AN INVESTIGATION OF MICROWAVE PACKAGING AND ASSOCIATED BONDING TECHNIQUES

Mrs. Christine Westcott, Spartan Microwave Limited

1. ABSTRACT

The work described in this paper was carried out as an ESTEC Development Contract to study die attachment, wire bonding and packaging of gallium arsenide devices.

A low mass and volume hermetic package suitable for single or multichip packaging was identified, and the mounting and wire bonding carried out within this package.

The objective of this work was to evaluate conductive epoxy resin die mounting and lid sealing, compare it with eutectic methods and to find if reliable thermosonic bonds could be made to devices without damaging the underlying material.

All test pieces were subjected to long term high temperature storage, environmental or mechanical stress. Bond strengths and visual appearance were examined before and after stress testing together with particular requirements such as hermeticity of sealed packages.

It was found that devices could be satisfactorily mounted in the packages using conductive epoxy resins, reliable thermosonic bonds made to the die without damaging the underlying material, and the package hermetically sealed using a conductive epoxy resin.

Packaging, die attachment, wire bonding, epoxy resin.

2. PACKAGE IDENTIFICATION AND EVALUATION

In order to use bare gallium arsenide die in a space environment, they must be sealed in a hermetic enclosure which is electrically compatible with the frequency being used.

Metal packages have generally been used for this purpose, but with ceramic or mixed ceramic and metal packages now becoming available, a reduction in mass and volume can be achieved while still achieving good microwave performance

Suppliers of ceramic or mixed type packages were identified at the beginning of the programme, but of these, only one was at that time able to supply standard packages in Europe.

The selected package was of co-fired ceramic construction, characterised to 18GHz and was designed to be hermetically sealed with a metal lid.

The package was mainly investigated as a sealed unit in conjunction with the materials described in section 5, but as an incoming inspection, the visual appearance, DC continuity, insulation resistance and a gross leak bubble test was carried out on the open package.

While some visual and bubble test failures were found on the early packages, those supplied later in the contract were satisfactory.

3. DIE PLACEMENT

Gallium arsenide die are temperature sensitive, the maximum temperature recommended by the manufacturers usually being 290C to 320C for as little as a few seconds. This limits eutectic die placement to

80/20 gold tin with a melting point of 280C, and even this material has poor wetting and flow characteristics just above its melting point making die bonding difficult.

Conductive epoxy resins have been developed significantly over the last few years to make them compliant with MIL-STD-883 Method 5011 which defines all important properties including outgassing, ionic content, thermal stability, adhesion, electrical and thermal resistance.

With the improvement in epoxy resins, they have become more attractive for mounting gallium arsenide devices as the curing temperature, usually between 100C and 200C presents no thermal hazard to the device.

The properties of the mounting media studied in this investigation were die shear strength, electrical resistance, visual appearance and handling. Four epoxy resins, three one-part designated Adhesives B, C and D, and one two-part, Adhesive A were evaluated and compared with 80/20 gold/tin eutectic.

To investigate the handling, four die sizes ranging from 0.382 mm x 0.330 mm to 5.16 mm x 4.16 mm were assembled using the epoxy resins, the adhesive being applied using a stainless steel probe or a cocktail stick. All the epoxy resins were cured according to the manufacturer's recommendations as close to 150C as possible. Some of the adhesives had a range of cure schedules, so this temperature was selected for the evaluation. Adhesive A was a little difficult to mix in small quantities, but all the adhesives were easy to apply. Some initial difficulties were experienced with the eutectic die placement, but these were overcome, although it became clear that if the gold on the die was affected by poor or long storage, wetting was very difficult at the enforced low temperatures.

Because on initial die shear testing it was found that the gallium arsenide die disintegrated leaving the mounting medium intact, all shear testing was carried out using 1mm squares of alumina coated on one face with thick film gold. Die shear tests were carried out on all materials before and after the stress tests described in Section 6. The results combined with the lid seal adhesives (E & F) are shown in Table 1.

ATTACHMENT MEDIUM	INITIAL	H.T. STORAGE		ENVIRONMENTAL		MECHANICAL	
	MEAN KG	MEAN KG	% INITIAL	MEAN KG	% INITIAL	MEAN KG	% INITIAL
Adhesive A	2.8	1.5	54	1.9	68	1.3	46
Adhesive B	3.0	2.2	73	3.5	117	2.2	73
Adhesive C	3.3	2.1	64	3.0	91	2.6	79
Adhesive D	3.3	2.1	64	3.0	91	1.9	58
Adhesive E	2.7 3.3	3.7	137	2.0	61	1.2	44
Adhesive F	4.1	4.4	107	3.8	93	3.8	93
80/20 Gold Tin	2.1	1.5	71	1.4	67	1.7	81

Table 1

One mix of Adhesive A gave very poor results after high temperature storage and environment stress. As it was suspected that the mixing was poor, these tests were repeated and the above results obtained.

The electrical resistance was not measured accurately, but the test was designed to show high resistance and significant changes after stress testing. All materials were satisfactory before and after stress.

All samples were visually inspected at each stage. No shear samples or die became detached or damaged. All pieces were satisfactory and the only change noted was darkening of the adhesives stored at high temperature in air.

The shear strength of Adhesive A seemed to be affected more by stress testing than the other adhesives, but as it had a wide range of cure temperatures if was expected to be useful in particular applications.

Adhesives B and C were found to be generally satisfactory and were compliant to MIL-STD-883 Method 5011. Adhesive D performed satisfactorily but was not compliant with MIL-STD-883 Method 5011 and little data was available from the manufacturer on properties such as purity.

4. WIRE BONDING

Thermosonic wire bonding has certain advantages over the more traditional thermocompression bonding: Lower temperatures and pressures can be used as some energy is supplied by the ultrasonics, which can also disrupt thin layers of contamination which can be present on even clean surfaces.

Ultrasonic energy was believed to damage gallium arsenide, so as well as finding conditions for making reliable bonds, the gallium arsenide under the bonds was examined for material damage.

Test bonds were made at established settings using different background temperatures, and the bonds microsectioned and microscopically examined for gallium arsenide damage. No damage was observed either initially or after stress testing.

The bonder settings were established by setting the hotplate temperature then carrying out a search until bonds with the correct deformation and with high bond strength were obtained. The hotplate settings were ambient, 50°C, 75C, 100C and 125C. To confirm the settings 100 bonds were made, visually inspected and destructively pull tested.

The test bonds were made between the die mounted in the package and the package metallisation. They were visually inspected and approximately one third destructively pull tested. The packages were lid sealed and stress tested. After lid removal the remaining bonds were visually inspected and destructively pull tested.

The results are shown in Table 2. The wires labelled 'b' were found broken on lid removal and this failure was attributed to the stress testing.

Background °C	HT Storage			Mechanical Stress			Environmental		
	Mean	%	No <3g	Mean	%	No <3g	Mean	%	No <3g
125	4.2	72	0	5.4	83	0	5.4	91	0
100	5.2	68	0	5.4	82	0(2b)	5.1	88	0
75	4.4	79	3	4.7	66	2(1b)	4.9	71	0
50	5.1	74	1	4.8	74	3	5.0	83	0
Ambient	5.1	84	0	4.1	80	5	4.8	98	2

Initial bond strengths were between 5g and 8g.

Table 2

It was concluded that gallium arsenide devices could be thermosonically bonded without causing die damage, and that reliable wire bonds could be achieved with a background temperature no lower than 125°C.

5. PACKAGE SEALING

Because of the temperature limitations of gallium arsenide, as described in section 3, epoxy resin package sealing is attractive when sealing assemblies containing these devices.

The conductive epoxy resins selected for evaluation and compared with 80/20 gold tin eutectic were Adhesive A and D, said by their manufacturers to be suitable for lid sealing, Adhesive E, a two-part paste adhesive, and Adhesive F a supported preform material.

The shear strength, visual appearance and electrical resistance were evaluated by the methods described in section 3. In addition, methods of sealing packages using the materials were investigated, and a number of packages sealed then hermeticity tested. Stress tests were carried out on all test pieces and the measurements repeated.

The die shear strength is shown in Table 1, and the result of attempting to seal 4 packages in each group shown in table 3.

Adhesive A was seriously affected by high temperature storage resulting in some packages becoming non-hermetic. Adhesive D had a tendency to blow hole formation, but the packages which sealed remained hermetic. Adhesives E and F were generally satisfactory, but as Adhesive F is an old material with poor outgassing properties, it can only be regarded as representative of B stage preform.

Sealing Medium	HT Storage Pass		Environmental Pass		Mechanical Pass	
	Pre Stress	Post Stess	Pre Stress	Post Stress	Pre Stress	Post Stress
Adhesive A	3	0	3	2	2	2
Adhesive D	0	0 1 Marginal	2	1 1 marginal	1 1marginal	1 1 marginal
Adhesive E	2	3	1	1	2	2 1 marginal
Adhesive F	1	1	4	2 1 marginal	3	2 1 marginal

Table 3

No packages were successfully sealed using 80/20 gold tin. However, although not fully investigated, the packages have been satisfactorily sealed in a conveyer furnace and a programmable vacuum furnace.

6. STRESS TESTING

Samples of each material or experimental condition underwent all stress tests, but no test piece was subjected to more than one type of stress. The stress tests carried out were:

6.1 High Temperature Storage

150°C for 2000 hrs. Visual inspection after 100 hrs, 500 hrs, 1000 hrs and 2000 hrs.

6.2 Mechanical Stress

Shock test	MIL-STD-883 Method 2002 Condition B +
Vibration	MIL-STD-883 Method 2007 Condition A +
Constant Acceleration	MIL-STD-883 Method 2001 Condition E (2 axis)

6.3 Environmental Stress

Temperature Cycling	MIL-STD-883 Method 1010 Condition C
	-65C to +150C 10 cycles +
Thermal Shock	MIL-STD-202F Method 107 Condition F
	-65C to +150C 5 cycles

6.4 Hermeticity Testing

Fine Leak	MIL-STD-883 Method 1014, Condition A
Gross Leak	MIL-STD-883 Method 1014 Condition C

7. CONCLUSION

Epoxy resins were selected and evaluated for die attachment and certain materials found to be satisfactory.

It was shown that reliable thermosonic wedge bonds could be made to gallium arsenide die using gold wire, and that under the conditions of the evaluation, no damage was caused to the die material under the bonds.

A package was identified and epoxy resins evaluated for lid sealing. It was found possible to obtain hermetically sealed packages using certain epoxy resins.