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BEAM LEAD
SEMICONDUCTOR
TESTING AND
HANDLING

BDX-613-194

September, 1970

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A prime contractor for the Atomic Energy Commission

Contract Number AT(29-1)-613 USAEC

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Section 1

SUMMARY

The objective of this project was to investigate testing and handling processes for beam lead semiconductor devices.

Handling and testing very small beam lead devices (BLD) is difficult but can be done successfully with proper handling equipment which must be developed for this purpose. The major problems are maintaining device orientation for proper chip pickup and achieving adequate contact to the device under test.

Testing performed to date has been accomplished with existing probe stations and units bonded to a substrate. However, a fixed point probe station with automatic chip handling capability will be required to interface with the Fairchild 600 and 5000/5800 semiconductor test systems available at BKC. A manual probe system will be required for low volume testing and failure analysis. Possible vendors for the automatic equipment are Fairchild Systems and Bulova Systems and Instruments. A Rucker and Kolls probe station and probe cards could be used with a vacuum pickup device for manual work.

Environmental testing was performed by bonding devices to a substrate and placing two substrates in an edge connector. Only six devices per substrate were used; however, this method could be expanded to larger substrates. This method, while satisfactory for environmental testing, must be considered destructive since the devices are bonded to the substrate.

Some methods of maintaining devices in an ordered array must be developed for non-destructive electrical testing. Possibilities are BLD carriers similar to normal chip carriers, vacuum loaded ceramic substrates with metallized test pads, and silicone impregnated glass discs.

A literature search was conducted as part of this project and many useful articles on beam lead technology were reviewed. A bibliography appears in this report as Appendix A.

Section 2

DISCUSSION

BEAM LEAD DEVICES

Open wire bonds in monolithic integrated circuits, hybrid microcircuits, and discrete semiconductors have long been a predominant failure mode. The beam lead device (BLD) has been developed to significantly reduce this failure tendency.

In the BLD structure, comparatively thick (typically 0.5 mil) gold leads which, like cantilever beams, extend beyond the edges of the die provide both electrical contact and structural support. Advantages of the BLD include small size; a single bonding operation for all leads; easy bond inspection; sealed junctions; no intermediate bonds; mounting by thermocompression, ultrasonic or compliant bonding; and compatibility with both thick and thin film technology.

BLD FABRICATION

In addition to established diffusion and planar processes, a new system of metal-silicon nitride junction sealing and beam lead processes is used in manufacturing beam lead devices. The major problem in the complex process, illustrated in the flow diagram (Figure 1), is attaining satisfactory yields.

A complex metal system is used to form the interconnections and beam leads. Layers of platinum silicide, titanium, platinum, and gold are formed by photo masking, etching, and metal deposition, and the thick gold leads are formed by electroplating. A cutaway of a BLD is shown in Figure 2.

Figure 2. Cutaway of a Beam Lead Device

Platinum silicide provides a low resistance ohmic contact to the silicon, titanium bonds the platinum layer to the nitride in the overlay area, and the platinum prevents gold from migrating into the silicon or silicon nitride. The nitride layer serves as a barrier to sodium or trace amounts of other contaminants which could migrate through the oxide layer and degrade the electrical properties of the device.

The finished BLD, which is ideally suited for hybrid circuit applications, has all leads in the same plane for a single bonding operation, and is encapsulated in its own hermetic package. Figure 3 is a photograph of a typical beam lead transistor. The sealed junctions completely protect the circuit from deleterious surface contaminants without external encapsulation.

BLD TESTING

One requirement for the testing of large quantities of BLD's is that individual device coordinates must be maintained through all operations until it is bonded into the final assembly. This is accomplished at vendor plants by maintaining individual die from a wafer in matrix form with a cementing resin, and by performing subsequent testing and handling operations on this matrix. Devices must be procured in some kind of defined array to economically test them at BKC. Figure 4 is a drawing of the BLD format used in this evaluation.

Figure 3. A Typical Beam Lead Transistor

The method used to prepare the BLD devices for test was to bond them to a substrate containing a metallized pattern. This method is quite satisfactory for environmental testing, but since the devices are bonded to the substrate, the testing must be considered destructive. Substrates used in the evaluations were fabricated by the Microelectronics Department. Substrates with devices attached are shown in Figure 5. The substrates are made with thin film deposition techniques using gold over chrome. The thicknesses used are 200 to 300 Å of chrome and 5000 to 6000 Å of gold. Approximately the first 500 Å of gold is phased with chrome. Presently the patterns are designed for 1 by 1 inch ceramic; however, 2 by 2 inch ceramic could be used to allow more devices per substrate. The artwork is programmed and cut by the computer so changes can be incorporated easily. Patterns can be made for any beam lead device. The substrates can be used for bonding evaluations, and devices can either be probed on the pads or tested by plugging into a connector for electrical evaluations. The thin film will withstand all of the environments to which the semiconductors are subjected. Resistors may be added for burn-in and life tests.

Figure 4. Drawing of BLD Used in This Evaluation

A. Unmounted Substrate

B. Substrate Mounted for Testing

Figure 5. Substrates with BLD's Attached

For high- and low-temperature testing, two of the 1-inch square substrates can be placed back-to-back in an edge connector which is mounted on an oven door. The same connectors can be used for HTRB, life test, and power burn-in testing. A Bendix-built manual probe set-up was used for room temperature electrical testing of the mounted BLD. Tables 1, 2, and 3 present the data from this testing. Contact was made to the large metallized pads on the substrate and not to the device itself. So long as the devices are bonded to the substrate and quantities are small, this probe set-up is adequate, but to test an unmounted individual die, or to test large quantities of mounted device, a fixed point probe system capable

(Text continued on page 9)

Table 1. Electrical Test Data for BLD 1N914
(Data taken at room temperature)

Sample	BV $I_R = 100\mu A$ (Volts)	I_R $V_R = 75v$ (nA)	V_F $I_F = 5mA$ (Volts)
1	135	100	0.676
2	127	110	0.673
3	0.2	---	0.672
4	133	99.2	0.670
5	136	97.0	0.674
6	129	97.5	0.672
7	125	97.0	0.672
8	136	103	0.675
9	136	100	0.675
10	4	---	0.675
11	136	54.7	0.684
12	136	15.0	0.683
13	136	15.0	0.673
14	134	14.1	0.676
15	116	17.1	0.671
16	70.0	---	0.673
17	136	14.5	0.674
18	134	13.4	0.672
19	126	14.7	0.674
20	135	12.4	0.677
21	127	14.8	0.676
22	110	23.1	0.671
23	123	15.7	0.675
24	133	14.0	0.675

Table 2. Parameter Data for BLT 2N2484

Sample	BV_{CBO} $I_C = 10 \text{ uA}$ (Volts)	BV_{CEO} $I_C = 10 \text{ mA}$ (Volts)	BV_{EBO} $I_E = 10 \text{ uA}$ (Volts)	I_{CBO} $V_{CB} = 45 \text{ V}$ (nA)	I_{EBO} $V_{EB} = 5 \text{ V}$ (nA)	h_{FE} $I_C = 1 \text{ mA}$ $V_{CE} = 5 \text{ V}$	V_{CESAT} $I_B = 100 \text{ uA}$ $I_C = 1 \text{ mA}$
1	106	50.4	9.8	2.11	2.11	318	0.088
2	100	.8	10.4	----	2.11	---	0.655
3	106	52.9	10.4	2.11	2.11	308	0.090
4	106	52.6	10.5	2.11	2.11	303	0.088
5	107	48.9	10.4	2.11	2.11	287	0.088
6	107	50.4	10.4	2.11	2.11	308	0.085
7	106	53.7	10.2	2.11	2.11	313	0.090
8	106	52.7	10.4	2.11	2.11	299	0.093
9	106	50.6	10.3	2.11	2.11	399	0.086
10	22.3	50.2	10.3	247 uA	2.11	370	0.087
11	106	51.1	10.4	2.11	2.11	346	0.089
12	106	50.3	10.4	2.11	2.11	349	0.086
13	.2	.8	10.2	----	2.11	---	0.655
14	106	52.6	10.4	2.11	2.11	298	0.090
15	25.8	52.5	10.4	290 uA	2.10	263	0.098
16	103	51.7	10.4	2.11	2.11	365	0.088
17	103	49.9	10.4	0	2.11	422	0.084
18	105	52.9	10.5	2.11	2.11	287	0.092
19	106	48.3	10.4	0.0	2.11	351	0.085
20	106	52.3	10.4	0.0	2.11	327	0.089
21	105	52.0	10.4	0.0	2.11	327	0.089
22	107	49.9	10.4	0.0	2.11	384	0.084
23	107	50.4	10.3	0.0	2.11	354	0.087
24	107	50.8	10.4	0.0	2.11	337	0.087

Table 3. Parameter Data for Part 3965

Sample	BV_{CBO} $I_C = 10 \text{ uA}$ (Volts)	BV_{CES} $I_C = 10 \text{ uA}$ (Volts)	h_{FE} $I_C = 10 \text{ uA}$ $V_{CE} = 5 \text{ V}$	h_{FE} $I_C = 1 \text{ mA}$ $V_{CE} = 5 \text{ V}$	BV_{EBO} $I_C = 10 \text{ uA}$ (Volts)
1	0.1	0.1	OR	OR	8.5
2	8.3	0.1	OR	OR	8.3
3	106	97.6	29.9	331	8.3
4	82.8	74.3	29.9	409	8.5
5	110	102	29.9	321	8.2
6	85.0	76.6	31.9	390	8.5
7	8.4	0.1	OR	OR	8.4
8	83.3	75.1	55.9	423	8.3
9	222	120	45.9	309	8.3
10	79.2	70.9	59.9	499	8.4
11	8.3	0.1	----	---	8.3
12	106	97.6	52.0	358	8.3
13	80.3	71.9	59.4	469	8.4
14	8.3	0.1	----	---	8.3
15	71.1	62.6	51.9	479	8.5
16	66.7	58.3	59.9	515	8.4
17	73.0	64.5	59.9	489	8.5
18	95.1	86.9	53.0	380	8.2
19	1.5	110	31.9	303	8.1
20	83.8	75.6	51.5	417	8.2
21	0.1	0.1	----	---	8.3
22	70.9	62.5	59.9	467	8.4
23	57.4	47.9	19.9	290	8.5
24	52.0	30.0	92.9	186	8.1
25	112	114	28.1	309	8.3
26	82.6	74.1	49.9	417	8.5
27	-----	-----	----	---	---
28	68.1	59.5	55.6	531	8.6
29	108	99.8	31.9	349	8.3
30	0.1	-----	----	---	---

of accurately contacting a device, then indexing automatically to the next device, must be developed and interfaced with the Fairchild test equipment already available at Bendix. A promising system is under development by Bendix Components Engineering. It consists of a Transistor Automation Company prober, which is normally used for testing semiconductor wafers prior to dicing, interfaced with a Fairchild 600D transistor tester.

Beam Lead Handling

For high volume work, a BLD handler capable of orienting a device in an array, positioning the device at the test probes and identifying reject units in the array or depositing the units elsewhere may be necessary.

Contacts were made with representatives from Bulova Systems and Instruments Division and Fairchild Systems regarding commercially available BLD testing and handling equipment. Fairchild has recently installed a test system interfaced with the 5000/5800 IC tester for Western Electric, and Bulova's handling equipment appears to be capable of interfacing with Fairchild test systems at BKC. Additional investigations must be conducted on the available equipment.

For low volume and failure analysis work, a manual device pickup and positioning setup could be established using techniques developed by Bell Laboratories.

A beam lead shipment tray similar to current semiconductor chip trays has been discussed with representatives of Floroware Inc., Chaska, Minnesota, and it may be possible to obtain an adequate tray. Drawings for the proposed tray are currently being made.

BEAM LEAD BONDING

Of the various methods of BLD bonding, the wobble method is the most accepted and the Kulicke and Soffa bonders are currently the best available. The wobble principle is to rotate the bonding tool and the work relative to each other and make sequential bonds around the BLD chip. Some of the advantages of wobble bonding are single bonding operation for all leads, sequential bonding, and uniform bonding pressure for all leads.

In compliant bonding, an intermediate material, such as aluminum foil, is used between the heated bonding tool and the beams to achieve a uniform bond; however, the wobble method will achieve the same results with less complexity in most applications.

Section 3

RECOMMENDATIONS

Since low volume D-testing (units mounted on substrates) can be accomplished presently, subsequent work should concentrate on efficient methods for handling large volume acceptance testing, non destructive environmental testing and low volume nondestructive testing at room temperature. Specific areas for investigation include the following:

- BLD handler, (capable of precise pickup, movement to test pad, and precise deposition of device).
- Handler-tester interface.
- Non destructive high and low temperature testing.
- Substrates for life test, HTRB, power burn-in.
- Manual test setup for BLD's.

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