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Conductive AFM study of the electronic properties of vertical GaN nanowires

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Electronic properties of III-N semiconductors make them important materials for the development of the light-emitting diodes and optoelectronic devices operating in the blue and near-ultraviolet range [1]. One of the problems that III-N-based devices fabrication technology is facing today is the high cost of Al_2O_3 or GaN substrates promoting researchers to develop the nitride compounds growth techniques on more accessible wafers, such as silicon and find new approaches for the defect free epitaxial growth of highly lattice mismatched systems [2]. In this work, we study influence of the Si (111) substrate surface preparation and buffer layer composition on the electronic properties of the GaN NWs synthesized via plasma-assisted molecular beam epitaxy (PA-MBE) in the same growth chamber.

The investigated GaN NWs were grown on Si (111) p-type wafers using Veeco GEN-III machine. Average length and diameter were approximately 500 and 50 nm respectively. Seven samples were grown with different substrate surface preparation and buffer or seeding layer deposition. A comparison study of GaN NWs growth on the bare Si (111) substrate, silicon nitride interlayer, predeposited AlN and GaO_x buffer layers, monolayer thick Ga wetting layer and GaN seeding layer prepared by the droplet epitaxy is performed.

Ntegra Aura (NT-MDT, Russia) setup with built-in current meter and AFM probes with W_2C conductive coating were used to obtain I-V curves of vertical GaN NWs. Grounded atomic force microscope (AFM) probe was used as an electric contact to NW free upper grain. The second contact was established between the highly doped Si substrate and a grounded sample holder of the AFM device. The use of the constant height mode with a stiff cantilever was considered more appropriate than constant force mode for accurate establishing the Tip-NW contact. The AFM probe's deflection was registered by an optical system consisting of a photodetector and a 650 nm laser.

We analyze the obtained I-V curves of the single NW and discuss its morphology and the substrate treatment on the semiconductor properties of the synthesized heterostructures. It is demonstrated that use of AlN buffer or Ga-droplet seeds may lead to the unintentional doping of Si substrate by Al or Ga which deteriorates diode characteristics and increase the reverse current by orders of magnitude. Formation of the vertical NW arrays with random azimuthal orientation was demonstrated on microcrystalline GaO_x wide bandgap semiconductor buffer layer. However, electronic transport of the latter is deteriorated due to high resistance of undoped GaO_x layer.

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