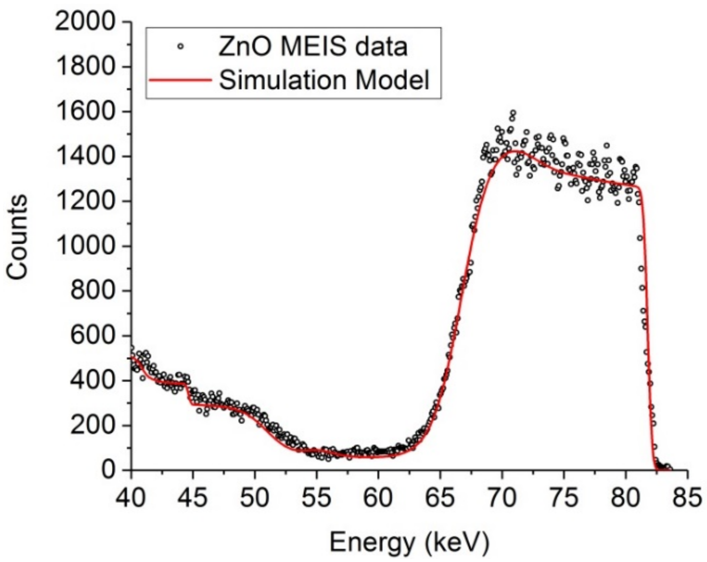
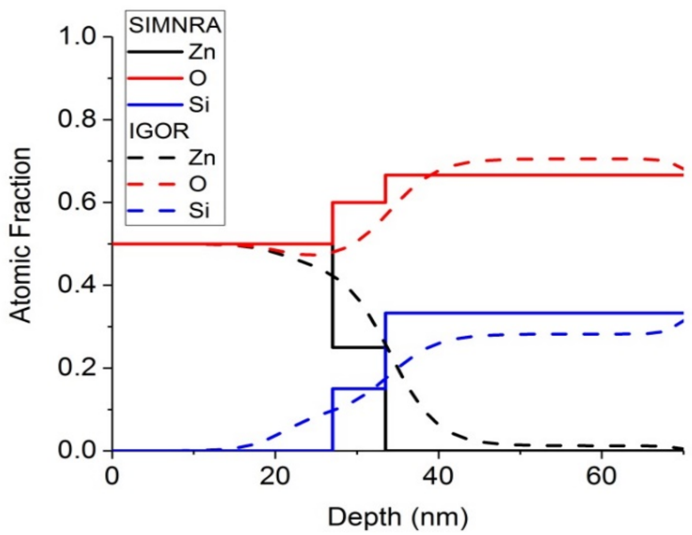
Case study 3

Plasma enhanced pulsed laser deposition

Plasma enhanced pulsed laser deposition (PE-PLD): Pulsed Laser Deposition (PLD) is a well-established thin-film deposition technique that is widely used in fundamental research as well as applications. One of the often-quoted advantages is the stoichiometric transfer of target material to a thin film. In practice metal-oxide films produced in vacuum can end up being oxygen deficient. Plasma-Enhanced Pulsed Laser Deposition (PE-PLD) aims to improve stoichiometric control by combining a standard PLD setup with a low-temperature, electrically produced oxygen plasma. This study presents the first experimental proof-of-concept results using **Medium Energy Ion Scattering (MEIS) depth profiling analysis.**

MEIS analysis of these samples was performed using 100 keV He^+ ions at both 90° and 125° scattering angle configurations. Energy spectra were initially converted into depth profiles using a spectrum simulation program which operates within the IGOR6 PRO© graphing software. To account for dual and multiple scattering events during the ion beam analysis, the SIMNRA simulation package was used to reassess the depth profile for each of the samples.





- A range of ZnO, Cu_2O and CuO thin films samples grown via PE-PLD at the University of York on Si (100) and SiO_2 substrates was analysed by MEIS
- The energy spectrum shown is for a ~30 nm thick ZnO film deposited on SiO_2
- The decaying edge of the surface Zn peak represents scattering from the SiO_2 /ZnO transition region which at 25 % of the film thickness appears to be high at first sight.
- Using SIMNRA to include the effects of multiple scattering (MS) confirms the layer thickness as simulated via the IGOR6 PRO macro but with a smaller inter-diffusion region.
- Film thickness was calculated by measuring the half height point of the transition metal profile as shown in the lower figure.
- These results demonstrate that the PE-PLD process yields a high deposition rate of 0.1 nms^{-1} with sub-nm control over the film thickness.
- MEIS analysis confirmed that by varying the oxygen pressure and RF power used to generate the inductively coupled plasma, the stoichiometry of the deposited film can be effectively controlled.

Conclusions: MEIS has been successfully used to determine the thickness, uniformity, and width of the transition region of a range of plasma-enhanced pulsed laser deposition (PE-PLD) produced ZnO, Cu_2O and CuO thin films. PE-PLD has been demonstrated to have a high deposition rate with increased control of the stoichiometry of the deposited film. MEIS depth profiling analysis has yielded important quantitative elemental depth profiles after each process stage with near nm depth resolution, not easily obtainable using alternative analytical techniques.

Work carried out as an collaboration with the University of York Plasma Institute (Erik Wagenaars)

Contact: Jaap van den Berg (j.vandenberg@hud.ac.uk) or Andrew Rossall (a.rossall@hud.ac.uk)
MEIS Lab, Ion Beam Centre, University of Huddersfield, HD1 3DH