frequency	Power Spectral Density (G^2/Hz)
20 to 180	0.02
180 to 2000	0.06

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15. Electrical test assembly

16. Mechanical shock operating

a. Longitudinal: 0.8 ms 1000g

b. Lateral: 1.0 ms 800g

17. Electrical test assembly

Ambient, -29°C, and 71°C

18. Disassemble assembly

19. HMC's ambient tested

20. HMC's submitted to D-test program

*Modified on later assemblies to 2 minutes on, 4 minutes off due to duty cycle problems on power transistors.

D-TEST RESULTS

Two assemblies were submitted to the D-test program and the results of D-testing these units are as follows:

Beam Lead Devices

Each D-test assembly contains HMC's with a total of 295 beam lead devices of 7 different formats and from 5 different vendors. Device types contained within the HMC's are shown in Table 2. Typical beam sizes are .0046 inch x .0035 inch x .005 inch nominal except for format 21 devices which are typically .004 inch x .005 inch x .0002 inch nominal for the anode and .0055 inch x .005 inch x .0002 inch nominal for the cathode.

Devices are tested by using a technique of coating them with polyvinyl acetate and pulling them off with a wire loop embedded in the polyvinyl acetate.

Results of the pull tests on the beam lead devices (approximately 50% per HMC pull tested) are as follows:

Format	Quantity Tested	$\bar{X}$ (Grams)	Range (Grams)	Percent Beams Delaminated
25-4	258	24.48	7.8-67.3	>.1
70-24	75	101.06	41.8-184.8	0
120-44	8	74.85	19.0-150.0	0
90-28	8	88.26	61.7-176.9	1.8
21-2	8	12.00	4.0-25.6	12.5

Crossovers

The HMC's contain 2 x5 mil ribbon crossovers for the purpose of circuit interconnections. Method of testing is to place a wire hook under the center of the crossover then pull to destruction. Pull test results on the ribbons pull tested are as follows:

Quantity Tested	$\bar{X}$ (Grams)	Range (Grams)	Percent Bond Delaminations
384	81.65	15-130	0

TC Bonded Lead Frames

Logic function type HMC's use TC bonded lead frames. Lead frame size is .007 x .015 inch nominally and the material is gold plated copper with a nickel barrier. For testing purposes after HMC cover removal and the sealing epoxy is removed from the bond sites, the leads are bent 90 degrees to their bond sites and peel tested. Results of the peel testing are as follows:

Quantity Tested	$\bar{X}$ (lbs)	Range (lbs)	Percent Metallization Failures
109	2.57	.5-4.35	0

The lead frame peel test is used at our facility to determine the quality of metallization adhesion also. Test results indicated no metallization failures.

Soldered Capacitors

The capacitors within our HMC's are soldered with 50/50 lead-indium solder using primarily a Browne Corporation Model AR-7 belt reflow solder machine and a few are hand soldered using the Browne Corporation Model SR-3 reflow solder machine. Each assembly contains HMC's with approximately 205 capacitors of 3 basic types and 5 different mounting terminal sizes. Capacitor information is supplied in Table 3. The test method is to apply a shear force on a non-terminal side of the capacitor and push-off the capacitor. The data below is the push-off data with all types of capacitors in the distribution. Following this data are the limits developed for capacitors of the various different sizes and mounting methods that are currently being used to evaluate our HMC's in the ongoing production D-test program.

Quantity Tested	$\bar{X}$ (lbs)	Range (lbs)
198	5.41	.94-9.5

Capacitor Type	Mounting Terminal Size (inch)	Minimum Shear Strength (lbs)
Porcelain Chip	.055 x .015	.75
Porcelain Chip	.065 x .015	1.5
Ceramic chip	.050 x .010	2.00
Ceramic chip	.040 x .010	2.00
Ceramic chip	.095 x .010	3.00

Fine Wires

Only a few gold fine wires were used in the HMC's tested since the capacitors are solder attached. Fine wires that were used are .001 inch in diameter and they are pull tested using a hook placed under the center of the wire loop. Results of the few wires pull tested are as follows:

Quantity Tested	$\bar{X}$ (Grams)	Range (Grams)	Fractured Bonds
32	10.68	1.5-13	0

Other

Other benefits that can be derived from the D-test program include a periodic analysis of the quality of components being installed within the HMC's. This paper will not deal with this subject but the D-test program has been beneficial to Bendix in this important area.

CONCLUSIONS

In general the test results from the two development assemblies indicated that the HMC's were reliable and durable. A few adjustments were necessary for incorporation of the program into the production phase on the assembly which included revision of the life test cycle, and revision of capacitor shear test minimum strength requirements for the different sizes and mounting techniques.

ACKNOWLEDGMENTS

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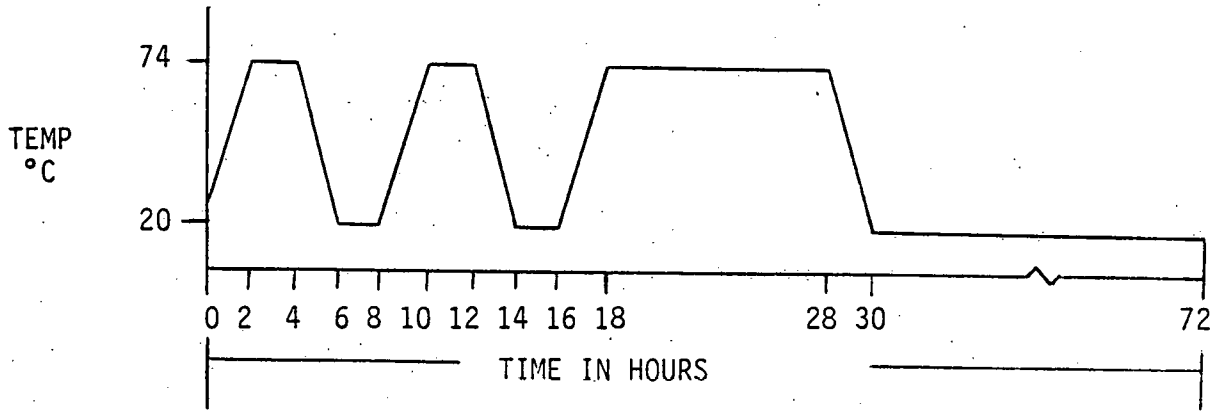

HUMIDITY EXPOSURE - TIME/TEMP PROFILE

Figure 1

TABLE 1

In-Process Testing - HMC Manufacture

1. Receiving inspection bondability, solderability and product parameter tests as applicable.

2. Bonder certifications

   a. Initial set up

   b. Daily

   c. Weekly

   d. Periodic calibration of gages and indicators

3. Soldering machines

   a. Heat source calibration

   b. Periodic calibration of gages and indicators

4. Metallization adhesion and bondability testing

   a. Thin film networks

   b. Lead frames

5. Dry processing

   a. Dry nitrogen storage of thin film networks and HMC's when not in actual manufacturing steps.

   b. Vacuum baking at 100°C prior to prelid testing and cover attachment.

6. HMC testing and conditioning

   a. Temperature cycle - 10 cycles, -40°C to +125°C, with essentially no time lapse between extremes, 15 minutes at each extreme.

   b. Visual inspection prior to HMC cover attachment.

   c. Seal testing after cover attachment using gross-leak techniques.

   d. Hot (85°C) and cold (-29°C) electrical testing.

TABLE 2

Device Type	Format Size - Beams
IC	70-24
Transistor, NPN, low current	25-4
Transistor, PNP, low current	25-4
Transistor, NPN, medium current	25-4
Transistor, PNP, medium current	25-4
Diode, general purpose	25-4
Diode, 6.4 volt Zener	25-4
Diode, 10.0 volt Zener	25-4
Diode, 12.0 volt Zener	25-4
Pin diode, RF	21-2
Step recovery diode, RF	21-2
Schottky barrier diode, RF	21-2
Quad pin diode array	30-4
27 K ohm resistor	36-4
IC	90-28
IC	120-44

TABLE 3

Capacitor Type	Terminal Type	Terminal Size (inch)
Porcelain chip, low-loss	50/50 lead-indium	.055 x .065 x .015
Ceramic chip, general purpose	Palladium silver coated with 50/50 lead-indium	.040 x .040 x .010
		.050 x .045 x .010
		.050 x .060 x .010
		.095 x .065 x .010
Ceramic chip, NPO characteristics	Palladium silver coated with 50/50 lead-indium	.040 x .040 x .010
		.050 x .045 x .010
		.050 x .060 x .010
		.095 x .065 x .010