ACT Node & WA Node NEWS

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Australian National Fabrication Facility

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AlGaN/GaN heterostructure cell-based biosensor

The Microelectronic Research Group (MRG) at the ANFF WA Node has investigated the ion sensitivity of ungated, uncapped AlGaN/GaN heterostructure-based devices.

Sensors based on AlGaN/GaN High Electron Mobility Transistor (HEMT) structures have high gate charge sensitivity, stability in harsh environments and are believed to have low toxicity. The conducting channel of an AlGaN/GaN HEMT consists of a two dimensional electron gas (see Fig. 1, below), the density of which is modulated by changes in the surface potential of the HEMT. Thus, transistor amplification can be achieved by directly sensing charged particles adsorbed onto the exposed gate area. A four contact bar structure device (see Fig. 2b, above) was fabricated to measure voltage between two points while applying constant current along the bar as function of pH. These measurements revealed a bath-tub like dependence of sheet resistance with pH, indicating the sheet resistance increased as a function of ionic concentration, regardless of whether the pH was acidic or basic, and showing that the uncapped AlGaN/GaN heterostructures are demonstrating selectivity towards negative ions over positive ions.

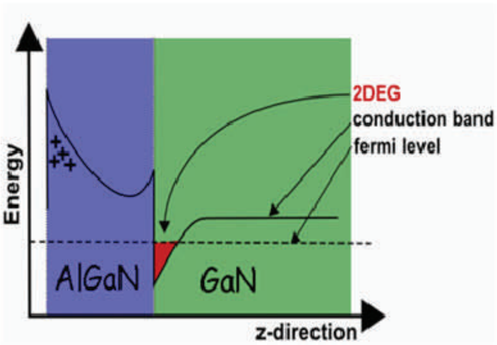
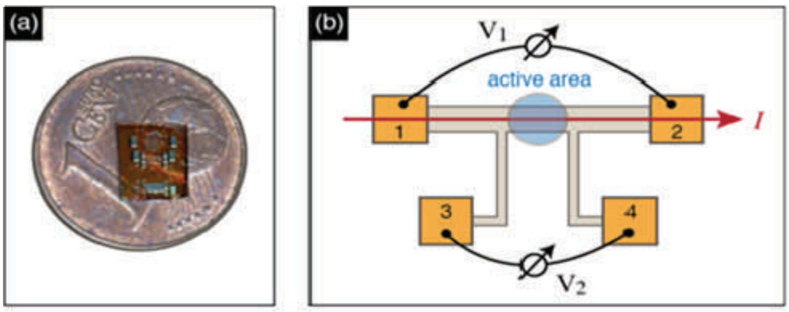


Figure 1 (above). AlGaN/GaN band structure diagram

Figure 2 (below). Photograph of an ungated AlGaN/GaN heterostructure-based device (a) and measurement configuration for Kelvin probe measurements (b)



Such selectivity towards negative ions can therefore be employed in cell-based bio-sensor applications via the detection of negative ion transport through the cell membrane/ion channels. Living cells are extremely organised microstructures containing a high concentration of chemicals, including enzymes, nucleic acids, ions, many types of proteins and small organic molecules. They process multiple incoming signals by means of parallel activation of different pathways and respond with a reaction pattern according to the type of stimulus, physical or chemical. In spite of the many difficulties and complications involved in using whole cells, including their limited lifespan, the most important reason for developing cell-based biosensors is that only by using living components capable of a direct response to incoming information can the effect of an external physical or chemical stimulus on living system be investigated.

Compatibility of living cells and AlGaN/GaN heterostructures for this application has been investigated through a number of qualitative optical observations, scanning electron microscopy (SEM) and focused ion beam (FIB) technique. The image of the semi-conductor/cell interface (see Fig.3, over) achieved by FIB/SEM demonstrates the cell attachment to AlGaN/GaN surface.

Investigation of this interface is crucial for understanding the cell-based biosensor performance and future optimisation. MRG researchers have also performed quantitative flow cytometry experiments to assess bio-compatibility of cells and AlGaN/GaN wafers with different Al mole fractions. The viability of cells on the AlGaN surface has been seen to be comparable for different Al mole fractions. These provide flexibility in design and optimisation of the AlGaN/GaN heterostructure for specific ion detection.

The four contacts bar structure device used in the pH sensitivity measurements was packaged in a special cell-compatible way and live cells were seeded on its active area. This device monitored the cells growth and proliferation inside the cell-culture incubator for more than 15 hours. Response to the added drug of 1.25mV was detected. Other

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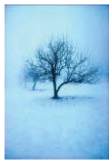


Well, the chill has returned to Canberra and it has even cooled down in Perth after their record heat-wave conditions through summer and into autumn. This has not, however, slowed down the activity at our Nodes.

This month's main story is from WA and focuses on the recent GaN sensor work by UWA PhD student, Anna Podolska, who you may recall was one of the prize winners at the COMMAD conference in December last year. Again, it is terrific that the facilities of the ANFF are being utilised by students doing research as well as being accessed by other institutions and industry users.

Please contact us if you think we can assist with your work.

Other news in this issue:

Next Issue:
due September 2011

ACT Node & WA Node info:

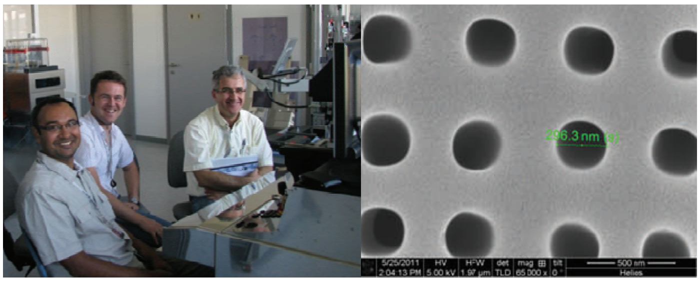
- The ACT Node specialises in III-V compound semi-conductors.
- The WA Node specialises in II-VI compound semi-conductors and MEMS.
- We can provide full support with the use of the equipment available.
- Full pricing policy and rates are available on the ANFF website at www.anff.org.au or contact us direct for more information - see contact details overleaf.

Node Staff attend EBL and NIL/HE training in Europe

Dr Gordon Li (EBL process engineer) attended two workshops at RAITH Dortmund during May 2011 relating to e-beam lithography. The two workshops covered proximity effect correction (PEC) using Monte Carlo Simulation, usage of Raith experiment scheme in relation to PEC, running of PEC experiments, automation training, including the use of Java script to write Raith programs and the usage of mix & match exposure.

More experiments at the ACT node are now scheduled to implement the knowledge gained in order to enhance and strengthen the node’s expertise in the field of e-beam lithography.

Also in May 2011, three staff members: Dr Kaushal Vora, Dr Gordon Li and, facility manager, Dr Fouad Karouta undertook a week of training at EVG related to nano-imprint technology that covered the basics of NIL technology and choice of polymers, making stamps (MD-40 on glass) from standard masters for both UV-curing and hot embossing, UV-curing of made stamps (lines and circles with various sizes) and hot embossing using made stamps.



Kaushal and Fouad during training on machine maintenance (left) and test sample patterned with square lattice photonic crystal like holes.

Welcome to our newest staff member - Dr Animesh Basak

A belated welcome to our newest staff member - Animesh Basak! Animesh joined us at the Australian National University in January this year to work jointly between the ACT node of the ANFF and the ANU Centre of Advanced Microscopy, which is part of the AMMRF ACT Node.

Animesh graduated in 2002 with a BSc. in Metallurgical Engineering from Bangladesh University of Engineering and Technology (BUET) and received his Masters and PhD degree in Materials Science and Engineering, in 2003 and 2009 respectively, from Katholieke Universiteit Leuven (KULeuven) in Belgium. His PhD work focused on tribology and tribo-corrosion behaviors of nanostructured cermet/ceramic coatings for engineering applications. He has also worked on a number of scientific projects for the European Union in Belgium. In 2009 he joined the Mechanical and Manufacturing Engineering Department at UNSW as a post-doctoral research fellow - now we are pleased to have him on board at the ANFF.

Animesh's research interests include nanostructured materials, nano-technology, nano-scale fabrication of materials, high resolution electron microscopy and probe analysis, FIB-SEM, TEM sample preparation techniques, nanoindentation, deformation mechanisms of semiconductor materials and bulk metallic glasses (BMG), nano-mechanics, tribology and tribo-corrosion, electrochemistry and electrochemical measurement techniques.

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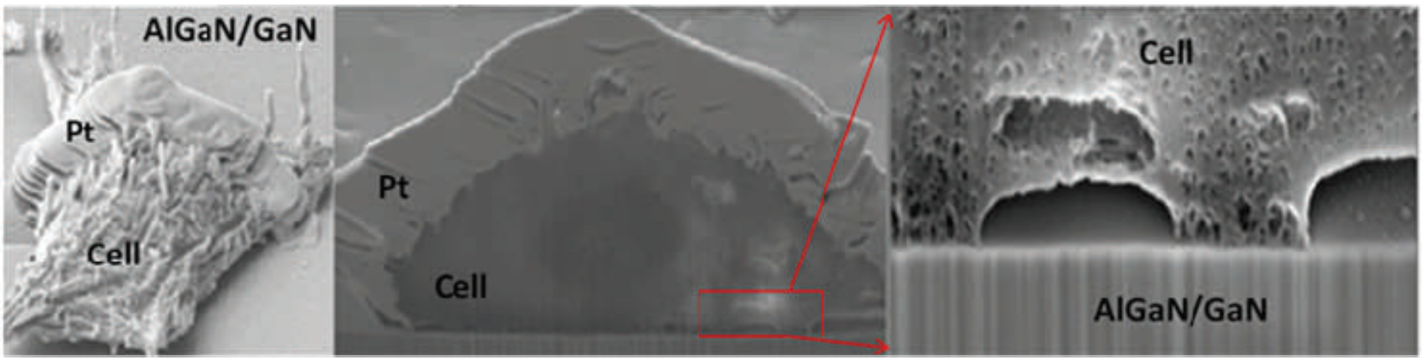

Figure 3. FIB/SEM cross-section of chemically fixed HEK-293 cell on AlGaN/GaN

signals obtained from this measurement indicate different stages of cell-life activity, however further data processing is needed to extract more information.

To conclude our story we would like to highlight the following:

- that cell-based biosensor on ungated uncapped AlGaN/GaN heterostructure has been fabricated, packaged and tested.
- the results obtained through the bio-compatibility studies allow us to further optimise the heterostructure in terms of layer composition. Initial pH measurements demonstrate response to different ions and this can be useful for future enhancement of device sensitivity.
- we demonstrated capability of AlGaN/GaN cell-based biosensor, however further investigation and optimisations are required to make this device a reliable tool to be used in microbiology research.

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