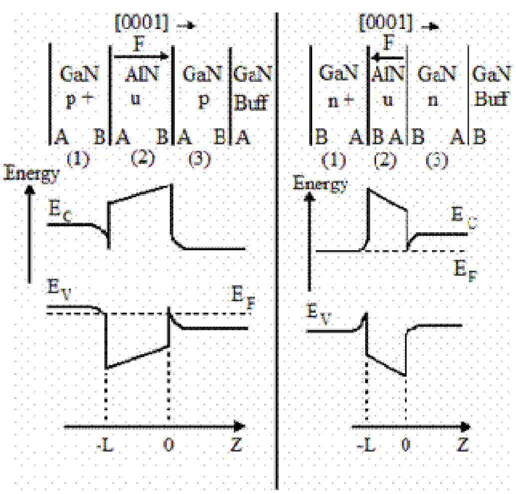
Physics of III-N-based Field Effect Transistors

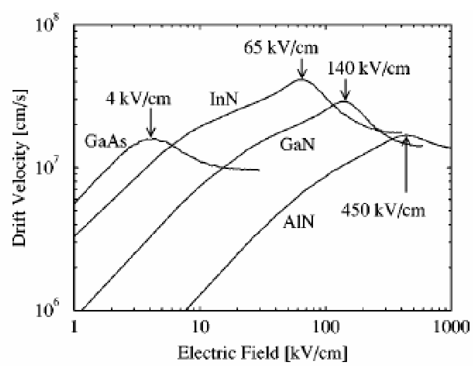
Michael S. Shur
ECSE and Physics
Rensselaer Polytechnic Institute
Troy, New York, 12180 USA
http://www.ecse.rpi.edu/shur/ shurm@rpi.edu

Michael Shur

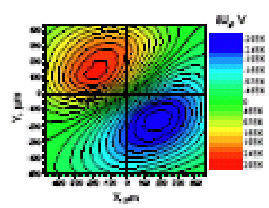
Wurtzite (hexagonal) symmetry makes the device physics of GaN/AlN/InN heterostructure field effect transistors (HFETs) to be quite different from that of more conventional GaAs/InAs/InP and Si FETs. Spontaneous and piezoelectric polarization at AlGaN/GaN and AlGaInN/InGaN interfaces leads to the formation of two-dimensional (2D) electron gas with concentrations 10 to 20 times higher than that for more conventional FETs and with enhanced electron mobilities but a reduced peak velocity. Quantum well designs (incorporating AlN spacers an InGaN quantum well between the wide band gap AlGaN barrier layer and GaN buffer) have been used to control the electron transfer from the 2D channel into adjacent layers. High electric fields at the gate edges leads to an additional strain and hot electron effects causing the current collapse and gate lag. Large electron densities in the HFET channels minimize 1/f noise making it to be smaller than even in highly doped GaN films. This device physics necessitates new approaches to the device design. Inverted HFET devices are expected to have a reduced access resistance, a larger current carrying capability, lower gate leakage and a better thermal control. Insulated gate heterostructure field effect transistors demonstrated superior performance and reliability. Field plates, recessed and double recessed gates, drain field controlled electrodes, and Low Conducting Layers (LCLs) control current collapse and improve device reliability. Power and RF switching applications of III-N based transistors have emerged to take advantage of superior current carrying capabilities, low access resistance, and high breakdown voltage.



Polarization doping. Circles show 2D electron and hole gases. (From A. Bykhovski, B. Gelmont, and M. S. Shur, J. Appl. Phys.74, 6734 (1993))



Electron velocities versus field. (from B. E. Foutz, S. K. O'Leary, M. S. Shur, and L. F. Eastman, *J. Appl. Phys.* **85**, 7727 (1999))



THz image of a HEMT. (from Veksler, D.B. Muraviev, A.V. Elkhatib, T.A. Salama, K.N. Shur, M.S. Plasma wave FET for subwavelength THz imaging, ISDRS December 12-14, 2007