# Microwave Noise Characterization of GaN HEMT's under UV Illumination

Giuseppe Salvo, *Student Member, IEEE*, and Alina Caddemi, *Member, IEEE*

***Abstract*—This work presents a complete characterization of a GaN HEMT device under UV illumination at microwave frequencies. The comparison of both DC and microwave (scattering and noise) parameters with and without illumination shows that the behavior of the device under test, a 100 μm gate width AlGaN/GaN heterostructure, is significantly affected by the light exposure.**

***Index Terms*—GaN HEMT, microwave measurements, noise parameters, light exposure**

## I. Introduction

NOWADAYS, extensive attention is being paid to the HEMT's based on GaN because of the well-known physical properties of its wide band-gap, useful for power application, and for the gradually best noise performance, slowly approaching levels typical of GaAs devices.

Previous studies on the light effects of GaAs devices have demonstrated that HEMT's exhibit interesting variations of their properties in terms of DC current, S-parameters, and Noise parameters [1]-[2]. These studies highlight the importance to use a light source having photons of energy near or higher than the energy gap of constituent materials of devices, to observe significant effects.

In the present work, we report the results of an experimental study performed on a GaN HEMT having a gate length of 0.25 μm and a gate width of 100 μm in dark and illumination conditions with a 355 nm wavelength beam. The DC behavior, the noise and the scattering parameters have been investigated.

## II. Description of the Measurement Setup

The configuration of the experimental set-up is illustrated in Fig. 1. To contact the tested devices, a Cascade Microtech M150 on wafer station equipped with GSG (ground-signal-ground) probes has been used. The light reaches the transistor layout by a focusing system connected to an optical quartz fiber, which is in turn connected to a monochromator. A knob allows to select the right wavelength light produced by a wide spectrum lamp. In this way, it was possible to search the most powerful wavelength to observe pronounced effects, having in mind the limits due to either the precision of the monochromator and the absorption region of the optical fiber. The configuration allows switching by means of the switch


Fig. 1. Photo of experimental set-up for measuring DC characteristics, S-parameters and extrapolation of N-parameters; particular of the optical focusing system on the down-left corner.

driver between the noise calibration/measurement chain and the S-parameter measurement chain without removing any part or connection. In particular, the device input is connected to a tuner (Maury MT-983BU01), which is in turn connected via an electromechanical SPDT (single-pole-double-throw) switch to either the input port of the vector network analyzer (Agilent E8364A PNA) and the smart noise source (Agilent N4002A SNS). The device output is connected via another SPDT switch to either the output port of the PNA and the input of the low noise receiver that includes a low noise amplifier, an attenuator, to set the correct power level that is handled by the noise figure analyzer (Agilent N8975A NFA). The N-parameters are determined with a source-pull procedure, which consists of measuring the noise figure F (or noise figure NF when expressed in dB) for different source impedances synthesized by the source tuner. This procedure is based on expressing F as a function of the source reflection coefficient by using the four N-parameters: the minimum noise factor $F_{min}$, which occurs when $\Gamma_s$ equals the complex optimum reflection coefficient $\Gamma_{opt}$, and the noise resistance $r_n$ representing how fast F increases as departs from $\Gamma_{opt}$, as you can see in the formula below.

$$F = F_{min} + 4r_n \frac{\left|\Gamma_{opt} - \Gamma_s\right|^2}{\left|1+\Gamma_{opt}\right|^2\left(1-\left|\Gamma_s\right|^2\right)}$$

Most commonly, the noise resistance used in technical reports and data sheet is re-scaled to 50 Ω and indicated as $R_n$ (Ω).

## III. Results

The results emphasize clear changes of DC characteristics, S-parameters, and N-parameters.

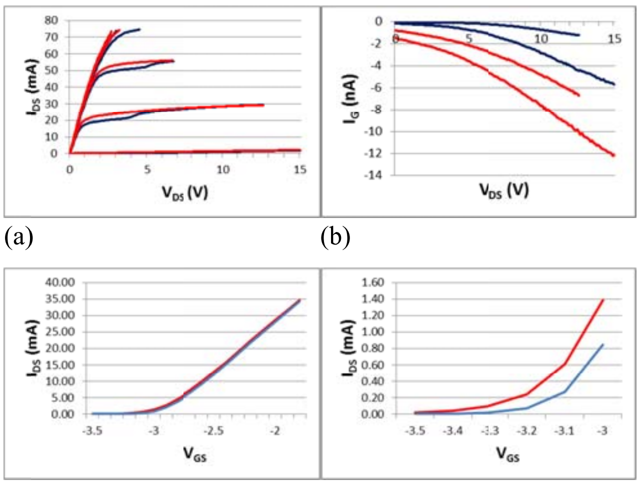
### A. DC Characteristics

As a first step, a DC analysis of the device has been

This work was supported by the Italian Ministry of Education, University and Research (MIUR) under the project PON01_01322 PANREX.

The authors are with DICIEAMA, University of Messina, Contrada di Dio, 98166 Messina, Italy. (e-mail: gsalvo@unime.it; acaddemi@unime.it)

performed to determine the device response in the 0-15 V drain-source $V_{DS}$ and the −3.5-1 V gate-source $V_{GS}$ voltage bias ranges by using precision bias supplies (Keithley SMU 2635A and 2611A, respectively for gate and drain voltage). Fig. 2 shows how the magnitude of both currents $I_{DS}$ and $I_{GS}$ rise when the device is illuminated. In addition, the $I_{DS}$ current, affected by a clear kink in dark condition, exhibits a regular behavior under light exposure. A shift of the threshold voltage is also recognizable in the transfer characteristic reported in Fig. 2(d), consistent with the process of charge generation due to UV illumination.




(a) (b) (c) (d)

Fig. 2. Drain current $I_{DS}$ and gate current $I_{GS}$ under dark (blue line) and light (red line) conditions. $I_{DS}$ vs. $V_{DS}$ at $V_{GS}$ values from −3 V to 1 V with 1 V step (a). $I_{GS}$ vs. $V_{DS}$ at $V_{GS}$ −3 V and −2 V (b). $I_{DS}$ vs. $V_{GS}$ at $V_{DS}$=10 V (c,d).

### B. S-parameters

The S-parameters measurement were made at $V_{DS}$=10 V and $I_{DS}$=10 mA. It is important to enlighten that the gate-source voltage $V_{GS}$ was not the same for the dark and illuminated conditions: in detail, the value of $V_{GS}$ during exposure was lower than the corresponding value in the dark condition to maintain the drain current at a constant value, as clearly shown in Fig. 2(c,d). A noticeable change in both four S-parameters was found: the magnitude of $S_{22}$ decreased while the other values increased, especially $S_{21}$ (Fig. 3).

### C. N-parameters

The N-parameters measurement were made as described above. It is interesting to note that, in contrast with the overall degradation of noise performance of GaAs devices, in this case the light has worsened the performance only up to about 9 GHz. In the upper frequency range, the noise behaviour was improved by the light exposure [1]-[2]. Fig. 4 shows that all the N-parameters have a crosspoint between the curves corresponding to the dark and illuminated conditions.

## IV. Conclusions

In this project, a 100µm gate width AlGaN/GaN device was characterized with and without a 355nm wavelength illumination. The light has produced marked effects on the entire measurement bandwidth. The noise parameters show a considerable change likely related with the charge generation process whose effects are clearly visible in the DC characteristics.

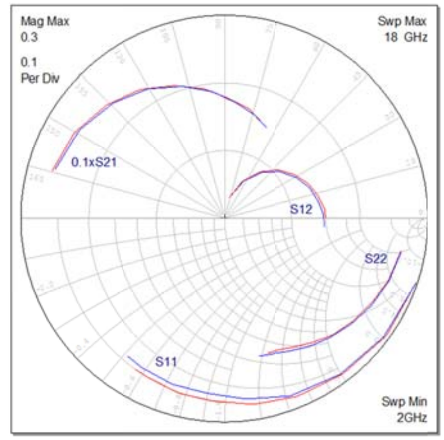
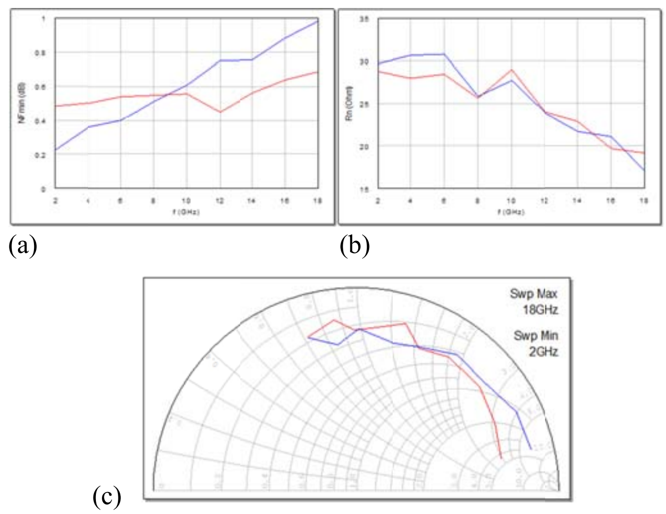



Fig. 3. Comparison between S-parameters under dark (blue line) and light (red line) conditions at $V_{DS}$ =10 V and $I_{DS}$ =10 mA.




(a) (b) (c)

Fig. 4. Comparison between N-parameters under dark (blue line) and light (red line) conditions at $V_{DS}$ =10 V and $I_{DS}$ =10 mA.

## V. Next Career Plans

The MTT-S Scholarship program gave to me a significant opportunity and one more reason to study and to spend my time in the microwave field. I am working in the microwave electronics laboratory of the university of Messina and I deal with the characterization of advanced devices, at the same time. I would like to continue working in this fascinating field, especially with measurements system and instrumentation.

## References


[1] A. Caddemi, G. Crupi, E. Fazio, S. Patanè, G. Salvo, "A complete microwave characterization of GaAs HEMTs under optical illumination," in *Microwave Review,* vol. 19, no. 2, pp. 112-118, Dec. 2013.

[2] A. Caddemi, G. Crupi, E. Fazio, S. Patanè, G. Salvo, "Remarks of an extensive investigation on the microwave HEMT behavior under illumination," *IEEE Microwave Wireless Components Letters*, vol. 24, no. 2, pp. 102-104, Feb. 2014.

[3] G. Crupi, A. Caddemi, A. Raffo, G. Salvo, A. Nalli, G. Vannini "GaN HEMT noise modeling based on 50-Ω noise factor," *Microwave and Optical Technology Letters*, vol. 57, no. 4, pp. 937-942, Apr. 2015.