

SYMPOSIUM P

Semiconductor Nanowires—Fabrication, Physical Properties, and Applications

April 18 - 21, 2006

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nanoporous silicon dioxide as growth masks. The nanoporous silicon dioxide on GaN surface was created by inductively coupled plasma etching (ICP) using anodic aluminum oxide (AAO) template as an etching mask. The diameter and density of the deposited nitride nanostructures can be tuned by the initial anodic alumina template structure, which is controlled by the anodization conditions. Faceted GaN based nanostructures have been selectively grown inside and over the nano-openings of the silicon dioxide masks. The behavior of the threading dislocations, including the blocking by the nanoporous silicon dioxide masks and bending laterally toward the interface of nanostructures and the oxide masks, has been observed by transmission electron microscopy.

P8.16

Controlled Growth of Phase-separated GaN/AlGaIn core/sheath Nanowires. Jung-Chul Lee, Myeong-Ki Lee and Yun-Mo Sung; Materials Sci. & Eng., Korea University, Seoul, South Korea.

Semiconductors nanowire (NW) structures have attracted considerable attention due to their novel electronic and optical properties, originated from high crystallinity, low defect concentration, quantum size effects, etc. GaN NWs have been spotlighted due to their superior optical properties such as blue or UV light emission. However, only a few number of results were reported on the synthesis and characterization of Al_xGa_{1-x}N alloy nanowires in which the energy band gap can be tuned and thus the light emission characteristics can be engineered. Moreover, only one group has reported the phase separation phenomenon in the Al_xGa_{1-x}N alloy nanowires so far. In this study, AlGaIn NWs were grown by the vapor-liquid-solid (VLS) mechanism using chemical vapor deposition (CVD) transporting trimethylgallium (TMG) and/or aluminum chloride (AlCl₃) onto the nickel-coated sapphire substrate under a flow of ammonia (NH₃). The formation of in situ GaN/Al_xGa_{1-x}N core/sheath NWs via phase separation was identified using high-resolution transmission electron microscopy (HRTEM) and energy dispersive x-ray spectroscopy (EDS) analyses. The morphological features of one-dimensional GaN/Al_xGa_{1-x}N NWs were identified by scanning electron microscopy (SEM). X-ray diffraction (XRD) was performed to analyze crystallinity of GaN/Al_xGa_{1-x}N NWs and approximate alloy composition of Al_xGa_{1-x}N sheath. The growth mechanism of GaN/Al_xGa_{1-x}N NWs was proposed as the gradual phase separations from homogenous Al_xGa_{1-x}N alloy NWs during processing at ~1000 °C. The effects of compositional and size (diameter) variation on the phase separation behavior of GaN/Al_xGa_{1-x}N NWs were carefully examined and discussed in detail. Also, the roles of substrates and heat treatment condition including temperature and time period were investigated for the phase separation in GaN/Al_xGa_{1-x}N NWs. Owing to the quantum well structure created by the band gap difference between the two components, we could enhance quantum efficiency as well as control the photoluminescence (PL) characteristics of GaN/Al_xGa_{1-x}N nanowires, thus making them an ideal candidate structure for blue or UV light-emitting diodes.

P8.17

Abstract Withdrawn

P8.18

Selective Area Growth of Gallium Oxide Nanowires on Gold Patterned Gallium Arsenide Using Implantation-assisted Technique. Kwong-Chun Lo², Ho-Pui Aaron Ho², Chi-man Lawrence Wu¹, K.Y. Fu¹ and Paul K Chu¹; ¹Physics and Materials Science, City University of Hong Kong, Hong Kong, Hong Kong; ²Electronic Engineering, Chinese University of Hong Kong, Hong Kong, Hong Kong.

In this paper, the selective area synthesis of gallium oxide (Ga₂O₃) nanowires on gold patterned gallium arsenide (GaAs) substrate by ion implantation will be reported. The GaAs substrate was first treated with implantation of acetylene ions, nitrogen ions or nitrogen and oxygen co-implantation, followed by coating the surface with a gold film of 40nm in thickness. After rapid thermal annealing at 950°C for 30 seconds, Ga₂O₃ nanowires were found on the gold patterned surface. The Ga₂O₃ nanowires with diameters of 50-500nm were examined and characterized by Raman spectroscopy, scanning electron microscopy, transmission electron microscopy, photoluminescence spectroscopy and cathodoluminescence spectroscopy. Nanoparticles of gold were found at the tip of the nanowires, suggesting that a vapor-liquid-solid mechanism was involved. However, the fact that other implanted species such as argon and oxygen would not lead to the formation of Ga₂O₃ nanowires also suggests that the nitrogen and carbon play an important role as a catalyst. The implanted nitrogen forms intermediate gallium nitride nano-grains, which may in turn lead to the formation of nano-grains of Ga₂O₃ upon reacting with ambient oxygen. These Ga₂O₃ nano-grains then act as a growth template for nanowires. Carbon has previously been reported to be a reduction agent for the formation of group III sub-oxides. Such

sub-oxides provide the vapor source for the growth of nano-materials through further oxidation. In addition, when we annealed the implanted samples in an ambient with oxygen concentration higher than 1%, a thick Ga₂O₃ film formed and nanoribbons was inhibited.

P8.19

Spectroscopy of Single InGaAs/GaAs Nanowires Grown by Selective-Area Metalorganic Vapor Phase Epitaxy.

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Semiconductor nanowires have been intensively investigated because of their enormous potential for new functional electronic and photonic device applications in next generation. We here report on the growth and spectroscopy of high-quality InGaAs embedded in a single GaAs nanowire to study their electronic states and to demonstrate a possibility for efficient light sources. GaAs/InGaAs/GaAs double-heterostructured nanowires were grown by selective-area metalorganic vapor phase epitaxy on GaAs (111)B substrates partially masked with SiO₂. After successive growth of GaAs, InGaAs, and GaAs at appropriate growth conditions, free-standing hexagonal nanowires were formed selectively in the circular opening area of the mask. One of the advantages of our approach is that it is free from catalyst to realize high-quality nanowires. Furthermore, we can grow nanowires in predetermined positions of the substrates by the design of the mask pattern. To facilitate the spectroscopy for a single nanowire, we defined holes of the mask in 3 μm pitch arranged in a triangular lattice. Diameter of the nanowires investigated here was in the range from 150 to 200 nm, which was mainly determined by the size of the mask opening. Though the alloy content of In in InGaAs was 2.4 % for reference (001) substrates, actual amount of In incorporated into nanowires seemed to be more than 10 %. In addition, we estimated the thickness of InGaAs layer to be about 10 nm, which is twice of that on a reference substrate. These differences between nanowires and the reference originate from the diffusion kinetics of source and constituent materials in selective epitaxy, resulting in the difference of the growth rate between them. Spectroscopy of individual nanowires was performed at 4K in a micro-photoluminescence setup with an excitation and correction spot of emission in a diameter of approximately 2 μm. HeNe laser was used for excitation source. Typical spectrum from the sample consisted of a single emission of InGaAs together with emission peaks of GaAs band-to-band and impurity-related transitions. The position as well as the width of the InGaAs emission differs from nanowires to nanowires, presumably due to alloy fluctuations inside and in between the nanowires. At the lowest excitation we could perform (~1.4 W/cm²), integrated intensity of the InGaAs photoluminescence was 20% of those of GaAs-related peaks. Thus, considering the size of the nanowires and excitation spot, the emission is reasonably bright. As the excitation power was increased, InGaAs emission in some nanowires showed considerable blue shift and exhibited an additional peak which was attributable to the excited states. This is explained by the band filling, and indicates efficient carrier injection into InGaAs from GaAs barriers and good optical quality of InGaAs embedded in GaAs nanowires.

P8.20

Interplay Between Strain and Effective Electron Mass on the Absorption Strength of Dilute Nitride Semiconductor Quantum Wires. Andrea Feltrin, Andenet Alemu and Alex Freundlich; Physics, University of Houston, Houston, Texas.

In the last decade semiconductor materials with diluted nitrogen content have attracted growing attention because of their unusual electronic properties. The incorporation of small amounts of nitrogen in III-V semiconductor produces a large reduction of the optical band gap with a huge bowing parameter. A further effect is the modification of the electron dispersion in the reciprocal space and the increase of the conduction band electron effective mass. Masses as high as 0.4 free electron mass have been measured in quantum confined structures and calculations seem to support these first experimental results. These properties give to diluted nitrogen materials, as GaNAs or GaInNAs (GINA), promising potentials for applications in the optical domain. Recently, it has been suggested that nano-structures made out of these materials might have a beneficial application in nano-engineered solar cells. Especially dilute nitride quantum wire based solar cells, apart from extending the absorption spectrum towards the infrared region, could potentially improve the charge extraction in comparison to solar cells containing quantum wells, leading to increased efficiencies. In this perspective it is important to assess possible advantages of diluted nitrogen materials in comparison to their non nitrogenated counterparts. In this work we carry out a systematic comparison between the quantum wire absorption spectra of dilute nitride materials with varying content of nitrogen and indium. The calculations are carried out in the dipole and effective mass