

Drift velocity limitation in GaN HEMT channels

Arvydas Matulionis

Fluctuation Research Laboratory at Semiconductor Physics Institute
A. Gostauto 11, Vilnius, 01108, Lithuania
matulionis@pfi.lt

A nitride high-electron-mobility transistor (HEMT) is a high power active device operated at microwave frequencies. The highest cut-off frequency for GaN-channel HEMTs exceeds 150 GHz. However, the reported values lag behind those typical for InP-based HEMTs of similar dimensions. Moreover, the electron drift velocity, extracted from the cut-off frequency of nitride HEMTs, is essentially below the values reported for GaN pin diodes. These results cannot be completely understood without considering electron transport in a high-density two-dimensional electron gas (2DEG) channels at high electric fields.

The electron drift velocity limitation in GaN channels may result from:

(i) accumulation of non-equilibrium longitudinal optical (LO) phonons (termed hot phonons), (ii) hot-electron penetration into the barrier layer where alloy scattering is important, (iii) channel self-heating, (iv) hot-electron detour into the GaN buffer layer, (v) activated hot-electron trapping, and other processes.

The report considers possibilities for resolving different contributions in HEMT channels grown and processed at Cornell University, University of California at Santa Barbara, Notre Dame University (Indiana), AMO GmbH (Aachen), Alcatel-Thales, and elsewhere. Experimental techniques for measuring channel temperature, equivalent hot-phonon temperature, and hot-electron temperature have been developed and applied for investigation of nitride, arsenide, silicon, and silicon carbide channels designed for microwave field-effect transistors. The experimental results will be presented and discussed together with those of Monte Carlo simulation. The hot-phonon effect is found the most difficult to avoid in 2DEG channels with a high-density electron gas. Possible ways for increasing electron drift velocity and improving frequency performance of nitride HEMTs will be considered.

The US Office of Naval Research (Grant N00014-03-1-0558 monitored by Dr. Colin E.C. Wood), the European Commission within the Network of Excellence SINANO (IST-506844), and the Lithuanian National Foundation for Science and Education (Contract LVMSF C-33/2006) are gratefully acknowledged for support.