Investigation of Space-charge Domain Formation in GaN Epilayers Under Pulsed Electric Field

R. M. Balagula[1], L. Subačius[1], P. Prystawko[2], and I. Kašalynas[1]

[1] *Center for Physical Sciences and Technology, Vilnius, LT-10257, Lithuania*
[2] *Institute of High Pressure Physics PAS, Warsaw, 01-142, Poland*

Current instabilities in semiconductors have been long investigated and used as a basis for high-frequency devices [1]. Gunn diodes based on domain formation in semiconductors were realized based on GaAs among other materials [2]. Gunn oscillations were theoretically predicted in GaN [3], but, as of now, there has been no experimental evidence of this effect. Meanwhile, acoustoelectric filters and modulators based on both surface and bulk acoustic waves in GaN were successfully realized [4]. Acoustic waves in piezoelectric semiconductors under electric field may result in appearance of negative differential resistance. The acoustoelectric domains were experimentally observed in various bulk semiconductors such as GaAs, CdS, ZnO, GaSb, and Te [5] and GaAs/AlGaAs quantum wells [6] but not in nitride semiconductors.

In present work we investigate the formation and propagation of the space charge domains in *n*-type GaN semiconductor under pulsed electric field at 300 K and 77 K. For this purpose, a 10 μm-thick GaN epilayer on a native semi-insulating substrate was developed with the electron density and mobility at 77 K of approximately 2×10^{15} cm^{-3} and 2600 $cm^2/V{\cdot}s$, respectively. Ohmic contact pads to the sample were formed with contact separation of 1, 2, 3 mm, and several values below 100 μm. Electric pulses with duration from 100 ns to 3500 ns were applied to find $j(E)$ and $\rho(E)$ characteristics of the material [7].

Traces of current pulses revealed space-charge domain formation and propagation only in the samples with contact spacing of 1.0 mm or larger. Period of current oscillations demonstrated clear dependence on the distance between the electric contacts, with estimated domain propagation velocity of approximately $4{\cdot}10^5$ cm/s. Measured value coincides well with the speed of acoustic wave in [100] direction of the wurtzite GaN crystal. Threshold electric field for domain appearance in current traces varied with the sample geometry. The critical field was also found to depend on lattice temperature. Spectrum of electric current pulses indicates the generation of fundamental and higher harmonics in the sample. Analysis of field dependence of harmonic amplitudes allowed the determination of the threshold field for propagating space charge domains in samples with different geometric parameters.

To summarize, space charge domains in GaN epilayers were observed and analyzed to obtain domain formation time, propagation speed, critical electric field, and their dependence on the sample geometry and temperature.

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