NAMBE
Room Cummings Ballroom - Session NAMBE2-WeA
Late News II

Moderator: John McElearney, Tufts University

3:15pm **NAMBE2-WeA-8 Growth and Properties of InSe Thin Films on GaAs(111)B and Si(111)*, Maria Hilse*,** *D. Liu, J. Rodriguez, J. Gray, J. Yao, S. Ding,* Penn State University*; M. Li, J. Young,* New Jersey Institute of Technology*; Y. Liu,* Penn State University*; R. Engel-Herbert,* Paul-Drude Institute for Solid State Electronics*; A. Lupini,* Oak Ridge Natinal Laboratory*; J. Redwing,* Penn State University

Urgent societal and environmental needs have sparked searches for high-mobility 2D layered materials with sizeable bandgap and decent stability under ambient conditions for potential use in ultra-low power, ultra-high performance field effect transistors. With a reported carrier mobility exceeding 1000 cm^2/Vs at room temperature, small electron effective mass, flat electronic band dispersions, excellent optoelectronic properties, possible ferroelectric properties and a close-to-ideal solar spectrum matched bulk bandgap of 1.26 eV, InSe shows high potential for future use in electronics.

In the presented study, InSe thin films were grown by MBE on GaAs(111)B and Si(111). The presence of many InSe phases and polytypes required a systematic and careful mapping of the growth parameters to identify conditions for single-phase, single-polytype, and single-crystal growth. Through structural characterization in- and ex-situ using reflection high-energy electron and X-ray diffraction, growth conditions for solely gamma-phase, crystalline InSe films were found. Although the structural properties of the films presented nearly unchanged over a small window of growth conditions, the film morphology was seen to sensitively depend on the Se:In flux ratio. Raman spectroscopy confirmed the phase and polytype assignment deduced from large-area structural characterization.

Microstructure analysis, however, revealed a high degree of structural defects in the films. Nano-scale domains of varying single layer stacking sequences, high-angle rotational domains as well as single layers of unusual bonding configuration resulting in a novel InSe polymorph were found in the films. The total number of defects and the general locations of the new polymorph varied in films across GaAs and Si. The highest structural homogeneity was found for InSe films grown on Si.

Density functional theory calculations for a representative selection of the experimentally observed defects confirmed that most defects, including the novel polymorph have formation energies at or below the thermal budget of the MBE synthesis process. Although the bandgaps of all InSe polytypes and polymorphs possess comparable values, large differences were found in their relative offsets. Due to the random distribution of polytypes and polymorphs in the film, our study suggests a high degree of electronic disorder in these films. Electrical transport showed a variable-range hopping-like behavior supporting the hypothesis of electronic disorder.

3:30pm **NAMBE2-WeA-9 Investigation of the Indium-flush Technique on InAs/InAlGaAs/InP (001) Quantum Dots for 1.55 µm Laser Applications*, Calum Dear*,** *J. Yuan, H. Jia, J. Park,* University College London, UK*; Y. Hou,* Swansea University, UK*; K. El Hajraoui,* University of York, UK*; H. Zeng, H. Deng, M. Tang,* University College London, UK*; Q. Ramasse,* University of Leeds, UK*; H. Liu,* University College London, UK

Growth of InAs/InP quantum dot (QD) materials for 1.55 µm laser applications faces two key challenges: (1) a morphological preference for elongated islands, known as quantum dashes, and (2) a large dispersion in island heights. Both issues are pronounced by the low lattice-mismatch interface of 3.2%. With respect to the optical characteristics, the former results in wire-like optical behaviour and the latter in a broadening of the photoluminescence (PL) spectra's full-width at half-maximum (FWHM). The work presented address these challenges in synchronous in pursuit of a high quality and optically active ensemble of QDs for high-performance laser applications on native and, potentially, on the important Si (001) platform.

To this end, we first optimised the island shape by reducing the indium surface migration using As_2 species [1], a V/III beam equivalent pressure (BEP) ratio of 18 [2], and an InAlGaAs buffer layer. A stable dot-like population of QDs with a high density of $4\times10^{10}cm^{-2}$ was achieved with 5.5 monolayers (ML) of InAs. However, the deposition thickness nucleated large QDs; resulting in a room temperature (RT) PL emission wavelength greater than 1.8 µm. Additionally, a considerable dispersion in island height was presented in a ~90 meV FWHM.

Second, by employing an indium flush (IF) [3] (fig. 1), the QD heights and uniformity were reduced and improved, respectively. 4 nm of InAlGaAs was grown immediately following QD deposition to partially cap the ensemble. By raising the substrate temperature under As-pressure, indium desorption occurred in the larger exposed QDs, effectively truncating them to the height of the partial cap. Thereby resulting in a 300 nm blueshift of the emission wavelength and a substantial linewidth narrowing to 47.9 (51.0) meV for single (five)-layer structures (fig. 2(d)).

By investigating the resulting characteristics through means such as high-resolution scanning transmission electron microscopy (HR-STEM), we present key insights into the morphological changes to the QD morphology resulting from the IF technique. Furthermore, laser structures utilising the IF technique have been grown and fabricated, including additional work on enhancing the InAlGaAs buffer quality via ex-situ cyclic rapid thermal processing.

[1] C. Gilfert et al., Appl. Phys. Lett., vol. 96, no. 19, May 2010.

[2] S. Banyoudeh and J. P. Reithmaier, J. of Crys. Grow., vol. 425, pp. 299–302, Sep. 2015.

[3] Z. R. Wasilewski et al., J. of Crys. Grow., vol. 201–202, pp. 1131–1135, May 1999.

3:45pm **NAMBE2-WeA-10 MBE Growth of Ge and GaAs on (111)-faceted V-groove Silicon*, Makhayeni Mtunzi*,** *H. Jia,* University College London, UK*; Y. Hou,* Swansea University, UK*; L. Bao,* University of Southampton, UK*; M. Masteghin,* University of Surrey, UK*; H. Deng, X. Yu, H. Zeng, J. Park, Y. Wang,* University College London, UK*; W. Li, A. Li,* Beijing University of Technology, China*; K. El Hajraoui,* York University, UK*; Q. Ramasse,* University of Leeds, UK*; I. Skandalos, F. Gardes,* University of Southampton, UK*; M. Tang, S. Chen, A. Seeds, H. Liu,* University College London, UK

Germanium (Ge) buffer layers on silicon (Si) substrates have long been developed for group IV and III–V devices by suppressing defect propagation during epitaxial growth. This is a key step for the development of highly efficient photonic devices on the Si platform. Patterned silicon substrates have increasingly been employed for their ability to restrict and hinder the motion of defects. In this work, we demonstrate the effectiveness of an optimised two-step growth recipe structure on a (111)-faceted V-groove silicon substrate with a 350 nm flat ridge. This strategy successfully reduces the threading dislocation (TD) density while growing a 1 µm Ge buffer layer via molecular beam epitaxy. As a result, a high-quality Ge buffer is produced with a low TD density on the order of 10^7 cm^{-2} and a surface roughness below 1 nm.

Furthermore, in order to move towards competent light emitting sources, the suppression of antiphase domains (APDs) from the polar on non-polar heterointerface of III-V GaAs on to group IV materials must also be considered. Such defect tolerant buffers are crucial for enabling highly effective GaAs based laser devices. Subsequently, we also demonstrate techniques to suppress the formation and propagation of APDs using a (113)-faceted Ge/Si virtual substrate as well as a (111)-faceted sawtooth V-groove Si substrate.

4:00pm **NAMBE2-WeA-11 Closing Remarks & Sponsor Thank Yous*,***

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