Process Qualification Report
CMDS PHEMT5 & PHEMT6 Wafer Process

QUALIFICATION TEST REPORT

Wafer Process: PHEMT5 & PHEMT6
Drawing No: 102579

CMD230                CMD281
CMD231                CMD281C3
CMD231C3              CMD282
CMD232                CMD282C3
CMD232C3
CMD233
CMD233C4
CMD272P3
CMD279
CMD279C3
CMD280
CMD280C3
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Introduction

CMDS offers GaAs PHEMT technology to its customers for RF and Microwave applications. Currently two processes that use different starting epi structures have been qualified and used in production. Both processes share the same process modules with the only difference being in epitaxy structures. In terms of active devices, each of these processes have to be qualified separately due to the difference in epi structures and device bias conditions. The passive elements and interconnections of these processes share the same physical structures, design rules, and process flow, therefore the qualification of the passive structures has been applied to both processes. The scope of this report will focus on the qualification of the active structures of both processes.

The CMDS PHEMT6 Process is a power pHEMT process, and the process used for the baseline qualification purpose. The CMDS PHEMT5 Process is an enhancement/depletion mode pHEMT process that is a slight modification to the power pHEMT process.

The definition of a qualification family, as defined by EIA/JESD47 Stress Driven Qualification of Integrated Circuits, is all devices that use the same wafer fabrication technology, wafer fabrication process and wafer fabrication site. This qualification report will outline the screening that was performed to satisfy the reliability requirements for a GaAs MMIC device using Custom MMIC’s PHEMT5 & PHEMT6 wafer processes.

All screening identified as die level was performed on foundry Standard Evaluation Circuits (SEC). The SEC identified as PHEMT6 is the evaluation circuit used to qualify the baseline process. The SEC identified as PHEMT5 is the active structure with differences in epitaxy structure and bias conditions and will therefore be subjected to individual HTOL screening.

Qualification testing will consist of the following:

- High Temperature Operating Life (HTOL): PHEMT5 & PHEMT6 SEC’s
- High Temperature Storage Test: PHEMT5 & PHEMT6 SEC’s
- Humidity/Temperature Test (HAST): PHEMT6 SEC
- MSL. Screening: Packaged devices
- ESD Classification: Packaged devices
The Active Standard Evaluation Circuits (SEC) designed for screening are identified below;

◊ PHEMT5 Process: 4x50um cell, Jds = 100mA/mm, Vds = 8.0 volts.
◊ PHEMT6 Process: 4x50um cell, Jds = 135mA/mm, Vds = 5.0 to 8.0 volts.

All screening identified as package level was performed on the CMD233C4 for the PHEMT5 process and the CMD279C3 for the PHEMT6 process.

The CMD233C4 is a wideband GaAs MMIC low noise amplifier housed in a leadless 4x4 mm surface mount package. The CMD233C4 is ideally suited for military, space and communications systems where small size and low noise figure are needed over a wide bandwidth. At 10 GHz the device delivers greater than 9 dB of gain with a corresponding noise figure of 4.5 dB and an output 1 dB compression point of +20.5 dBm. The CMD233C4 is a 50 ohm matched design which eliminates the need for external DC blocks and RF port matching.

The CMD279C3 is a positive controlled, wideband GaAs MMIC 5-bit digital attenuator housed in a leadless 3x3 mm surface mount package. Each bit of the attenuator is controlled by a single voltage of either 0 V or +5 V. The attenuator bit values are 0.5 (LSB), 1, 2, 4, and 8 dB, for a total attenuation of 15.5 dB. The CMD279C3 has a low insertion loss of 3.5 at 9 GHz and the attenuation accuracy is typically 0.2 dB step error. The CMD279C3 is a 50 ohm matched design which eliminates the need for RF port matching.

Please refer to our product datasheets for detailed device information.
Products Selected, cont’d

CMD233C4 in a ceramic, air cavity QFN 4x4 mm x 24 lead smt

CMD279C3 in a ceramic, air cavity QFN 3x3 mm x 16 lead smt

CMD233C4 Functional Block Diagram

CMD279C3 Functional Block Diagram
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**PHEMT5, High Temperature Operating Life, (HTOL)**

Three separate PHEMT5 lots were selected to go through the HTOL reliability testing. 30 samples from each of the 3 lots were separated into 3 groups of 10 each and subjected to bias stress conditions at 3 different junction temperatures. The failure criteria was selected to be 10% degradation in dc current from the one hour data reference point.

The first group of 10 devices from each of the 3 lots were subjected to a Tj of 280°C and a bias condition of 8.0vdc. The second group of 10 devices from each of the 3 lots were subjected to a Tj of 304°C and a bias condition of 8.0vdc. The last group of 10 devices from each of the 3 lots were subjected to a Tj of 327°C and a bias condition of 8.0vdc.

- The deduced Activation energy for all 3 lots was 1.58eV.
- The projected MTTF at a Tj of 125°C is 2.8e9 hours.

**PHEMT6, High Temperature Operating Life, (HTOL)**

Three separate PHEMT6 lots were selected to go through the HTOL reliability testing. 3 lots with a total of 76 devices were subjected to bias stress conditions at 3 different junction temperatures. The failure criteria was selected to be 20% degradation in Idss current.

Lot 1 and Lot 2 each consisted of 23 devices, and Lot 3 was separated into 3 groups of 10 devices. Lot 1, Lot 2, and one group of 10 from Lot 3 were subjected to a Tj of 306°C and a bias condition of 8.0vdc. The second group of 10 devices from lot 3 was subjected to a Tj of 288°C and a bias condition of 8.0vdc. The last group of 10 devices from lot 3 was subjected to a Tj of 330°C and a bias condition of 8.0vdc.

- The deduced Activation energy for all 3 lots was 1.4eV.
- The projected MTTF at a Tj of 125°C is 1.5e9 hours.

**PHEMT5, High Temperature Storage Test**

One group of 10 devices was subjected to a high temperature storage of 150°C for 1000 hours. The Idss was monitored during the test and remained stable with no noticeable degradation.

The devices were tested at the conclusion of the 1000 hours and there were no changes in device characteristics.
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PHEMT6, High Temperature Storage Test

One group of 10 PHEMT6 devices was subjected to a high temperature storage of 225°C for 3000 hours. The Idss was monitored during the test and remained stable with no noticeable degradation.

The devices were tested at the conclusion of the 3000 hours and no degradation in device characteristics was seen.

PHEMT6, Biased Humidity and Temperature Test

15 PHEMT6 devices were randomly selected and subjected to Highly Accelerated Temperature and Humidity Stress Testing per JESD-22-A110. The bias current of the devices were 40mA and the Vds was 5.0 volts. The devices were subjected to an environment of 110°C and 85% Relative Humidity. The total test duration for the HAST test was 264 hours.

The normalized RF Gain was measured prior to, and following the HAST test per the screening identified above. No changes in device characteristics were seen.

Package Ass'y, Moisture Sensitivity Level Classification

Material samples from 2 non-consecutive build lots were electrically tested before and after being subjected to the procedure specified in J-STD-020E, classification level MSL1. Visual inspection and acoustic microscope inspection (CSAM) was performed before and after moisture soak and reflow per MSL1 levels specified by IPC/JEDEC J-STD-020E. No degradation in product performance was seen.

All material passed the criteria specified in Section 6.0 of IPC/JEDEC J-STD-020E, therefore the conclusion of this qualification testing is that our QFN ceramic air cavity surface mount package style is qualified to a moisture/reflow sensitivity classification level of MSL1 per the IPC/JEDEC J-STD-020E.
Samples from each of the 5 different P/N’s were subjected to testing per Method 3015 of MIL-STD-883 to determine their Electrostatic Discharge Sensitivity Classification. The devices were stabilized at room temperature prior to, and during testing. ESD simulator charging voltages were applied to the devices per the information detailed below.

### Human Body Model (HBM)
All tests were performed at $T_A=25^\circ$C

<table>
<thead>
<tr>
<th>No. of Samples Tested</th>
<th>Applied ESD Simulator charging voltage ($V_S$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>&lt; 125V, Class 0A</td>
</tr>
<tr>
<td>5</td>
<td>125V to &lt; 250V, Class 0B</td>
</tr>
<tr>
<td>5</td>
<td>250V to &lt; 500V, Class 1A</td>
</tr>
</tbody>
</table>

The test results show that no degradation in electrical performance was seen following the ESD Sensitivity Classification testing per MIL-STD-883, Method 3015. All material has successfully passed the requirements necessary for a Classification Level 1A rating.
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PHEMT5 & PHEMT6 Process Qualification Tests & Results Table

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Vehicle</th>
<th>Test Condition</th>
<th>Failure Criteria</th>
<th>Inspection</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTOL</td>
<td>PHEMT5 SEC</td>
<td>Tj = 280°C, 304°C, &amp; 327°C</td>
<td>10% degradation in Idss</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jds = 100mA/mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vds = 8.0 Vdc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTOL</td>
<td>PHEMT6 SEC</td>
<td>Tj = 288°C, 306°C, &amp; 330°C</td>
<td>20% degradation in Idss</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jds = 135mA/mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vds = 8.0 Vdc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Temperature</td>
<td>PHEMT5 SEC</td>
<td>1000 hrs. @ 150°C</td>
<td>No change in product</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td>performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Temperature</td>
<td>PHEMT6 SEC</td>
<td>3000 hrs. @ 225°C</td>
<td>No change in product</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td>performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAST</td>
<td>PHEMT6 SEC</td>
<td>Ta = 110°C, RH = 85%</td>
<td>No change in product</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vds = 5.0 Vdc</td>
<td>performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duration = 264 hrs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture Sensitivity</td>
<td>QFN 4mm x 4mm</td>
<td>24 hour bake @ 125°C</td>
<td>Per J-STD-020E, MSL1</td>
<td>CSAM</td>
<td>Passed</td>
</tr>
<tr>
<td></td>
<td>24 leads</td>
<td>168 hours @ 85°C &amp; 85% RH</td>
<td></td>
<td>Electrical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3X Reflow at 235°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture Sensitivity</td>
<td>QFN 3mm x 3mm</td>
<td>24 hour bake @ 125°C</td>
<td>Per J-STD-020E, MSL1</td>
<td>CSAM</td>
<td>Passed</td>
</tr>
<tr>
<td></td>
<td>16 leads</td>
<td>168 hours @ 85°C &amp; 85% RH</td>
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<td>Electrical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3X Reflow at 235°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD Classification</td>
<td>CMD279C3</td>
<td>Per MIL-STD-883, Method 3015 Class 1A, 499 volts</td>
<td>Datasheet Parameters</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
<tr>
<td>ESD Classification</td>
<td>CMD233C4</td>
<td>Per MIL-STD-883, Method 3015 Class 1A, 499 volts</td>
<td>Datasheet Parameters</td>
<td>Electrical</td>
<td>Passed</td>
</tr>
</tbody>
</table>

Conclusions

All material passed the criteria specified in the above Table. The conclusion of this reliability screening is that our PHEMT5 and PHEMT6 GaAs wafer processes are qualified to the specified environmental tests.