Investigation of the structure of InN(0001) surfaces following atomic hydrogen cleaning

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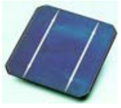
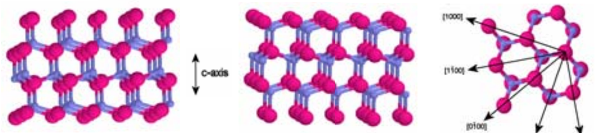
Introduction

- InN films identified for use in:
  - High efficiency solar cells.
  - Light emitting diodes (InGaN).
  - Photodetectors
  - THz frequency / high power devices (due to high mobility).



- Electronic properties of the surface are governed by polarity. This is determined by identifying which atomic species has a bond pointing towards the surface. The surface termination also plays a role in the electronic characteristics.

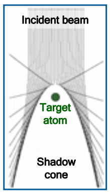


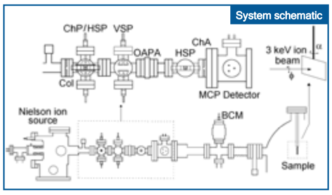
N-polarity, InN(000$\bar{1}$) In-polarity, InN(0001)

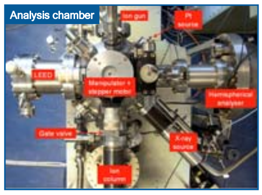
- In-polar and N-polar material have different electronic characteristics and hence different applications. Therefore, need to be able to identify the material polarity and surface structure of the InN films produced by certain growth conditions.

Coaxial impact collision ion scattering spectroscopy (CAICISS)

- Coaxial impact collision ion scattering spectroscopy [5] offers the chance to probe the structure and composition of surfaces with a high degree of surface specificity. The technique has been used to study a range of surface science problems, including real-time growth, surface reconstructions and metal oxide / alloy formation.
- Time-of-flight ⇒ composition information from binary collision. Shadow cones ⇒ structural information from ion-target interaction. In these experiments an incident beam of He^+ with an energy of 3 keV was used and data collected in the [1000] direction.
- Extract intensity vs. polar angle plot for each element and compare to simulations generated using the FAN code [6].
- More information at http://uk.geocities.com/phrxaj/CAICISS.htm .

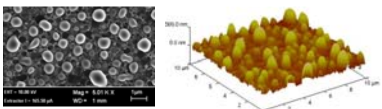




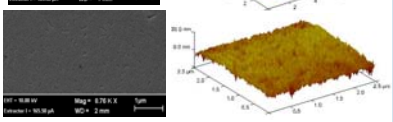


Atomic hydrogen cleaning

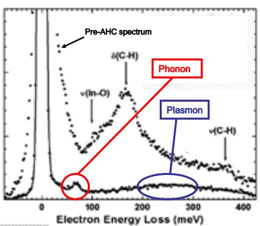
- On exposure to the atmosphere, the InN surface oxidises to form In_2O_3, whose dissociation temperature is higher than that of InN. Therefore cannot clean by simply annealing.
- Ion bombardment leads to the preferential sputtering of N atoms, leaving behind an In-rich surface.
- Atomic hydrogen (H*) has been used to clean many III-V surfaces [1-3]. The oxide and H* react and are readily desorbed along with hydrocarbons by a low-temperature anneal.
- Initial AHC recipe comprised a 16 kL H* dose at 550 K, followed by a 60 minute anneal at the same temperature with P < $1x10^{-9}$ mbar.
- SEM and AFM indicated the formation of In droplets on the surface following AHC.

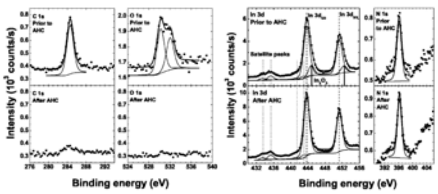


- AHC recipe revised in order to study the surface structure of InN films. SEM and AFM both showed a flat surface.



- Cleaning recipe for samples studied with CAICISS:
  - 8 kL dose at 300 K (chamber pressure of $5x10^{-6}$ mbar).
  - 8 kL dose at 450 K.
  - Anneal at 575 K for 2 hours in pressures below $1x10^{-9}$ mbar.
  - Allow sample to cool to room temperature.
- Low energy electron diffraction (LEED) showed a (1x1) reconstruction at 79.5 eV. However, the pattern has quite a high background intensity, indicating some disorder at the surface.
- Both high resolution electron energy loss spectroscopy (HREELS) and X-ray photoelectron spectroscopy (XPS) indicated the removal of In_2O_3 and native hydrocarbons from the InN surface. No signs of removal of N or In atoms from the near-surface region [4].

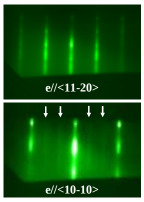


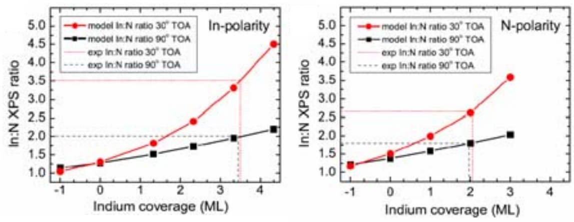


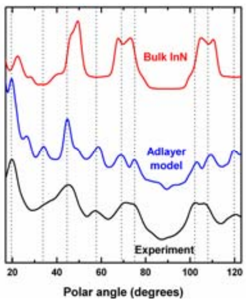
LEED (79.5 eV)

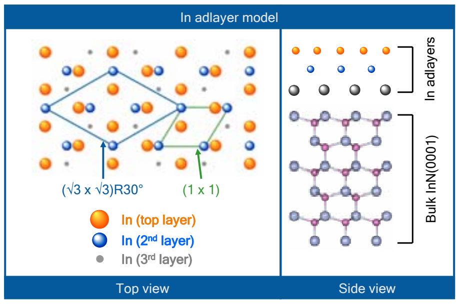
Structural analysis

- Results from high resolution XPS work at the National Centre for Electron Spectroscopy and Surface Analysis (NCESS - Daresbury, UK) and RHEED observations suggests In layers on top of In-terminated indium nitride structure. 3.4 ML of In is suggested for In-polarity, 2 ML for N-polarity [7] - in both cases this is 1 ML more than in the case of GaN.









- CAICISS data were recorded in the [1000] direction from Cornell sample GS1532.
- The peaks in the CAICISS data at 32° and 59° were not reproduced in the simulation of bulk InN(0001), but instead were found to be due to shadowing within the In adlayers.
- The surface layer was found to posses a (√3 x √3)R30° structure, similar to the GaN bilayer structure [7]. Two additional layers of In were also required in order to fit the experimental data. The underlying InN(0001) structure was found to be In-terminated.

Conclusions & future work

- Atomic hydrogen cleaning is found to be an effective method of preparing InN(0001) surfaces. However, In droplets may be formed with an excess H* dosage or temperature.
- CAICISS has been used to determine the polarity of InN. In the case of In-polar material, CAICISS proved the existence of a (√3 x √3)R30° reconstructed outermost layer, with two further layers of In between the surface layer and the underlying bulk, In-terminated InN(0001) structure. This is in line with the In:N ratio observed with XPS.
- Further CAICISS work is required to verify the In:N ratio and structure of N-polarity surfaces.

References

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