Dr Richard F. Webster

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Research Interests

My interests lie in the application of electron microscopy methods to determine composition, structure and defect nature of semiconductors, mainly III-nitrides. My present research includes the application of electron microscopy to $In_xGa_{1-x}N$ nanorods and films for use in LED and transistor devices. More specifically:

- the compositional profiling, using energy dispersive X-ray spectroscopy, of $In_xGa_{1-x}N$ nanorods to understand the growth mechanisms of these structures,
- the application of electron diffraction techniques to determine the structure of materials, mainly semiconductors and
- the use of novel substrates, such as polycrystalline diamond, for improved thermal characteristics of semiconductor devices.

Employment

University of Bristol, *School of Physics*

Research Associate *Nov 2015 – Present*

- *Summary*: To study the growth of GaN films grown on polycrystalline diamond to utilise its high thermal conductivity and improve the reliability of HEMT and LED devices. This work mainly used TEM and related methods. This work included the dislocation analysis of III-N films grown directly on diamond and with a novel epitaxial layer overgrowth method and the effect of AlN thickness on thermal boundary resistance.
- *Additional rôles:* Sample preparation using FIB/SEM and mechanical polishing. Work on external industrial contracts. Routine TEM maintenance – filament replacement, microscope alignment and consulting service engineers when necessary. Training new TEM users including data analysis.

Education

University of Bristol, *School of Physics*

Ph.D. Physics *Sept 2011 – Sept 2015*

- *Thesis*: 'Transmission Electron Microscopy of Indium Gallium Nitride Nanorods'
- *Supervisor*: Professor David Cherns
- *Summary*: $In_xGa_{1-x}N$ nanorods were grown on silicon substrates grown using molecular beam epitaxy (MBE) at Nottingham University for solar cell applications. The focus of my Ph.D. thesis was the characterisation of the structure and composition of these nanorods. This was primarily achieved using electron microscopy techniques. The main findings of this work includes:
  - the demonstration that $In_xGa_{1-x}N$ nanorods spontaneously grow with a core-shell structure. Energy dispersive X-ray (EDX) spectroscopy was used to show that the cores are significantly more In-rich than the shells and to map the composition,
  - direct observation of spinodal decomposition within the $In_xGa_{1-x}N$ nanorod cores using EDX mapping and high angle annular dark field STEM imaging and
  - devising a model to predict the vertical and lateral growth rates of $In_xGa_{1-x}N$ nanorods for a given growth temperature and composition.

  Additional research included an electron diffraction and HRTEM study of a novel defect structure in tungsten oxide nanorods, dislocation analysis of gallium nitride films and characterisation of tin disulphide thin films.

MSci. Physics, (2:1) *Oct 2007 – Jul 2011*

- *Dissertation*: The response of a monolithic active pixel sensor to incident X-rays from a Fe-55 source was characterised. This detector was to be used as a vertex tracker in a particle detector such as the LHC.
- *Relevant courses*: Condensed Matter Physics, Mathematical Methods, Modern Optics, Nanoscience, Particle Physics, Quantum Mechanics, Soft Condensed Matter Physics.

Skills

Electron Microscopy

- 4 years experience using transmission electron microscopy techniques, including: dark field electron microscopy, electron diffraction: selected area and convergent beam (CBED) techniques, energy dispersive x-ray spectroscopy (EDX), high resolution electron microscopy (HRTEM) and high angle annular dark field (HAADF) STEM
- Routine TEM maintenance: filament replacement, microscope alignment, film development and liaising with service engineers
- TEM sample preparation techniques including mechanical polishing, argon ion polishing and focused ion beam (FIB)
- SEM imaging and alignment

Structural Characterisation

- Characterisation of dislocations using dark field $\vec{g} \cdot \vec{b}$ analysis and burgers circuit methods
- Determination of crystal structure, elemental composition and polarity using electron diffraction and EDX

Computing

- Programming languages: Python and C
- Typesetting: LaTeX and HTML
- Software: Digital Micrograph, ImageJ, Inkscape, and Microsoft Office
- Operating systems: Linux (Fedora and Ubuntu) and Windows

Teaching

- 3 years of teaching in an undergraduate laboratory environment: demonstrating 1st and 2nd year experiments and teaching in group tutorial sessions
- 2 years experience in training new users and students in the use of TEMs and associated data analysis

Awards

- UK Nitrides Consortium (UKNC) Travel Bursary - Sept 2013

References

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Publications

Ph.D. Thesis

1. **R. F. Webster**, “Transmission Electron Microscopy of Indium Gallium Nitride Nanorods”, Ph.D. Thesis (University of Bristol, 2015).

Research Articles

1. L. A. Burton, T. J. Whittles, D. Hesp, W. M. Linhart, J. M. Skelton, B. Hou, **R. F. Webster**, G. O'Dowd, C. Reece, D. Cherns, D. J. Fermin, T. D. Veal, V. R. Dhanak, and A. Walsh, Electronic and optical properties of single crystal SnS2: an earth-abundant disulfide photocatalyst, *J. Mater. Chem. A* **4**, 1312–1318 (2016).
2. **R. F. Webster**, D. Cherns, M. Kuball, Q. Jiang, and D. Allsopp, Electron microscopy of Gallium Nitride growth on Polycrystalline Diamond, *Semiconductor Science and Technology* **30**, 114007 (2015).
3. **R. F. Webster**, Q. Y. Soundararajah, I. J. Griffiths, D. Cherns, S. V. Novikov, and C. T. Foxon, Microstructure of $In_xGa_{1-x}N$ nanorods grown by molecular beam epitaxy, *Semiconductor Science and Technology* **30**, 114014 (2015).
4. D. Cherns, **R. F. Webster**, S. V. Novikov, C. T. Foxon, A. M. Fischer, F. A. Ponce, and S. J. Haigh, Compositional variations in $In_{0.5}Ga_{0.5}N$ nanorods grown by molecular beam epitaxy, *Nanotechnology* **25**, 215705 (2014).
5. L. E. Goff, R. E. L. Powell, A. J. Kent, C. T. Foxon, S. V. Novikov, **R. F. Webster**, and D. Cherns, Molecular beam epitaxy of InN nanorods on Si-and C-faces of SiC substrates, *Journal of Crystal Growth* **386**, 135–138 (2014).
6. B. Hou, D. Benito-Alifonso, **R. F. Webster**, D. Cherns, M. C. Galan, and D. J. Fermin, Rapid phosphine-free synthesis of CdSe quantum dots: promoting the generation of Se precursors using a radical initiator, *Journal of Materials Chemistry A* **2**, 6879–6886 (2014).
7. P. Huang, M. Kalyar, **R. F. Webster**, D. Cherns, and M. N. R. Ashfold, Tungsten oxide nanorod growth by pulsed laser deposition: influence of substrate and process conditions, *Nanoscale* (2014).
8. D. Cherns, **R. F. Webster**, S. V. Novikov, C. T. Foxon, A. M. Fischer, and F. A. Ponce, The growth of $In_{0.5}Ga_{0.5}N$ and InN layers on (111) Si using nanorod intermediate arrays, *Journal of Crystal Growth* **384**, 55–60 (2013).

Conference Proceedings

1. **R. F. Webster**, D. Cherns, S. V. Novikov, and C. T. Foxon, Transmission electron microscopy of Indium Gallium Nitride nanorods grown by molecular beam epitaxy, *Physica Status Solidi (c)* **11**, 417–420 (2014).
2. **R. F. Webster**, D. Cherns, L. E. Goff, S. V. Novikov, C. T. Foxon, A. M. Fischer, and F. A. Ponce, Indium Nitride and Indium Gallium Nitride layers grown on nanorods, *Journal of Physics: Conference Series* **471**, 012025 (2013).