Structural and Electronic Properties of InN Surfaces and Interfaces

THE UNIVERSITY OF WARWICK

L. Fishwick
Surface, Interface and Thin Film Group

Post-grad Seminar
12 February 2009

Highly Mismatched Compounds@warwick

The Highly Mismatched Compounds group:
Academics:

Prof. Chris McConville
Supervisor

Dr. Tim Veal
EPSRC career acceleration fellow

PhD students:

Mr. Philip D. C. King
3^{rd} year

Ms. Louise R. Bailey
2^{nd} year

Mr. Liam Fishwick
Mr. Wojciech Linhart
1^{st} year

I also work closely with Dr. Marc Walker and Mr. Matthew Brown performing ion scattering experiments.

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Highly Mismatched compounds

A highly mismatched compound is compound with a distinct cation/anion size and electronegativity mismatch. The particular branch of HMC that is the focus of research in the group at warwick are SCAMS.

- SCAMS: Significantly Cation-Anion Mismatched Semiconductors. The cation is much larger and less electronegative than the anion, e.g. InN, ZnO, CdO.

Importance of indium nitride

Indium nitride is a narrow band gap semiconductor with a band gap of $\sim$ 0.64 eV.

- Exhibits an electron accumulation layer at the surface
- InGaN ternary alloy is known now to have a band gap spanning from the near IR for InN to the UV for GaN.
- Branch point energy is well above the conduction band minimum (~ 1.5 eV).

Mahboob *et al.*, Phys. Rev. Lett., **92**, 036804, 2004
King *et al.*. Phys. Rev. B., **77**, 045316, 2008

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Importance of scandium nitride

Scandium nitride was initially thought to be a semi-metal, but after more careful calculation was found to be a semiconductor with a direct transition at the Γ point of $\sim$ 2.1 eV.

- Interest in use as buffer layers in III-N compounds, e.g. GaN/InN.
- Demonstrates downwards band bending at the surface.
- May exhibit interesting electronic properties.

Lambrecht, Phys. Rev. B, **62**, 20, (2000)

Techniques

Important techniques for this project:

- X-ray photoelectron spectroscopy
- Co-axial impact collision ion scattering spectroscopy
- Low energy electron diffraction

Some complementary techniques that will also be utilised:

- Scanning electron microscopy
- Hall measurements

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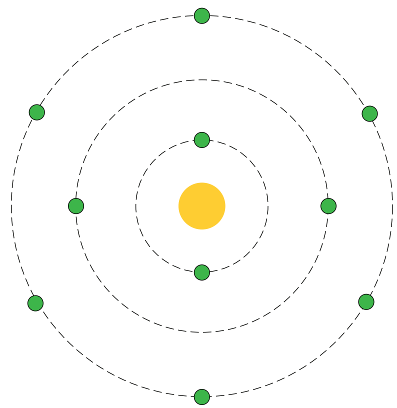
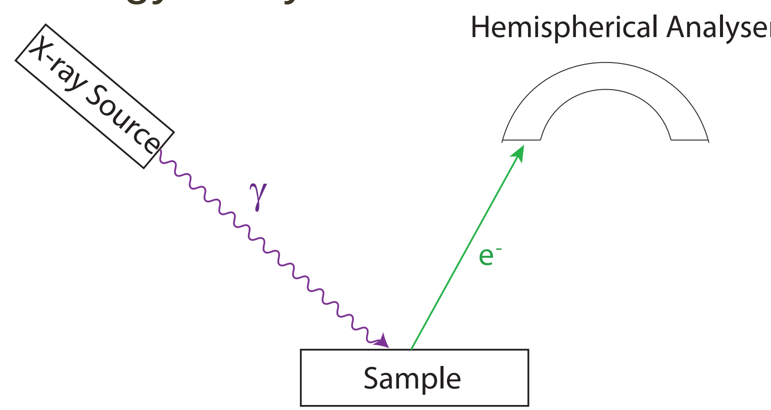
X-ray photoelectron spectroscopy

An incident x-ray photon causes the ejection of a core level electron, which is then accelerated towards an electron energy analyser.





The binding energy of the detected electron is:

$$E_{\mathrm{B}} = E_{\gamma} - E_{\mathrm{k}} - \phi_{\mathrm{analyser}}$$

Each element produces a characteristic set of peaks in the spectra at specfic binding energies directly identifying that species (usually!)

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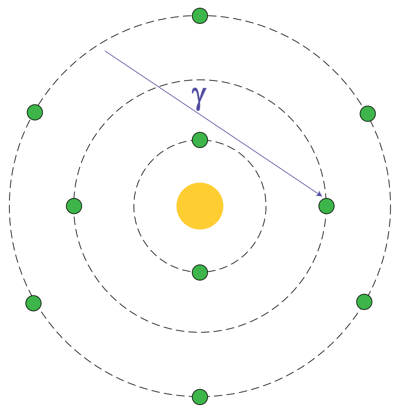

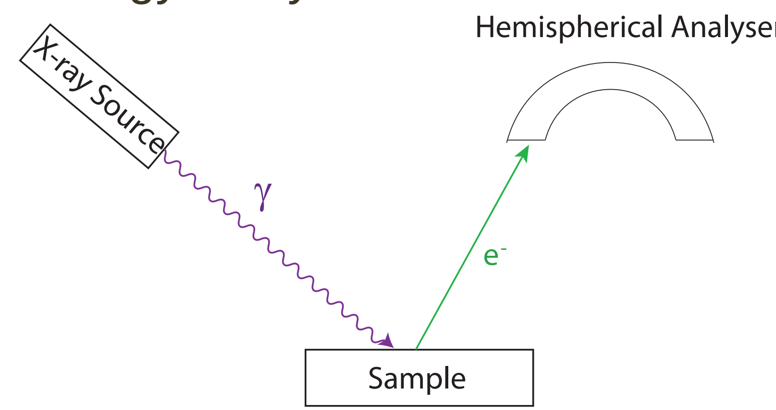

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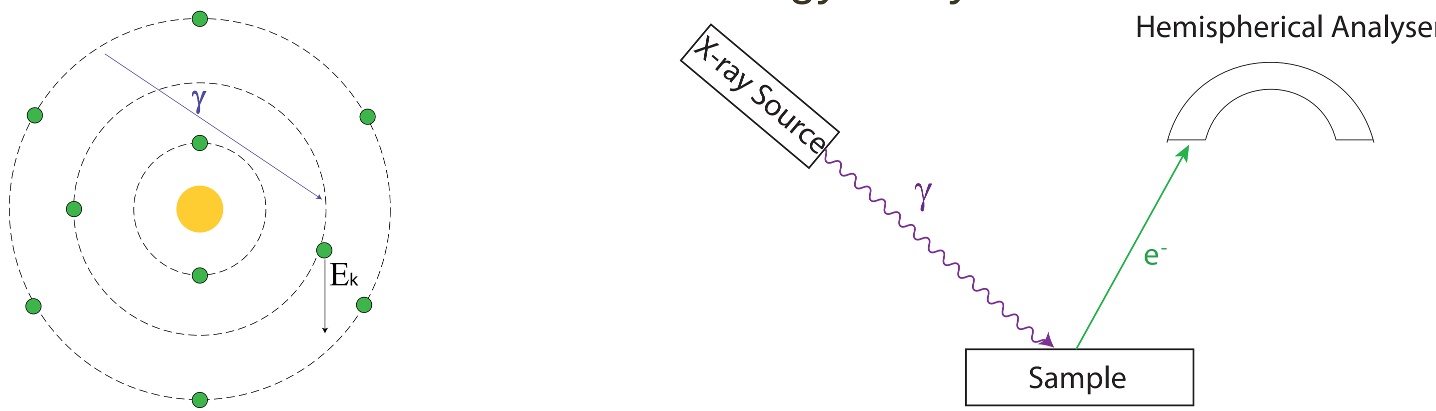

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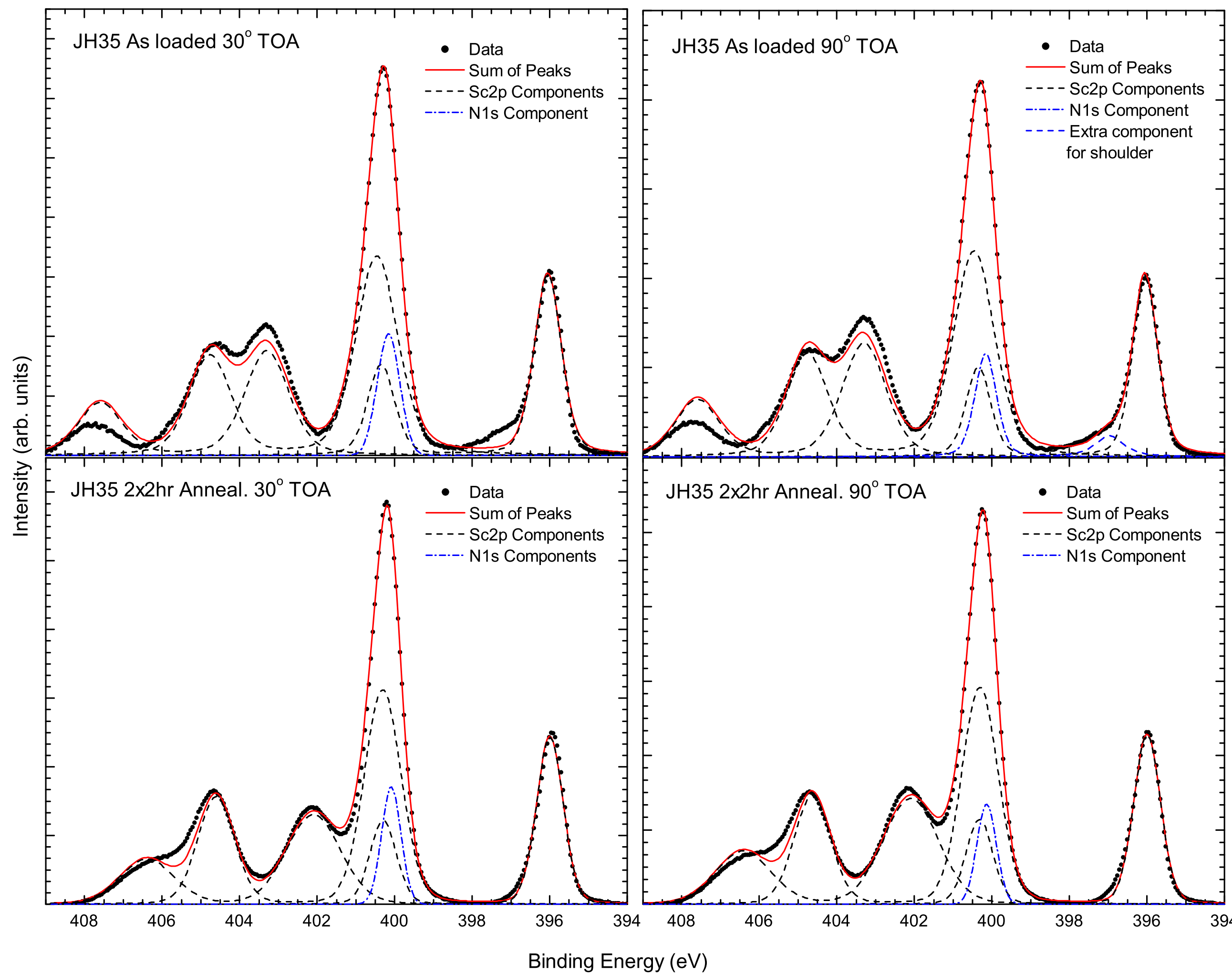
XPS Data

Sample XPS spectra for a Sc2p region. Fitted for different surface preparations and take off angles.



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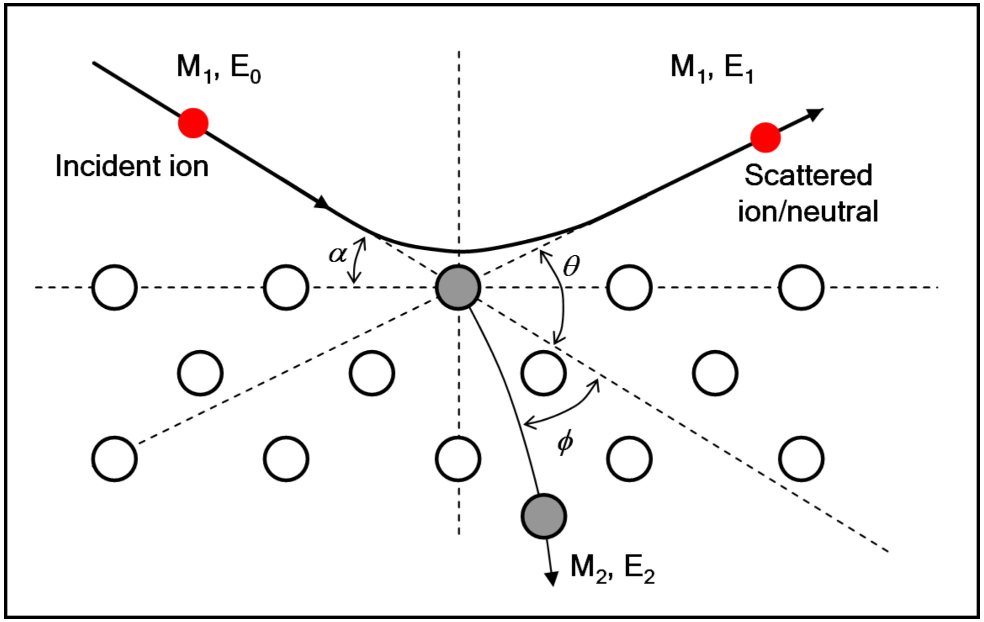
Co-axial impact collision ion scattering spectroscopy

Ion scattering can be illustrated as a simple collision between hard spheres. Incident ions scatter off atoms in the near surface region.



CAICISS is a novel low energy ion scattering technique, where ions with incident energy of 1 – 5 keV are incident on the surface and 180° backscattering geometry is utilised for detection.

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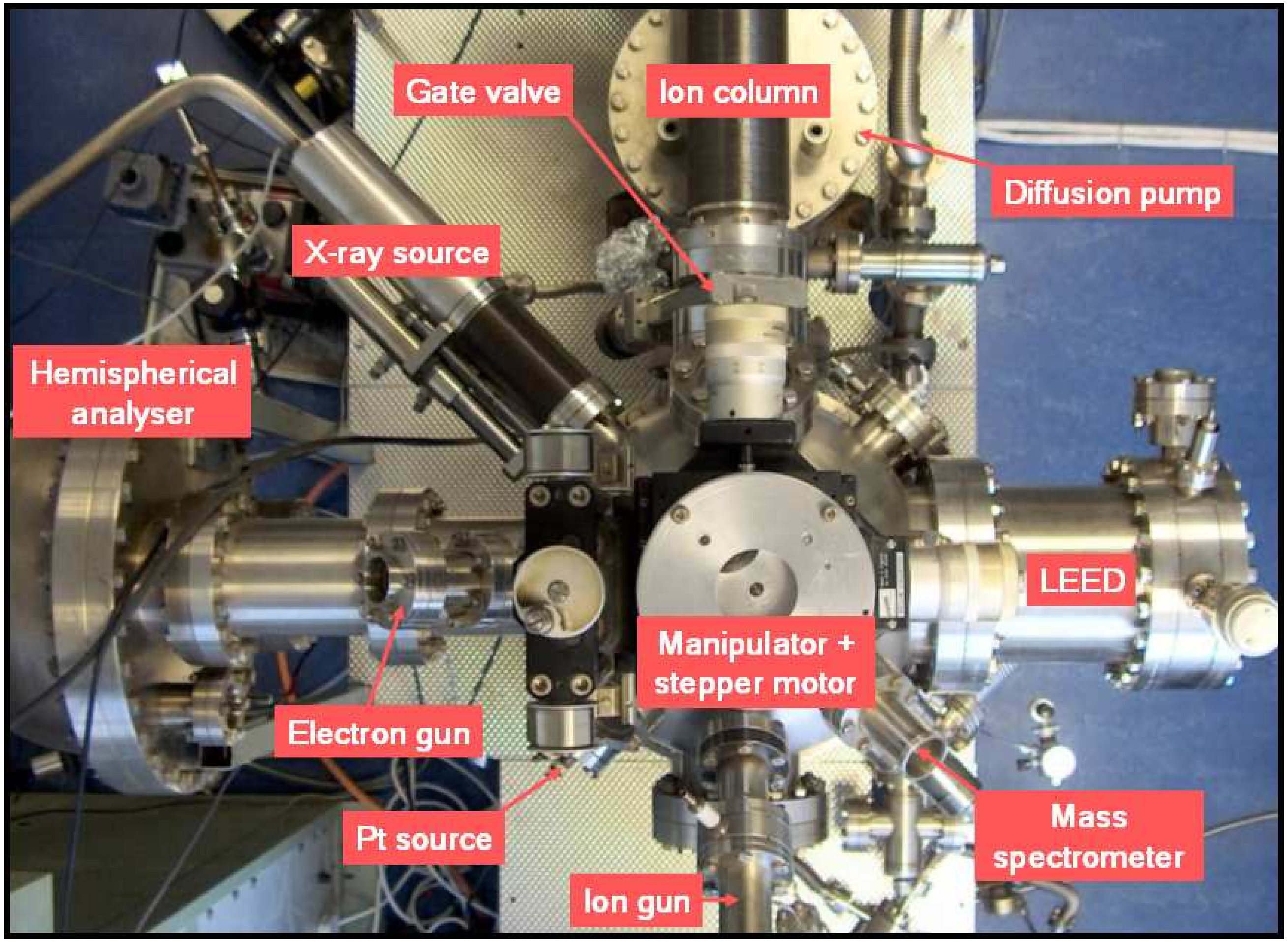
Co-axial impact collision ion scattering spectroscopy



At Warwick we have the only CAICISS chamber in the country.

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Co-axial impact collision ion scattering spectroscopy

The data is compared with simulations such as those created by the FAN package

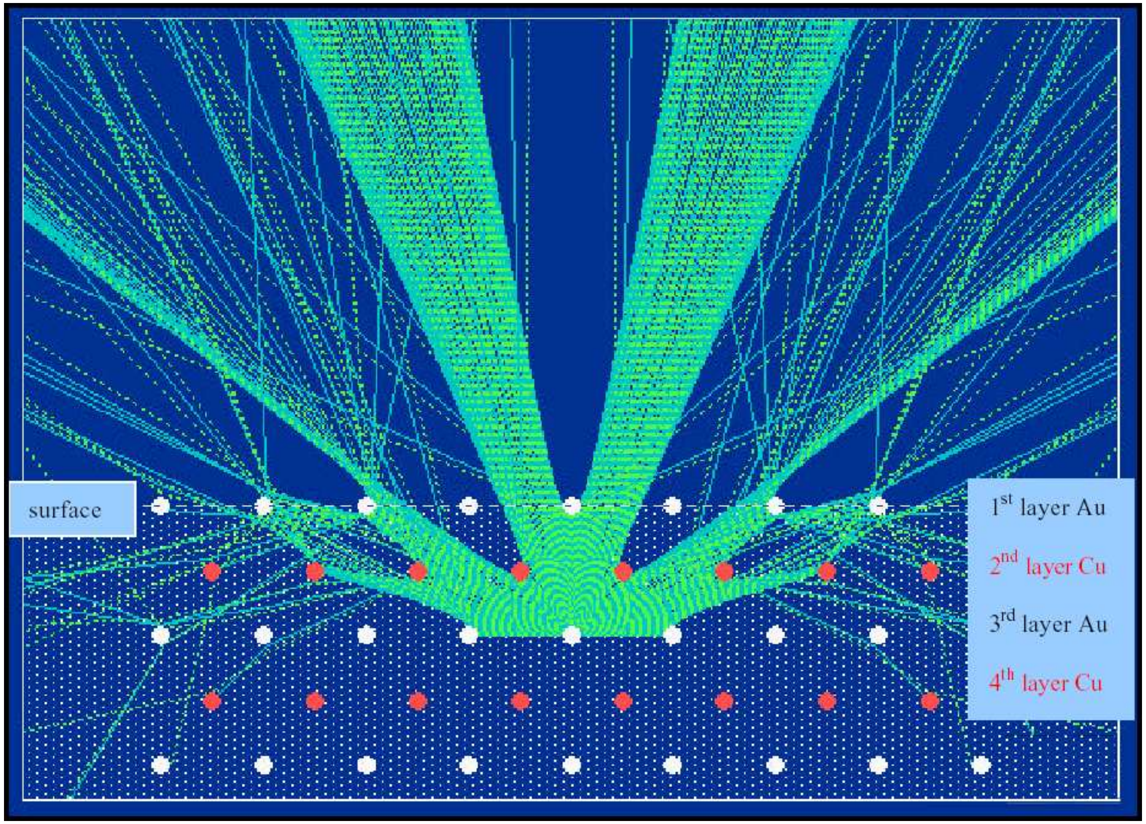
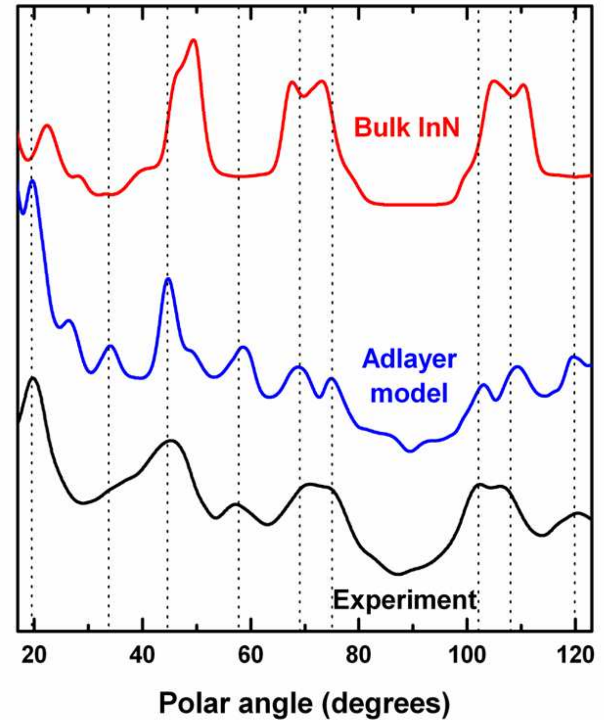


Figure 1: FAN trajectory cones from the near surface region of Au/Cu

In-adlayers in InN

Previous CAICISS work performed by the group has led to a model for wurtzite InN to be formed with In adlayers at the surface of In terminated InN.



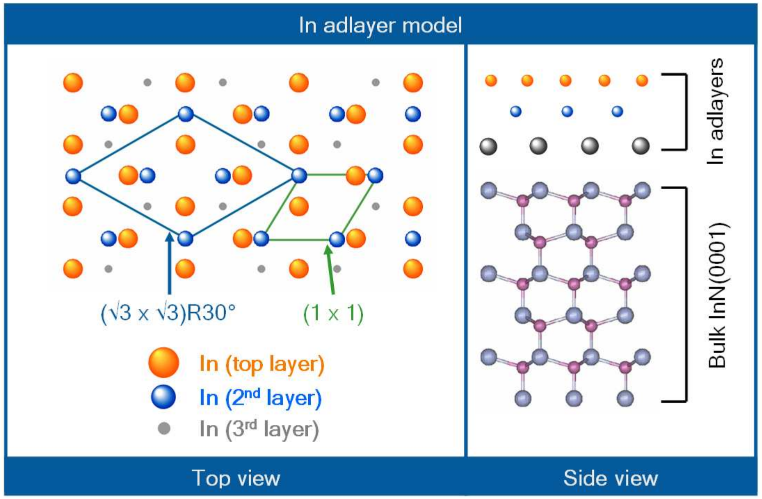


Figure 3: InN adlayer schematic, top view and side view shown

Figure 2: Idealised bulk terminated InN and In adlayer model shown with experimental result below

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Future Research

- Further investigation into the structural and electronic properties of InN and ScN.
- Study other HMC's.
- Develop cleaning techniques for InN.

Cleaning InN

Some issues faced when cleaning InN are:

- Low non-congruent temperature $\sim$ 450°C.
- Preferentially sputter N from surface.
- Weak material so cannot withstand Ar^{+} ion bombardment.

Need to develop cleaning methods that maintain both the electronic and structural properties of the surface, without introducing many defects. Currently atomic hydrogen cleaning is performed, however, hydrogen acts as a donor defect altering the electronic properties.