Tip based nanometrology and nanolithography using high aspect ratio GaN nanowires

M. Behzadirad, A. Rishinaramangalam, D. Feezell, S. R. J. Brueck, T. Busani
Center for High Technology Materials (CHTM), University of New Mexico (UNM), Albuquerque, NM 87106, USA
mbehzadirad@unm.edu

J. Ballard, J. H. G. Owen
Zyvex Labs, 1301 Plano Rd, Richardson, TX 75081, USA

Scanning Tunneling Microscopy (STM), in both imaging and lithography modes, requires sharp (~1 nm) tips and field emission from the tip. Atomic Force Microscopy (AFM) requires stiff tips with minimal sidewall roughness for probing 3D structures. III-N materials, such as GaN, have recently received attention by the scientific community since they have shown exceptionally strong bonds and can easily be grown as single crystals with a sharp termination (< 1 nm radius) defined by crystal planes. Here we report state of the art achievements on fabrication of high aspect ratio GaN nanowires (NWs), with almost perfect sidewalls through (i) top-down approach for AFM tips and (ii) bottom up approach for STM tips. Planar single crystal n-GaN wafers and single crystals NWs, with different doping concentrations, were grown by metalorganic chemical vapor deposition (MOCVD) and patterned by using interferometric lithography (IL). The planar GaN wafers were etched using inductively coupled plasma (ICP) to create tapered GaN NWs. KOH-based wet etch solution was used to smooth the NW sidewalls to increase their optical quality and aspect ratio. Pitch size during lithography, dry etch parameters, dry and wet etch time, wet etch temperature, and KOH concentration were optimized to control the NWs aspect ratio and roughness of the sidewalls. The aspect ratio of the fabricated NWs varies from 9 to 36 with a minimum obtained diameter of 37 nm. The quality of the fabricated NWs was inspected by transmission electron microscopy (TEM) and optical luminescence, which reveals the quality of the NWs with sidewall roughness of less than 1 nm. Optically-pumped lasing at 367 nm confirms the low sidewall roughness. AFM and STM tips were fabricated using these high quality NWs. AFM scanning results show GaN tips are capable of providing very accurate data in scanning high aspect ratio nanostructures with perfect vertical walls, compared to commercial Si tips (Fig. 1), while possessing higher scanning durability. GaN STM probes are demonstrated to be as good as state-of-the-art W probes. We show the creation of 10,000 boxes (100×100 array) patterned on Si with Scanning Tunneling Lithography (Fig. 2). The results confirm that GaN tips can be competitive, if not superior, in nanometrology and nanolithography and give superior image resolution in AFM. They may prove to have superior lifetime for STM lithography, and enable tip-metrology for many nanoscale applications.

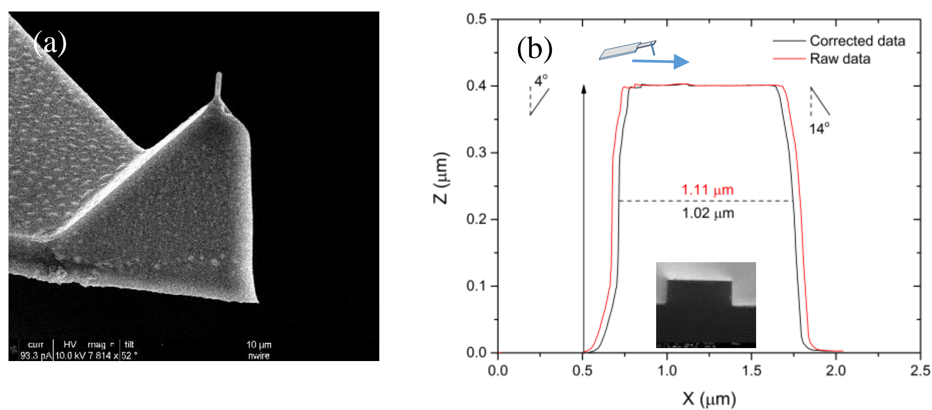

Fig. 1: (a) Fabricated GaN NW AFM probe, and (b) the scanning result on a nanostructure with straight sidewalls using this tip. (Inset shows Si trench with straight sidewalls we used as inspection sample for AFM measurements)

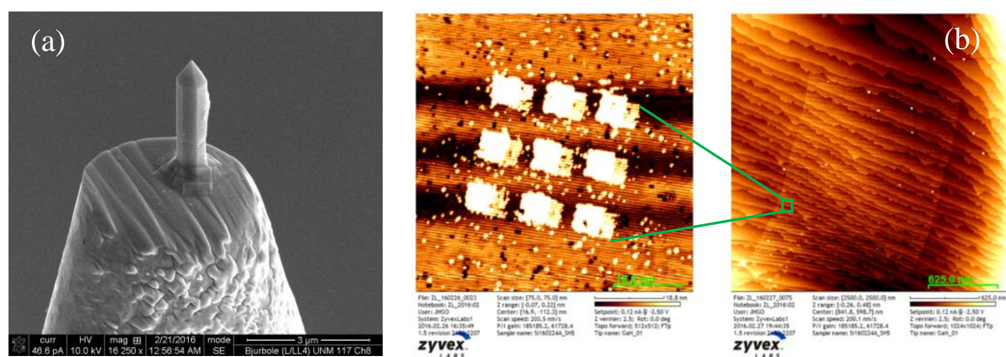

Fig. 2: (a) Fabricated GaN STM tip, and (b) Nanolithography results of 10,000 boxes on Si using this tip. (Lithography images provided by Zyvex Labs)