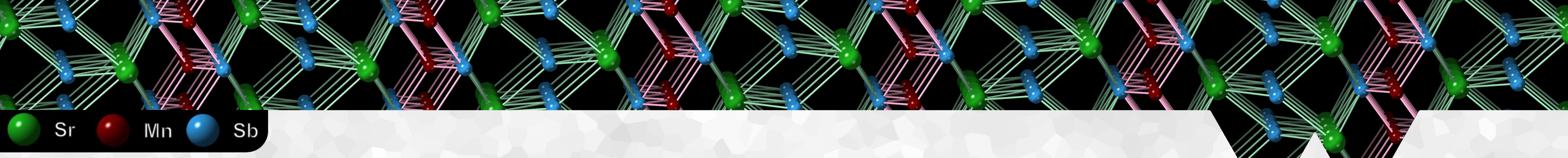

$SrMnSb_2$ Thin Film Growth With MBE

Thomas Rehaag

Supervisor: Dr Gavin Bell

WARWICK
THE UNIVERSITY OF WARWICK

What is $SrMnSb_2$?

Many materials have been theorised as potential topological insulators or topological semimetals, of which few have been verified experimentally. $SrMnSb_2$ has been successfully synthesised in a bulk single crystal[1] although its topologically non-trivial nature is disputed[1][2]. It does nevertheless show promising optoelectronic properties[3] that may be exploited to control band structure optically. This exotic behaviour can be uniquely leveraged by growing the material as a thin film, which is made possible by utilising molecular beam epitaxy (MBE).

Strontium in MBE

Strontium is rarely used in MBE systems due to a number of limiting factors:

- Strontium reacts rapidly with oxygen.
- The deposition temperature of SrO is much larger than strontium.
- Strontium is often packaged in oil, which must be thoroughly removed prior to use.

Due to the unconventional geometry of the MBE system and requirement for rapid loading of deposition material, a new effusion cell was necessary. Therefore, a homemade cell was created (Fig. 1) to match the specific needs of the system, avoiding the high cost and lead time of a custom commercial cell.

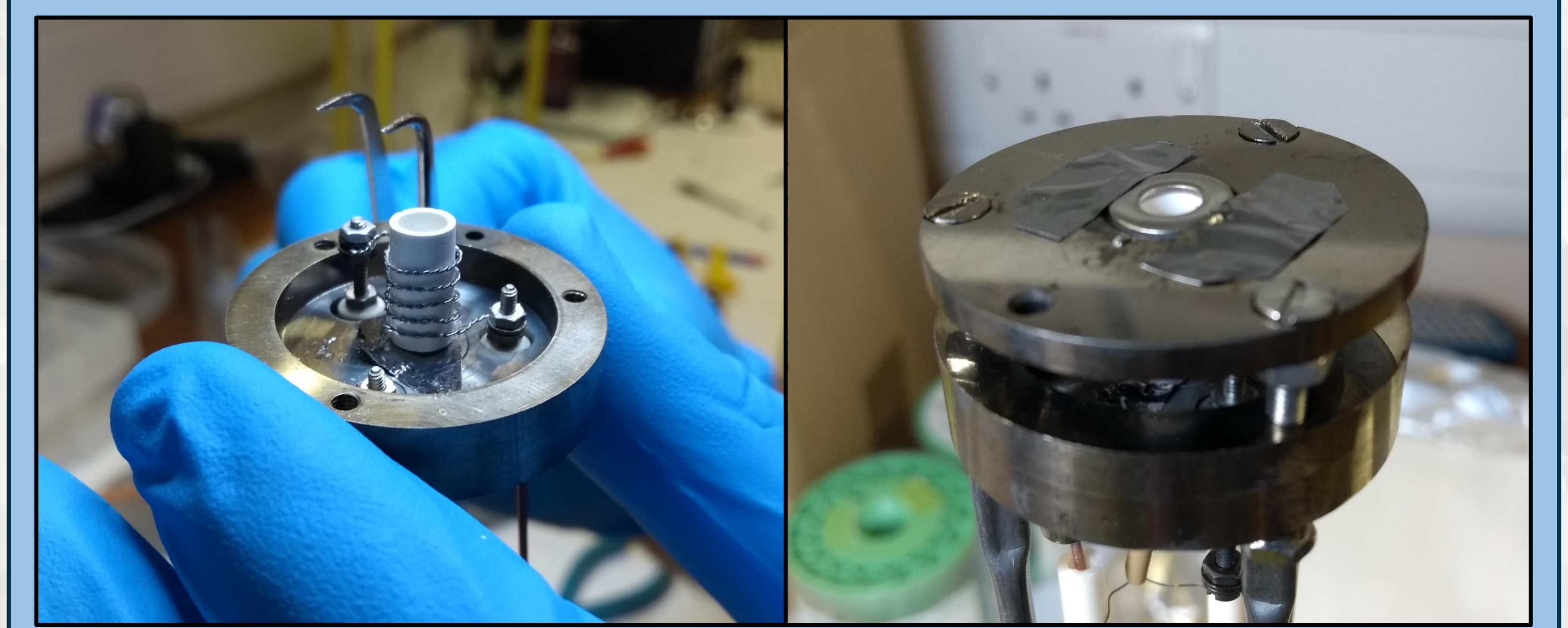

Figure 1 – A homemade effusion cell designed for depositing strontium in a system with elongated cell ports.

Film Growth and Structural Characterisation

Structural analysis of a sample can be conducted in-situ during growth using reflection high-energy electron diffraction (RHEED). The lattice parameter of the film changes marginally during growth from the substrate lattice parameter, indicating a well-matched interface layer is formed. However, the RHEED pattern often fades during long deposition periods, signifying a transition from crystalline to amorphous growth.

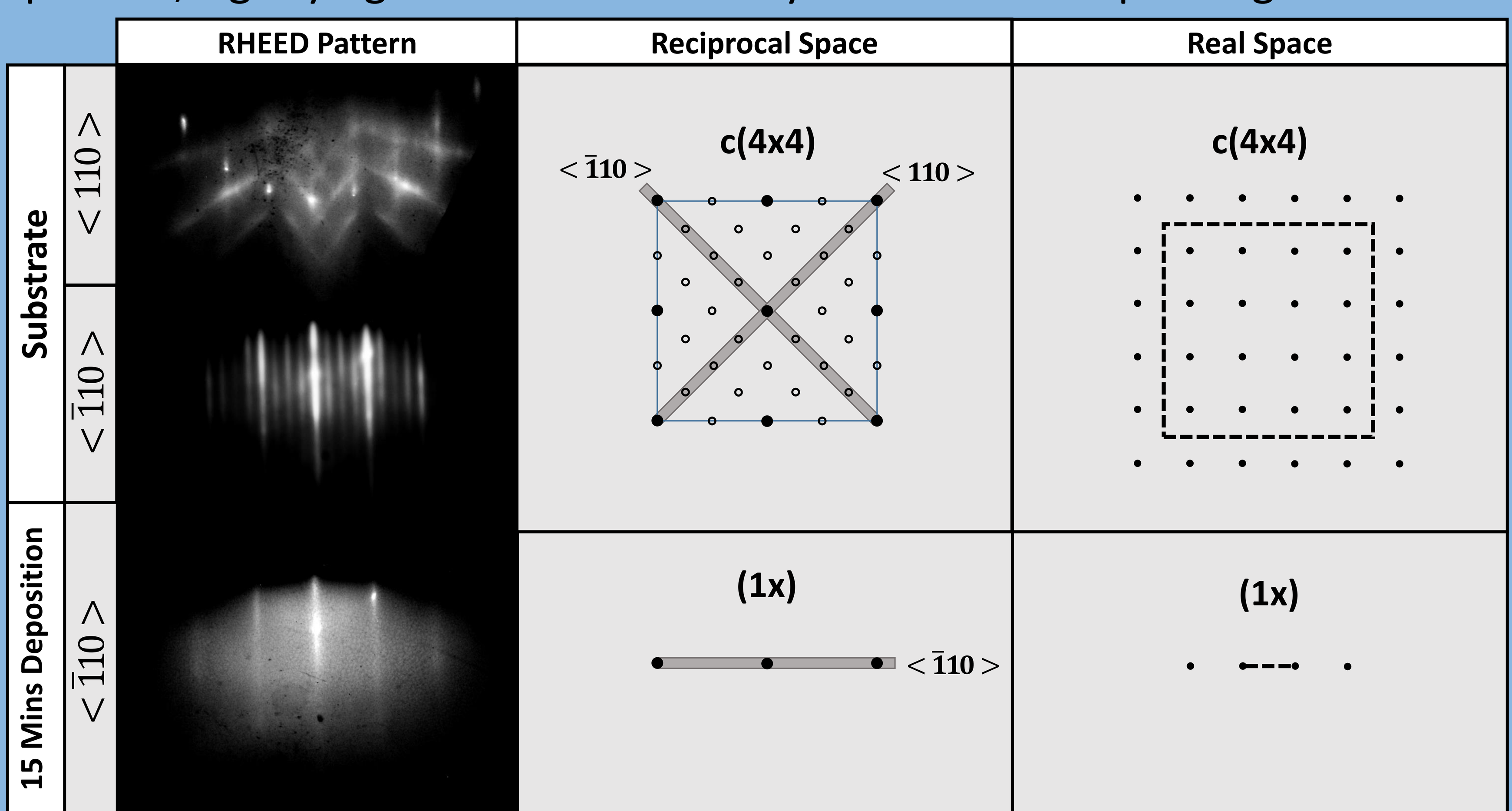

Figure 2 – RHEED analysis of InAs(001) substrate and a $SrMnSb_2$ film during growth. RHEED patterns were only distinct in one direction during growth, hence periodicity can only be established in one direction.

Composition Analysis

Deposition of a ternary alloy necessitates a careful balance of beam fluxes to achieve the desired crystal structure. Preliminary growth studies have used X-ray photoelectron spectroscopy (XPS) to determine the composition of films and allows the fine tuning of growth parameters for further iterations of the MBE process.

The film consists of elements that are very susceptible to oxidisation, which can be detected using XPS. Some analytical methods such as XPS analysis must be performed in a separate vacuum system to growth, so a suitable ex-situ transfer method is required. Two such methods have been compared, with one allowing brief exposure to atmosphere and the other using a portable vacuum suitcase transfer system, with both samples including an antimony capping layer (Fig. 3).

	Partial Atmospheric Exposure	Vacuum Suitcase
Total Carbon	20%	<1%
Sr : SrO	73% : 27%	87% : 13%
$Sb : Sb_2O_3$	64% : 36%	72% : 28%

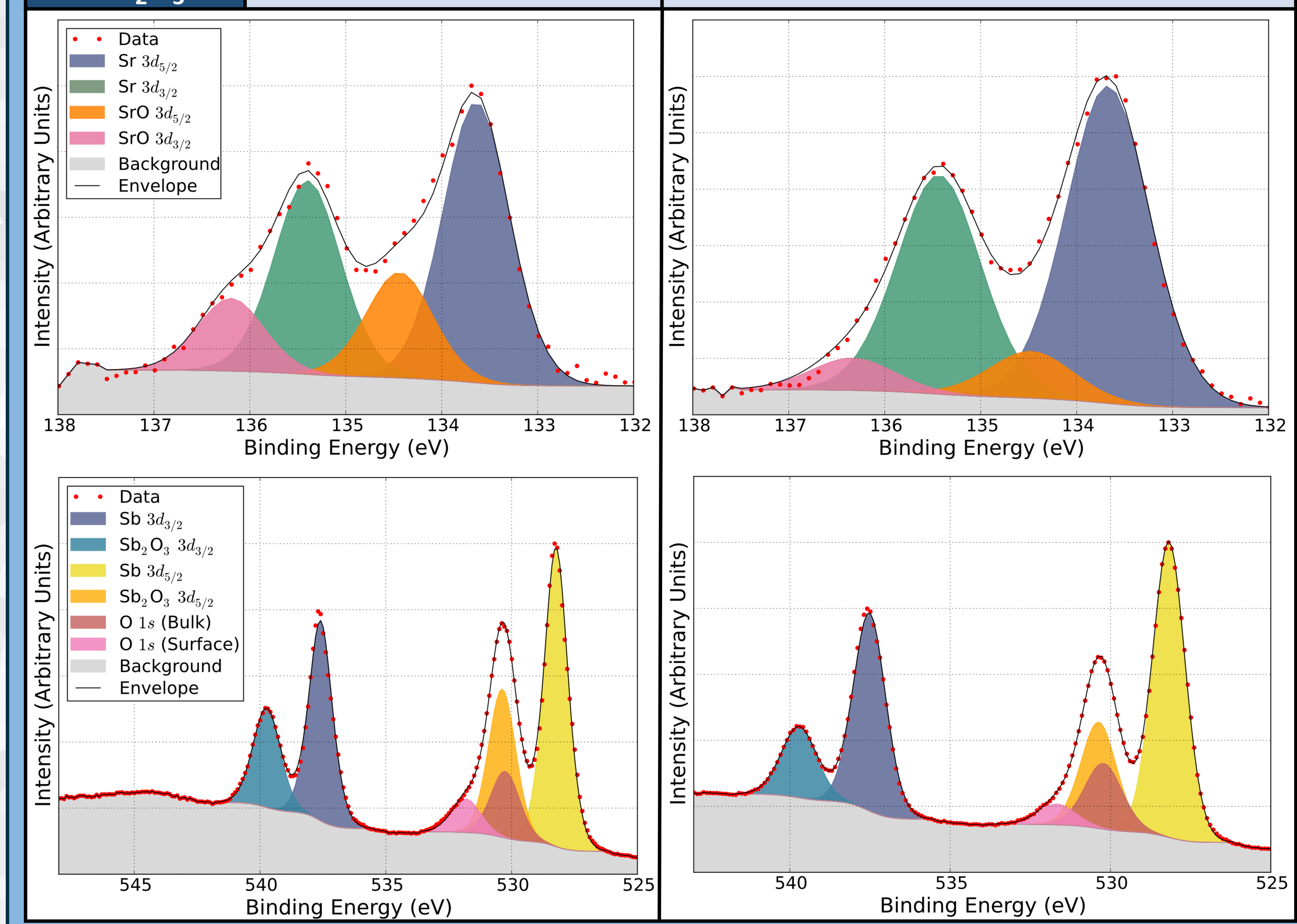

Figure 3 – Fitted XPS spectra comparing oxidisation in strontium and antimony components using different transfer methods (both including an antimony capping layer).

Future Research

Currently MBE growth of $SrMnSb_2$ is in the early stages of development, but a number of procedures are planned:

- Test a faster vacuum suitcase transfer without a capping layer.
- Fine tune the composition of the film by adjusting beam fluxes.
- Achieve fully crystalline growth by optimising substrate temperature.
- Measure electrical properties using a Hall effect measurement system.
- Investigate optoelectronic properties using pump-probe techniques with time-and angle-resolved photoelectron spectroscopy (trARPES).

Acknowledgements

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