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Symposium B: Progress in Semiconductor Materials IV — Electronic and Optoelectronic Applications

ZnO/GaN Heteroepitaxy

K.W.Jang, D.C.Oh, T.Minegishi, H.Suzuki, T.Hanada, H. Makino, M.W.Cho, and T. Yao

ABSTRACT

This paper presents the recent achievements of ZnO/GaN heteroepitaxy. The general controlling method and mechanism for the polarity of heteroepitaxial ZnO and GaN films by interface engineering via Plasma-assisted Molecular beam epitaxy(P-MBE) are introduced in a viewpoint of principle for polarity control. We propose the principle of crystal polarity: Crystal
polarity can succeed at the heterointerface when no interface layer is formed, while an interface layer with inversion symmetry is formed, the crystal polarity is inverted at the heterointerfae. The effects of polarity on the interface, surface and bulk structure, and the structural and optical
properties of ZnO/GaN epitaxy are also included. The polarity of GaN on ZnO is successfully controlled based on the proposed principle for control of crystal polarity. Additionally, the
electronic characteristics such as electron concentration, band-line-up, and C-V characteristics of ZnO/GaN heterointerface are dicussed.

Electrical and Optical Properties of n-type and p-type ZnO

D.C. Look and B. Claflin

ABSTRACT

In recent years, ZnO has been proposed for new electronic and optoelectronic devices, such as transparent transistors and UV light-emitting diodes (LEDs). The LED application will require both n-type and p-type ZnO, but the latter is difficult to produce, and progress in this area will require a detailed knowledge of the various impurities and defects that affect the electrical and optical properties. The dominant donors in as-grown ZnO are usually thought to be interstitial H and substitutional AlZn, with activation energies of about 40 and 65 meV, respectively. However, interstitial Zn and its associated
complexes may also contribute free electrons. The dominant acceptor, at least in vaporphase-grown material, is the Zn vacancy; however, substitutional NO is also present, although sometimes passivated by H. To produce p-type ZnO, it is necessary to dope with acceptor-type impurities, and some success has been achieved with N, P, As, and Sb. However, only N has been proven to have simple substitutional character (NO), and more complicated acceptor structures, such as AsZn-2VZn, have been proposed for some of the other group V elements. Both homostructural and

heterostructural UV LEDs have been fabricated, although not of high luminescent power so far. The main objective of this paper is to review the Hall-effect and photoluminescence results on n-type and p-type ZnO.

Roughness Analysis of Episurfaces Grown on Ion-Beam Processed GaSb Substrates

K. Krishnaswami, D.B. Fenner, S.R. Vangala, C. Santeufemio, M. Grzesik, L.P. Allen, G. Dallas, and W.D. Goodhue

ABSTRACT

High-quality GaSb substrates with minimal surface roughness and thin, uniform oxide layers are critical for developing low-power, epitaxy-based, electronic and optoelectronic devices.
Ion-beam processing techniques of gas-cluster ion beam (GCIB) and bromine ion-beam assisted etching (Br-IBAE) were investigated as to their potential for improving the suitability of substrate surfaces for molecular beam epitaxial (MBE) growth. Statistical analysis of the residual surface roughness provides insight into ion-beam processing and its impact on epitaxial
growth. Images of episurfaces grown on chemical mechanical polished (CMP), Br-IBAE, and GCIB finished substrates were obtained using atomic force microscopy (AFM) and these were
statistically analyzed to characterize their surface roughness properties. Autocorrelation analysis of the first two types of episurfaces showed a quick loss of correlation within ~100 nm. The episurface with Br-IBAE also showed isotropic mound roughness with sharp point-like protrusions. The GCIB prepared episurfaces exhibited the formation of uniform step-terrace
patterns with monatomic steps and wide terraces as indicated by the strong, long range (>0.5 ìm) correlations. Statistical analysis of the GCIB episurfaces showed self-similar random fractal behavior over eight orders of magnitude in the power spectral density (PSD) with a fractal dimension of ~2.5.

Correlation between Photoreflectance Spectra and Electrical Characteristics of InP/GaAsSb Double Heterojunction Bipolar Transistors

Hiroki Sugiyama, Yasuhiro Oda, Haruki Yokoyama, and Takashi Kobayashi Masahiro Uchida and Noriyuki Watanabe

ABSTRACT

We report a photoreflectance (PR) characterization of InP/GaAsSb double-heterojunction bipolar transistor (DHBT) epitaxial wafers grown by metal-organic vapor-phase epitaxy (MOVPE). The origin of the Franz-Keldysh oscillations (FKOs) in the PR spectra was identified by step etching of the samples. FKOs from the InP emitter region were observed in the wafer with low recombination forward current at the emitter-base (E/B) heterojunction. In contrast, they did not appear when recombination current was dominant. The absence of the FKOs from the emitter indicates the high concentration of the recombination centers at the E/B heterojunction. We have also measured PR spectra from InAlP/GaAsSb/InP DHBT wafers. Pronounced FKOs from InAlP
emitter reflect the suppression of recombination at E/B heterojunctions.

Processing of deeply etched GaAs/AlGaAs quantum cascade lasers with grating structures

S.Golka, M.Austerer, C. Pflügl, W.Schrenk, and G.Strasser

ABSTRACT

Gratings in GaAs/AlGaAs mid-infrared quantum cascade lasers (QCLs) are fabricated with a structure depth of more than 10 μm. A N2/SiCl4 inductively coupled plasma reactive ion
etching (ICP-RIE) process was employed to achieve extremely smooth sidewalls and selectivities to the SiNX etch mask of up to 70:1. EDX spectra measured on as-etched samples

show that sidewall etch inhibition is caused by a thin Si containing layer on the sidewalls that is formed simultaneously with ICP etching of GaAs at the bottom of the trenches. To demonstrate device application gratings with a pitch of 1.72 µm are applied to long rib waveguide -based QCLs emitting at ë = 10.7 µm. When etched laterally together with the rib the grating gives rise to stable single mode emission up to 295K from these QCLs. The respective grating coupling coefficient is determined to be ê = 29 cm-1.

Spectroscopic analysis of external stresses in semiconductor quantum-well materials

Jens W. Tomm,1 Mark L. Biermann, B. S. Passmore, M. O. Manasreh, A. Gerhardt, and Tran Q. Tien1

ABSTRACT

We present an approach for spectroscopic strain analysis in semiconductor quantum-well devices. This approach is applicable to all types of semiconductor materials, and to spectroscopic techniques which employ the electronic band-structure of the material, such as photoluminescence, photoreflection, photocurrent, and transmittance. The approach is based on
two components, namely the theoretical calculation of the strain-sensitivity of the spectral positions of the relevant quantum-confined optical transitions within a particular quantum-well,
and the spatially resolved measurement of a substantial part of the optical transition sequence within the quantum-well. The primary experimental technique applied in our approach is photocurrent spectroscopy. InAlGaAs/GaAlAs/GaAs, high-power lasers serve as the model species.

Nominal PbSe nano-islands on PbTe: grown by MBE, analyzed by AFM and TEM

Peter Moeck, Mukes Kapilashrami, Arvind Rao, Kirill Aldushin, Jeahuck Lee, James E. Morris, Nige D. Browning, and Patrick J. McCann

ABSTRACT

Nominal PbSe nano-islands were grown in the Stranski-Krastanow mode on (111) oriented PbTe/BaF2 pseudo-substrates by molecular beam epitaxy (MBE). The number density and morphology of these islands were assessed by means of atomic force microscopy (AFM). Transmission electron microscopy (TEM) was employed to determine the strain state and crystallographic structure of these islands. On the basis of both AFM and TEM analyses, we distinguish between different groups of tensibly strained islands. The suggestion is made to use such nano-islands as part of nanometrology standards for scanning probe microscopy.

Intersubband Transitions in In0.3Ga0.7As/GaAs Multiple Quantum Dots of Varying Dot-Sizes

Y.C. Chua , Jie Liang , B.S. Passmore, E.A. DeCuir , M.O. Manasreh , Zhiming Wang , and G.J. Salamo

Abstract

The optical absorption spectra of intersubband transitions in In0.3Ga0.7As/GaAs multiple quantum dots (MQDs) grown by molecular beam epitaxy were investigated. By varying the number of In0.3Ga0.7As monolayers deposited, a series of samples with varying dot sizes ranging from 10 – 50 monolayers were obtained. The quantum dots grown with size less than 15 monolayers or more than 50 monolayers did not yield any observable measurements of intersubband transition. This suggests that there exist a critical upper and lower limit of In0.3Ga0.7As quantum dots for infrared detectors. A wavelength range of 8.60 – 13.70 ìm is achieved for structures grown with the above monolayers range. The theoretical line-shape of the intersubband transition absorption was compared to the experimental measurements. From the lineshape, it was deduced that bound-to-continuum transtition is present in thick quantum dots and bound-to-bound transition is present in thinly grown quantum dots.

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地　址：北京市海淀区紫竹院路62号4102室　联系人：陈　辉
电　话：010-68710443　传　真：010-68722033　网址：www.c-mrs.org.cn

c-mrs@c-mrs.org.cn

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