GaN on Si HEMT Process Transfer and Qualification

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Abstract

Nitronex pioneered AlGaN/GaN HEMTs on commercially available 100mm high resistivity Silicon substrates. Since demonstrating the reliability of these Nitronex NRF1 HEMTs in 2006, well over 500,000 units have been shipped worldwide to top tier customers. Nitronex has further advanced the manufacturability of HEMTs by successfully transferring the wafer fabrication process to Global Communication Semiconductors, Inc. (GCS). This move increases operational excellence in manufacturability for Nitronex products, utilizing GCS' strengths as a pure-play foundry with state-of-art dual thread process platform. This paper will discuss the detailed plans and rapid process transfer execution between these two fabs and the resultant qualification studies.

The AlGaN/GaN high electron mobility transistor (HEMT) is ideal for RF high power applications because of its high power density. The power density is a result of the ability to operate at high voltage combined with high channel current and this power density enables smaller and lighter very wideband power amplifiers with high system efficiency.

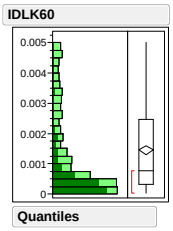
The NRF1 process is comprised of the following unit process modules; ohmic contact, isolation, gate formation, passivation, interconnects and backside processing. The process typically produces a contact resistance of <0.4ohm-mm, a channel sheet resistance of 490ohm/square, peak transconductance of 290mS/mm, maximum channel current of 830mA/mm, and drain-gate breakdown voltage of >100V (inline PCM testing), and RF loadpull measurements of 3.9w/mm saturated power and maximum drain efficiency of 57% at 28V and 2.14GHz (inline PCM testing).

Core team members developed a three tier transfer strategy comprised of process module development, integration and qualification. A flexible transfer philosophy was adopted by the team: Copy Nitronex key process modules and re-use GCS existing processes for others when possible. This philosophy added new risks over copy exact, requiring additional process development. However, benefits of this philosophy included the use of more advanced equipment and materials as well as reduced time and expense of procuring and integrating new equipment. Execution of the transfer strategy required a total of 8 integration and qualification lots. The data below is a comparative analysis of DC and RF device performance.

DC Measurements

Dark Green GCS – Light Green Nitronex

IDLK60



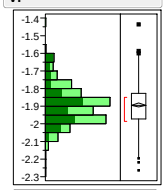
Quantiles

100.0%	maximum	0.00500
99.5%		0.00499
97.5%		0.00483
90.0%		0.00388
75.0%	quartile	0.00246
50.0%	median	0.00076
25.0%	quartile	0.00032
10.0%		0.00012
2.5%		0.00004
0.5%		0.00002
0.0%	minimum	0.00002

Moments

Mean	0.0014503
Std Dev	0.0014515
Std Err Mean	0.0000726
upper 95% Mean	0.001593
lower 95% Mean	0.0013076
N	400

VP



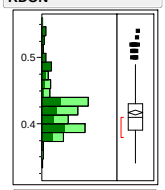
Quantiles

100.0%	maximum	-1.437
99.5%		-1.589
97.5%		-1.638
90.0%		-1.738
75.0%	quartile	-1.825
50.0%	median	-1.895
25.0%	quartile	-1.972
10.0%		-2.018
2.5%		-2.093
0.5%		-2.218
0.0%	minimum	-2.268

Moments

Mean	-1.89328
Std Dev	0.1154315
Std Err Mean	0.0057716
upper 95% Mean	-1.881934
lower 95% Mean	-1.904626
N	400

RDON



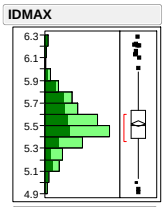
Quantiles

100.0%	maximum	0.54000
99.5%		0.52995
97.5%		0.51000
90.0%		0.47000
75.0%	quartile	0.43000
50.0%	median	0.41000
25.0%	quartile	0.39000
10.0%		0.38000
2.5%		0.37000
0.5%		0.35000
0.0%	minimum	0.34000

Moments

Mean	0.41685
Std Dev	0.0350592
Std Err Mean	0.001753
upper 95% Mean	0.4202962
lower 95% Mean	0.4134038
N	400

IDMAX



Quantiles

100.0%	maximum	6.2808
99.5%		6.2195
97.5%		6.0052
90.0%		5.7863
75.0%	quartile	5.6346
50.0%	median	5.4978
25.0%	quartile	5.3895
10.0%		5.2597
2.5%		5.0954
0.5%		4.9359
0.0%	minimum	4.9128

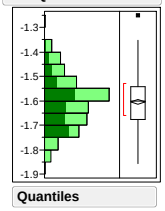
Moments

Mean	5.518365
Std Dev	0.2211505
Std Err Mean	0.0110575
upper 95% Mean	5.5401033
lower 95% Mean	5.4966267
N	400

RF Measurements

Dark Green GCS – Light Green Nitronex

VGSQ1



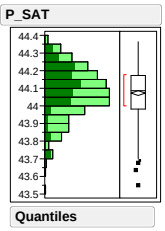
Quantiles

100.0%	maximum	-1.253
99.5%		-1.350
97.5%		-1.383
90.0%		-1.463
75.0%	quartile	-1.541
50.0%	median	-1.601
25.0%	quartile	-1.677
10.0%		-1.733
2.5%		-1.801
0.5%		-1.839
0.0%	minimum	-1.856

Moments

Mean	-1.604788
Std Dev	0.1036026
Std Err Mean	0.0051801
upper 95% Mean	-1.594604
lower 95% Mean	-1.614972
N	400

P_SAT



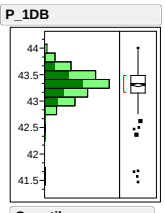
Quantiles

100.0%	maximum	44.364
99.5%		44.359
97.5%		44.320
90.0%		44.251
75.0%	quartile	44.173
50.0%	median	44.085
25.0%	quartile	43.984
10.0%		43.869
2.5%		43.740
0.5%		43.633
0.0%	minimum	43.548

Moments

Mean	44.072709
Std Dev	0.1434702
Std Err Mean	0.0071735
upper 95% Mean	44.086812
lower 95% Mean	44.058607
N	400

P_1DB



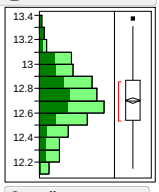
Quantiles

100.0%	maximum	44.000
99.5%		43.970
97.5%		43.840
90.0%		43.660
75.0%	quartile	43.487
50.0%	median	43.344
25.0%	quartile	43.164
10.0%		42.980
2.5%		42.786
0.5%		41.580
0.0%	minimum	41.466

Moments

Mean	43.311898
Std Dev	0.3125627
Std Err Mean	0.0156281
upper 95% Mean	43.342622
lower 95% Mean	43.281174
N	400

G_SS



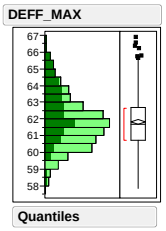
Quantiles

100.0%	maximum	13.372
99.5%		13.306
97.5%		13.178
90.0%		13.032
75.0%	quartile	12.869
50.0%	median	12.700
25.0%	quartile	12.537
10.0%		12.359
2.5%		12.198
0.5%		12.162
0.0%	minimum	12.146

Moments

Mean	12.701371
Std Dev	0.249927
Std Err Mean	0.0124964
upper 95% Mean	12.725938
lower 95% Mean	12.676804
N	400

DEFF_MAX



Quantiles

100.0%	maximum	66.866
99.5%		66.562
97.5%		65.435
90.0%		63.999
75.0%	quartile	62.682
50.0%	median	61.687
25.0%	quartile	60.718
10.0%		59.925
2.5%		58.958
0.5%		58.143
0.0%	minimum	57.825

Moments

Mean	61.818788
Std Dev	1.594736
Std Err Mean	0.0797368
upper 95% Mean	61.975545
lower 95% Mean	61.662031
N	400