



# Optical and Electrical Properties of n- and p-type GaN Nanorod Arrays

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## Introduction

Synthesis of nanoscale device using 1-D materials



Bottom-up assembly to nanoelectronics

- Miniaturization
- Lower driving voltage
- Lower leakage current



## GaN nanorods Growth

- Growth conditions :

Growth Temperature ( $T_g$ ) = 450 ~ 550 °C

HCl = 30 ~ 150 sccm,  $N_{2(HCl)}$  = 300 ~ 2000 sccm

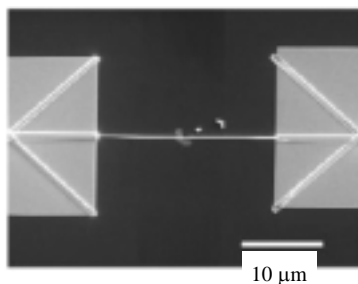
$NH_3$  = 300 ~ 2000 sccm,  $N_{2(NH_3)}$  = 300 ~ 2000 sccm

$N_{2(main)}$  = 3 ~ 5 slm,  $P_{tot}$  = 1 atm

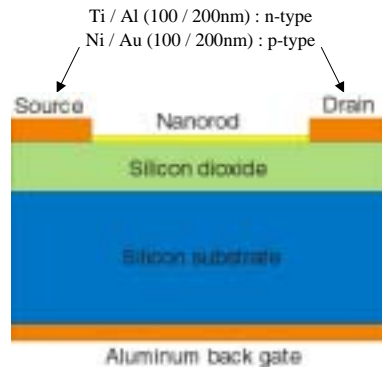
- n, p-type GaN nanorods Growth



## GaN nanorods FET



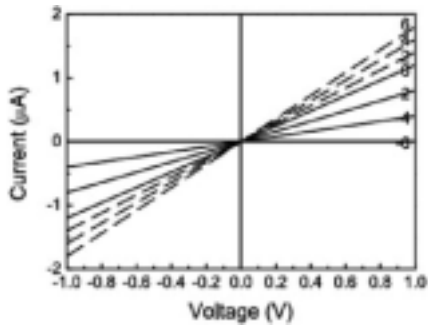
SEM image of a GaN nanorod FET



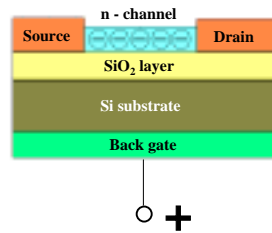
Schematic of a nanorod FET structure



## I-V of GaN nanorods FET < n-type >



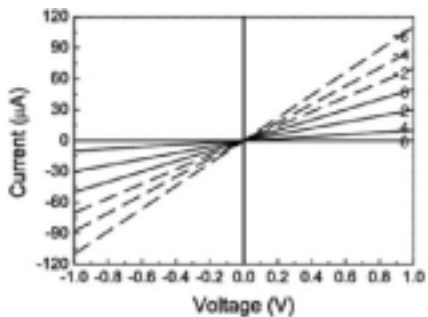
I-V data recorded on an 80 nm diameter  
n-type GaN nanorod



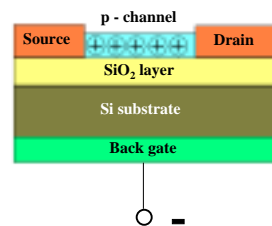
- Ohmic contact
- Nanorods performed as a n - channel



## I-V of GaN nanorods FET < p-type >



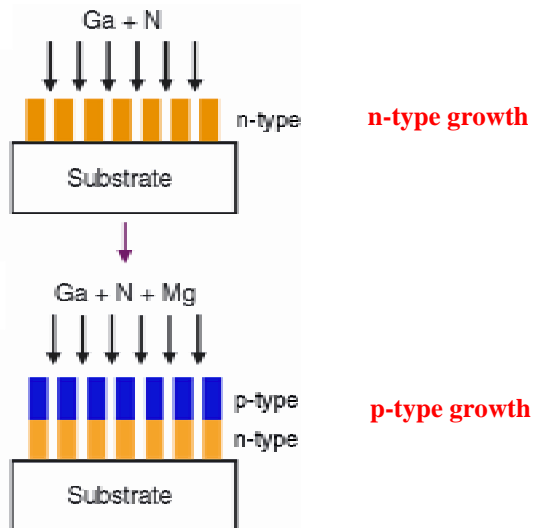
I-V data recorded on an 80 nm diameter  
p-type (Mg-doped) GaN nanorod



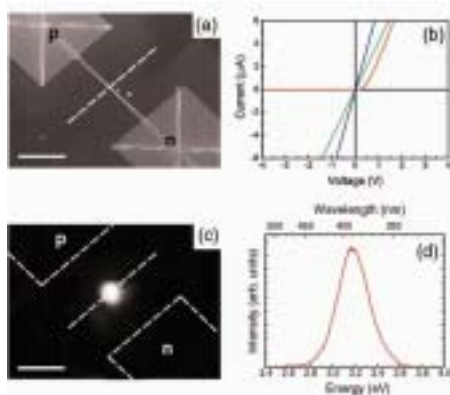
- Ohmic contact
- Nanorods performed as a p - channel



## p-n Junction in Nanorods



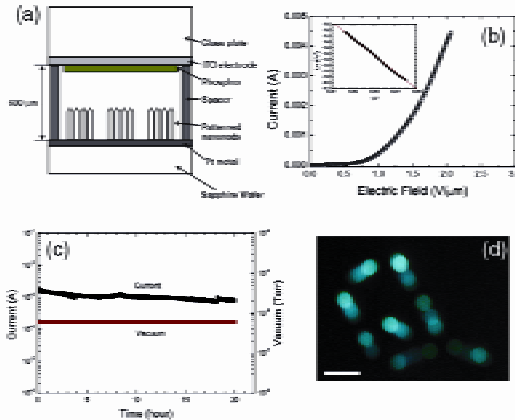
## UV LEDs of GaN Nanorods



- (a) SEM image of a p-n junction within GaN nanorod with Ni/Au contact electrode for p-type and with Ti/Al contact electrode for n-type. Scale bars, 10  $\mu\text{m}$ . The diameter of the nanorod is 50 nm. The diameters of the nanorods used to make devices were in the range of 30–80 nm.
- (b) I-V behavior of n-n, p-p and p-n junctions, respectively. The blue and green curves correspond respectively to the I-V behavior of the individual n- and p-type nanorods. The red curve represents the I-V behavior of the GaN nanorod p-n junction.
- (c) Luminescence image of the light emitted from a forward-biased nanorod p-n junction at 3 V correspond to (a). Scale bar, 10  $\mu\text{m}$ .
- (d) Luminescence spectrum from the forward-biased p-n junction shown in (c). The spectrum peaks at 3.179 eV (390 nm). All data were recorded at room temperature in high-resolution SEM with a CL system.



## Field Emission Displays of GaN Nanorods



- (a) Schematic structure of the GaN nanorods field emission displays.
- (b) Emission current of GaN nanorod as a function of electric fields.  
Inset corresponding Fowler–Nordheim (F–N) plot of GaN Nanorods, indicating a conventional field-emission mechanism.  
The emission current significantly deviated from F–N behavior in the high–field region.
- (c) Fluctuation of GaN nanorods field electron emitter, which was measured in a vacuum chamber and sealed GaN nanorods field electron emitter setup at constant voltage (electric field of 1.3 V/μm).
- (d) Anode image of field electron emission from “Q” character patterned GaN nanorods sample. Scale bar, 1 mm.



## Summary

- n- and p-type GaN nanorods was directly grown by HVPE.
- The p-n junction in the GaN nanorods was fabricated.
- Nanoscale UV-LEDs were fabricated by using GaN nanorod.
- GaN nanorods can be used to the display device such as FED.