Elektronų pernaša 2D AlGaN/(AlN)/GaN ir 3D GaN dariniuose stipriame elektriniame lauke

Electron transport in 2D AlGaN/(AlN)/GaN and 3D GaN structures in a strong electric field

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Gallium nitride (GaN) has many attractive properties for high-power and high-frequency applications due to a wide bandgap of 3.4 eV and a high electron peak velocity of ~3x10^7 cm/s achieved at high electric fields [1]. In particular, the velocity of two-dimensional electron gas (2DEG) in nitride-based heterostructures varies from 1x10^7 to 3x10^7 cm/s depending on the presence of barrier layer [2]. In this work, layers for the AlGaN/AlN/GaN sample (U79) were grown on 6H-polytype SiC substrate. A nominally undoped $Al_{0.25}Ga_{0.75}N$ barrier layer was grown capping it with GaN and SiN_x passivation layers. A similar structure, but without an AlN spacer - AlGaN/GaN (U78) was developed on a 4H-polytype SiC substrate where a $Al_{0.25}Ga_{0.75}N$ barrier was capped by a GaN layer. Lightly doped GaN epitaxial layers were grown on semi-insulating GaN substrates. The ohmic contacts were fabricated of a Ti/Al/Ni/Au metal stack annealed in nitrogen ambient. The mesas were formed either by plasma reactive ion etching or by implantation of Al ions into a depth. The TLMs of width w = 250 µm and of length L = 6, 12.5, 25, 35, 45, 55, 65 µm were used to evaluate the contact resistance R_c = 1-22.5 Ω at low electric fields. The Hall effect experiments in Van der Paw geometry at temperature of 300 K revealed the density n and mobility μ values of 2DEG channels in used samples to be of 8.3 x 10^{12} cm^{-2} and 9.3 x 10^{12} cm^{-2} and of 1.9x10^3 cm^2/Vs and 1.9x10^3 cm^2/Vs, respectively. The GaN epilayers with a thickness of d = 10 µm demonstrated three-dimensional electron density (3DEG) and low-field mobility values of 1.1x 10^{16} cm^{-3} and 1021 cm^2/Vs at 300 K. More details about the device growth and processing have been reported elsewhere [3, 4]. Current-voltage (I-U) characteristics were measured at room temperature using voltage pulse duration of 2 ns and 3 ns for the samples from U79 and U78, respectively, where the average electric field was determined as $E=U/L$. The pulse duration for the GaN sample was 20 ns. The use of nanosecond duration pulses enables minimization of lattice self-heating effects and avoiding of space-charge domain formation in GaN [5]. Current density value of 1.24 A/mm at the highest field were reached for U79 with a 45 µm channel length while the highest current density value of 1.8 A/mm were measured for U78 with a 35 µm channel length. The highest current density of 320 A/mm^2 was measured for the 3D GaN. The strongest electric field of 75 kV/cm was applied to U78 with a channel length of 12.5 µm and showed current saturation. Electron drift velocity v_{dr} was estimated from data of measured current density j and the Hall electron density (v_{dr} = j/en, where e is elementary charge) with a highest value of 1.2x10^7 cm/s at 69 kV/cm for U78 heterostructure while the lowest value of 0.9x10^7 cm/s at 42 kV/cm was obtained for U79 heterostructure (Fig. 1). The electron velocity in the hetero-structures grown without the AlN spacer on SiC substrate was found to be 10-20 % lower than that measured for AlGaN/GaN structures but grown on sapphire substrate [2]. The highest electron velocity of 1.6x10^7 cm/s at 95 kV/cm was attained for the GaN. The drift velocity at high fields in the 2D GaN channel is lower than that in the 3D GaN as a result of stronger hot-phonon effect. Self-heating of the contacts leading to the increase of the contact resistance can play the role in determining the excess noise temperature in GaN-based heterostructures [4].

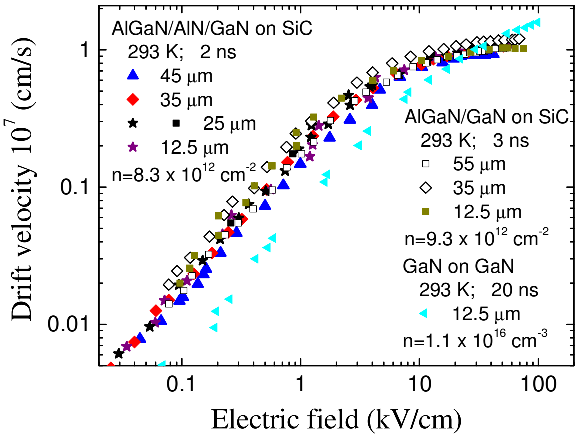

Fig. 1. Electron drift velocity dependence on the average applied electric field at room temperature in AlGaN/(AlN)/GaN heterostructures grown on SiC substrate and GaN grown on GaN substrate.

Keywords: electric field strength, nanosecond electrical pulses, electron drift velocity, GaN, AlGaN/(AlN)/GaN, 2D-3D electron gas

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