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Surface- and Microanalysis by Low Energy Ion Scattering

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Recently, Low Energy Ion Scattering (LEIS) has gained some momentum with the availability of high-end instrumentation for real-world surface analytical applications. These instruments make the unique capabilities of LEIS accessible by implementing a special analyzer design, allowing the quantitative analysis of the elemental composition of the outermost atomic layer of a material with high sensitivity and mass resolution.

The technique [1] is based on the scattering of noble gas ions that are directed at the surface with a kinetic energy of 1 – 8 keV. In binary collision some of the ions are scattered back from the surface and can be detected by the energy analyzer. In the collision event, the ions exhibit a characteristic energy loss that is measured and used to determine the mass of the surface atom that was acting as the scattering partner. In contrast to non-dedicated instruments, the sensitivity of the analyzer [FIG. 1] is high enough to detect all required information of a given area before the surface is modified by the ion bombardment. The energy resolution and scattering geometry allow separating virtually any pair of elements, even with overlapping isotopes [2].

Applications of LEIS range from fundamental research to industrial materials, especially in the field of thin films and catalysis. The extreme surface sensitivity and the ability to analyze extremely rough and insulating samples make it the ideal technique for catalysis applications, where the functionality of the material is localized in the outer surface and simultaneously the concentrations of the analyte on the support may be very low. With detection limits in the range of a few atomic per cent for light elements up to the 10 ppm range for heavy elements – always as a fraction of the outermost atomic layer – modern LEIS does not have a need for model systems with higher concentrations of the active phase, but works on productions catalysts. On these samples, the technique can determine the amount of metal on the support that is really available to the catalysis, which is important for optimizing material usage. Amongst others, poisoning processes and formation of coke can be studied, including the localization of nucleation of coke. Recently [3] even the size of nanoparticles has been determined with a non-imaging methodology that does not suffer from statistical errors caused by the limited field of view of imaging techniques.

In thin film technology the ultimate surface sensitivity is used to study growth modes and nucleation behavior in the early stages of film formation. In combination with the in-depth information that is contained in the spectra, island formation and diffusion are observed. For thicker films the depth range of 5 - 10 nm that is covered by the in-depth information of the static (non-destructive) spectra is not sufficient. Since recently, LEIS can be combined with sputter depth profiling to cover a depth range of up to a few microns, with good sensitivity and easy quantification. The first results of this new mode show the complementarity with other depth profiling techniques like (TOF-)SIMS.

An overview of recent developments to further optimize the instrumental possibilities (increase of detection limit by time-of-flight filtering, *in-situ* sample preparation and modification, etc.) and examples for their applications will be given.

References
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[3] Tanabe et al., *Appl. Cat. A* 370 (2009) 108.

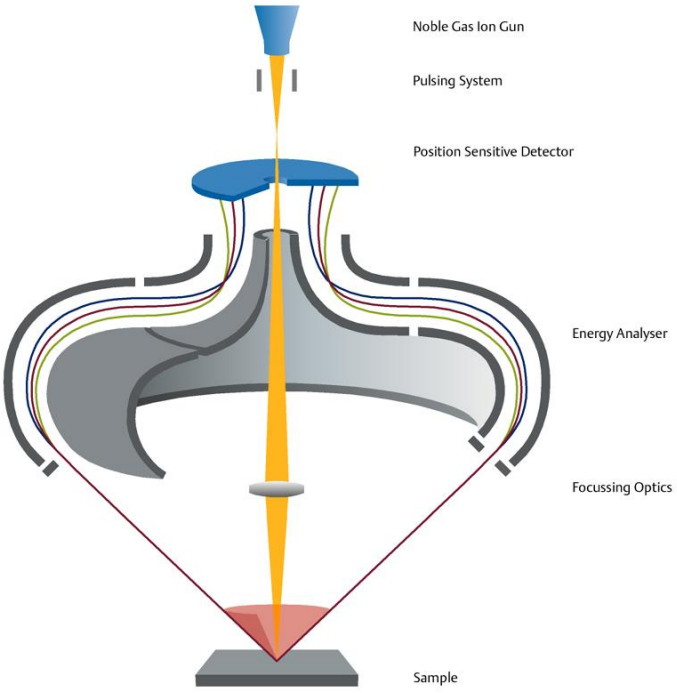

FIG. 1: Schematics of the unique analyzer design. The primary ion beam (normal incidence) is directed through the analyzer towards the sample. Scattered ions are detected over all azimuths and analyzed with respect to their energy in the electrostatic analyzer. On the position sensitive detector ions in a range of energies are detected in parallel.

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