**Session 30: Power Devices - GaN Power Devices**
Wednesday, December 5, 9:00 AM
Continental Ballroom 4
*Co-Chairs: E. Morvan, CEA-Leti*
*T. Narita, Toyota Central R&D Labs, Inc.*

9:05 AM - 9:30 AM
**30.1 Parallel-Plane Breakdown Fields of 2.8-3.5 MV/cm in GaN-on-GaN p-n Junction Diodes with Double-Side-Depleted Shallow Bevel Termination,** *T. Maeda, T. Narita*, H. Ueda*, M. Kanechika*, T. Uesugi*, T. Kachi**, T. Kimoto, M. Horita, and J. Suda, Kyoto University, *Toyota Central R&D Labs., Inc., **Nagoya University*

We report homoepitaxial GaN p-n junction diodes with novel beveled-mesa structures. The n-layers and p-layers, the doping concentrations of which are comparable, were prepared. We found that electric field crowding does not occur in the structure using TCAD simulation. The fabricated devices showed the breakdown voltages of 180-480 V, small leakage currents, and excellent avalanche capabilities. The breakdown voltages increased at elevated temperature. At the breakdown, nearly uniform luminescence in the entire p-n junctions was observed in all the devices. These results are strong evidences that the uniform avalanche breakdowns occurred in the devices. We carefully characterized the depletion layer width at the breakdown, and the parallel-plane breakdown electric fields of 2.8–3.5 MV/cm were obtained, which are among the best of the reported non-punch-through GaN vertical devices.

9:30 AM - 9:55 AM
**30.2 Demonstration of avalanche capability in polarization-doped vertical GaN pn diodes: study of walkout due to residual carbon concentration,** *C. De Santi, E. Fabris, K. Nomoto*, Z. Hu*, W. Li*, X. Gao**, D. Jena*, H. G. Xing**, G. Meneghesso, M. Meneghini, and E. Zanoni, University of Padova, *Cornell University, **IQE*

We demonstrate and investigate the avalanche capability in vertical GaN-on-GaN pn diodes with polarization doping. We describe the dependence of breakdown voltage on temperature and monochromatic illumination and demonstrate the presence of avalanche walkout, caused by charge trapping due to residual carbon. We develop a model to explain the data.

9:55 AM - 10:20 AM
**30.3 Suppressed Hole-Induced Degradation in E-mode GaN MIS-FETs with Crystalline $GaO_xN_{1-x}$ Channel,** *M. Hua, X. Cai, S. Yang, Z. Zhang, Z. Zheng, J. Wei, N. Wang, and K. J. Chen, The Hong Kong University of Science and Technology*

Under reverse-bias stress with a high drain voltage, hole-induced gate dielectric degradation in the E-mode GaN MIS-FETs could lead to non-recoverable VTH shifts and devastating time-dependent breakdown. Such a degradation can be effectively suppressed by converting the GaN channel into a crystalline $GaO_xN_{1-x}$ channel in the gated region. The valence band offset between GaOxN1-x and the surrounding GaN creates a hole-blocking ring around the gate dielectric, preventing holes from flowing to the gate dielectric and therefore mitigating the hole-induced degradation.

10:20 AM - 10:45 AM
**30.4 Recent advancement of GaN HEMT with InAlGaN barrier layer and future prospects of AlN-based electron devices (Invited),** *J. Kotani, A. Yamada, T. Ohki, Y. Minoura, S. Ozaki, N. Okamoto, K. Makiyama, and N. Nakamura, Fujitsu Ltd.*

We have successfully achieved high-power operation of InAlGaN/GaN HEMTs in the wide-frequency range from S-band to W-band. A re-grown n+-GaN contact layer and an InGaN back-barrier layer was employed for the W-band GaN HEMTs. For the S-band GaN HEMTs, 2DEG mobility was improved using the atomically flat AlGaN spacer layers. This technology allows us to reduce the 2DEG densities while maintaining the low access resistance, which contributes to the lower electric-field concentration at the edge of the gate electrodes i.e. enables high voltage operation. Furthermore, we must pay more attention on the thermal-related issues for the S-band, as the increased heat generation hinders stable operation of GaN HEMTs and seriously degrades long-term reliability. In addition to the re-grown n+-GaN layer and the InGaN back-barrier layer used for W-band GaN HEMTs, we employed a single-crystal diamond substrate as a heat spreader and successfully confirmed the further output power density improvement. Finally, we investigated the possibility of AlN- or high Al composition AlGaN-based electron devices as a possible candidate for the next generation devices. In order to break the trade-off between maximum drain current and breakdown voltage, an asymmetric 2DEG channel was investigated. It was found that the thin AlGaN barriers with high Al composition are suitable for high-power devices with asymmetric 2DEG density as the strain effectively applied to the AlGaN/GaN interfaces. To estimate the potential of AlN-based electron devices from a viewpoint of thermal-related issues, we compared the thermal resistance of the AlN devices on AlN substrates with the conventional GaN HEMTs on SiC substrates. It is expected that AlN/AlN structures can reduce the thermal resistance by 26% compared to the conventional GaN on SiC structures. It is believed that the lower thermal resistance will be a large advantage for future high-power devices.

10:45 AM - 11:10 AM

**30.5 Power GaN HEMT degradation: from time-dependent breakdown to hot-electron effects (Invited),** *M. Meneghini, A. Barbato, M. Borga, C. De Santi, M. Barbato, S. Stoffels*, M. Zhao*, N. Posthuma*, S. Decoutere*, O. Haeberlen**, T. Detzel**, G. Meneghesso, E. Zanoni, University of Padova, *imec, **Infineon*

This paper describes our most advanced results in the field of GaN-HEMT degradation, with focus on power devices. We discuss three main aspects: (i) the dependence of breakdown voltage on substrate and buffer properties; (ii) the existence of time-dependent breakdown of GaN buffer submitted to high vertical stress;(iii) the role of hot-electrons in limiting the dynamic performance of the devices.