11th International Conference on Nitride Semiconductors (ICNS-11)

UKNC Bursary Report

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Introduction

The 11th International Conference on Nitride Semiconductors (ICNS-11) was held in Beijing International Convention Centre from 30th August to 4th September. This is one of the major conference for the III-Nitrides community, which is held once every two years. 821 participants from 33 countries and regions have attended this conference. The conference involves plenary sessions, parallel topic sessions (growth, optical devices, electrical devices and basic physics), poster sessions and rump sessions.

My research focuses on MOVPE GaN epitaxial growth especially on Si substrates. Therefore, in this conference report, I would like to present the latest and interesting research results about GaN growth by MOVPE. In the first part, few selected talks about GaN grown on Si will be demonstrated. In the second part, few talks and a poster about GaN rod growth will be presented.

The Growth of GaN on Si Substrates

GaN-on-Silicon for LED, Laser Diode, and HEMT

Qian Sun, Chinese Academy of Sciences (CAS)

This invited talk demonstrated their group's excellent results based on the GaN-on-Si LED, LD and HEMT grown by MOVPE. The basic idea of the research is to grow the AlN/AlGaN multilayers before GaN growth, which can compensate the GaN tensile stress. By using this method, they can achieve crack-free 4 µm GaN on (111) Si with high quality. The FWHM of XRC GaN (0002) and (10-12) are 272″ and 293″ respectively, which are comparable with that of GaN on sapphire. Based on this technology, the thin film flip chip LEDs by removing the Si substrate have been commercialised. Different sizes of the LED chips have been fabricated. For example, the 45 mil × 45 mil LED in a 3535 ceramic package has 150 lm/W at a forward current of 350 mA. The group also fabricated the first 414 nm GaN-on-Si laser with a threshold of 270 mA, corresponding to a current density of 8.4 kA/cm^2. This AlN/AlGaN multilayers technology has been applied for the HEMT growth, as well. In addition, the crack-free AlGaN has also achieved by using the AlN/AlGaN multilayer, with a good XRD rocking curve. The FWHM of XRC AlGaN (0002) and (10-12) are 372″ and 383″, respectively.

Dislocation Reduction with Migration Enhanced Epitaxy AlN Buffer on 200mm GaN-on-Si

Li Zhang, Singapore-MIT alliance for research and technology

In this talk, they studied the influence of the AlN buffer for the GaN layer on Si in detail. After deposition of 40nm low temperature AlN nucleation layer by MOVPE, they grew a high temperature

AlN buffer with two different growth methods. One is the conventional AlN growth with the continuous NH_3 and TMAl supply. Another is the pulse model, where the NH_3 and TMAl are alternatively supplied. The second growth method is named by migration enhanced epitaxy AlN MOCVD growth (MEE), which is believed can enhance the surface migration of Al adatoms and eliminate random nucleation at terrace and promote lateral growth. For the conventional growth method, there are many pits on the AlN surface measured by AFM. On the other hand, the AlN grown by the MEE method has no pit at all. After the AlN growth, 1.5 µm GaN was grown subsequently with three Al-containing step-graded AlGaN intermediate layers. The sample with the MEE AlN buffer has smaller wafer bowing than that of the sample with the conventional AlN buffer. More importantly, the GaN with the MEE AlN buffer shows much better XRD rocking curve line width. The FWHM of GaN (10-12) rocking curve is reduced from 620″ to 560″, comparing with the GaN with conventional AlN buffer. This crystalline quality improvement was studied by TEM. They found that the mixed dislocations bended in the pit-free MEE AlN surface. On the other hand, the pits on the AlN surface can hinder the dislocation bending at the compressively strained AlN/AlGaN interface.

High Mobility AlGaN/GaN Heterostructure Grown on Si Substrates Using a Large Lattice-Mismatch Induced Stress Control Technology

Jiangpeng Cheng, Peking University

In this talk, the 3 µm GaN was grown on 4-inch Si with one AlGaN intermediate layer and 270 nm AlN buffer. By changing the Al content of the AlGaN layer, the large lattice-mismatch induced stress control can be achieved. This technology can reduce the dislocations due to the dislocation annihilation with the aid of compressive stress. Moreover, the introduced high residual stress can compensate the tensile stress of GaN. By measuring the Raman spectroscopy, XRD and TEM images, they have found the AlGaN intermediate layer with 23.4% Al content has the better results. The strain of GaN is 0.098%. The FWHM of GaN (0002) and GaN (10-12) rocking curves are 389″ and 527″, respectively. The electron mobility of AlGaN/GaN heterostructure is 2040 $cm^2/(v\cdot s)$ at sheet charge density of 8.4×10^{12} cm^{-2}.

High Quality GaN Material Grown on Polycrystalline N-polar AlN on (001) Si for M-LED Application

Gautier Laval, University of Grenoble Alpes

This talk presented the growth of micro-LED on Si substrate by a bottom-up process. The LED with the micro-structure can eliminate the wafer bowing and crack on the large size Si substrate. In order to achieve the GaN micro-platform for the next LED growth, the selective area growth (SAG) was employed. Firstly, 100 nm AlN was grown to protect Si surface from the Ga melt back etching. Then, the SAG was performed for GaN growth. However, no matter how to modify the growth condition and the mask pattern, the GaN was always pyramidal shape. This is due to the AlN is Al-face, which causes Ga-face GaN. In order to achieve N-face, the physical vapour deposition (PVD) was utilised for the AlN deposition on Si. Although the N-face AlN is polycrystalline with grain diameter around 30 nm, GaN micro-platform can be achieved by a 2-step MOVPE growth. The H_2 carrier gas can give more flat GaN platform surface due to its surfactant effect. This paper gives me quite lots of useful information. Since GaN with Ga-face is very difficult to be grown into rod shape by MOVPE. AlN PVD deposition maybe is an alternative method to get N-face III-nitrides.

Nanoheteroepitaxy of GaN on Nano-patterned AlN/Si Substrate

Donghyun Lee, Seoul National University

In this talk, the nano-patterned AlN/Si substrate was utilised for GaN growth. Firstly, 170 nm AlN was grown on (111) Si by MOVPE. Then, the nanosphere lithography was proceeded to etch the Si substrate into Si nanorods with AlN on the top. After this, a fully coalesced 1.85 µm GaN film with AlGaN buffer was grown on the AlN/Si nanords. A great stress relaxation is achieved as measured by micro-Raman and PL spectra. The GaN crystalline quality is also improved by the dislocations bending to sidewalls and termination at stacking faults. Comparing with GaN on planar AlN-on-Si, the FWHM of GaN (10-12) rocking curve is reduced from 1009″ to 728″, and the TD density measured by AFM is reduced from 1.5×10^9 to 7.5×10^8 cm^{-2}.

The Growth of GaN Rods

Growth and Optical Properties of GaN-based Quantum Dots for Single Photon Emission

Yasuhiko Arakawa, University of Tokyo

This talk first illustrated the advantages of nanowire. Mainly, there are three major advantages, which are dislocation free crystal, high light extraction efficiency and strong quantum confinement. Subsequently, the selective area nanowire growth by MOVPE was presented. A thin layer of SiO_2 with 25 nm aperture was used as the patterned mask. TMG flow rate was set as 10 µmol/min, and the growth time was 8 min. The growth temperature and NH_3 flow rate were optimized in the range of 920 to 1000 ^oC and 5 to 25 sccm, respectively. Typically, the very low V/III ratio was required for the nanowire growth. After the nanowire growth, the $Al_{0.8}Ga_{0.2}N$/GaN core shell structure and the single GaN/$Al_{0.8}Ga_{0.2}N$ quantum dot were grown, respectively. After the growth, the crystal and optical properties were carefully characterised by TEM micrograph, PL and micro PL spectra.

3D GaN Nanowire Devices: Strategies for Solid State Lighting and Beyond

A.Waaga, Braunschweig University of Technology

In this talk, the advantages of core shell LED were illustrated such as large the light emitting area, high crystallinity, fast growth rate (50 µm/h), no quantum confined stark effect, etc. Then, the MOVPE growth mechanisms for GaN rod were discussed. The selective area growth was employed for the nanoLEDs. It is found that the ratio between growth area and passivated area determines the growth rate and the aspect ratio of the GaN columns. The small mask openings can increase the height of GaN columns. Another critical effect is the SiH_4 flux. The flow rate of SiH_4 was changed from 10.8 to 165 nmol/min. It is found that more silane can increase the sidewall diffusion and the height of GaN columns. By using the low V/III ratio and high silane flux, the GaN rods with low defect density and good homogeneity were achieved. The aspect ratio is up to 40. Then, the core shell InGaN quantum well was grown on the GaN microrods. A large gradient in emission along the microrods under UV excitation was observed. And it is found that the lower growth pressure can reduce the gradient in In incorporation along the microrods. After this, the p-GaN was grown. The p-doping decreased the IQE from 43 % to 16 %. Finally, the micro-grain phosphor was deposited between microrods. After the chip process, the first white 3D core shell LEDs was demonstrated. On the other hand, the electronic devices and sensor based on 3D GaN were discussed as well.

Orientation-Controlled Growth of Horizontal and Inclined GaN Nanowires without Catalyst by Metal Organic Chemical Vapor Deposition

Kyuseung Lee, Korea Polytechnic University

In this talk, the growth of horizontal and inclined GaN nanowires on m-plane sapphire was demonstrated. For the inclined GaN nanowire growth, the in-situ SiN_x mask was deposited first. Then, the 10 sec nucleation and 300 sec vertical growth were carried out with the continuous flow mode without metal catalyst. N_2 and H_2 carrier gas was used. It is found that with nitridation, nanorods were grown along (11-22) direction with the inclined angle of 31.6 ^oC respect to substrate. Without nitridation, nanords were grown along (10-13) direction with the inclined angle of 58.4 ^oC. The (11-22) and (10-13) nanord density are 9.6×10^4 cm^{-2} and 1.9×10^5 cm^{-2}, respectively. The length of (11-22) and (10-13) nanord can be up to 8 um. The average diameter of nanorod is 450 nm. On the other hand, for the horizontal GaN nanowire growth, the ex-situ photolithography mask was used. After the nanorod growth, the XRD measurement was performed, confirming the pure single-crystalline wurtzite structures. There is no defect was found in the nanowire by TEM measurement. The optical property was investigated by low-temperature PL and time-resolved PL.

Ultra-long GaN Wires for Piezoelectric Applications

Joël Eymery, University Grenoble Alpes

This talk demonstrated a catalyst free GaN wires by MOCVD. Firstly, the sapphire substrate was cleaned by H_2. Then, the nitridation was performed to form a Al(O)N polar layer. After this, the SiN_x layer was deposited with simultaneous injection of Silane and NH_3 at high temperature. Finally, GaN wires were grown with two steps. The short time nucleation with high V/III ratio was first performed. Subsequently, the growth condition was switched into low V/III ratio and the silane was introduced for the wire growth. The GaN wire growth rate can be up to 200 µm/h with the diameter from 0.6 to 3 µm. The wire length can up to 200 µm, then it is saturated at longer growth time. The wire density is around 10^7 to 10^8 cm^{-2}. After growth, the GaN wires were removed from the substrates by sonication in propanol and were assembled into flexible piezoelectric sensor. Few mV to hundreds mV were generated by the force of 46 mN to 2.3 N. The sensitivity of this piezoelectric sensor is 30 mV/N.

Optical and Structural Properties of Self-organized GaN/InGaN Microrod-based Core/Shell heterostructures Grown on Si(111) by MOCVD (poster)

Bartosz Foltynski, AIXTRON SE

The (111) Si was first nitridated by 5sec to enhance the mix polarity. Then, the AlN buffer was grown at 1000^oC or 1100^oC for 300 sec. Subsequently, the SiN_x in-situ mask was grown by 150 to 600 sec. Next, the GaN nucleation was carried out for 20 sec in order to form hexagonal pedestals formation. Then, GaN vertical growth can performed at 980 to 1060 ^oC with silane injection to enhance 3D growth mode. Finally, the three InGaN/GaN core shell MQWs were grown. SEM, PL and CL measurements were performed. High density of GaN microrods with was achieved. Most microrods are vertical structure. They found that two distinct wavelength regions, that the most emission of the MQWs is from the upper parts of the microrod. The striation like CL contrast was only observed at bottom part, which indicated that there are defects, stacking faults or cubic inclusions in the bottom part of microrods.

Conclusions

In conclusion, attending this conference is a real valuable experience for myself. Many presentations and posters presented interesting and excellent research ideas and results. I have obtained a lot of useful information and been inspired. Moreover, during the conference, I have met many researchers, who I had lots of discussions about the research obstacles and ideas with. On the other hand, it was also a great experience for myself to give a presentation in front of the international community.

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