Development and Applications of Neutron and Proton Based Nuclear Analytical Methods for Non-destructive Chemical Characterization of Materials

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Chemical characterization of materials is one of the important steps in chemical quality control (CQC) exercise. Compared to conventional wet-chemical and spectroscopic techniques, Nuclear Analytical Techniques (NATs) have several advantages like simultaneous multielemental capability at major to trace concentration levels, often non-destructive in nature, quantitative information on total elemental and isotopic concentrations and negligible or less spectral interference and matrix effects. Commonly used NATs utilizing neutron, charged particles and photon as probes are Instrumental Neutron Activation Analysis (INAA), Prompt Gamma-ray NAA (PGNAA), Charged Particle Activation Analysis (CPAA), Particle Induced Gamma-ray Emission (PIGE) and Photon Activation Analysis (PAA).

Since 1994, different nuclear analytical facilities and methods have been developed for non-destructive chemical characterization of materials of diverse matrices utilizing neutrons from research reactors as well as low energy proton beams from tandem particle accelerators of BARC, Mumbai. The developed methods, namely k_0-based conventional and Internal Monostandard Neutron Activation Analysis (IM-NAA) and *in situ* current normalized vacuum chamber and external (in air) Particle Induced Gamma-ray Emission (PIGE), were optimized for quantification of low to high Z elements including REEs. Methods were validated utilizing suitable CRMs/SRMs as a part of QC. These methods were applied to various samples relevant for fields like geology, environment, biology, food & agriculture, archaeology, forensic sciences, materials sciences and nuclear technology. IM-NAA method in conjunction with *in situ* detection efficiency was successfully applied for standard-less compositional characterization of large sized and non-standard geometry reactor structural materials for CQC and for grouping/provenance studies of archaeological samples. INAA methods utilizing high flux reactor neutrons were utilized for trace element determination in many samples including high purity graphite and aluminium. *In situ* current normalized vacuum chamber PIGE method was utilized for simultaneous quantification of low Z elements in glass and ceramic samples as well as total B and its isotopic composition (IC) in neutron absorbers. External (in air) PIGE facility developed at our institute is very useful for rapid and non-destructive analysis of "as received" samples of glass, ceramics and alloys for quantification of low Z elements as well as IC of B in B_4C and other refractory materials, which are difficult to be analysed by conventional analytical techniques. Both INAA and PIGE methods were utilized for forensic studies of automobile (car) windshield glass samples with help of trace elements including REEs as a part of an IAEA CRP work and also for evaluating quality of coal and cement samples.

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