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ADVANCED HIGH SPEED DEVICES

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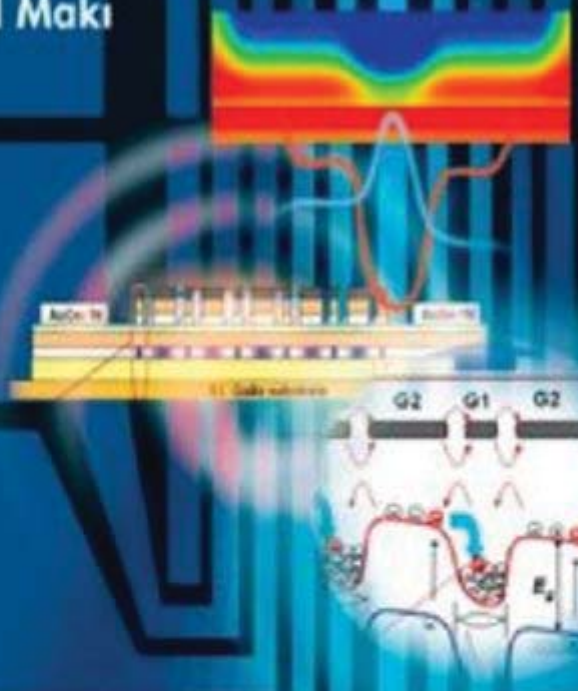

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PREFACE

Professor Lester Eastman

This volume contains the Proceedings of the 2008 biennial Lester Eastman Conference (LEC), which was held on the Cornell University of Delaware campus on August 5-7, 2008. Originally, the conference was known as the IEEE/Cornell University Conference on High Performance Devices. It was named to honor Prof. Lester Eastman, a renowned device pioneer and technology leader.

The book covers five areas of advanced device technology: terahertz and high speed electronics, ultraviolet emitters and detectors, advanced III-V field effect transistors, III-N materials and devices, and SiC devices.

Very appropriately, the first paper in the issue is co-authored by Professor Lester F. Eastman. The paper presents experimental results on GaN based ultra-short planar negative differential conductivity diodes for THz power generation.

Reaching higher frequencies and higher powers using III-N materials system has become a hot topic. Monte Carlo simulations predict that III-N field effect transistors with nanometer gates should be able to penetrate the THz range of frequencies, and recent experimental results are encouraging. However, the extension of the effective gate length beyond the metallurgical gate, parasitic contact resistances and resistances of the gate-to-source and gate-to-drain regions adversely affect the high frequency performance of these devices. These issues are addressed in the paper by Simin et al who propose a novel five terminal design for THz GaN-based transistors with 10 nm gates and validate the design with ADS simulations.

A different approach in controlling short channel effects impeding high frequency operation is to use nanowire field effect transistors. Wang et al present performance comparison of scaled III-V and Si ballistic nanowire MOSFETs analysis and simulations of Si and III-V Gate-All-Around nanowire MOSFETS assuming ballistic or quasi-ballistic transport.

The next paper by Diduck et al proposes ballistic deflection transistor that uses the change in the current pathway. The authors consider possible operation of such devices at room temperature.

Otsuji et al present an excellent review of using plasma waves – waves of electron density – in dual-grating-gate HEMTs for emission and intensity modulation of terahertz electromagnetic radiation. This innovative approach has already led to the observation of THz emission from short channel HEMTs at room temperature.

Ken O et al discuss the feasibility of CMOS circuits operating at frequencies in the upper millimeter wave and low sub-millimeter frequency regions. They refer to the demonstrated 140-GHz fundamental mode VCO in 90-nm CMOS, a 410-GHz push-push VCO in 45-nm CMOS, and a 180-GHz detector circuit in 130-nm CMOS have been

demonstrated and conclude that, with the continued scaling of MOS transistors, 1-THz CMOS circuits will be possible.

Several papers in the Proceedings are devoted to with ultraviolet light emitting diodes (UV LEDs) and detectors. Sampath et al discuss the effects of nanometer scale compositional inhomogeneities in the active regions of UV LEDs with high Al mole fraction in AlGaN active regions. They report on prototype flip chip double heterostructure UV LEDs operating at 292 nm.

Chivukula et al demonstrate a strong effect of pulsed sub-band ultraviolet illumination on surface acoustic wave propagation in GaN-on-sapphire.

The paper by Alexey Vert et al on solar-blind single-photon 4H-SiC avalanche photodiodes reports on the record performance. The paper shows that SiC UV photodetectors can successfully compete and even outperform III-N based UV photodiodes.

The next section of the book deals with advanced III-V Field Effect Transistors. Ayubi-Moak et al present the results of the Monte Carlo simulations of $In_{0.75}Ga_{0.25}As$ MOSFETs at 0.5 V supply voltage for high-performance CMOS operation.

Karimy et al describe the first 70 nm 6-inch GaAs PHEMT MMIC process. This millimeter wave technology demonstrated excellent performance from Ka-band through W-bands. The device DC and RF characteristics have excellent uniformity across the wafer.

Dong Xu et al report on high-performance 50-nm metamorphic high electron-mobility transistors with high breakdown voltages. This has been achieved by the optimization of the epitaxial layer design (including a high indium composite channel and the double-sided doping), by the selection of the proper gate recess scheme, and by using an asymmetric gate recess. Their results demonstrate that these devices are excellent candidates for ultra-high-frequency power applications.

Papers on III-N materials and devices are included into the next section, which starts from the paper by Chen et al MBE growth and characterization of Mg-doped III-nitrides on sapphire.

Ke Tang et al. discuss the performance of MOSFETs on reactive-ion-etched GaN surfaces. They report on field effect mobilities reaching 170 cm^2/V-s and subthreshold slope of 3.8 V/decade for as grown GaN MOSFETs.

Shi et al present new results for high current density/high voltage AlGaN/GaN HFETs on sapphire. For a gate-drain spacing of 10μm, they achieved a specific on-resistance of 1.35mΩ-cm^2 and off-state breakdown voltage of 770V.

M. Alomari et al report on InAlN/GaN MOS-HEMT with thermally grown oxide. The gate leakage current was reduced by two orders of magnitude, and pulse measurements showed lag effects similar to those for devices without oxidation, indicating a high quality native oxide. The MOS-HEMT yielded a power density of 5 W/mm at 30 V drain voltage at 10 GHz, power added efficiency of 42% and F_t and F_{max} of 42 and 61 GHz respectively.

Tetsuzo Ueda et al. review their state-of-the-art GaN-based device technologies for power switching at low frequencies and for future millimeter-wave communication systems. They established crack-free epitaxial growth of GaN on Si and proposed a novel device structure called Gate Injection Transistor (GIT) that achieved normally-off operation with high drain current. Short-gate MIS-HFETs using in-situ SiN as gate insulators achieved f_{max} up to 203GHz and enabled compact 3-stage K-band amplifier MMIC with the small-signal gain is as high as 22dB at 26GHz.

Zimmermann et al reported on 4-nm AlN barrier all binary MISHFETs with SiN_x gate dielectric. They achieved very low sheet resistances, ~ 150 Ohm/sq, a high carrier mobility and concentration (~ 1200 cm^2/Vs and ~ $3.5x10^{13}$ cm^{-2} at room temperature) and output current densities of 1.7 A/mm and 2.1 A/mm with the intrinsic transconductances of 455 mS/mm and 785 mS/mm for 2 μm and 250 nm gate-length devices, respectively

The last section of the book deals with SiC Devices. Naik, Tang, and Chow report on effect of gate oxide processes on 4H-SiC MOSFETs. Naik, Wang, and Chow discuss characterization and modeling of integrated diode in 1.2kV 4H-SiC Vertical Power MOSFET. O'Brien and Koebke consider packaging and wide-pulse switching of 4 mm x 4mm silicon carbide GTOs. And, finally, Urciuoli and Veliadis report on bi-directional scalable solid-state circuit breakers for hybrid-electric vehicles

The conference was under the technical sponsorship of the Institute of Electrical and Electronic Engineering (IEEE). We are grateful to the National Science Foundation, Air Force Office of Scientific Research (AFOSR), the Office of Naval Research (ONR), and the University of Delaware for their support of the Lester Eastman Conference, 2008.

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