Surface Engineered Nanostructure based GaN Ultraviolet Photodetectors

Monu Mishra, Abhiram Gundimeda, Shibin Krishna, Neha Aggarwal and Govind Gupta

Advanced Materials and Devices Division, CSIR-National Physical Laboratory, Dr. K.S. Krishnan Marg, New Delhi 110012, India
and,
Academy of Scientific and Innovative Research, CSIR-NPL Campus, New Delhi 110012, India.
monumishra.phy@gmail.com

We report the formation of wet chemical etching induced nanostructures on polar and nonpolar epitaxial GaN films. Morphological transformations from planar to faceted pyramidal, flat/trigonal rod like nanostructures along with development of porous structures on the film were observed. The oxidation states of chemically modified (etched) surface were probed via photoemission spectroscopic measurements which revealed the elimination of hydroxyl species and adsorbed water molecules in polar GaN. Further, dissociation of Ga-N bonds and traces of metallic gallium were observed on the surface of porous GaN film after repeated etching. Fermi level pinning, band bending & alteration in the surface polarity with significant change in the electron affinities were perceived. The wettability of the samples was reduced drastically and surfaces became highly hydrophilic. A great extent of stress relaxation with negligible in-plane compressive stress was pragmatic in the developed nanostructures. The temperature dependent I-V analysis displayed significant enhancement in current conduction with reduced sample resistance. Further, the surface engineered nanostructured nonpolar GaN based high performance ultraviolet (UV) photodetectors (PDs) were fabricated. An enhancement in photocurrent (5.5 folds) as well as device responsivity (6 folds) was observed. The fabricated UV PsD exhibited significant increment in the detectivity (7 folds) and pursued a very low noise equivalent power (~ 10^{-10} $WHz^{-1/2}$). The fast switching of the devices were ensured via a response and decay time of 151 ms and 453 ms which were >5 times faster with respect to pristine film based UV Photodetector. The improvement in device performance was attributed to increased light absorption, efficient transport of photogenerated carriers and enhancement in conduction cross section via elimination of recombination/trap centres related defects states which could be a promising approach to enhance the performance of GaN based photodetector technology.

References:
[1] M. Mishra, A. Gundimeda, S. Krishna, N. Aggarwal, B. Gahtori, N. Dilawar, V. Agrawal, M. Singh, R. Rakshit, G. Gupta, Phys. Chem. Chem. Phys. 19, 8787 (2017).
[2] M. Mishra, A. Gundimeda, S. Krishna, N. Aggarwal, L. Goswami, B. Gahtori, B. Bhattachryya, S. Husale, G. Gupta, ACS Omega 3, 2304 (2018).