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# Studying device processing steps with neutron reflectometry: Examples from quantum technology

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Nanoscale thin films and surface coatings play an integral role in advanced devices for electronics, energy, spintronics and quantum technology. In order to prepare devices, the materials are typically subjected to a wide range of device processing conditions. This may include dozens of steps including film deposition, gas exposure, heat treatment, photolithography, liquid etching and ion beam implantation. Each individual step can introduce chemical and structural modifications, and unwanted defects, so it is essential to track and characterise the film between steps, and where possible, deploy in-situ techniques to optimise the processing in real-time.

Here I will give an overview of the neutron reflectometry beamlines at ANSTO, including the new technical capabilities added since 2023, highlighting methods for studying electronic device processing steps. The capabilities include:

• Rapid vacuum annealing to temperatures of 1100 ℃ whilst measuring neutron reflection;
• Parallel beam optic diffraction experiments to enable simultaneous reflectometry and grazing incidence diffraction studies on Spatz for nanometer and angstrom-scale information on surface regions;
• In-situ four-probe resistivity measurements during heating or hydrogen gas treatments;
• Cryogenic magnetic field experiments to measure polarised neutron reflectometry on spintronic or superconducting layers from 5 K to 300 K, in 1 Tesla under in-plane field rotations up to 270 degrees;
• Off-specular and half-polarised reflectometry of microscale lithographic patterns (5-50 μm);
• Complementary ion implantation experiments using a MEVVA ion source and isotopically-resolved (mass separated) low energy implanter;
• Complementary susceptibility, quantum oscillations, magnetoresistance, resistivity and Hall Effect measurements ;
• Complementary X-ray reflectometry, grazing incidence diffraction and ellipsometry measurements;

To show the capabilities in action, I'll highlight collaborative work applied to quantum technology. This includes growth of novel superconducting films, in-situ growth of graphene-on-SiC, studying ion implantation in topological insulator materials and metal-polymer hybrid structures [1-4]. If time permits, I will discuss several upcoming and optional developments with the goal of getting feedback from the user community on:

• A vacuum suitcase for transporting air-sensitive samples between processing steps;
• Thin film deposition system integrated with vacuum suitcase for adjusting isotopic contrast;
• 3He fully enabled polarization analysis of off-specular and grazing incidence;
• In-situ ferromagnetic (spin-wave) spectroscopy of thin films ;

## Topics

Advanced functional materials and devices

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