Growth of GaN Nanorods with Low Carrier Concentration

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One-dimensional nanostructures, such as nanotubes, nanowires, and nanorods, have great potential for understanding fundamental physics about the roles of dimensionality and size in characteristics and for various nano-technological applications. Since the nanowire-like structure can be used to form one-dimensional semiconductor devices or superlattice structures, the development of new methods for fabricating or synthesizing nanowires has recently attracted considerable attention. GaN-based nitride semiconductors having large bandgap and strong chemical bonding have been extensively studied due to their versatile optoelectronic and electronic devices. There have been many reports on the formation of one-dimensional GaN structures using various methods by several groups: GaN nanorods were synthesized through a carbon-nanotube-confined reaction, and subsequently, GaN-carbon composite nanotubes and nanorods were produced by arc discharge in nitrogen atmosphere. Single-crystal GaN nanowires were formed by laser-assisted catalytic growth and wirelike structures were fabricated using polycrystalline indium powder as a catalyst. GaN nanorods were grown by a sublimation of GaN powder under an ammonia flow. In a parallel effort, GaN nanowires in anodic alumina membranes were formed through a gas-phase reaction of Ga_2O vapor with flowing NH_3. Self-organized GaN nanocolumns on Al_2O_3 substrates were grown by rf-radical-source molecular-beam epitaxy. In addition, three-dimensional GaN structures were prepared by direct reaction of Ga vapor with flowing NH_3 above 900 °C.

Although irregular type GaN nanorods have been prepared using transition metal nanoparticles, such as Ni, Co, and Fe as the catalyst, and carbon nanotubes as the template, there is no report of the preparation of a controllable regular array and straight GaN nanorods so far. Fabrication and characterization of well-ordered nanostructures with high density are very important for the practical device applications.

We report on the growth of low carrier concentration GaN nanorods by hydride vapor phase epitaxy (HVPE) and cathodoluminescence (CL) characteristics of individual GaN nanorod. The high density of straight and well-aligned nanorods with a diameter 80-120 nm formed uniformly over the entire 2 in. sapphire substrate. Size controls of the well-aligned GaN nanorods diameters were achieved by adjusting the growth temperature, the growth time and the V/III ratio. Structural characterization of the GaN nanorods by X-ray diffraction (XRD) and transmission electron microscopy (TEM) indicates that the nanorods are preferentially oriented in the c-axis direction. Carrier concentration of undoped GaN nanorod by Hall measurement was 1×10^{16} cm^{-3} and type of conduction was n-type. Cathodo-luminescence (CL) measurements for GaN nanorods show slightly blueshifts in the CL peak position compared to bulk GaN.

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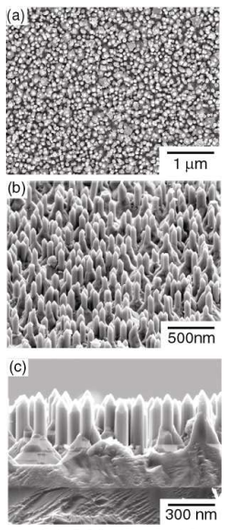

Fig.1. (a) Top View, (b) 30° tilted side view, and (c) cross section view SEM images of GaN nanorods grown on sapphire substrates.

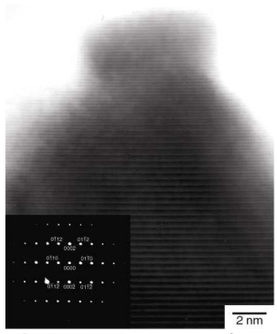

Fig. 2. High-resolution TEM image of a single crystalline GaN nanorod and the corresponding electron diffraction pattern (inset).

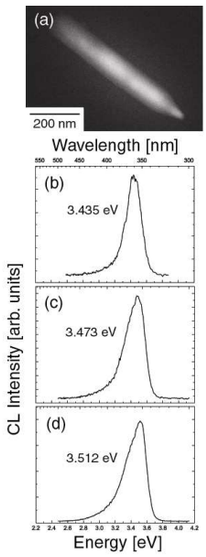

Fig. 3. (a) Panchromatic CL image and (b)-(d) CL spectra for three individual GaN nanorods taken at room temperature (Eb = 10 keV, Ib = 220 pA, and CL bandpass = 2.4 nm). The CL peak energies of the individual GaN nanorod with a diameter of (b) 120, (c) 100, and (c) 80 nm are found to be 3.435, 3.473, and 3.512 eV, respectively. The CL image is taken from the GaN nanorod with a diameter of 100 nm.