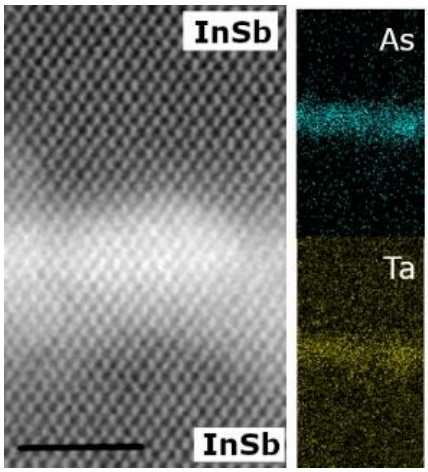
PhD Project Outline – Department of Physics – University of Warwick

Topological optoelectronics through semiconductor / semimetal heterostructures

The theme of this experimental project is the growth by molecular beam epitaxy (MBE) of topologically non-trivial semimetals which are compatible with the family of III-V semiconductors (GaAs, InSb, etc.). These materials are highly promising for spintronic and electronic applications, which could underpin highly energy-efficient computing, data storage and scalable quantum computing. We will focus on the Weyl semimetals from the (Ta,Nb)(As,P) family, on the topological semimetal InBi, and on the Dirac semimetal $SrMnSb_2$. These can all be grown by MBE on III-V family substrates. We are presently the only group worldwide to demonstrate InBi and $SrMnSb_2$ growth by MBE, while recently we demonstrated growth of unique InSb/TaAs/InSb heterostructures. High resolution transmission electron microscopy (TEM) data of such a structure are shown in the figure.



Initial TEM results on InSb/TaAs/InSb (001) heterostructure growth by MBE. Left: electron image of TaAs layer embedded in InSb (scale bar 5 nm). The TaAs atomic structure is not well resolved in its ultra-thin film form, but the typical InSb "dumbbells" are clearly resolved in both the substrate and MBE-grown epitaxial overlayer. Right side panels (not to scale) show the EDX signal for As and Ta, confirming confinement of these elements to the ultra-thin layer.

This opens up the possibility to tailor quantum structures for fundamental investigations and optoelectronic devices. The MBE systems in Warwick allow in situ analysis of films as they grow, by electron diffraction, XPS and scanning tunnelling microscopy. We can also transfer samples by UHV suitcase to other analysis facilities. The project will involve MBE growth of semiconductor / semimetal heterostructures and their analysis by advanced methods such as synchrotron surface X-ray diffraction (SXRD) and ultra-fast angle resolved photoelectron spectroscopy (ARPES). As well as travelling to synchrotron sources for experiments, we will work with collaborators in the USA (Prof. Chris Weber, Santa Clara U.), France (Prof. Christine Richter, CY Cergy Paris Université) and Czech Republic (Prof. Ján Minár, University of West Bohemia). Extensive hands-on training and support in MBE growth and surface science will be provided along with a range of taught postgraduate modules tailored to your needs.

For further information and to apply, please contact Gavin Bell gavin.bell@warwick.ac.uk and Physics Postgraduate Admissions.

The project will suit candidates with a strong background in experimental physics, physical chemistry or materials engineering. Experience with any of the following would be advantageous: ultra-high vacuum (UHV), epitaxial growth, surface science, or X-ray photoelectron spectroscopy (XPS).