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Analytical Instrumentation for Nano-Analysis

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Focused research efforts are necessary for addressing the needs of nanotechnology in materials science. These efforts should give rise to significant advances of the beam methodologies to be addressed at 3 distinct levels:

- Improvement of the characteristics for application well into the sub-100 nm range laterally and with depth resolution below the nm level.
- Advances in the accuracy and the study of sources of systematic errors, which should lead to quantitative/traceable results and systematic errors whose measurement uncertainty can be reproduced in laboratories using the same techniques. This implies establishing a measurement traceability scheme for key-methods in each class of instruments.
- The experimental methods mentioned often deliver images that require subjective judgment. In order to make measurements objective and quantitatively traceable, tools for image analysis adhering to concepts of modern metrology must be developed.

The direct needs and potential users of characterization methods for the near future are summarized concisely in Table I. Table II summarizes the present state-of-the-art characteristics of SIMS, AES and TEM

Two promising areas will be reviewed as an illustration of present development efforts to reach the goal of nanoscopic analysis and characterization: beam analysis with focused ion beams as exploited in secondary ion mass spectrometry (SIMS) and various application of synchrotron radiation (SR) sources.

For SIMS the goal is to develop enhanced sensitivity and develop methodological innovations for lateral resolution below 100 nm, SIMS will hence need to reach the following capabilities during the coming 5 years:

- A lateral resolution (X, Y) to 10 nm in order to keep pace with development in microelectronics and other development areas of materials science;
- A depth resolution (Z) towards the atomic scale as increasingly shallow implantations are needed in microelectronics (the “microelectronics roadmap”) and micro-miniaturisation;
- The ability to detect all elements as well as their isotopic composition and small molecules;
- The increase of sensitivity with a realistic goal of 1 ion detected and mass analysed for 2-100 atoms sputtered in order to be able to analyse nanoscale materials at the level of 10 cubic nanometre (corresponding to ca 50,000 atoms).

The EU has devoted attention to these specific issues in the 6th Framework Programme by financing a network of excellence “NANOBEAMS” with the goal of increasing lateral resolution to the levels described above for ion beam and electron beam methods.

SR methods can extend the application of existing techniques to sub-μm analysis down to 100 nm at present, below that limit in the near future. There is a diverse range of scientific and technological investigations that are feasible by the application of SR based X-ray techniques at high spatial resolution. Developments in both focusing/imaging optics and in detector technology can yield enormous benefits to the fundamental understanding of phenomena spanning as diverse fields such as cellular biology, chemical engineering and semiconductor physics. SR based techniques will also contribute in the quality assurance of measurements, including traceability and uncertainty analysis, and are instrumental for the elaboration of reference materials and the validation of other methods of analysis.

Table I: Milestones and users of results of analytical methods for nanotechnology

Expected Result	Users of Results
Improvement of analytical methodology of a number of beam methods of analysis	Science community. Industry for various applied research activities
Enhancement of the accuracy and the traceability of results of chemical analysis	Metrological institutes, fabrication of reference materials
A stronger position in the market for analytical instrumentation	Companies producing analytical instruments
Improving technology forecasting and technology assessment	Private, advise national and supranational policy making
An improved measurement structure for nano-structured materials	Industrial use and solution of problems in Society

Table II: Actual state-of-the-art characteristics of SIMS, AES and TEM

Technique	Lateral resolution X, Y (nm)	Depth resolution Z (nm)	Analyte	Remarks
Dynamic SIMS	50-100	0.5-3	Inorganic/isotopic (limited)	Quantitative information (limited)
Static SIMS	100 (element) 500-10,000 (molecular)	0.1	Inorganic/speciation /organic	Semi-quantitiative
AES	20	0.5-1.0	Inorganic/speciation	Conductive samples
TEM	1	1	Inorganic/organic (limited)	Specimen preparation; beam damage

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