Welcome to

The GaN Workshop 2012

A joint event with ORF-RE: GaN Project

MaRS Discovery District, Toronto, Ontario
February 21, 2012
CMC WELCOMES YOU TO THE GaN WORKSHOP 2012

Join in the discussion as leaders from industry and academia present on recent developments and challenges in this research space. Presentations and focus groups will center on gallium nitride market updates, fabrication results and technology roadmaps.

GaN 2012 WILL BE FEATURING PRESENTATIONS BY EXPERTS FROM:

Yole Développement
Canadian Photonics Fabrication Centre
   FBH Germany
   Agilent
   Meaglow
   Ericsson
   GaN Systems

Communications Research Centre
University of British Columbia
   University of Waterloo
   University of Calgary
   Carleton University
   University of Toronto

FEATURES OF THIS WORKSHOP INCLUDE:

-- Market status of GaN offered by Yole Développement
-- GaN challenges and recent developments
-- Canadian Photonics Fabrication Centre GaN Roadmap
-- Latest results from previous GaN runs
-- Focus group

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GaN in the CMOS Power Fab: A Market and Industry Vision to 2020:

Two thirds of the CMOS Power Electronics market falls in the 0-900V voltage range: mostly cost-driven consumer, lighting and IT applications. These segments require high-volume manufacturing capability as well as aggressive price positioning. GaN-on-Si appears as the most cost effective setup to reach these 0-900V applications. It has been shown that GaN-on-Si HEMT could be 50% cheaper than the same SiC device. However, current state-of-the-art remains 2x and even 3x more expensive than the similar silicon device. The next challenge for GaN devices will be to shrink its intrinsic cost structure and to be 100% CMOS compatible in order to enter in the existing 6” and 200mm CMOS fabs for mass production.

GaN Based Energy-Aware Electronics for Wireless, Satellite, and Power Applications:

GaN will enable the development of “next generation” of wireless and satellite communication systems that are needed to meet emerging demands for high-data throughput, energy-efficient wireless systems, reduced carbon footprints of wireless networks, ubiquitous network development, interoperability among diverse communication standards, and improved network and coverage for remote areas. It will also enable clean-tech power electronic solutions for smart and efficient, renewable energy grids and information technology (IT) applications. However, challenges at multiple levels of GaN technology (device, circuit and system) need to be overcome. The challenges present in maximizing the impact of GaN technology transcend disciplinary boundaries and necessitate collaboration between diverse areas of specialization within electronics and material science. Hence, the GaN Based Energy-Aware Electronics for Wireless, Satellite, and Power Applications project is organized into four interrelated theme areas: Semiconductor fabrication, GaN devices modeling, GaN based microwave circuits for energy aware radios and GaN power electronics. The project is supported by the Ontario Research Fund-Research Excellence program. The principal investigator and three of the co-investigators will each lead a theme area of this project. Three research sites in Kingston, Ottawa, and Waterloo were selected for their state of the art, innovative facilities and equipment available to support the work of this project. The approach taken from both the micro and macro levels concurrently will directly result in improving the GaN devices, model accuracy, and circuit performance beyond what is possible with traditional non-systemic approaches. The presentation will give a brief introduction to the scope of each theme and the goals to achieve for the next four years.
**Overview of GaN R&D Activities at CRC:**

GaN HEMTs are promising candidates for robust low-noise applications owing to their low noise performance combined with high-power handling capability, linearity, and robustness. To date there have been few studies on the use of GaN HEMTs for high power microwave and RF control applications including RF switching devices. This presentation will address some of the work done at CRC in this area and specifically we’ll focus on the design, fabrication and RF performance of broadband MMIC SPDT switches, based on a lumped spiral inductor and stacked GaN HEMT on SiC technology, demonstrating the good maturity level reached in terms of fabrication yield and performance. The circuit techniques presented will include: the use of stacked HEMT; to improve power handling; to minimize the loss and to maintain high isolation. Furthermore, the use of a resonance inductor in parallel to the series HEMTs to improve the isolation of the SPDT switch will be considered. Simulation and experimental results will be presented in support of the novel SPDTs.

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**GaN Technology for Wireless Base Station:**

GaN has been widely accepted as a promising technology for wireless base station industry for many advantages over other technologies like LDMOS, especially for applications of high frequency (>3GHz) and broad instantaneous bandwidth (>100MHz). But the reality is that GaN power transistors, which are the main focus of GaN technology on wireless base station industry, haven’t been widely used so far. This presentation will discuss some key factors limiting GaN applications in power amplifiers, such as trapping effect and reliability issues. It will also discuss some other areas where GaN technology may find new applications.

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**GaN MMICs for Digital PA Architectures:**

The presentation provides a brief overview on the GaN activities at FBH, addressing L-band discretes, X-band power amplifiers, and robust low-noise amplifiers. The second part of the talk is devoted to recent results on advanced digital power amplifiers using GaN MMICs. They follow the class-S approach, which offers also compatibility with digital baseband processing. Its potential is evaluated based on realizations for the 450 MHz frequency band. The PA modules use both current-mode and voltage-mode topologies for the final stage. Applying dedicated coding schemes, maximum output powers of 19 W and up to 40% drain efficiency for a 3 W PA under 10 dB back-off operation are achieved.
**GaN500 Foundry Process at CPFC:**

**Present Offering and Future Enhancements:**

The Canadian Photonics Fabrication Center provides a foundry service for GaN electronics for both university and industry clients. The GaN500: Gallium Nitride on Silicon Carbide (SiC) process combines high power density, excellent thermal conductivity, and high gain performance. Applications include defense, 3G/WiMAX, VSAT, SatCom, power supplies, UPS, and hybrid automotive. The process includes NiCr resistors, MIM capacitors, two levels of interconnect metallization, airbridges and spiral inductors, at a gate length of 0.5 microns. Future enhancements include: suggested field plate layouts with accompanying models, reduced gate leakage (even without field plates), and enhancement mode devices. A process for backside vias is also under development.

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**Compact and Behavioral Modeling of III-V FET Devices:**

This paper presents and compares a wide spectrum of modern measurement-based approaches to advanced nonlinear modeling of III-V FETs. A unifying theme is the primacy of new waveform measurements enabled by recently available nonlinear network analyzers (NVNAs). One approach is an advanced time-domain compact model including dynamic self-heating and trap capture and emission dynamics. Direct identification of temperature and trap-dependent current and charge functions is accomplished through artificial neural network training methods applied to functionals of the waveforms. Another approach is the application of recently introduced X-parameters at the bare transistor level. Several significant advances will be highlighted, making X-parameters an increasingly attractive alternative to conventional compact models of III-V devices. A detailed comparison of the respective merits of the different approaches is presented.

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**Gallium Nitride Epitaxial Film Growth by Migration Enhanced Afterglow:**

MEAglow (migration enhanced afterglow) is a new film growth technique that is being developed to improve the quality of gallium nitride and indium nitride films (and their alloys) at low growth temperatures. A scalable hollow cathode plasma source is used to supply active nitrogen species, while recent advances in pulsed deposition have been incorporated in the process development. To date both InN and GaN films have been grown with low RMS surface roughness of < 0.5 nm. In fact Ga face GaN has been grown directly on sapphire at temperatures as low as 540o C. The prototype MEAglow system has been built at Lakehead University and is being used there to develop an innovative FET design using electrons accelerated from excitonic sites at the boundaries between InN (or InGaN) layers and their heterojunction with GaN. Some preliminary growth layers have so far been investigated for this device structure.
INNOVATIONS IN GaN POWER DEVICES:

This presentation will outline some of innovations using GaN compound semiconductors for power electronics. In particular, it will cover topics such as breakdown voltage, leakage current, techniques to maximize Wg, thermal density and using RF GaN fabrication processes. The key challenges that GaN Systems have had, or avoided, will be outlined along with their patent-pending layout topology for nitride devices. These subjects will be illustrated using some simulation results, as well as high voltage device measured results from a recent fabrication cycle.

EDWARD XU
University of Toronto

BREAKDOWN VOLTAGE ENHANCEMENT TECHNIQUE FOR POWER AlGaN/GaN HEMTs USING AIR-BRIDGE FIELD PLATE:

The field plate structure is vital for achieving high breakdown voltage in lateral power devices. The AlGaN/GaN HEMT devices from NRC-CPFC’s GaN800 platform do not have optimum dielectric thickness to implement conventional field (FP) plates. In this work, a source-connected Air-bridge Field Plate (AFP) is proposed and implemented via layout changes only. Experimental results showed that the device with AFP achieves 3x higher OFF-state breakdown voltage (375 V versus 125 V at VGS = −5 V) and one order of magnitude lower drain leakage current when compared to similar size devices with conventional FP and with lower parasitic gate-to-source capacitance. The specific on-resistance at VGS = 0 was found to be 0.36 mΩ·cm² and 0.47 mΩ·cm² for devices with AFP and conventional FP, respectively.

GREG KLOWAK
GaN Systems

S-BAND HIGH-EFFICIENCY BROADBAND CLASS-J GaN MMIC AMPLIFIER:

This work presents the first monolithic microwave integrated circuit (MMIC) class-J power amplifier (PA) design in GaN HFET technology. The wideband performance is achieved by selecting and engineering a specific class-J load network configuration. Measurements show greater than 40% drain efficiency from 2.3 to 3.1 GHz. A bandwidth improvement of 100% is obtained in comparison with the conventional class-B PA to achieve more than 40% drain efficiency with almost equal output power and gain in both amplifiers.

SAEED REZAEI
University of Calgary

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University of Calgary
**GaN Devices and the Prospects for RF Switch-mode Power Amplifier Technology:**

High power high efficiency RF power amplifiers have many diverse applications ranging from wireless base stations to industrial heating applications. GaN device technology can be employed in many of these applications and a review of the applications, amplifier architectures, and current research activities in the Microwave Technology Lab at UBC will be presented.

![Image of Langis Roy](http://cmc.ca/community/forums)

**Langis Roy**  
Carleton University

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**Microwave Power Amplifier and Opto-Switch:**

A two stage K band monolithic GaN based power amplifier (PA) with an integrated on-chip fractal antenna is first presented. The designed proof-of-concept PA operates in class A, providing a gain of 10 dB with an impedance bandwidth of 5.4% at 24 GHz. The simulated PAE of the amplifier is 13% for an output power of 30 dBm. The amplifier is integrated with a 3rd order Sierpinski carpet fractal antenna. A gain of 2.2 dB is achieved from the antenna with a bandwidth of 6.3% at 24 GHz. This design is useful for highly efficient and ultra compact stand-alone wireless transmitters, or for active feeds in higher gain antenna systems. An optically controlled GaN RF switch and its preliminary test results are finally presented.

![Image of Thomas Johnson](http://cmc.ca/community/forums)

**Thomas Johnson**  
University of British Columbia

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