GaN/Si MMIC process for mmW applications

Marc Rocchi
OMMIC profile and strategy
100nm GaN MMIC processes
Design kit and Foundry service
Conclusions
OMMIC: French & independent III/V MMIC foundry

Founded by Philips Semiconductors

OMMIC

Innovating with III-V’s
•Offer High added value, Unique III/V MMIC solutions to complement Si solutions up to 400GHz for the following professional markets:
  - Aviation
  - Cellular Infrastructure
  - Space
  - Defence
  - Security
  - Automotive
  - Optical fiber
  - Instrumentation
  - Radio astronomy

•Offer foundry services based on long term partnership
Value chain and FAB+ services

- Epitaxial growth
- Process development
- Custom MMIC design
- Foundry service and MPW
- MMIC Production
- Packaging
- Modules with MC2
- HiRel Test & Qualification
D01GH

100nm GaN/Si process
For mmW MMICs
GaN processes and applications

Power electronics:

- Replacement of Si solutions Si to improve the DC efficiency of DC power converters
  - Switching Transistors
  - Schottky Diodes

RF Transistors and MMICs

- 0.5µm and 0.25µm HEMTs to replace high power LDMOS (> 100W)
- 100nm et 60nm GaN HEMTs to replace GaAs PHEMTs thanks to higher breakdown voltage and even better NF and gain:
D01GH : MMIC « PROCESS FLOW »
D01GH : I/V curves

Gm max = 650 mS/mm; Ron = 0.8 ohms * mm

Lg = 100 nm

Vgs = +0.2 V

Vds (V)

Id (mA/mm)

0 5 10 15 20 25 30

0 100 200 300 400 500 600 700 800 900

0 V

- 0.2 V

- 0.4 V

- 0.6 V

- 0.8 V

- 1.0 V

- 1.2 V

- 1.4 V

- 1.6 V

- 1.8 V

02/04/2015

OMMIC CONFIDENTIAL 2015
Pulsed IV curves

Pulsed I-V: 1µs pulses, FET 2x20 µm, Lg = 100 nm

Vgs = +0.6 V

Vgs = 0 V

Vgs = -0.6 V
Vds = 12V  Vgs sweep: -2 to -0.5V  by step: 0.25V
D01GH_trans 4x50µm _Vds 5V

Ft & Fmax (Vgs) @ Vds=5V

Vgs sweep: -1.5 to -0.25V by step 0.25V

Vds=5V

f_t & Fmax (GHz)

vgs (V)

02/04/2015

OMMIC CONFIDENTIAL 2015
Loadpull results at 24GHz

2*50µm
12V
3.5W/mm
17dB gain
24GHz
46%PAE
CW
D01GH mini power bars at 30GHz

![Graph](image)
Measured NF min and associated gain

4*50μm, 40GHz, 5V, 42mA, NF = 1, 54 dB, 8dB Associated gain

Evolution de NFMIN

Evolution de Gdip
## Measured NF min and associated gain at 40GHz

<table>
<thead>
<tr>
<th>4*50µm</th>
<th>D01PH (135nm GaAs PHEMT)</th>
<th>D01GH (100nm GaN/Si HEMT)</th>
<th>D01MH (120nm GaAs MHEMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vds (Volt)</td>
<td>3V</td>
<td>5V</td>
<td>1V</td>
</tr>
<tr>
<td>Ids (mA)</td>
<td>15</td>
<td>42</td>
<td>30mA</td>
</tr>
<tr>
<td>Rs (Ohm)</td>
<td>1,0</td>
<td>1,2</td>
<td>0,8</td>
</tr>
<tr>
<td>Rg (Ohm)</td>
<td>0,65</td>
<td>0,70</td>
<td>0,7</td>
</tr>
<tr>
<td>NFmin</td>
<td>1.72 dB</td>
<td>1.54 dB</td>
<td>1,13 dB</td>
</tr>
<tr>
<td>Associated gain</td>
<td>4.5 dB</td>
<td>8 dB</td>
<td>12,4dB</td>
</tr>
</tbody>
</table>
DC « Step stress » results

**Evolution of Ig/Vgs during Step-stress**

- **IG (Vgs)**
  - 250C, 270C, 280C, 1000h (no drift after burn-in)

- **ID (Vgs)**

- **Vth**
D01GH: specifications and RF performances

- $I_{dss} (0V) = 650$ mA/mm
- $V_t = -1.6V G_m \max \ ext = 650$ mS/mm
- $F_t = 115$ GHz, $F_{\max} = 155$ GHz @ up to $V_{ds} = 12$ V
- $MSG(2*50\mu m) = 14$ dB @ 30 GHz
- $V_{bgd \ min} = 30$ V, typical = $40$ V ( $V_{ds \ max} = 25$ V)
- $V_{dd} = 12$ V
- $P_{sat} > 3.5$ W/mm at 24 GHz ( $V_{ds} = 12$ V)
- $NF_{min} (30$GHz$) : 1.3$ dB
Conclusions

- **End of 2014, project „OMMIC opened its GaN/Si foundry service based on the 100nm D01GH process up to 50GHz**

- **Customer foundry runs:**
  - May 2015
  - June 2015
  - September 2015

- **This process is a full replacement of D01PH**