RELIABILITY EVALUATION OF THE D07A PROCESS FROM PHILIPS MICROWAVE LIMEIL

J.P Pasquali
L.E.P/Philips Microwave Limeil
22, avenue Descartes BP.15
94453 Limeil Brévannes Cedex (France)
Tel : (33) 1.45.69.96.10 / Fax : (33) 1.45.69.44.77

ABSTRACT

The results of the reliability evaluation of the D07A process from the Philips Microwave Limeil Foundry are presented. First the parametric evaluation of the discrete elements is described, showing that the most sensitive element is the diode, due to a surface degradation in the access areas. Then the reproducibility of the D07A process is demonstrated on 10 wafers coming from 4 different batches.

Keywords: Reliability, GaAs MMIC, Process evaluation

1. RELIABILITY EVALUATION PROGRAMME

Philips Microwave Limeil is carrying out an internal reliability evaluation programme for all its processes in production. This programme has been specifically in progress for more than two years for the D07A 17 GHz MMIC Analogue process.

It involves three different phases : a parametric evaluation, a reproducibility evaluation and the reliability assessment of an MMIC demonstrator.

1.1 Parametric evaluation

The parametric evaluation phase is performed to study the reliability of each discrete element used in a GaAs MMIC, such as GaAs resistors, capacitors, diodes, transistors, and also interconnection between the two metallization levels. For each element three different dimensions corresponding to the minimum, typical and maximum design rules given in the Design Manual are evaluated. Storage and life tests are performed at three various temperatures in order to determine the degradation mechanisms and the associated activation energy. In this phase, only DC parameters are characterized.

1.2 Reproducibility evaluation

The transistor element is used like a test vehicle to study the batch to batch reproducibility of the process. A high temperature storage and life test is performed with the monitoring of the DC FET parameters.

1.3 I.C demonstrator evaluation

The test vehicle is a one-stage amplifier. It is bonded into a RF Flatpack package in order to evaluate its R.F performance. Three high temperature storage and life tests are performed to determine the degradation mechanisms and to correlate them with the reliability figures derived from the parametric evaluation phase.

1.4 Failure definition

Two types of failures have been taken into account, the catastrophic failure like a short or open circuit, a "sudden" drift of a parameter and the drift failure due to a "soft" drift of a parameter beyond the maximum specified criteria described in the table below.

INTERCONNECTION		+ 50 %
NON-ETCHED RESISTOR		+ 25 %
ETCHED RESISTOR		+ 25 %
INDUCTOR		+ 25 %
CAPACITOR	≤ 1 pF	± 0.2 pF
	> 1 pF	± 20 %
TRANSISTOR	I_{dss}	-20 %
	V_{gsoff}	± 20 %
	G_{ml}	-20 %
	I_{gss}	> 50 μA/mm
	V_{brgdo}	-20 %
DIODE	V_{br}	-20 %
	I_{gss}	> 100 μA/mm
	R_{ser}	+ 25 %
	V_{bi}	± 25 %

Table 1. Failure criteria

2. D07A PROCESS

The D07A process of the Philips Microwave Limeil has been developed for Microwave and Analogue applications with a medium integration level. The main process features are :

- Active layer by direct implantation in LEC GaAs substrate
- Two metallization levels
- Etched or non-etched GaAs resistors giving a broad range of values
- Si_3N_4 MIM capacitor
- Depletion mode .7 μm recessed gate FETs
- Full Si_3N_4 passivation and protection
- SiO_2 interlevel isolation
- 200 μm substrate with metallized backside
- 17 GHz typical cut-off frequency

3. RELIABILITY RESULTS

3.1 Parametric evaluation

About ***900 components*** have been mounted in a 70 mil ceramic package for this evaluation and all storage and life tests have been pursued up to 100 % cumulative failure or 6000 hours of aging.

3.1.1 Resistor

At the highest storage temperature (275°C), ***no catastrophic or drift failure occurred after 187,488 device-hours***. The most sensitive resistor is the lowest value (10 Ω) and its drift is about + 17 % after 6,000 hours. This resistance increase is due to a degradation of the ohmic contact.

The conditions for the highest life test was an ambient temperature of 175°C with a current density of 10^5A/cm^2. ***No catastrophic or drift failure occurred after 181,440 device-hours***. An 6% increase is observed in the value of the 10 Ω resistor after 6,000 hours.

3.1.2 Capacitor

For the storage test at 275°C and the life test at 175°C with 5V bias, ***90,720 device-hours have been accumulated with zero catastrophic or drift failure***. Complementary tests, performed at 300°C during 1,800 hours on 10 components and at 175°C/10 V during 6,000 hours on 5 devices, did not allow to see any capacitance degradation.

3.1.3 Inductor

After three high storage tests at 250°C, 275°C and 300°C, the MTTF versus reciprocal absolute ambient temperature has been drawn for 20 percent decrease of the resistance value as shown in figure 1 for the 3 turn inductor.

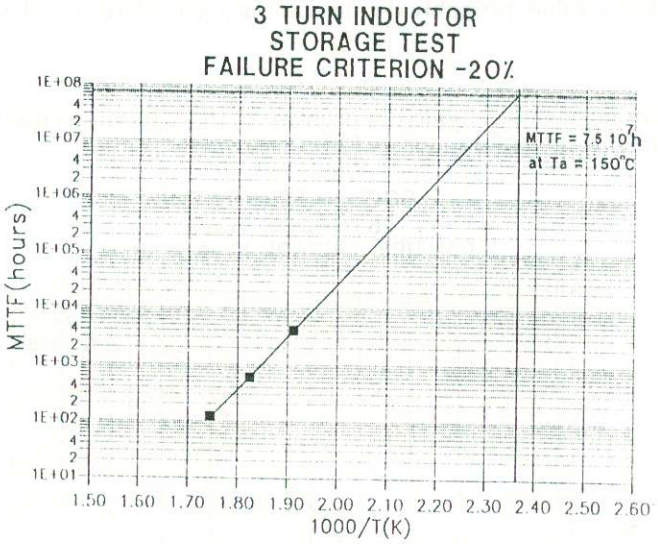

Figure 1. MTTF versus reciprocal absolute ambient temperature : Inductor storage tests

The activation energy has been determined to be approximately ***1.8 eV***, and by extrapolation, ***a MTTF value of about 7.5 10^7 hours*** has been obtained for an ambient temperature of 150°C. The major degradation mechanism is here a metal interdiffusion of the second metallization level (TiAU).

No catastrophic failure occurred during the highest life test at 175°C with a current density of 10^6A/cm^2. During this test only 3 components out of 14 devices failed in drift criterion after 6,000 hours of aging.

3.1.4 Interconnection

Each chip used for reliability tests contains 50 series interconnections, so that the 100 pieces evaluated in these tests corresponds to a total of 5000 interconnections.

No drift appeared during the 275°C storage and 175°C&10^6A/cm^2 life tests. Only nine catastrophic failures occurred randomly during the various tests, corresponding to the degradation of one interconnection out of the 50 series interconnections. Although it is difficult to establish with certainty the exact cause of these failures after analysis, it is expected they are due to a differential thermal expansion of the two metallization levels.

These 9 failures out of 5000 interconnections in reliability tests correspond to 28,576,800 device-hours and a mean failure rate can be calculated to be ***315 FIT***.

3.1.5 Diode

In storage tests at 225°C, 250°C and 275°C, ***3 catastrophic and 6 drift failures*** occurred out of 48 devices giving a total of ***280,224 devices-hours***.

214,488 device-hours have been recorded in -5 V reverse life tests at 125°C, 150°C and 175°C with the appearance of ***3 catastrophic and only 1 drift failures***.

In +0.8V forward tests at 125°C, 150°C and 175°C, ***3 catastrophic and 6 drift failures*** have been observed after ***200,592 device-hours***.

All these failures are randomly distributed between the various temperatures, showing that the major degradation mechanism is not significantly dependent on the temperature. The failure mode is a degradation of the I.V characteristic of the diode, translating into a drift of the leakage current, breakdown voltage or parasitic resitance value, probably due to a surface degradation in the access areas.

3.1.5 Transistor

In storage tests, the major degradation mode is a decrease of the saturation current value Idss. The figure 4 shows the MTTF curve for the 600 μm gate width transistors.

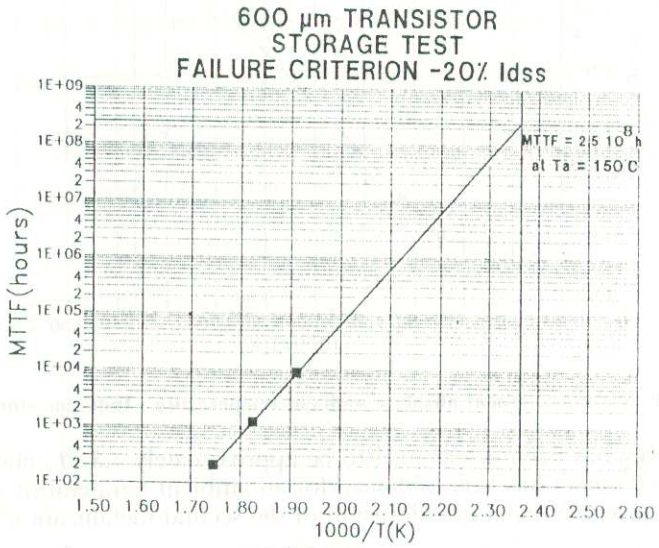

Figure 2. MTTF versus reciprocal absolute ambient temperature : transistor storage tests

The activation energy is estimated at 1.8 ev and a MTTF of 2.5 10^8 hours is extrapolated at Ta = 150°C. The degradation mechanism is a degradation of the ohmic contact in the source and drain metallization. A slight decrease of the pinch-off voltage (-10 % after 300 hours of aging at 300°C) is also noticed due to a gate metal sinking.

During the highest life test at a channel temperature of 190°C with a bias current at .5 Idss, ***no catastrophic or drift failure*** occurred on the various transistors (200, 300 and 600 μm width), giving a total of ***163,296 device-hours without failures. No drift in the pinch-off voltage and the saturation current*** has been observed ***after 6000 hours of aging***. The results of this test also show an improvement of the leakage current (typ.-50%) and of the breakdown voltage (typ. + 10%) after aging.

3.2 Reproducibility evaluation

A 200 μm width FET is used as a test vehicle. 160 pieces coming from 10 wafers and 4 different batches have been tested under storage test at 275°C and life test at 185°C channel temperature with Vds = 5V and Ids = 30mA.

3.2.1 Storage test (Ta = 275°C)

After a duration of 2,000 hours corresponding to ***179,424 device-hours, no catastrophic failure occurred*** and the figure 5 gives the Idss and Vpinch drift for all the wafers.

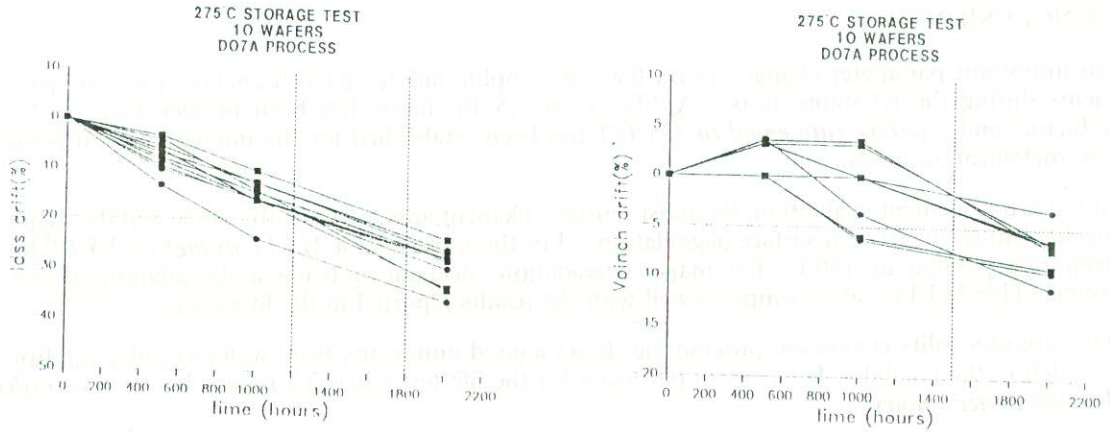

Figure 3. 275°C storage test : Idss and Vpinch drift versus aging time

Except for one wafer, the typical time for a -20% drift of the saturation current value is between 1200 and 1800 hours with a mean time at 1500 hours. At this time the typical pinch-off voltage degradation is -5%.

3.2.2 Life test (Tch = 185°C)

The life test results show that no sensitive Idss or Vpinch degradation appears after 5,000 hours (Figure 6).

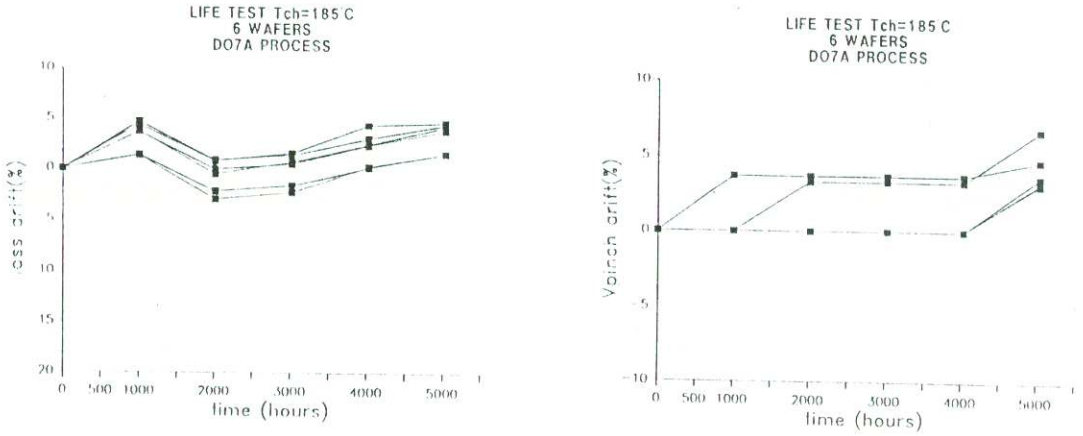

Figure 4. Life test Tch = 185°C : Idss and Vpinch drift versus aging time

Zero catastrophic failure has been recorded during this test corresponding to ***302,400 device-hours.***

3.3 IC demonstrator evaluation

This evaluation phase is supported by an ESA/ESTEC contract (n°9514/91/NL) and the reliability tests are still in progress. The end of the contract is scheduled in june 1992 and a future paper will give the reliability results of this part of the reliability evaluation programme of the D07A process.

CONCLUSION

No important parameter changes and a few catastrophic failures have been found for the passive elements during the reliability tests. A MTTF of 7.5 10^7 hours has been projected at 150°C for the inductors and a ***failure rate equal to 315 FIT*** has been established for the interconnection between the two metallization levels.

In the active element evaluation, the most sensitive element appears to be the diode and the major failure mechanism seems to be a surface degradation . For the transistors ***a MTTF as high as 2.5 10^8*** hours has been extrapolated at 150°C, the major degradation mechanism being a degradation of the ohmic contact.This MTTF value compares well with the results reported in the literature.

The reproducibility evaluation programme shows a good uniformity from wafer to wafer and from batch to batch in the reliability behavior in particular for the life test where ***no failure has been recorded after 302,400 devices-hours***.