Accurate RBS

On 1st December 2015 UKAS accredited the University of Surrey Ion Beam Centre as a Calibration Laboratory under the ISO 17025 standard to obtain the retained ion doses in ion implanted samples by Rutherford backscattering spectrometry (RBS) at standard uncertainties as good as 1%.

This is applicable to 150 keV 10^{15}As/cm^2 ion implants into silicon measured by 1.5 MeV He-RBS, and to any other samples with similar spectroscopic signals. The technical case was established in an important paper which summarises the quality assurance (QA) protocol and results for our 200 kV Danfysik ion implanter (Analyst, 2015), also showing that RBS is a primary direct reference method.

This capability is directly and immediately applicable for certifying many of the ion implanted SIMS standards that we make using the Danfysik implanter and supply to many laboratories.

This establishes RBS for the first time as a 1% analytical technique, with a robustness adequate for auditing by the QA departments of industry. RBS has long been thought to be very accurate since, unlike other analytical methods, the interaction cross-sections are known almost exactly. The traceability of these measurement relies on the intrinsic measurement standard represented by a stopping power factor of silicon which was determined with a standard uncertainty of 0.8% in 2014 (Colaux & Jeynes, Analytical Methods, 2014) in a measurement traceable to the Certified Reference Material IRMM ERM-EG001/BAM-L001.

It is also worth pointing out that these methods have also led to the establishment of a new beam energy standard valuable for calibrating the accelerator terminal voltage instrumentation and using the non-Rutherford elastic backscattering (EBS) reaction $^{16}O(\alpha,\alpha)^{16}O$ for which the resonant energy 3038 keV has been determined with a precision of 300 eV and an absolute accuracy of 1.3 keV (Colaux, Terwagne & Jeynes, Nucl. Instrum. Methods B, 2015). These EBS cross-sections are consistent with (and validate) the compilations, and are implemented in SigmaCalc 2.0.

Our 2012 paper on accurate RBS is "round robin" between three labs (Surrey, Budapest, Lisbon) showing that 1% accuracy is achieved. It also includes a detailed treatment of the technique including secondary and tertiary issues and has become an **authoritative reference** for the RBS technique with two notable papers in 2015: an account in Scientific Reports from Leeds of femtosecond laser treatment of Er-doped silica for photonic applications; also in an account in Nature from Sandia, Los Alamos Lawrence Livermore and others of X-ray absorption measurements at enhanced temperatures relevant to solar opacity estimation.

Accreditation is of particular interest for (for example) real **Forensics** applications, where quality documentation for the analytical laboratories is of great importance.

Accreditation for RBS is a world-first for ion beam analysis (IBA) methods. There have been significant developments over the last few years to extend the power of IBA by taking advantage of the synergy between nuclear reaction (RBS etc) and atomic excitation (particle-induced X-ray emission, PIXE) methods: so-called "**Total-IBA**".

We are now in a position where IBA is a **general-purpose thin film analysis method**, unlike PIXE which (like XRF, SEM-EDX etc) by itself cannot solve multi-layer samples, and unlike RBS which by itself cannot solve samples which need good mass resolution (or indeed light elements in or on a heavy matrix). By themselves these techniques were applicable to a limited subset of the interesting samples, but the joint technique can handle pretty well any sample. (Of course, every technique has its limitations!) And the joint technique can **inherit the properties** (including accuracy) of the individual component methods.

An article describing this application for a general audience was published on 24th December 2015 by TheConversation.

The Royal Society of Chemistry published a "Tutorial Review" for analytical chemists, including this application in the context of a wider review of thin film depth profiling, in their journal Analyst on 31st August 2016 (vol.141:21 issued 7th November 2016).