Project description for RS654:

This highly innovative PhD project will develop new analysis tools for investigating semiconductor wafers and devices – focussing on the latest semiconductor materials (including compound semiconductors).

This studentship is linked to an exciting new Doctoral Training Initiative "UK Semiconductor Industry Future Skills" (UK-SIFS). UK-SIFS will provide valuable and highly practical skills relevant to the UK semiconductor industry such as formal cleanroom fabrication training, vacuum systems, process control (six sigma) in semiconductor manufacturing, semiconductor supply chains and export control, semiconductor packaging, and technology translation in the semiconductor sector. This PhD will be part of two cohorts of students in 2024 and 2025 across Swansea University and the University of Leeds, the Royce Institute, and partners including KLA, and the National Physical Laboratory (NPL), amongst others. Our partners will co-deliver the training content, plus co-supervise PhD research projects, and supervising a programme of secondments at partner sites. UK-SIFS provides not only the considerable benefits of research training and collaboration across a multidisciplinary cohort working in areas such as semiconductor devices, device characterisation and metrology, power electronics, clean energy, bioelectronics and sensing, THz devices, optoelectronics, molecular semiconductors, quantum technology, electronic glass and advanced heterogeneous integration, but is also a unique opportunity for those students who may want to connect closely with the semiconductor and related industries for their PhD and aspire to be the future leaders of the sector in the UK and beyond.

This highly innovative PhD project, led by Swansea University and based at NPL in London, aims to create new tools for analysing semiconductor wafers and devices, focusing on the latest materials like compound semiconductors. Compound semiconductors, important in the UK's semiconductor strategy, are used in various technologies like electric vehicles, sensors, and quantum technologies. They are more efficient than traditional silicon, but are sensitive to defects, which can lead to production issues and high costs. The project will develop methods to inspect wafers more effectively, using machine learning to identify critical defects in the latest semiconductor materials like SiC, GaN and β-Ga2O3. These materials offer profound advantages for power devices over silicon technologies. This PhD work is critical as low production yields lead to wastage and slow market growth.

The project is funded by an iCASE award to the National Physical Laboratory (NPL). The award will fund a Swansea University student to undertake a PhD at NPL's Teddington laboratories near London.

This PhD scholarship is aligned with another studentship, based at Swansea University and sponsored by global metrology company KLA. Collaboration between two

studentships will be supported by KLA. The NPL student will use existing tools like scanning probe microscopy and develop new methods for better analysis, while the Swansea student will focus on machine learning for defect classification. They will work together, sharing data and expertise.

This research aligns with NPL's Metrology Roadmaps, aiming to advance semiconductor metrology, integrate new sensing technologies, and apply machine learning. It will result in new scientific publications and potentially be used by companies like KLA. The project also supports the development of new semiconductor fabrication facilities in Swansea.

The student will need high-level skills in metrology and semiconductor materials, with training provided by NPL and exposure to industry through KLA. The project will use and develop new equipment, allowing for innovation and scientific creativity. It addresses the UK's need for skilled workers in semiconductor metrology, particularly in data-driven areas, and contributes to NPL's expertise in machine learning.

Compound Semiconductors are a priority area in the UK National Semiconductor Strategy. Their applications include power electronics (electric vehicles and net zero), sensors, displays, communications, and quantum technologies. The optoelectronic properties of compound semiconductor materials can be precisely controlled, and materials like SiC, GaN and β-Ga2O3 offer profound advantages for power devices over silicon technologies.

Many compound semiconductor technologies are already commercial but there is growing interest in developing new, high-value products. However, advanced compound semiconductor devices are highly intolerant of material and processing defects, which are a major cause of manufacturing yield losses. Low yields contribute to high costs, wastage, and inhibiting market growth. As a result, wafer-scale inspection is industrially important, but it remains a challenge to achieve the required high-throughput and accurate classification to identify and mitigate “killer“defects and performance-reducing defects. Machine learning is a powerful approach for tackling this but is reliant on the quality of training data and accuracy of measurement data. This project will develop and demonstrate metrological tools to address this challenge, with a focus on the application to Silicon Carbide and Gallium Oxide for power electronics.

This studentship will be awarded by Swansea University and is funded via the iCASE award scheme. Please note that the PhD will be based full-time at NPL Teddington, London.

This iCASE studentship is aligned with a second studentship funded by KLA and based at University of Swansea. The two students will collaborate closely on linked projects. Both studentships will link closely with the South Wales Compound Semiconductor Cluster – the World’s first compound semiconductor cluster.

NPL has existing capability and expertise in metrology of compound semiconductor materials and wafer-scale inspection. The NPL-based student will apply existing metrology tools (scanning probe microscopy and Raman/PL spectroscopy) to provide datasets for developing machine learning defect classification. This student will also develop new metrology methods based on compressive sampling to demonstrate improvements in sensitivity and throughput. The project continues work from the EMPIR PowerElec project. The development of machine learning methods for defect classification will be carried out at Swansea, requiring close interaction and dataset-sharing between the paired students.

This project aligns with the NPL Metrology Roadmaps for 'Advanced Manufacturing and Productivity' and 'Net Zero Energy Technologies'. It will develop new capability for wafer scale semiconductor metrology, including the integration of compressed sensing. It will result in peer-reviewed publications demonstrating NPL expertise in compound semiconductor metrology including the integration with machine learning. The industrial potential of the new wafer inspection methods will be assessed through the collaboration with KLA, which is a multinational semiconductor metrology company and potential end-user of project outcomes. The project will also support development of new SiC and β-Ga2O3 fabrication facilities at the Centre for Integrative Semiconductor Materials (CISM) in Swansea.

This project requires high-level technical skill in experimental metrology and understanding of semiconductor materials. Support and training will be provided by experts at NPL. The student will also gain direct industrial exposure through the relationship with KLA. The project will use existing equipment, as well as developing new instrumentation, which will enable progress in the early stages as well as providing novelty and opportunity for freedom and scientific creativity.

The National Semiconductor Strategy highlights a critical gap in skilled workers for the UK semiconductor industry, exacerbated by rapid growth of the South Wales cluster. Skills for data-driven metrology are particularly recognised as an acute need for the future of the UK industry, which this project will address. Research in this area will also develop NPL's expertise in applied machine learning, which is highlighted on the NPL Metrology Research Roadmaps.